https://www.dubrovnik2025.sdewes.org/

Energy-water-air-food: a nexus approach

A Research Story

ITEWA Innovative Team for Energy Water and Air

Ruzhu WANG

Shanghai Jiao Tong University

06/10/2025

SJTU

Big Picture
of Sustainable development

- Energy
- Water
- Air
- Food

- **Multidisciplinary Research**

Contents

Origins of Establishing the ITEWA Team

Reflections on a Science Paper:
Accepted in Late 2016, Published in April 2017

Science

REPORTS

Cite as: H. Kim *et al.*, *Science* 10.1126/science.aam8743 (2017).

Water harvesting from air with metal-organic frameworks powered by natural sunlight

Hyunho Kim,[1] Sungwoo Yang,[1] Sameer R. Rao,[1] Shankar Narayanan,[1]* Eugene A. Kapustin,[2] Hiroyasu Furukawa,[2] Ari S. Umans,[1] Omar M. Yaghi,[2,3]† Evelyn N. Wang[1]†

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*Present address: Department of Mechanical, Aerospace and Nuclear Engineering, Rensselaer Polytechnic Institute, 110 8th Street, Troy, NY 12180, USA.

†Corresponding author. Email: yaghi@berkeley.edu (O.M.Y.); enwang@mit.edu (E.N.W.)

Atmospheric water is a resource equivalent to ~10% of all fresh water in lakes on Earth. However, an efficient process for capturing and delivering water from air, especially at low humidity levels (down to 20%), has not been developed. We report the design and demonstration of a device based on porous metal-organic framework-801 [$Zr_6O_4(OH)_4(fumarate)_6$] that captures water from the atmosphere at ambient conditions using low-grade heat from natural sunlight below one sun (1 kW per square meter). This device is capable of harvesting 2.8 liters of water per kilogram of MOF daily at relative humidity levels as low as 20%, and requires no additional input of energy.

nature COMMUNICATIONS

ARTICLE

DOI: 10.1038/s41467-018-03162-7 OPEN

Adsorption-based atmospheric water harvesting device for arid climates

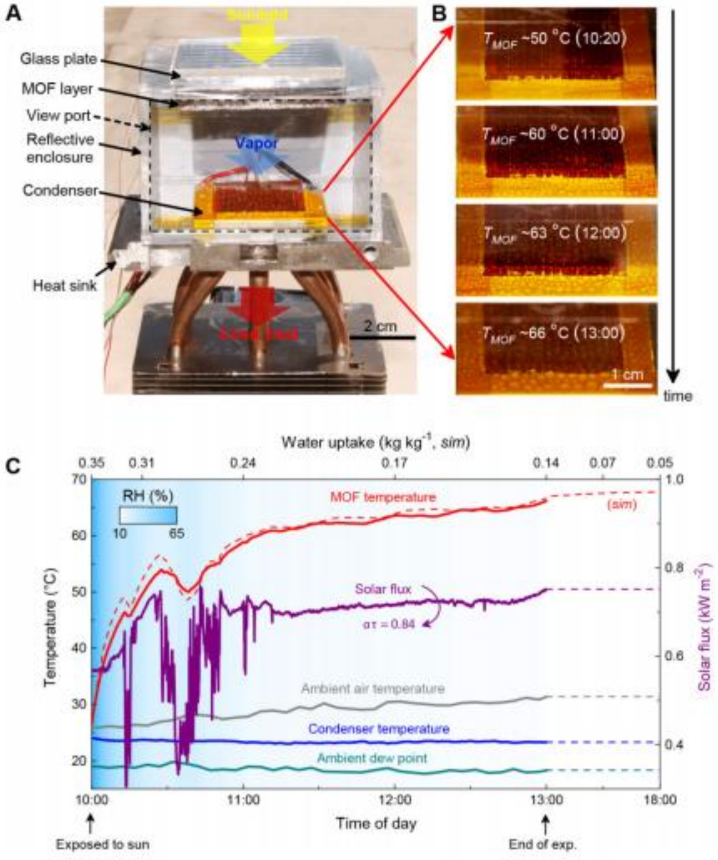
Hyunho Kim[1], Sameer R. Rao[1], Eugene A. Kapustin[2,3], Lin Zhao[1], Sungwoo Yang[1], Omar M. Yaghi[2,3,4] & Evelyn N. Wang[1]

Water scarcity is a particularly severe challenge in arid and desert climates. While a substantial amount of water is present in the form of vapour in the atmosphere, harvesting this water by state-of-the-art dewing technology can be extremely energy intensive and impractical, particularly when the relative humidity (RH) is low (i.e., below ~40% RH). In contrast, atmospheric water generators that utilise sorbents enable capture of vapour at low RH conditions and can be driven by the abundant source of solar-thermal energy with higher efficiency. Here, we demonstrate an air-cooled sorbent-based atmospheric water harvesting device using the metal–organic framework (MOF)-801 [$Zr_6O_4(OH)_4(fumarate)_6$] operating in an exceptionally arid climate (10–40% RH) and sub-zero dew points (Tempe, Arizona, USA) with a thermal efficiency (solar input to water conversion) of ~14%. We predict that this device delivered over 0.25 L of water per kg of MOF for a single daily cycle.

MIT's Evelyn N. Wang & UC Berkeley's Omar M. Yaghi:
MOF-801-Based Atmospheric Water Harvesting (Science 2017)

Attempt 1

Science 2017



2002

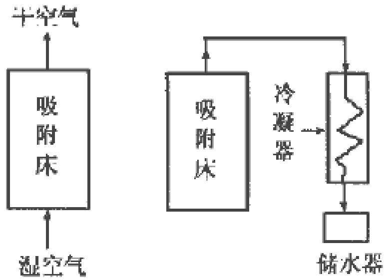


图 1　一种间歇式吸附空气取水器系统原理图

DOI：10.16085/j.issn.1000−6613.2002.10.007
2002 年第 21 卷第 10 期　化　工　进　展　CHEMICAL INDUSTRY AND ENGINEERING PROGRESS　· 733 ·

空气中取水用的新型复合吸附剂的吸附和解吸性能

刘业凤　王如竹
（上海交通大学制冷与低温工程研究所，上海，200030）

摘　要　介绍了一种便携式吸附空气取水器，以及为了改进现有吸附剂的取水性能研制的一种由粗孔球形硅胶和氯化钙组成的新型复合吸附剂 $SiO_2 \cdot xH_2O \cdot yCaCl_2$，对氯化钙质量分数分别为 34.9%和 43.3%的复合吸附剂样品 A，B。在 25 ℃相对湿度 50%空气中，对两个样品和常用吸附剂进行了吸附对比实验，结果表明：复合吸附剂 B 的平衡吸附量 x_e 可达 0.4515 kg/kg，是粗孔球形硅胶的 4.9 倍、细孔球形硅胶的 2.0 倍、分子筛 13X 的 2.2 倍。吸附曲线和 80 ℃下的解吸曲线表明复合吸附剂具有更高的吸水量、更快的吸附和解吸速度，可用太阳能加热解吸，是一种理想的取水用吸附剂。

关键词　吸附式空气取水器，新型复合吸附剂，吸附，解吸
中图分类号　TQ 028　**文献标识码**　A　**文章编号**　1000−6613（2002）10−0733−03

2016-2018

Energy 165 (2018) 387–395
Contents lists available at ScienceDirect
ELSEVIER
Energy
journal homepage: www.elsevier.com/locate/energy

Universal scalable sorption-based atmosphere water harvesting

J.Y. Wang [1], R.Z. Wang [*,1], Y.D. Tu [1], L.W. Wang
Institute of Refrigeration and Cryogenics, Shanghai Jiao Tong University, 800 Dongchuan Road, Shanghai, 200240, China

ARTICLE INFO
Article history:
Received 13 August 2018
Received in revised form
9 September 2018
Accepted 15 September 2018
Available online 18 September 2018

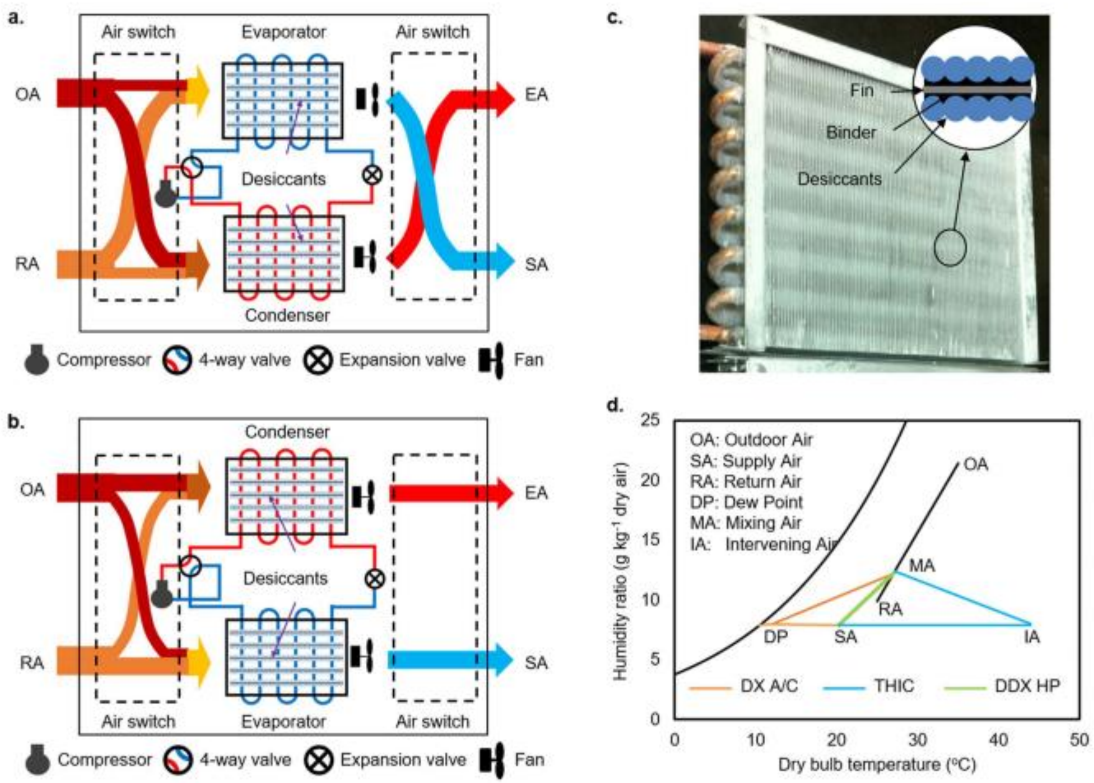
ABSTRACT
Air water harvesting (AWH) is a prospective way to make people live in extreme conditions, such as arid desert and remote islands. However, the refrigeration-based AWH suffers from ineffectiveness at low humidity, while the current sorption-based solar driven AWH has low area specific water production. To provide affordable water, it is essential to design universal and scalable systems to effectively capture moisture from air year-round with less energy consumption at different locations. Here we develop a theoretical framework and demonstrate a scalable prototype on the sorption-based AWH. The prototype adopts a temperature-insensitive and *RH*-broadband desiccant, achieving a large water harvesting capacity in different regions. Scalable modular sorbers with sinusoidal honeycomb structure are used. The prototype harvests ca. 38.5 kg fresh water per day, consuming ca.7.2 MJ heat/kg fresh water. The performance analyses show that our device can harvest freshwater universally, which is a promising solution to relieve the thirsty world.

Lesson 1: Manuscript sent for review in Nat. Commun. but rejected due to prior publication in ATE journal. Incremental innovation insufficient for top-journals' requirements

Universal scalable sorption-based atmosphere water harvesting. Energy, 2018.

Attempt 2

2016-2017：Desiccant heat exchanger based heat pump, COP 100% increase



SCIENTIFIC REPORTS

OPEN

Comfortable, high-efficiency heat pump with desiccant-coated, water-sorbing heat exchangers

Received: 20 October 2016
Accepted: 06 December 2016
Published: 12 January 2017

Y. D. Tu, R. Z. Wang, T. S. Ge & X. Zheng

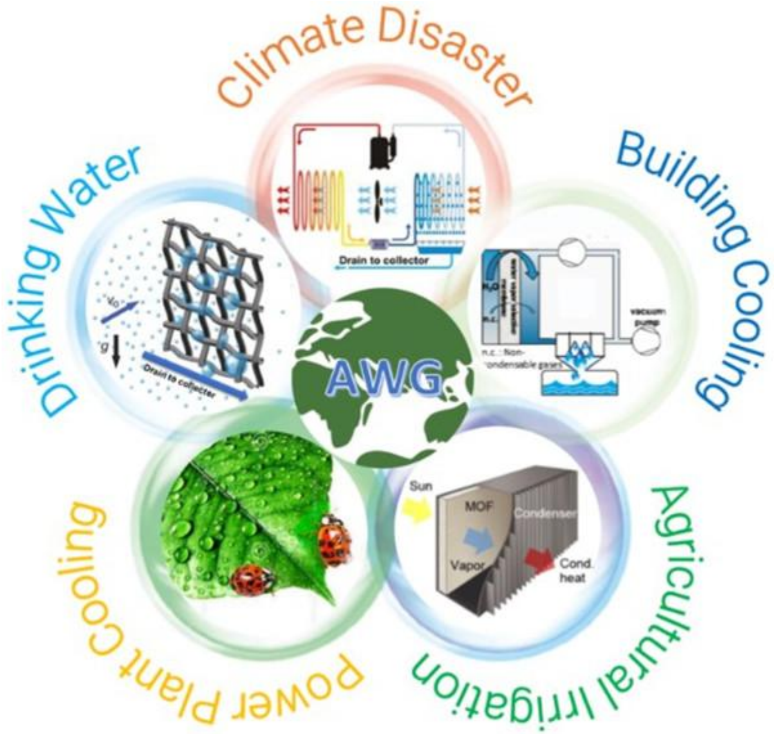
Comfortable, efficient, and affordable heating, ventilation, and air conditioning systems in buildings are highly desirable due to the demands of energy efficiency and environmental fr
vapor-compression air conditioners exhibit a lower coefficient of performance (CO
owing to the cooling-based dehumidification methods that handle both sensible a
together. Temperature- and humidity-independent control or desiccant systems h
to overcome these challenges; however, the COP of current desiccant systems is q
additional heat sources are usually needed. Here, we report on a desiccant-enhan
heat pump based on a water-sorbing heat exchanger with a desiccant coating that
COP value of more than 7 without sacrificing any comfort or compactness. The pu
doubled compared to that of pumps currently used in conventional room air condi
revolutionary HVAC breakthrough. Our proposed water-sorbing heat exchanger c
handle sensible and latent loads at the same time. The desiccants adsorb moisture
and can be regenerated by condensation heat. This new approach opens up the po
ultrahigh efficiency for a broad range of temperature- and humidity-control applic

Lesson 2: Expanded publication scope and visibility achieved, yet *Scientific Reports* remains distant from top journals.

Comfortable, high-efficiency heat pump with desiccant-coated, water-sorbing heat exchangers. Scientific Reports, 2017.

Attempt 3

Aug. 2018: Joule review on atmospheric water harvesting unlocked access to top tier journals



Joule

Review

Progress and Expectation of Atmospheric Water Harvesting

Yaodong Tu,[1] Ruzhu Wang,[1,*] Yannan Zhang,[1] and Jiayun Wang[1]

Even if people live in an arid desert, they know that plenty of water exists in the air they breathe. However, the reality tells us the atmospheric water cannot help to slake the world's thirst. Thus an important question occurs: what are the fundamental limits of atmospheric water harvesting that can be achieved in typical arid and semi-arid areas? Here, through a thorough review on the present advances of atmospheric water-harvesting technologies, we identify the achievements that have been acquired and evaluate the challenges and barriers that retard their applications. Lastly, we clarify our perspectives on how to search for a simple, scalable, yet cost-effective way to produce atmospheric water for the community and forecast the application of atmospheric water harvesting in evaporative cooling, such as electronic cooling, power plant cooling, and passive building cooling.

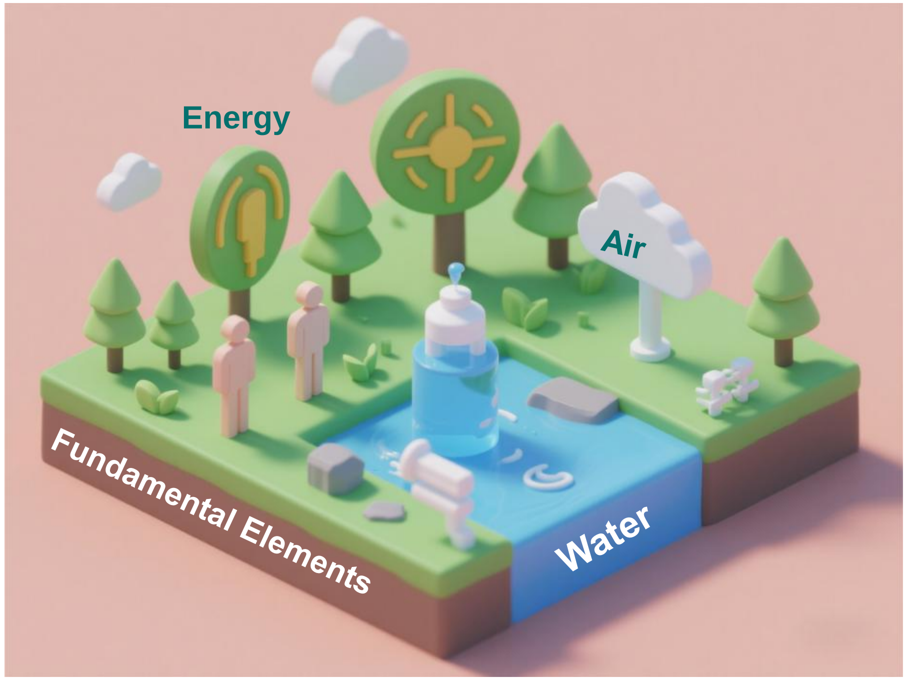
Context & Scale

Airborne moisture is a potential source of a plentiful amount of freshwater that is accessible everywhere and can be easily co-operated with a renewable energy source (solar energy). This paper presents a comprehensive and critical review of state-of-the-art research on atmospheric water harvesting. From the viewpoint of applications, we are concerned

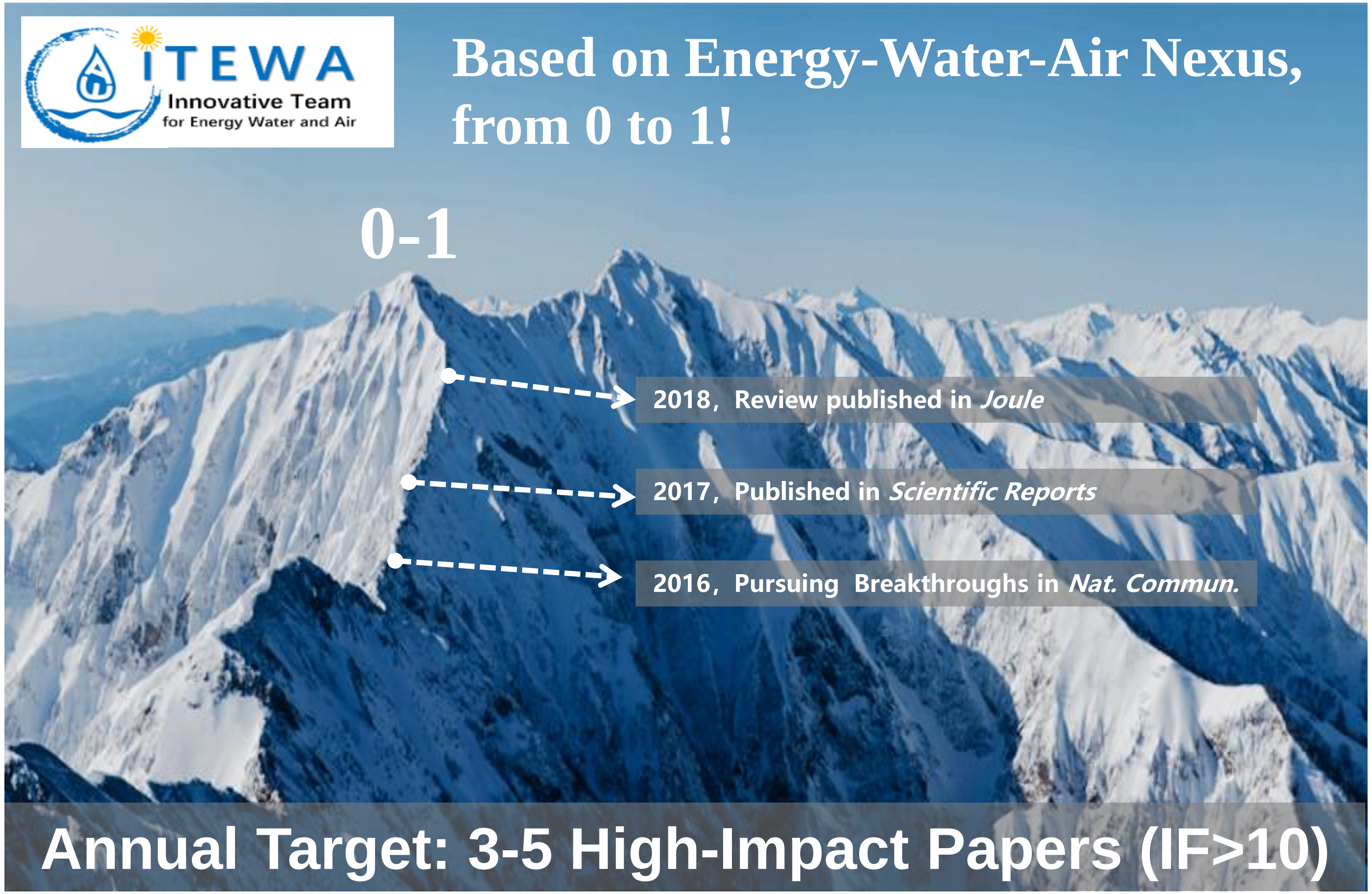
Progress and expectation of atmospheric water harvesting. *Joule*. 2018; 2(8): 1452-75.

The foundation of ITEWA

September 2018: Established Innovation Team, Collaborated with World-Leading Research Groups to Expand Academic Vision



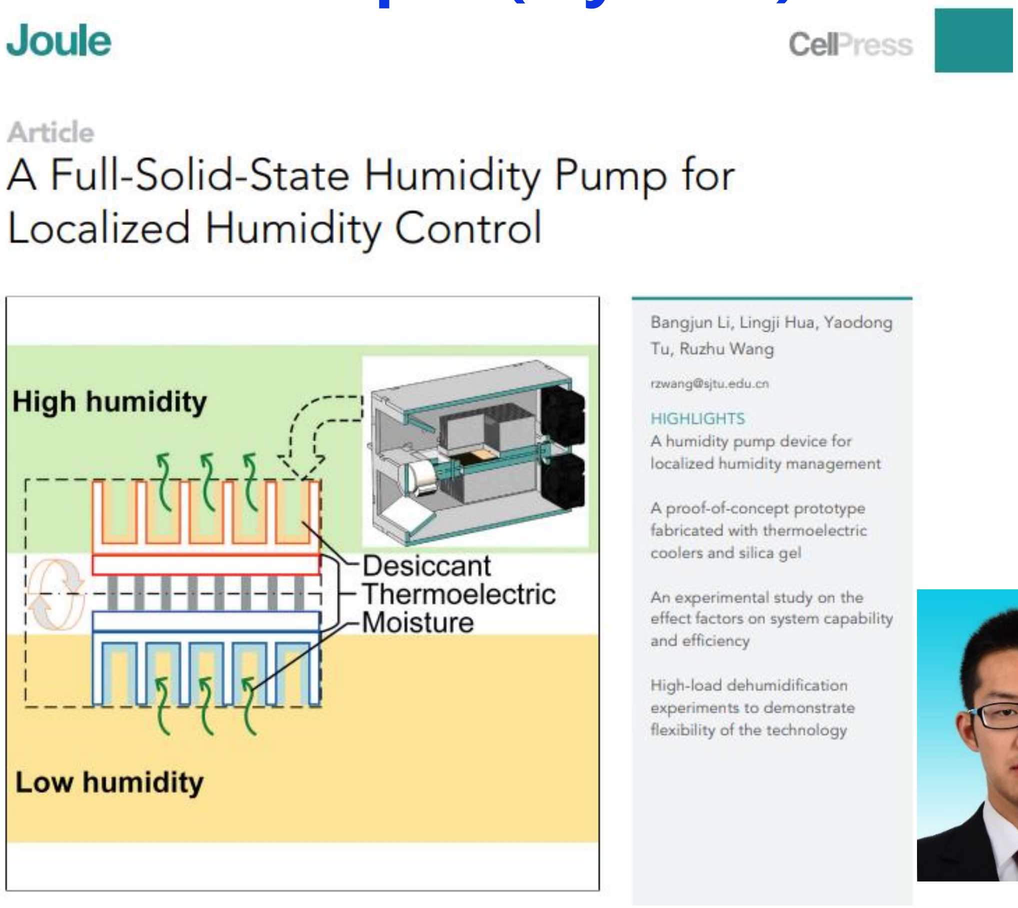
The Three Fundamental Elements for Human Survival: Energy, Water, and Air



Contents

Exploration

April 2019: Completion of the First Research Paper (2 years)


Joule

CellPress

Article

A Full-Solid-State Humidity Pump for Localized Humidity Control

Bangjun Li, Lingji Hua, Yaodong Tu, Ruzhu Wang

rzwang@sjtu.edu.cn

HIGHLIGHTS

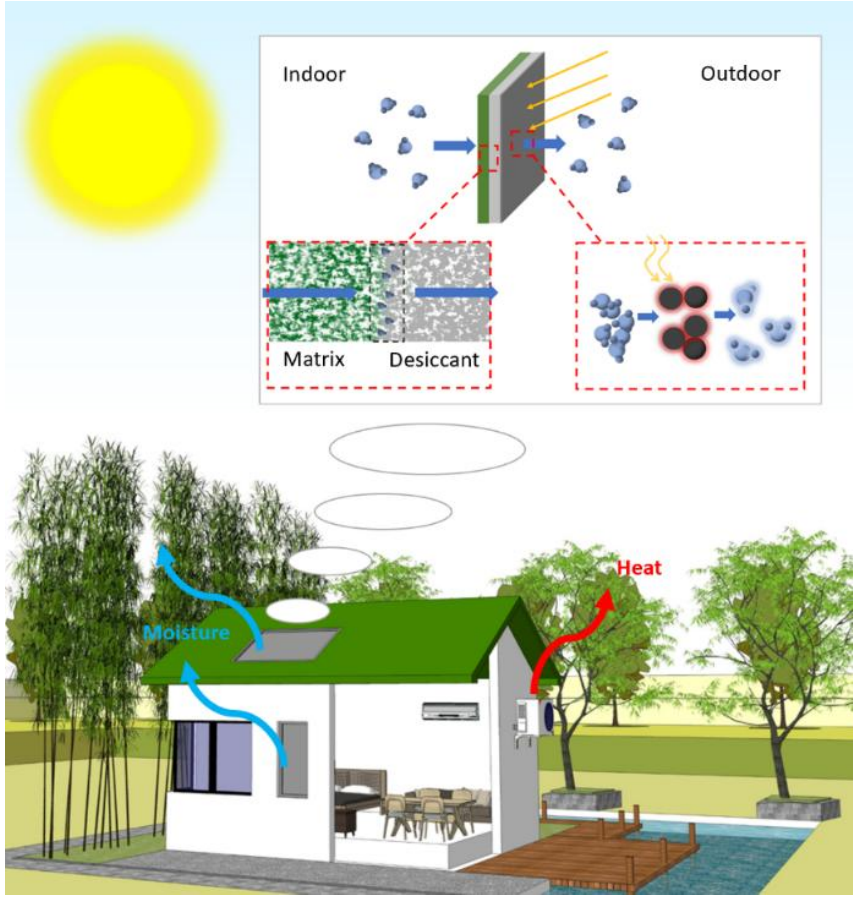
A humidity pump device for localized humidity management

A proof-of-concept prototype fabricated with thermoelectric coolers and silica gel

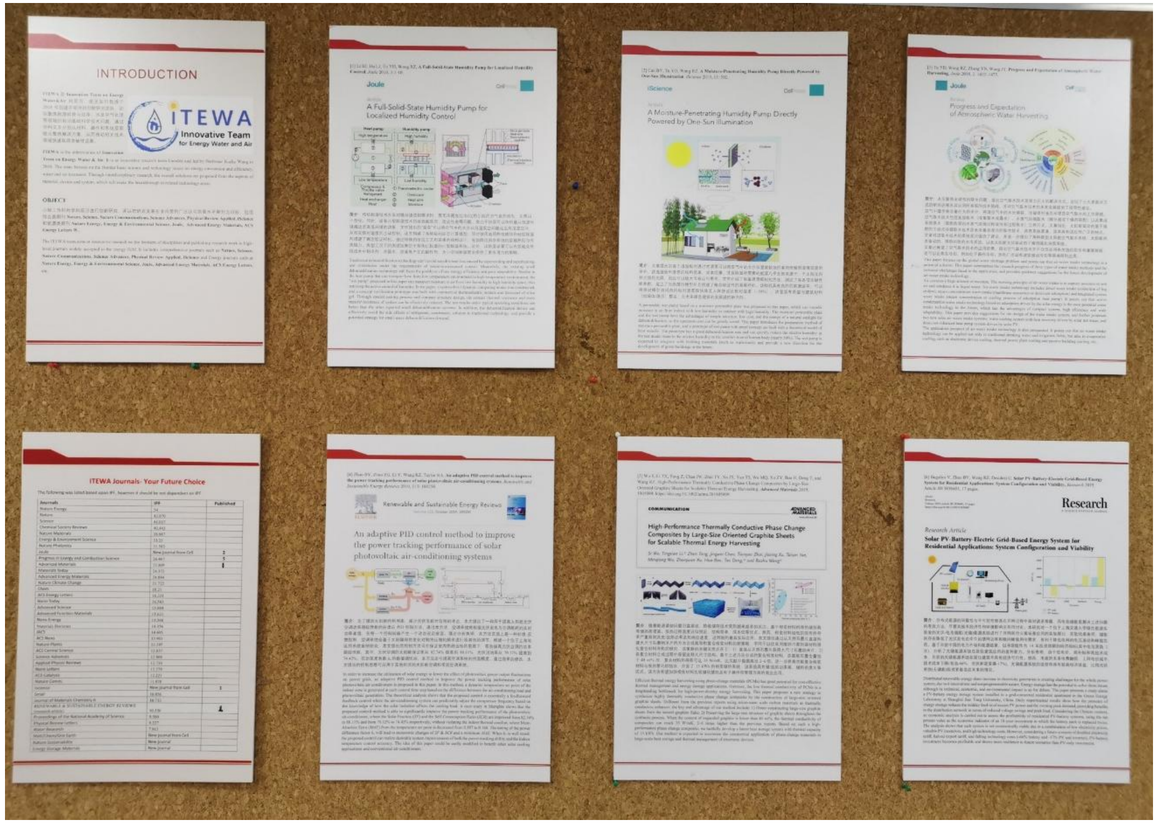
An experimental study on the effect factors on system capability and efficiency

High-load dehumidification experiments to demonstrate flexibility of the technology

May 2019: Second Research Paper *iScience*



June 2019: ITEWA Laboratory

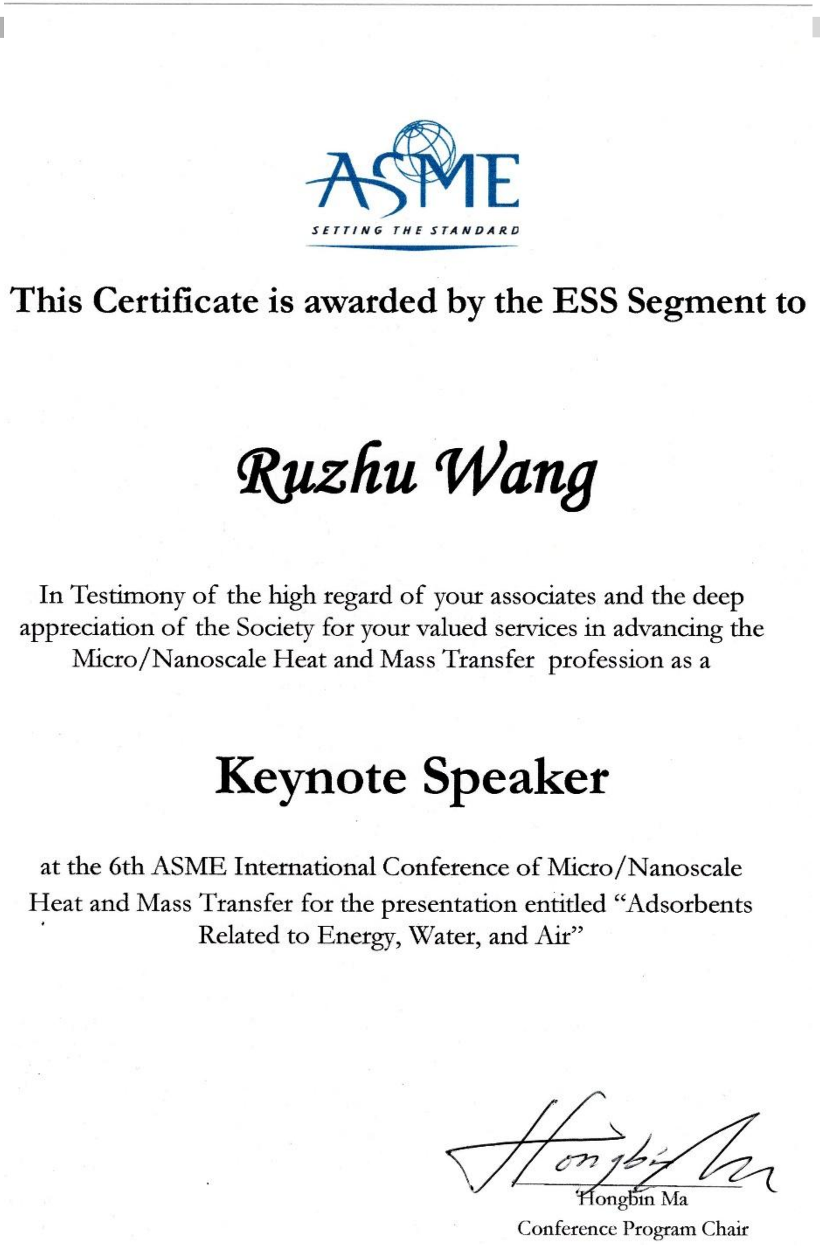


Adsorbents related to energy, water, and air

Ruzhu WANG

Shanghai Jiao Tong University

6th ASME International Conference of Micro-Nano Scale Heat and Mass Transfer, Sweetland Hotel, Dalian, China, July 8-10,2019



ASME
SETTING THE STANDARD

This Certificate is awarded by the ESS Segment to

Ruzhu Wang

In Testimony of the high regard of your associates and the deep appreciation of the Society for your valued services in advancing the Micro/Nanoscale Heat and Mass Transfer profession as a

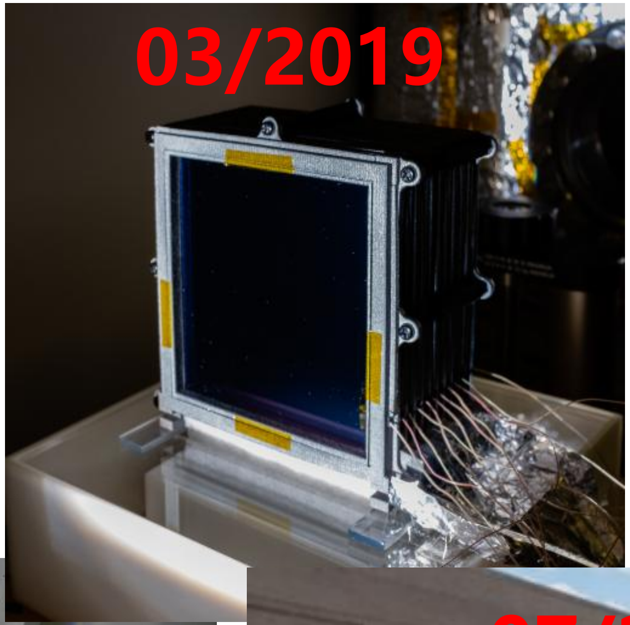
Keynote Speaker

at the 6th ASME International Conference of Micro/Nanoscale Heat and Mass Transfer for the presentation entitled "Adsorbents Related to Energy, Water, and Air"

Hongbin Ma
Conference Program Chair

Exploration


上海交通大学
Shanghai Jiao Tong University
太阳能蒸汽发生
Solar Vapor Generation
徐震原
2018-05-30



Exploration

October 2019: Breakthrough in Advanced Materials (Submission-to-Acceptance Timeline Exceeding One Year)

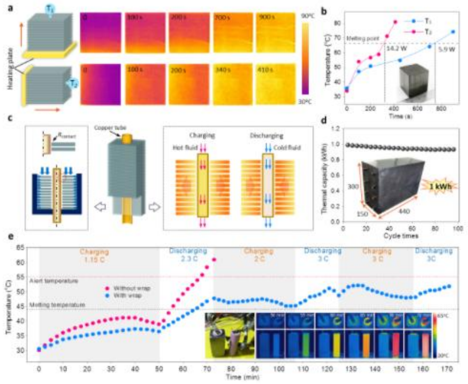
COMMUNICATION

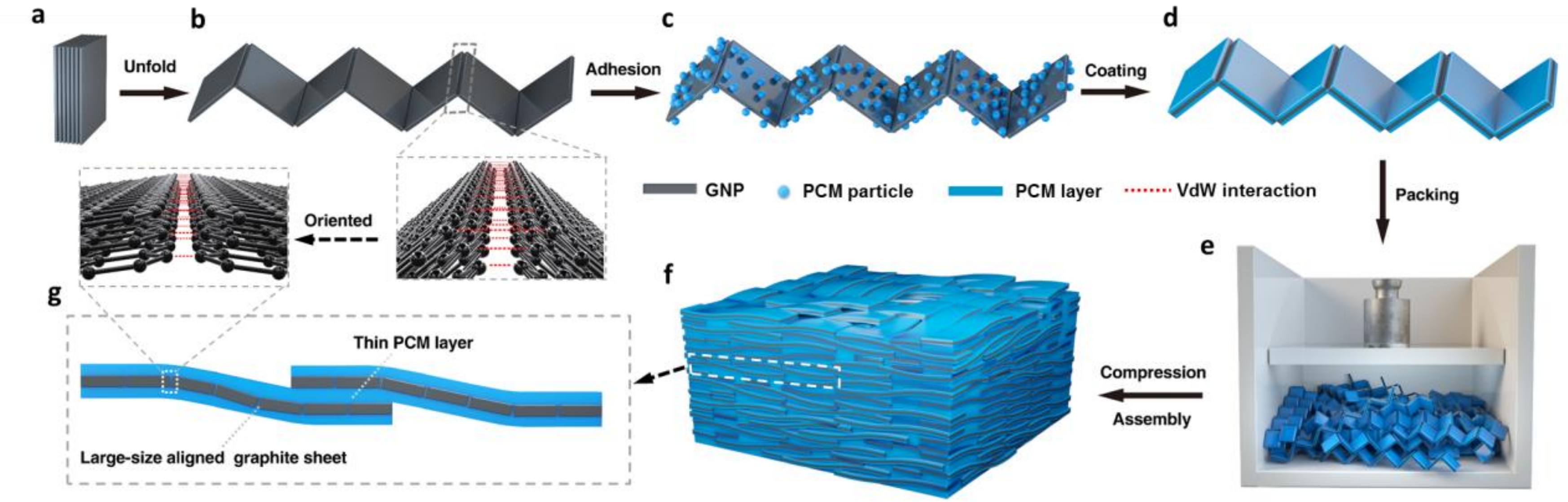
ADVANCED MATERIALS

www.advmat.de

High-Performance Thermally Conductive Phase Change Composites by Large-Size Oriented Graphite Sheets for Scalable Thermal Energy Harvesting

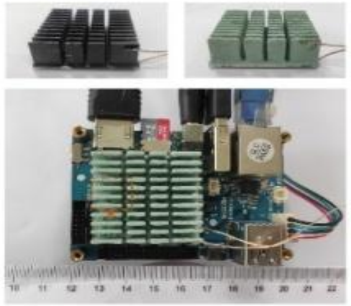
Si Wu, Tingxian Li, Zhen Tong, Jingwei Chao, Tianyao Zhai, Jiaxing Xu, Taisen Yan, Minqiang Wu, Zhenyuan Xu, Hua Bao, Tao Deng,* and Ruzhu Wang**

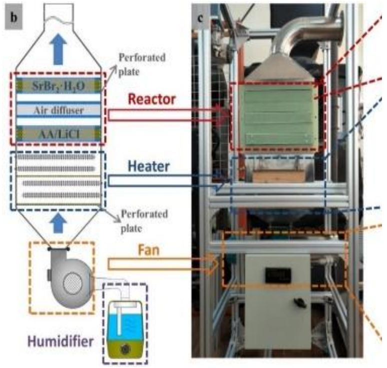


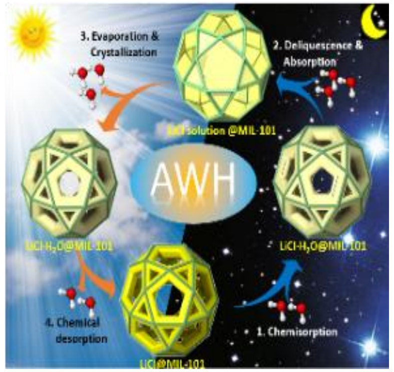


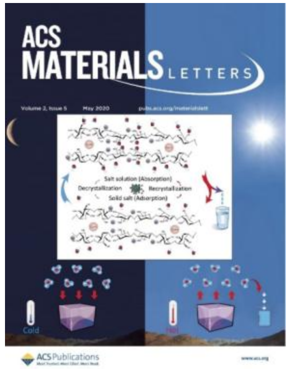
Surge in Academic Publications: The Spring Festival in 2020

January Joule、Energy Storage Materials、
February Energy & Environmental Science，Angewandte Chemie
March Energy Storage Materials、 ACS Materials Letters









07/2020:MIT International Colloquia on Thermal Innovations

Invited Online Lecture Series Presentation during COVID-19 by Prof. Gang Chen and Prof. Evelyn N. Wang at MIT.

International Colloquia on Thermal Innovations

Extracting Water from Air

Energy-Water-Air Nexus

Ruzhu WANG

Institute of Refrigeration and Cryogenics

Engineering Research Center of Solar Energy, MOE China

Shanghai Jiao Tong University

July 8, 2020

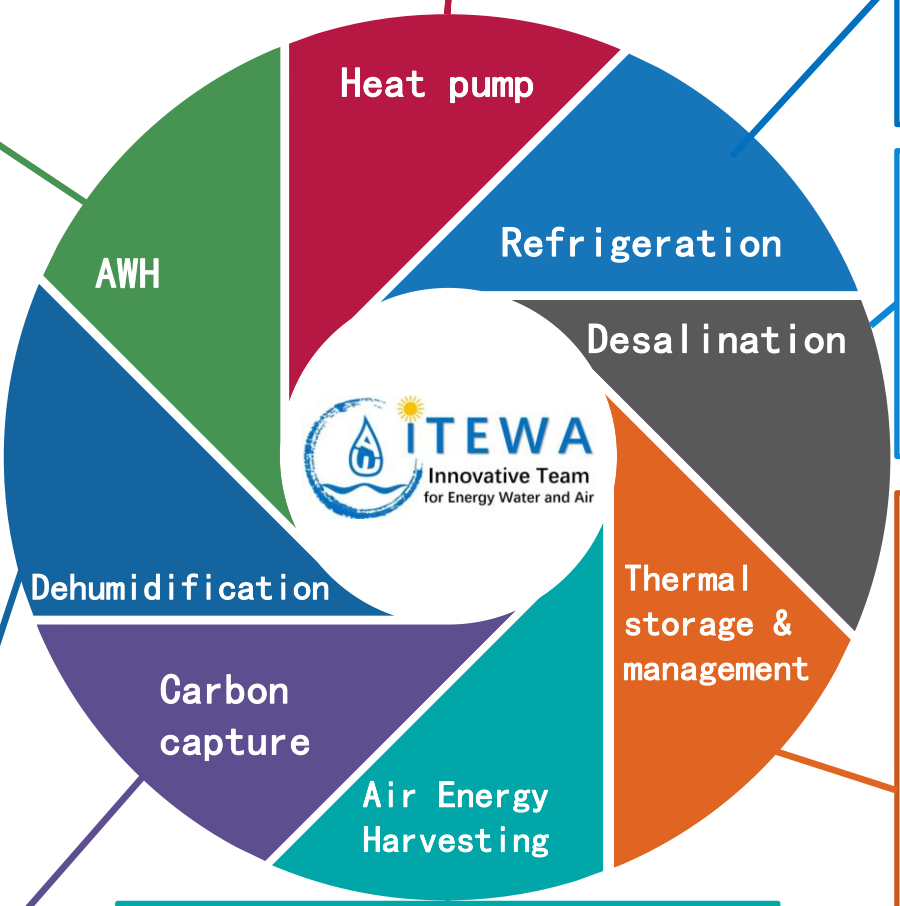
ITEWA Innovative Team for Energy Water and Air

Achievements of ITEWA Since Establishment

- Nat Rev Mater, 2024, 9, 699
- Nat Water, 2024, 2, 663
- Nat Water, 2023, 1, 971
- Joule, 2024, 8, 280-286
- Joule, 2021, 7, 1678-1703
- Joule, 2018, 8, 1452-1475
- Energy Environ Sci, 2024, 17, 1083
- Energy Environ Sci, 2024, 17, 4988
- Energy Environ Sci, 2022, 15, 4867
- Energy Environ Sci, 2022, 15, 3223
- Energy Environ Sci, 2021, 14, 5979
- Nat Commun, 2024, 15, 7678
- Nat Commun, 2022, 13, 5406
- Nat Commun, 2022, 13, 6771
- Adv Mater, 2024, 2408977
- Adv Mater, 2023, 2210957
- Adv Mater, 2023, 2302038
- Angew Chem Int Edit, 2020, 59, 5202
- Adv Funct Mater, 2024, 2402839
- Adv Funct Mater, 2024, 2407127

- Energy Environ Sci, 2024, 17, 2081
- Energy Environ Sci, 2024, 17, 6943
- Engineering, 2023, 23, 13
- DeCarbon, 2024, 3, 100033

- Science, 2023, 380, 458
- Nat Energy, 2023, 8, 226
- Energy Environ Sci, 2024, 17, 2336
- Nat Commun, 2022, 13, 193
- Adv Energy Mater, 024, 2402667
- Device, 2023, 1, 100122
- Sci Bull, 2023, 68, 1493



- Nat Water, 2023, 1, 391
- Joule, 2023, 10, 2274
- Energy Environ Sci, 2024, In press
- Energy Environ Sci, 2023, 16, 5325
- Energy Environ Sci, 2020, 13, 830
- Nat Commun, 2024, 15,7980
- Nat Commun. 2022, 13, 849

- Joule, 2020, 2, 435
- Energy Environ Sci, 2024, 17, 800
- Nat Commun, 2023, 14, 8060
- Adv Mater, 2024, 2402897
- Adv Mater, 2023, 2310177
- Adv Mater, 2019, 31, 1905099
- Acs Energy Lett, 2023, 8, 1921
- Acs Energy Lett, 2023, 8, 5184
- Acs Energy Lett, 2021, 6, 1795
- Acs Central Sci, 2020, 6, 1542
- Matter, 2023, 6, 2490
- Matter, 2021, 4, 3385
- Acs Mater Lett, 2023, 5, 2019
- Nano Energy, 2021, 89, 106338
- Energy Storage Mater, 2024, 71, 103602

- Joule, 2022, 7, 1390
- Joule, 2019, 6, 1427
- Chem Eng J, 2023, 452, 139116
- Small Struct, 2023, 4, 2300055

- Chem Soc Rev, 2022, 51, 6574
- Matter, 2024, 7, 123
- Device, 2024, 2, 100510
- Adv Sci, 2023, 10, 2207253

- Nat Rev Mater, 2024, 9, 722
- Nat Nanotechnol, 2024, 19, 1243
- Matter, 2023, 6, 19–22
- Nano Energy, 2024, 126, 109673

Contents

Research Focus of ITEWA Team

What we have done? **0-1** and **1-100** in Energy-Water-Air-Food nexus.

Research Focus of ITEWA Team

01. Atmospheric Water Harvesting

What we have done? **0-1** and **1-100** in Energy-Water-Air-Food nexus.

AWH1: Target design R&D, The origin of ITEWA establishment

Jiayun Wang
First author

Freshwater Shortage

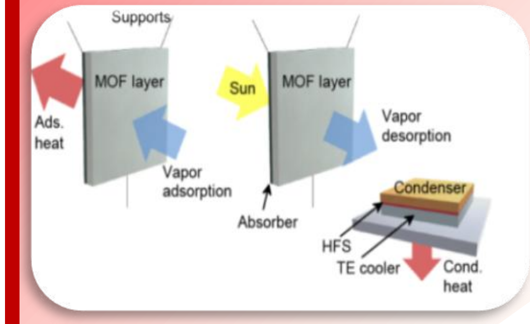
South China Sea Safety

Belt &Road Initiative

SAWH

- Off-grid water production
- Zero energy consumption
- Modular & Portable
- Disaster emergency water supply

Kim et.al 2017 Science



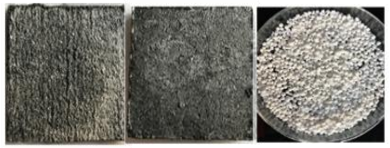
0-1 VS 1-100

Energy, 2018, 165, 387-395

Energy, 2017, 138, 542-551

ATE 2017,121,941-950
ATE 2017, 127, 1608-1616

ATE 2016,100,893-901



ACF Graphite Silica gel

2014
Material selection

2015
0.3 kg water
open system
Solar utilization

2016
14.5 kg water
Semi-open system
Electric heating

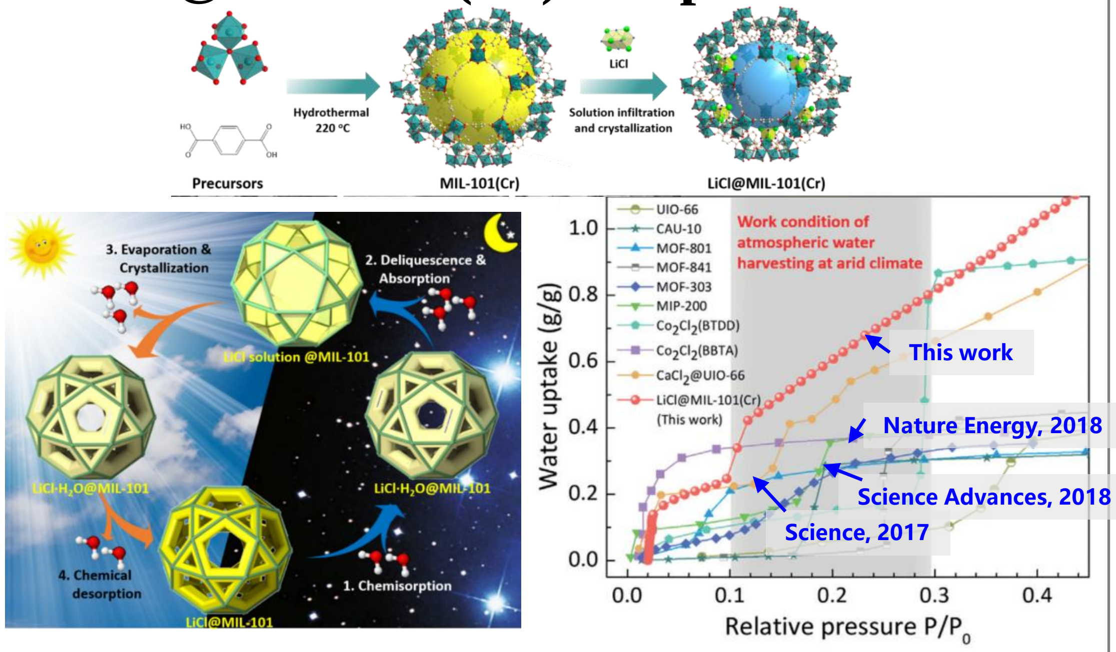
2017
50 kg water
Intelligent system
Honeycomb-type
adsorbent bed

AWH2: MOF-based composite for efficient AWH

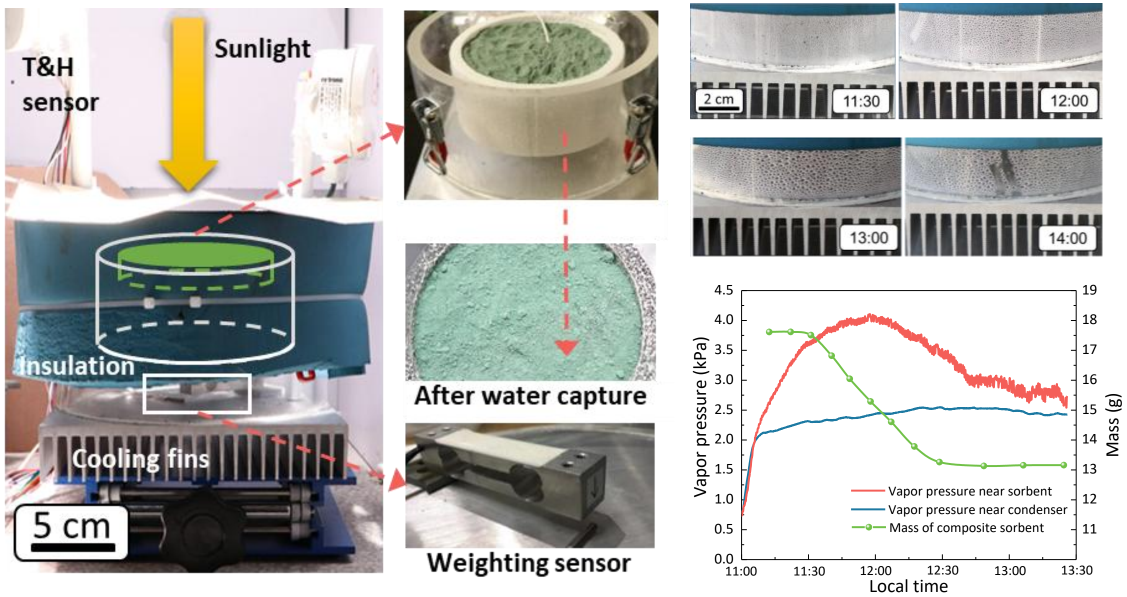
First author

Angew. Chem. Int. Ed.: Efficient solar-driven water harvesting from arid air with metal–organic frameworks modified by hygroscopic salt. 2020, 59, 5202-5210. **(ESI highly cited paper)**

❑ LiCl@MIL-101(Cr) composite sorbent



❑ Passive solar-driven AWH device



Developed a high-performance composite sorbent for efficient AWH by confining hygroscopic salt in a metal-organic framework matrix (LiCl@MIL-101(Cr))

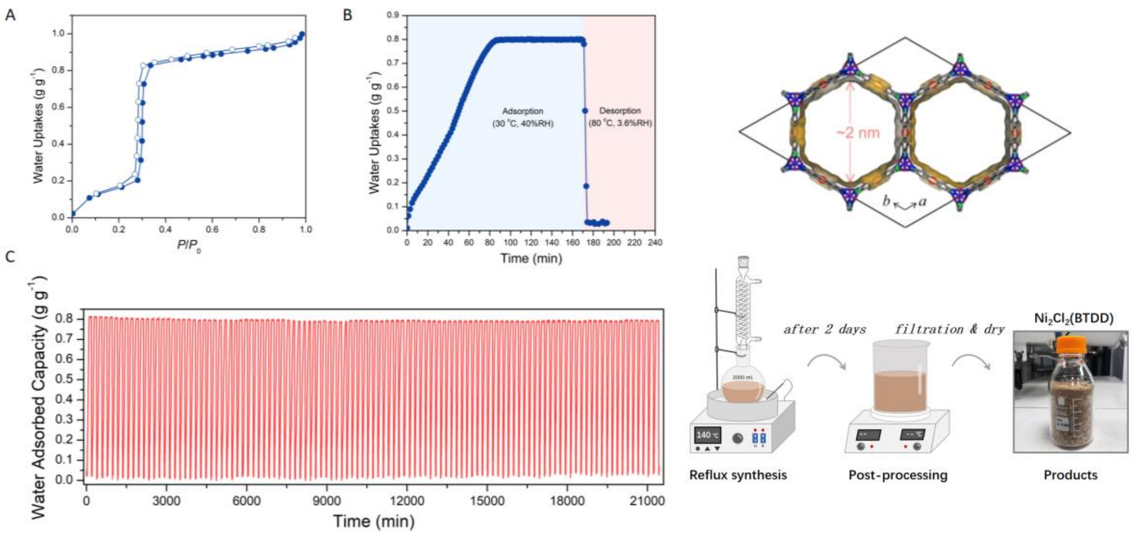
AWH3: Modular MOF AWH device and reflux synthesis of Ni_2Cl_2(BTDD)

Device: High-performance solar-driven MOF AWH device with ultra-dense integrated modular design and reflux synthesis of Ni2Cl2(BTDD), 2023, 1, 3, 100058

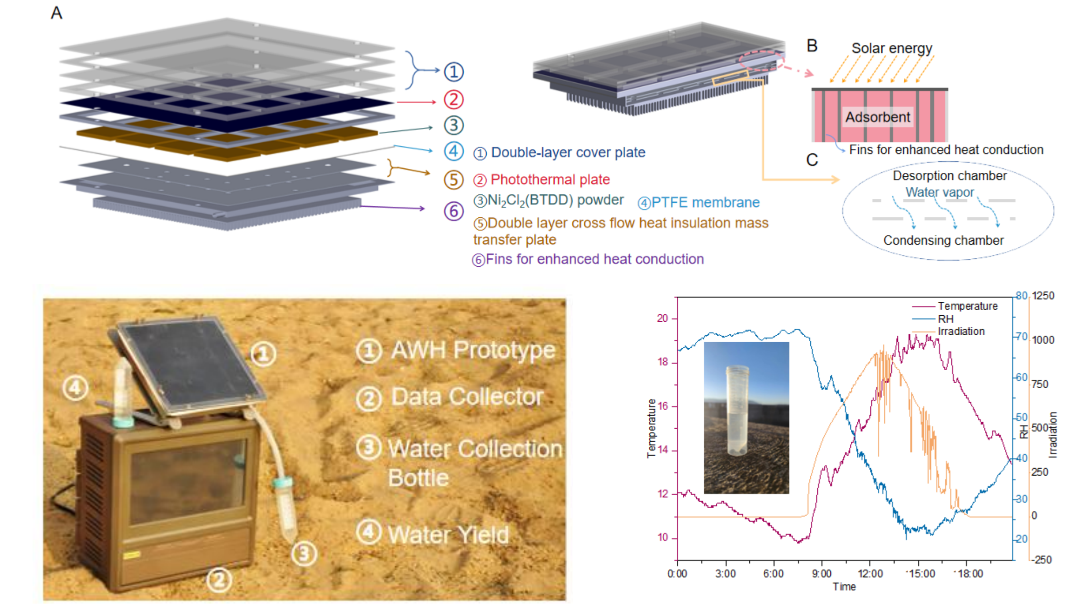
Zhao Shao

First author

❑ Reflux synthesis of Ni_2Cl_2(BTDD)



❑ Modular solar-driven MOF AWH device



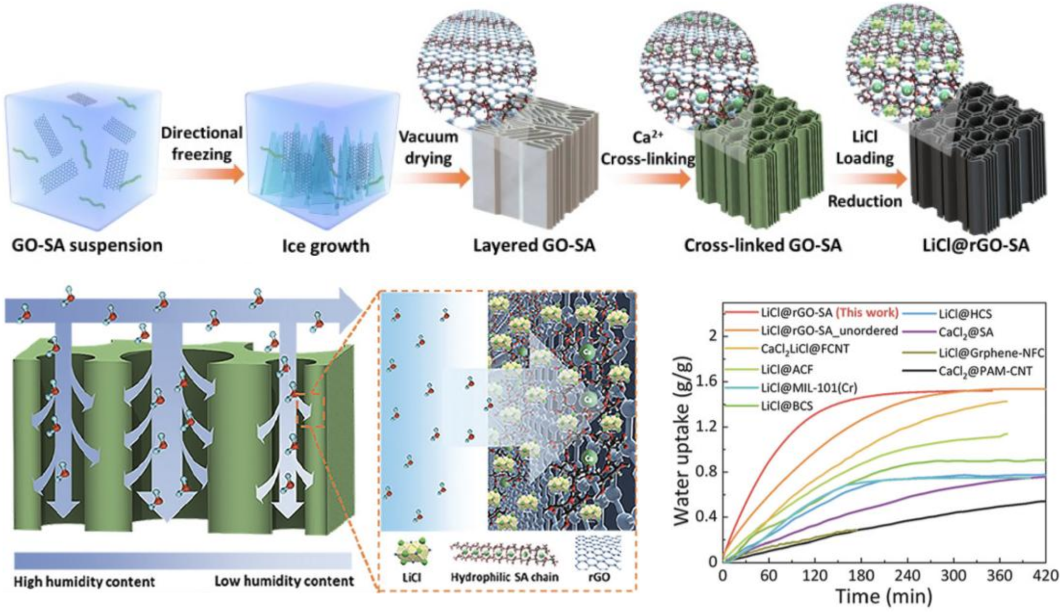
The proposed device with an integrated modular design showed ultrahigh water harvesting per unit volume of 23 L m^{-3} and water yield up to 840.5 g m^{-2} under one sun in 7 hours.

AWH4: Vertically aligned porous sorbent for rapid-cycling AWH

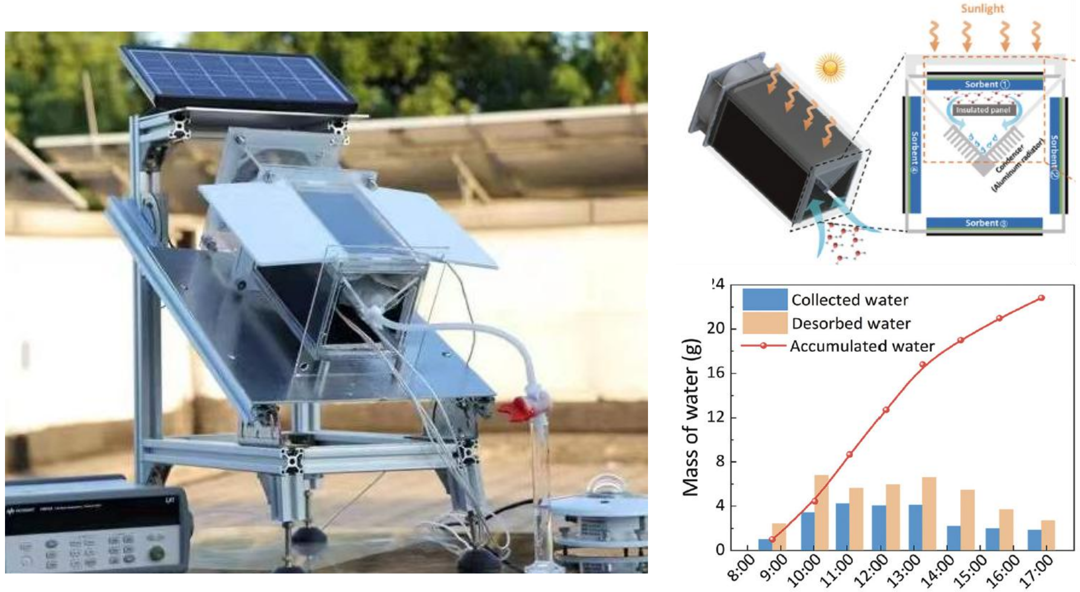
Jiaxing Xu
First author

Energy & Environmental Science: Ultrahigh solar-driven atmospheric water production enabled by scalable rapid-cycling water harvester with vertically aligned nanocomposite sorbent. 2021, 11, 5979-5994. **(ESI highly cited paper and ESI hot paper)**

❑ LiCl@rGO-SA nanocomposite sorbent



❑ Solar-driven rapid-cycling AWH device



Developed a vertically aligned nanocomposite sorbent and a rapid-cycling AWH device,
realizing eight water capture-collection cycles and high water productivity up to 2.3 L/m²/day

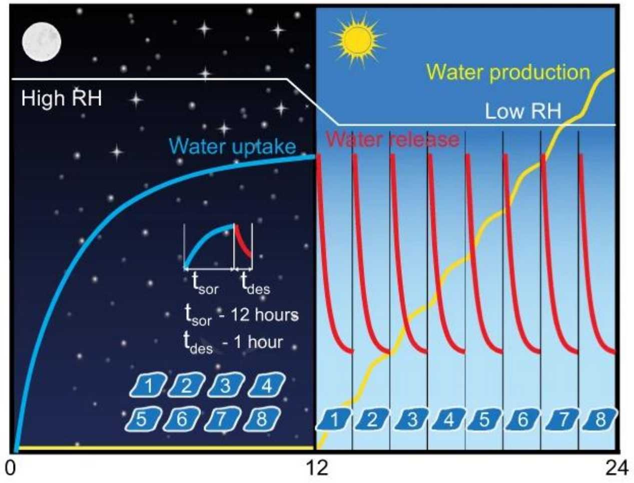
AWH5: Batch-processing method for high-yield AWH in arid area

He Shan

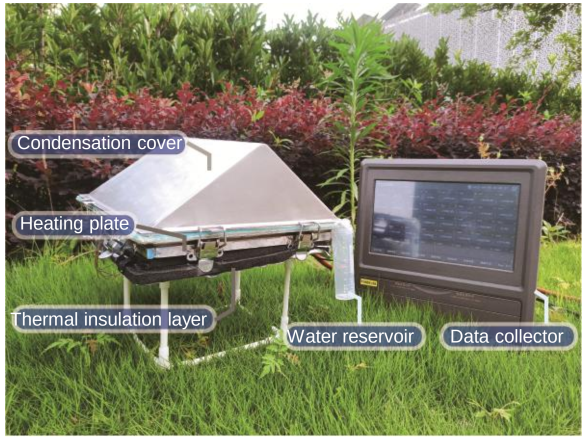
First author

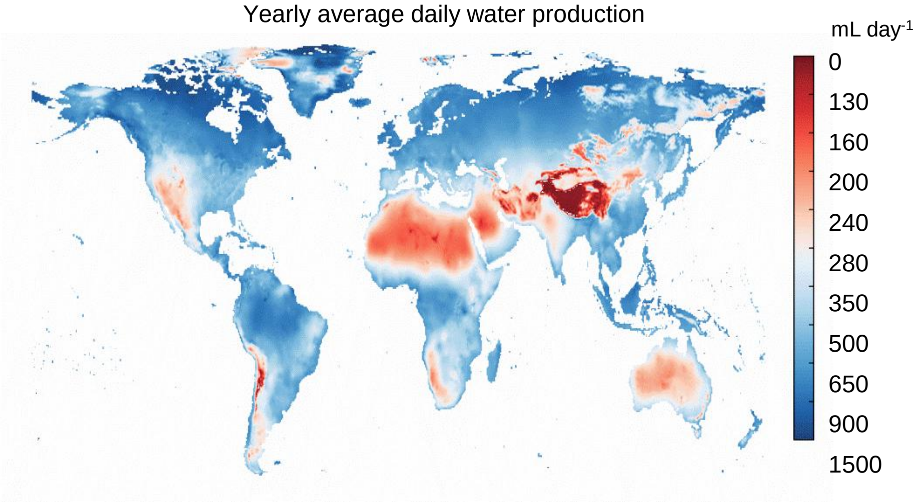
Nature Communications: Exceptional water production yield enabled by batch-processed portable water harvester in semi-arid climate. 2022;13(1):5406.

❑ Batch-processing method



❑ Real field test in Lanzhou and its global potential





A new batch processing is developed for the climates in arid areas, which matches the sorption rate and the desorption rate, thereby breaking through the water production limit of AWH.

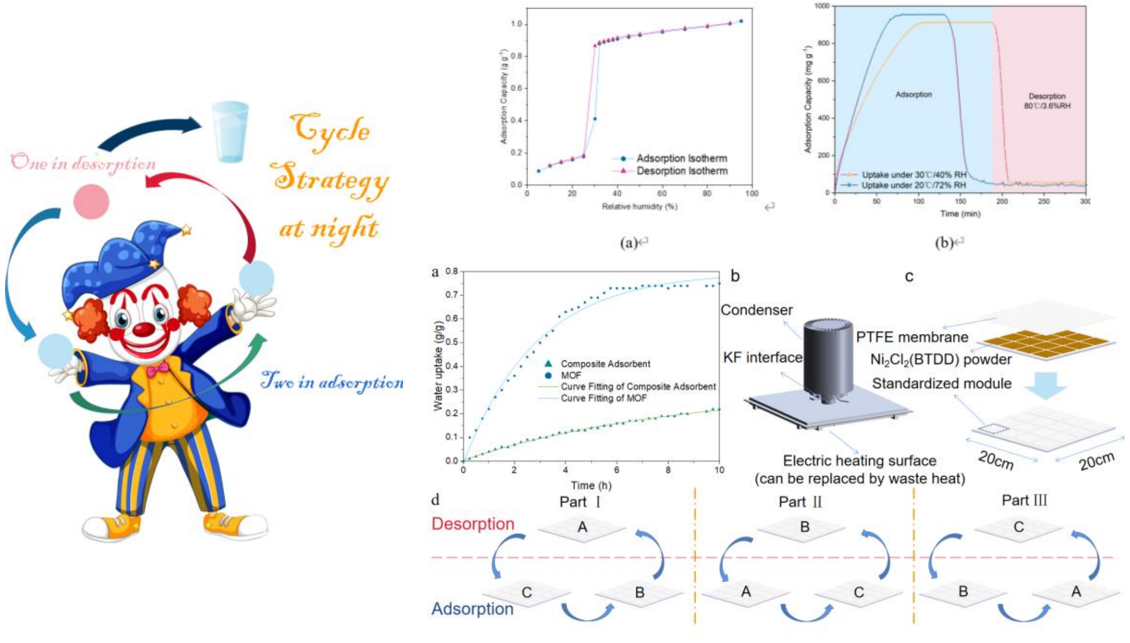
AWH6: Modular all-day continuous thermal-driven AWH

Zhao Shao

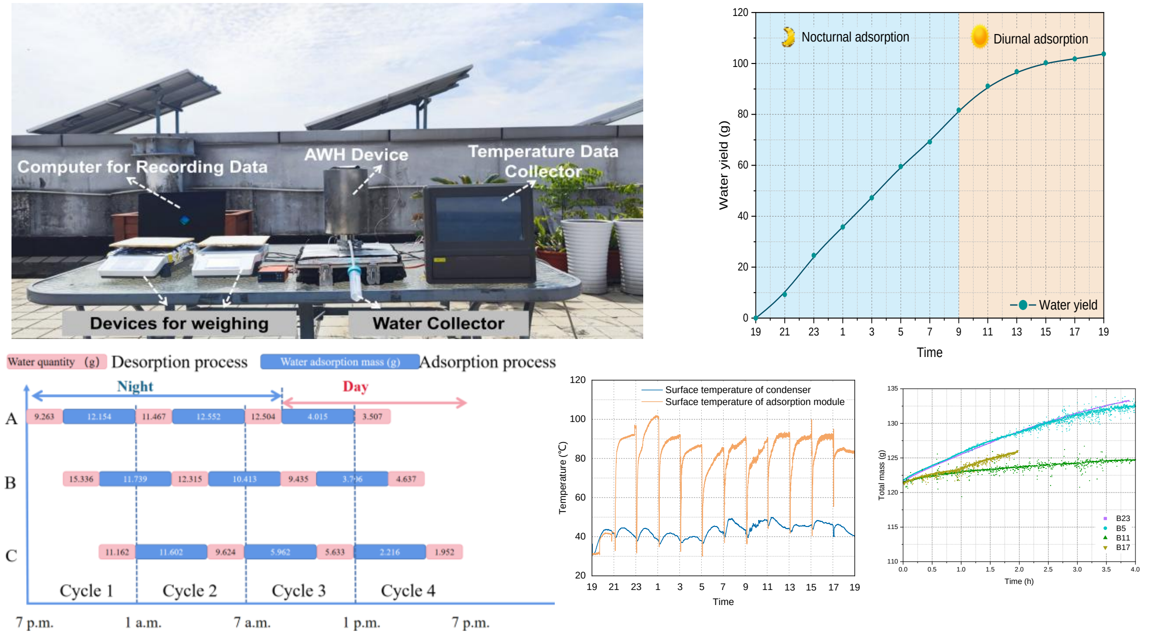
First author

Applied Physics Reviews: Modular all-day continuous thermal-driven atmospheric water harvester with rotating adsorption strategy. 2023, 10 (4): 041409.

❑ Rotating adsorption strategy

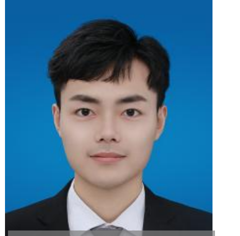


❑ Continuous thermal-driven AWH



A rotational operation strategy based on adsorption-desorption kinetic matching was developed, then an efficient waste-heat driven AWH was developed, which achieved continuous water yield for 12 cycles per day driven by low-grade heat and high water production performance of 2.11 L_{water} kg_{MOF}^{-1} day^{-1}

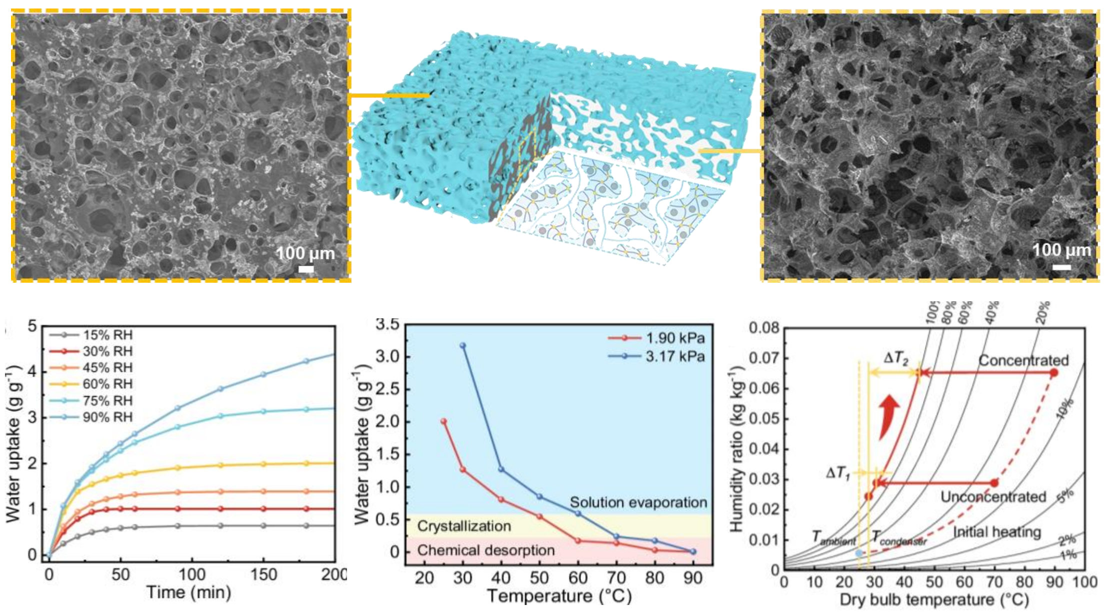
AHW7: Interconnected porous gel for highly efficient continuous SAWH



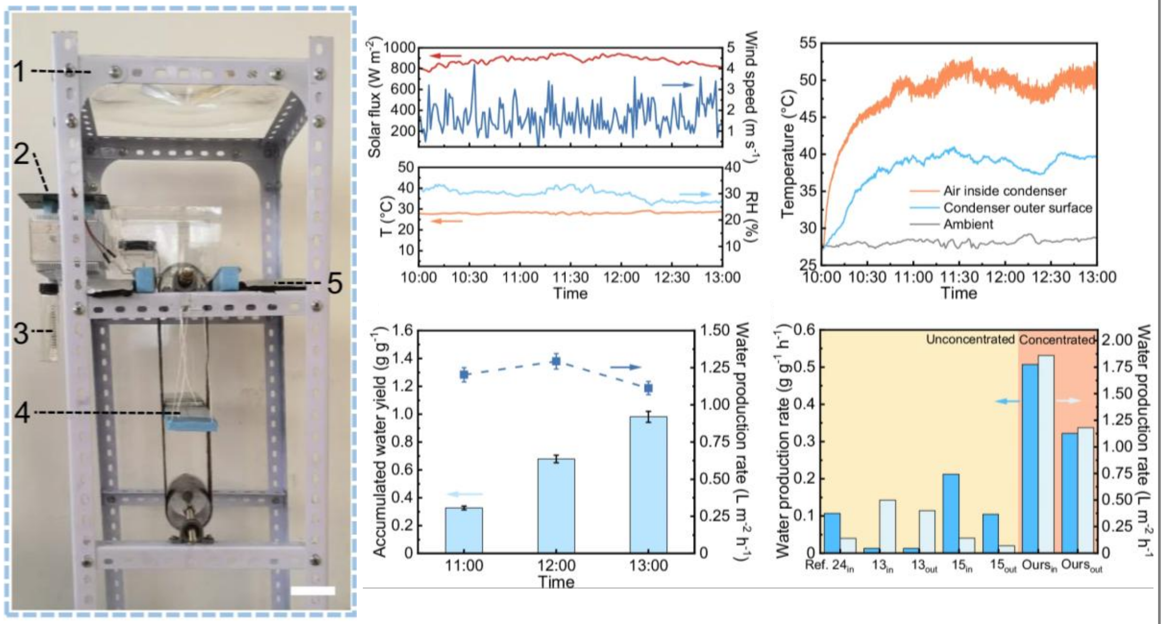
Xinge Yang
First author

Nature Communications: Enhanced continuous atmospheric waterharvesting with scalable hygroscopic gel driven by natural sunlight and wind. 2024, 15(1), 7678.

❑ Hygroscopic interconnected porous gel



❑ Solar-wind combined driven SAWH device



Developed an interconnected porous gel and a solar-wind combined driven AWH device, realizing high water productivity up to 14.9 L/m²/day and high energy utilization efficiency of 25.7%

Research Focus of ITEWA Team

02. Electronic Thermal control

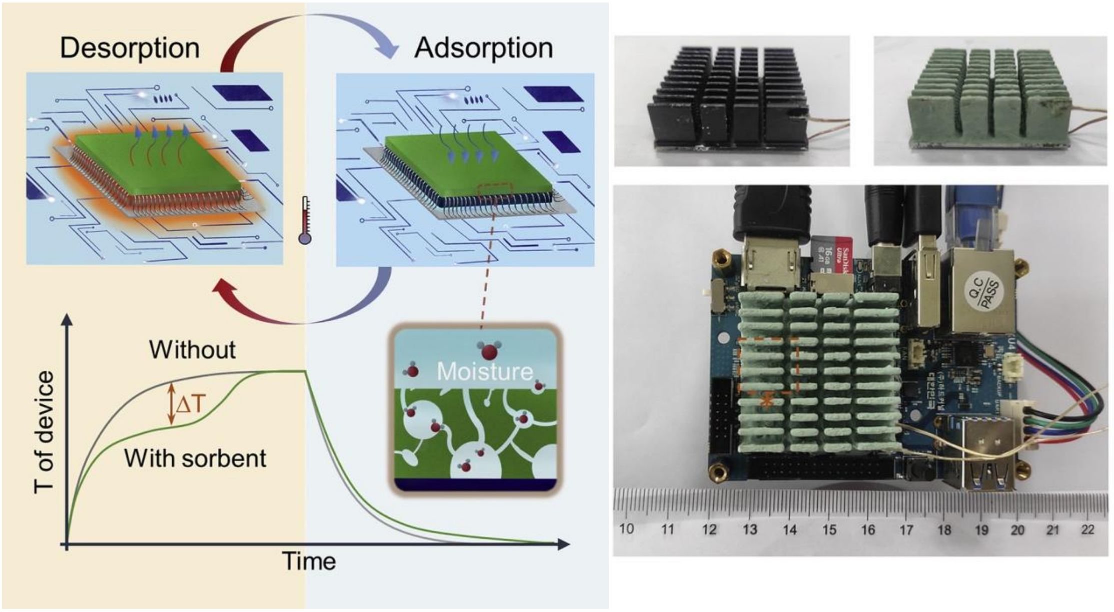
What we have done? **0-1** and **1-100** in Energy-Water-Air-Food nexus.

ETC1: Cooling electronic devices using moisture desorption

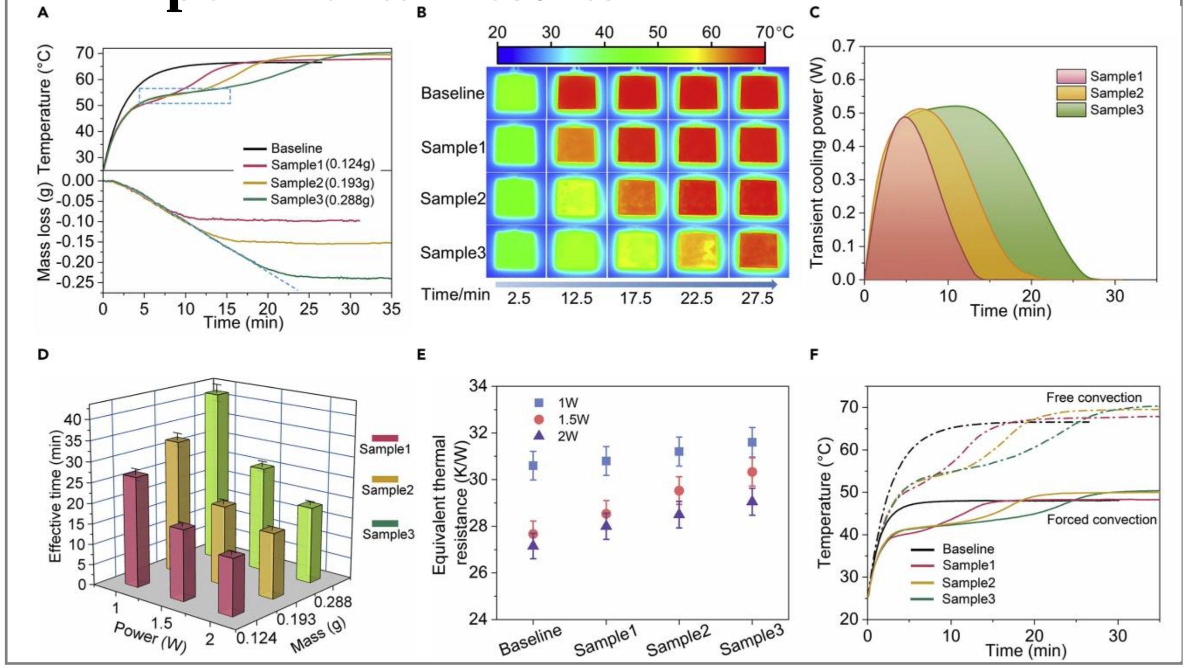
First author
Chenxi Wang

Joule: A thermal management strategy for electronic devices based on moisture sorption-desorption processes. 2020, 4(2): 435-447.

❑ Working principle & Experimental setup



❑ Experimental results



Demonstrate a passive thermal management strategy through desorption process

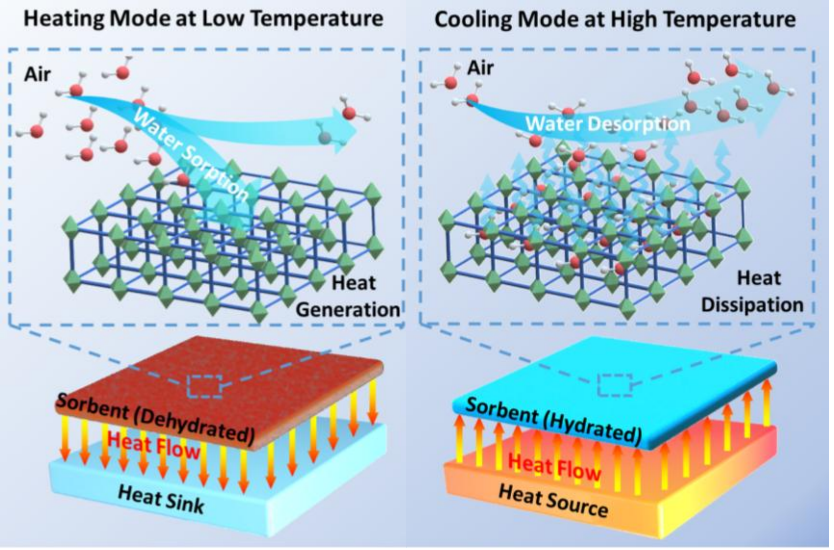
Maximum temperature drop of 8.6 ^{o}C, equivalent enthalpy of 1,950 J/$g_{coating}$

ETC2: Smart battery thermal management based on water sorption

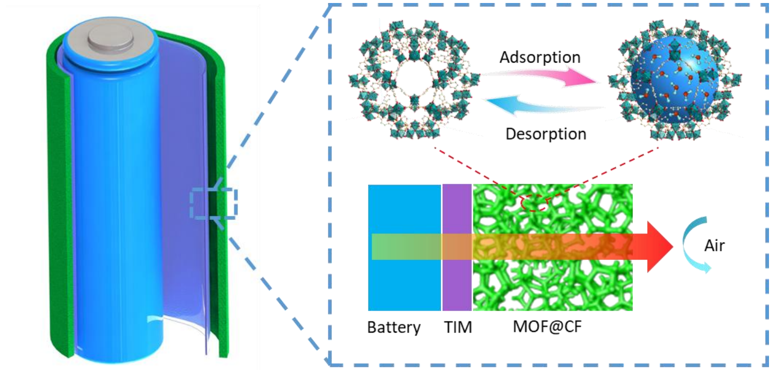
Jiaxing Xu

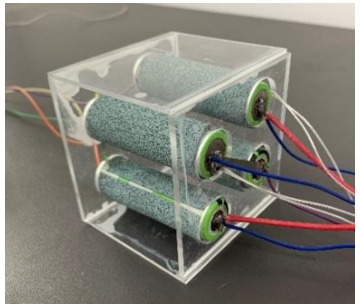
First author

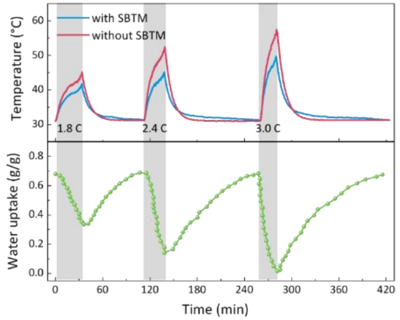
ACS Central Science: Near-Zero-Energy Smart Battery Thermal Management Enabled by Sorption Energy Harvesting from Air. 2020, 6, 1542–1554. **(Cover Paper)**

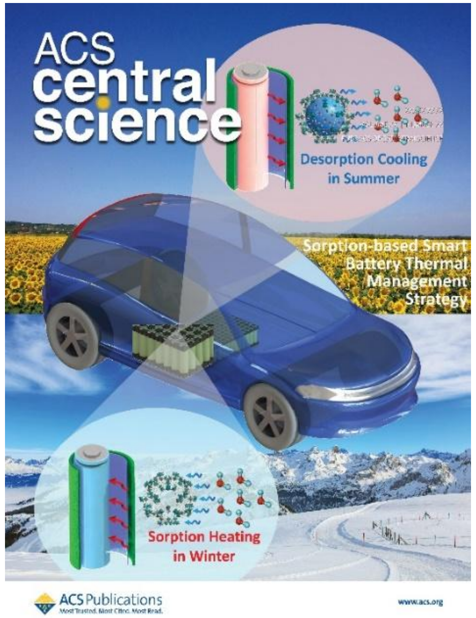


Smart battery thermal management strategy based on sorption energy harvesting from air









Cover Paper

Proposed a near-zero-energy smart BTM strategy: control the battery temperature below 45 °C, and realize self preheating with an increase in the battery capacity of 9.2%

ETC3: Cooling 5G base station via desorption

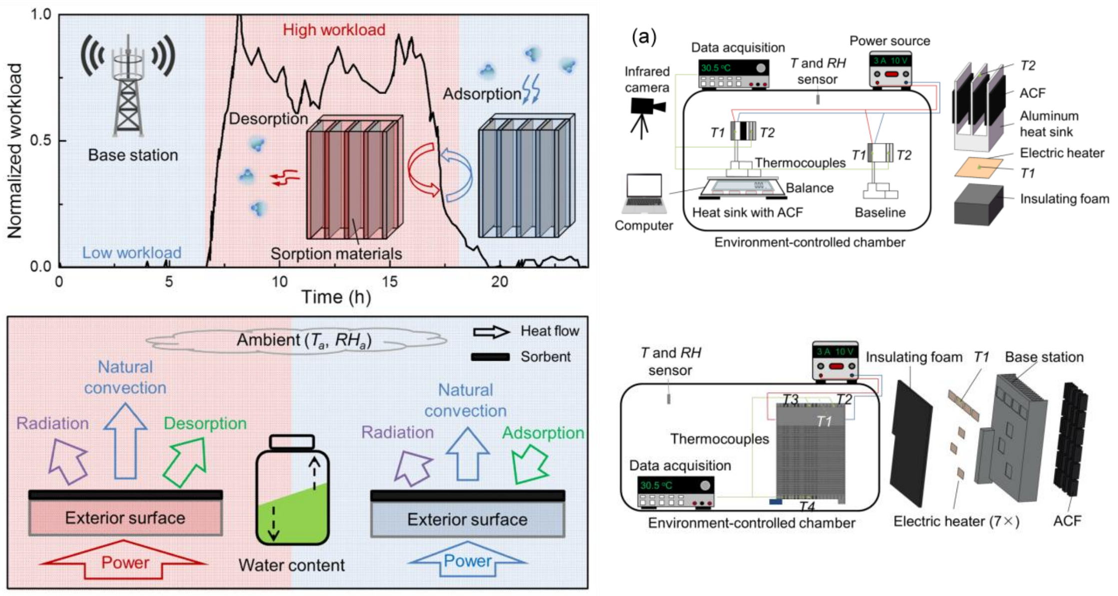
Haoran Liu

Jiaqi Yu

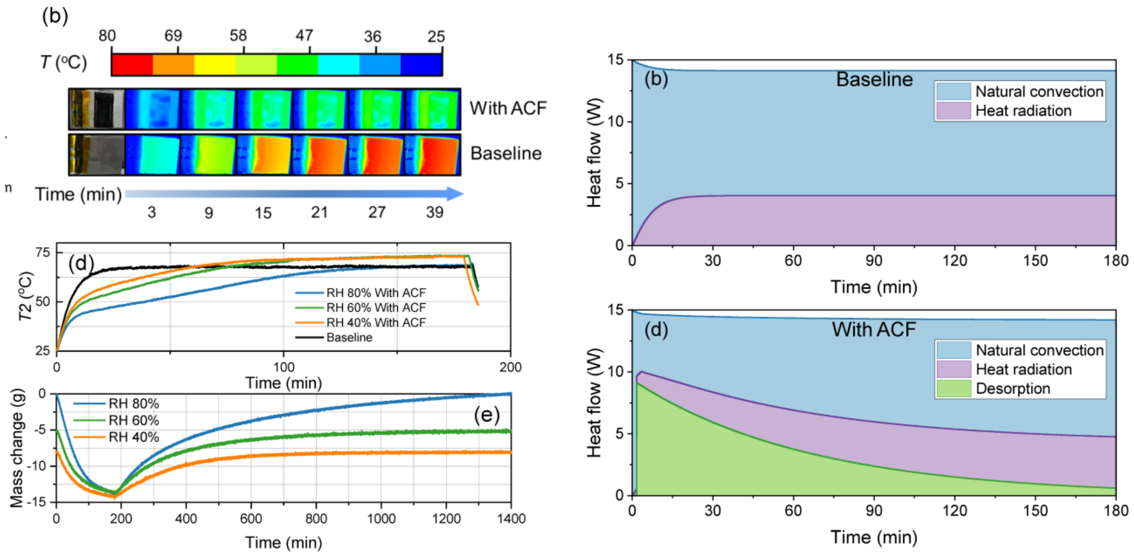
Co-first author Co-first author

Device: Passive thermal management of electronic devices using sorption-based evaporative cooling. 2023, 100122.

❑ Working principle & Experimental setup



❑ Experimental & simulation results



Evaluate the performance of sorption-based evaporative cooling on 5G base station

20 °C maximum temperature reduction, 602 W/m² maximum cooling power

ETC4: Passive thermal management of electronic devices

Device: Passive thermal management of electronic devices. 2025, 100684

Haoran Liu

First author

❑ Different cooling technologies

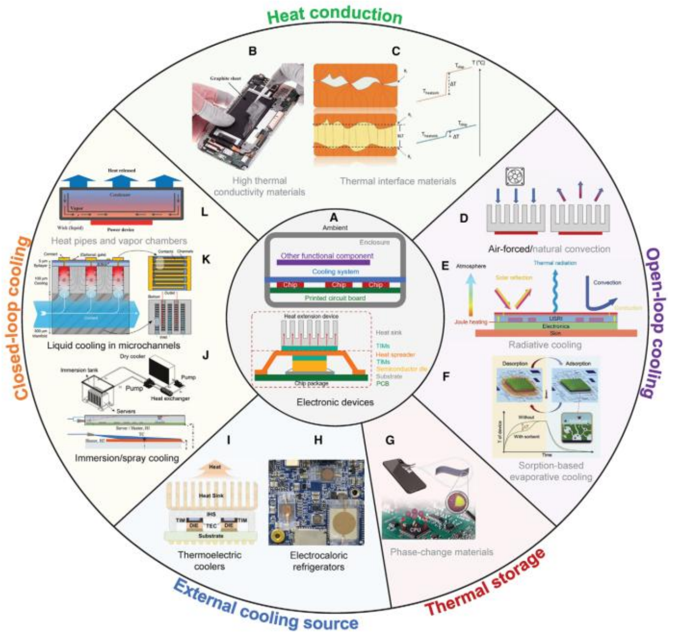
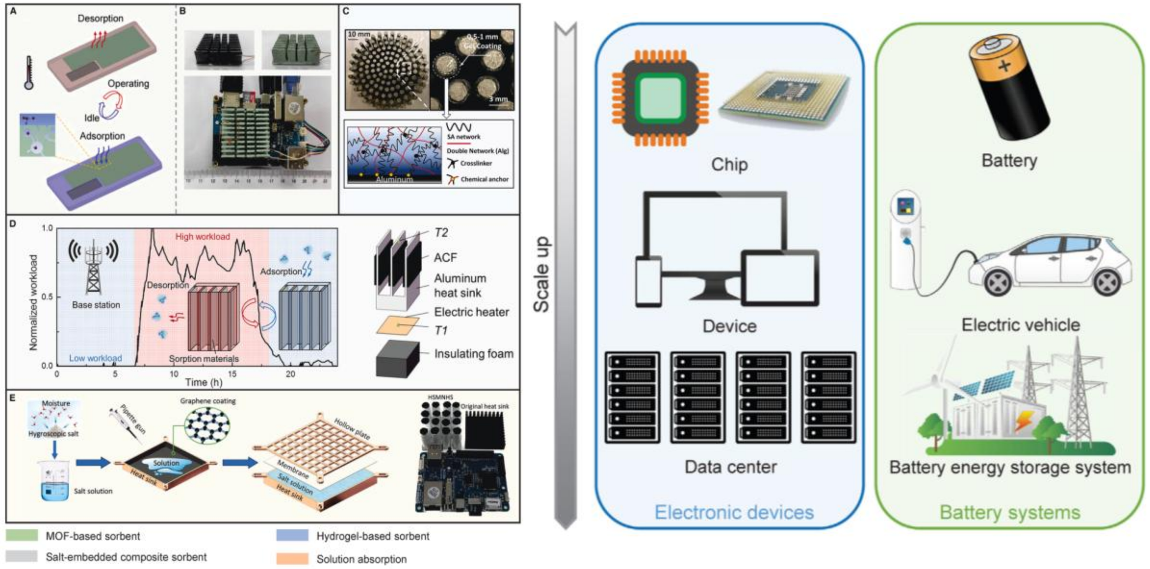


Table 1. Summary of different cooling technologies, corresponding physical variables, and approximate value

Cooling technologies	Physical parameter	Quantitative value (order of magnitude)
Soft-control cooling		
Control of source terms	Φ	N/A
Control of cooling systems	h	N/A
Hardware-based cooling		
Conduction		
Thermal interface materials[9]	k	~ 10 (W m^{-1} K^{-1})
High-thermal-conductivity materials[13]	k	$\sim 10^3$ (W m^{-1} K^{-1})
Closed-loop cooling		
Heat pipes and vapor chambers[14]	k	$\sim 10^4$ (W m^{-1} K^{-1})
Microchannel cooling[1,6]	h	10^4–10^5 (W m^{-2} K^{-1})
Immersion[43]	h	10^3–10^4 (W m^{-2} K^{-1})
Spray and jet impingement[20,23]	h	10^4–10^5 (W m^{-2} K^{-1})
Open-loop cooling		
Natural convection[44]	h	1–10 (W m^{-2} K^{-1})
Air-forced convection[44]	h	10–10^2 (W m^{-2} K^{-1})
Sorption-based evaporative cooling[45]	q_{ev}	10^2–10^3 (W m^{-2})
Sky radiative cooling[46]	q_{ra}	$\sim 10^2$ (W m^{-2})
External cold source		
Thermoelectric coolers[25]	Φ	$\sim 10^6$ (W m^{-2})
Electrocaloric refrigerators[26]	Φ	~ 10 (W g^{-1})
Thermal storage		
Phase-change materials[32]	c	phase-change enthalpy of $\sim 10^2$ (J g^{-1})

❑ Application in different devices



Summarize the classification, evaluation indexes , application scenarios, and key challenges of different thermal management technologies.

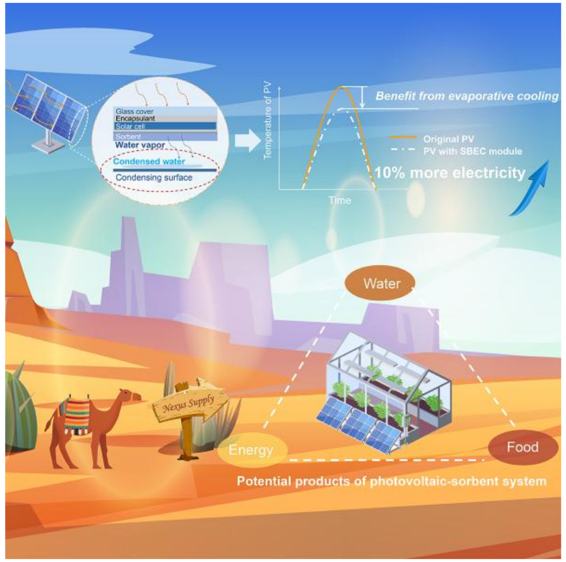
ETC5: PV-sorbent system for coupled water and electricity production

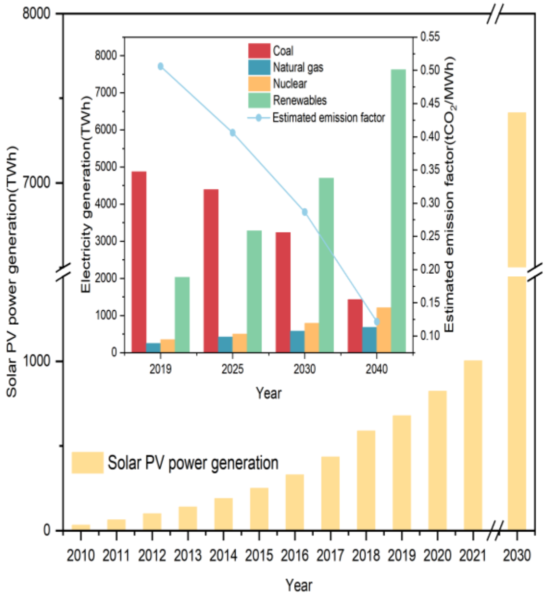
Zhao Shao

First author

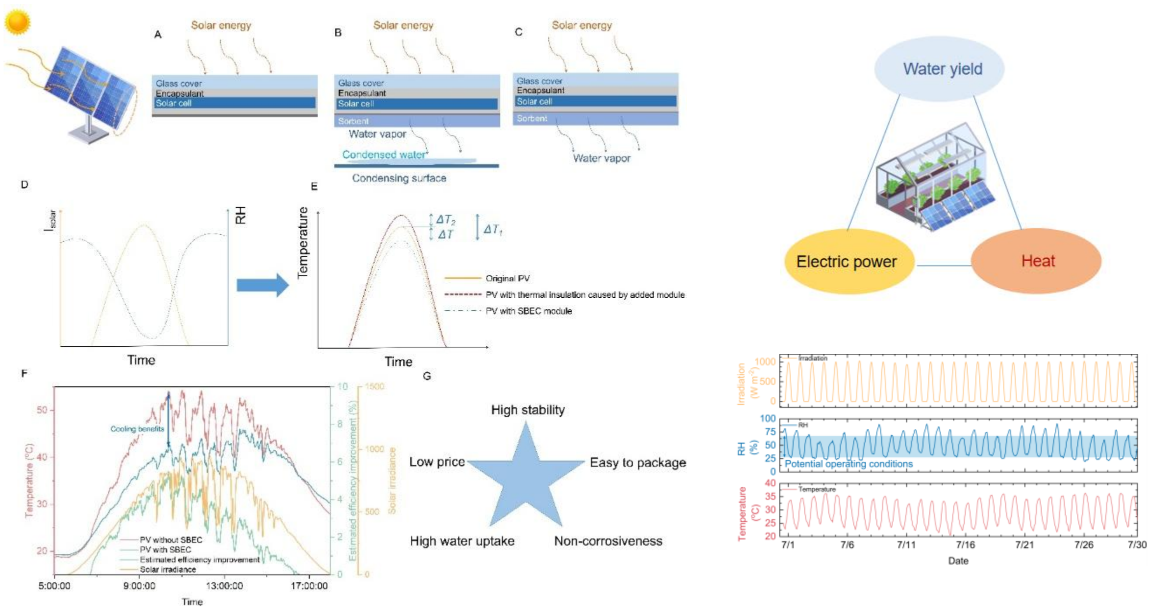
Joule: Photovoltaic-sorbent system for water and electricity generation. 2024, DOI: https://doi.org/10.1016/j.joule.2024.01.006

❑ Analysis of PV-sorbent system based on the global carbon neutrality strategy





❑ Analysis framework and application scenario analysis for the system



PV-adsorbent system for co-production of water and electricity is analyzed from the global carbon-neutral perspective. The comprehensive analytical framework is presented.

Research Focus of ITEWA Team

03. Dehumidification & Humidity Control

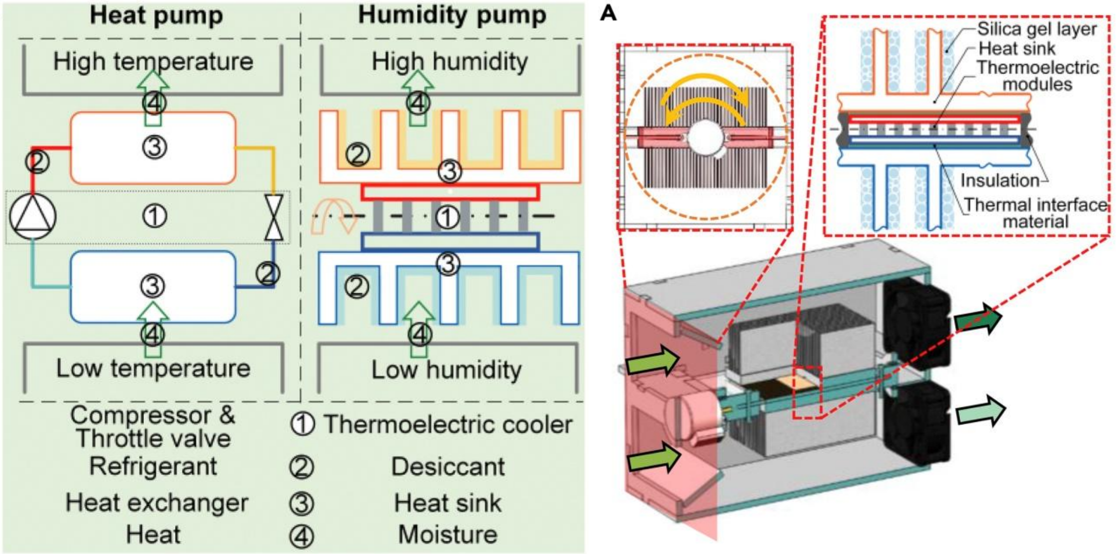
What we have done? **0-1** and **1-100** in Energy-Water-Air-Food nexus.

DH1: A full-solid-state humidity pump for humidity control

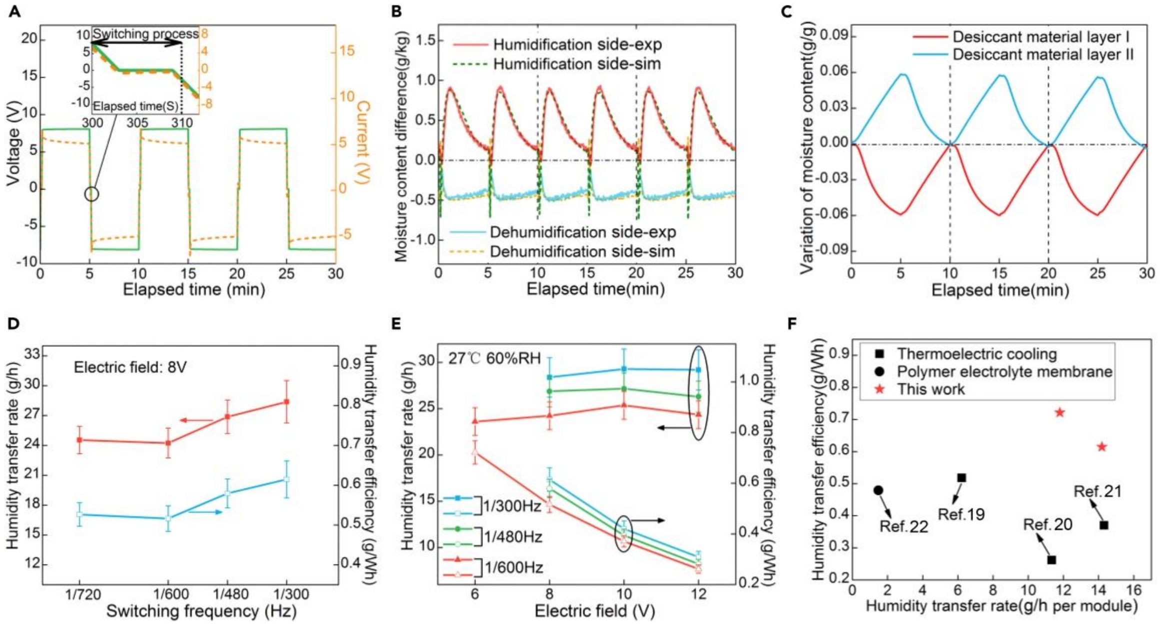
First author
Bangjun Li

Joule: A full-solid-state humidity pump for localized humidity control. 2019, 3(6): 1427-1436.

❑ Working principle & Experimental setup



❑ Experimental results



Demonstrate a full-solid-state humidity pump using thermoelectric

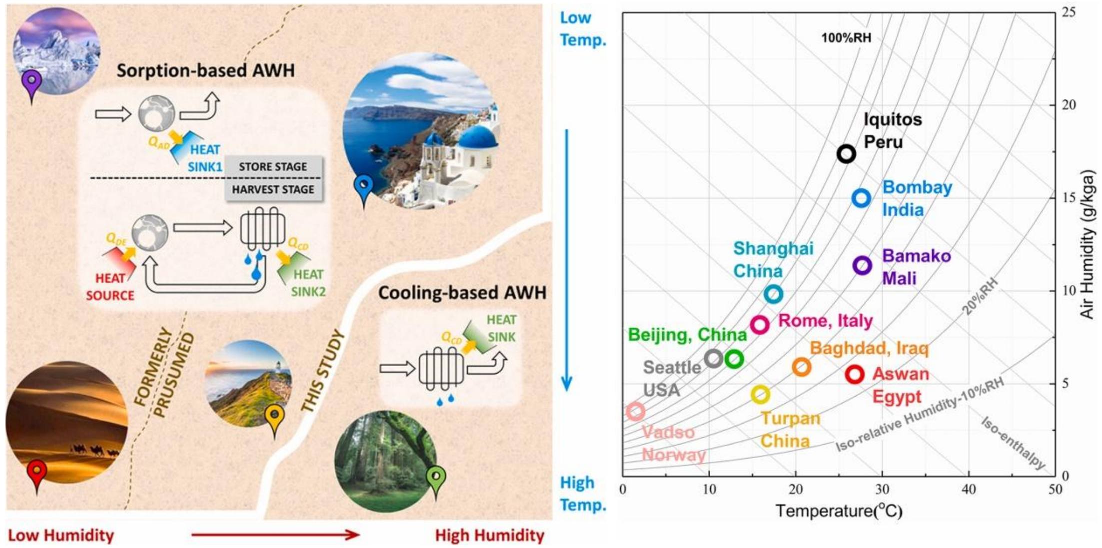
Liquid water free with the humidity transfer rate of 0.61 g W^{-1} h^{-1} (28.38 g h^{-1})

DH2: Exergy-efficient boundary and design guidelines for humidity control

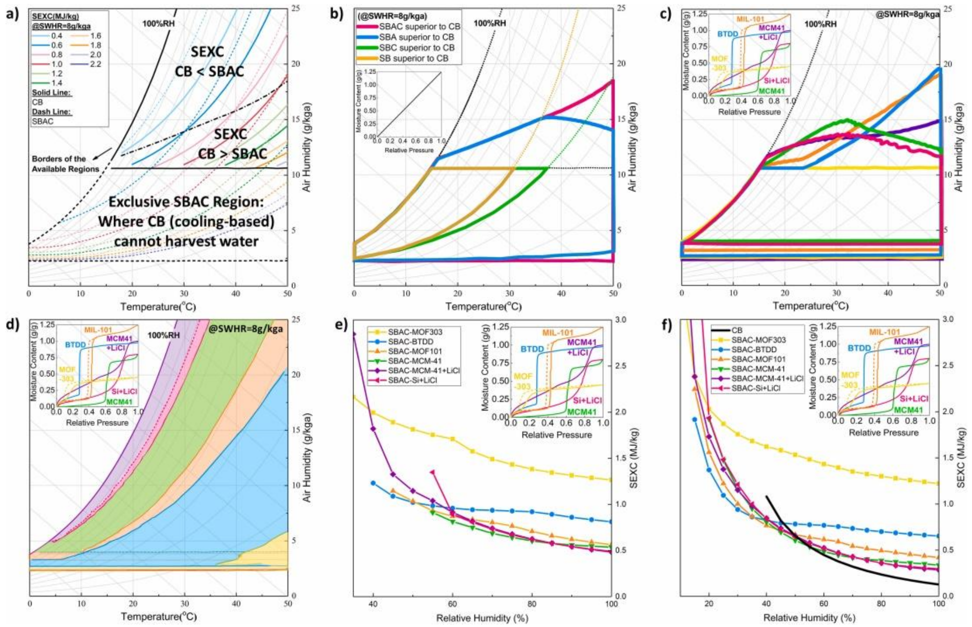
Nano Energy：Exergy-efficient boundary and design guidelines for atmospheric water harvesters with nano-porous sorbents. 2021, 85: 105977.

First author
Lingji Hua

❑ Working principle



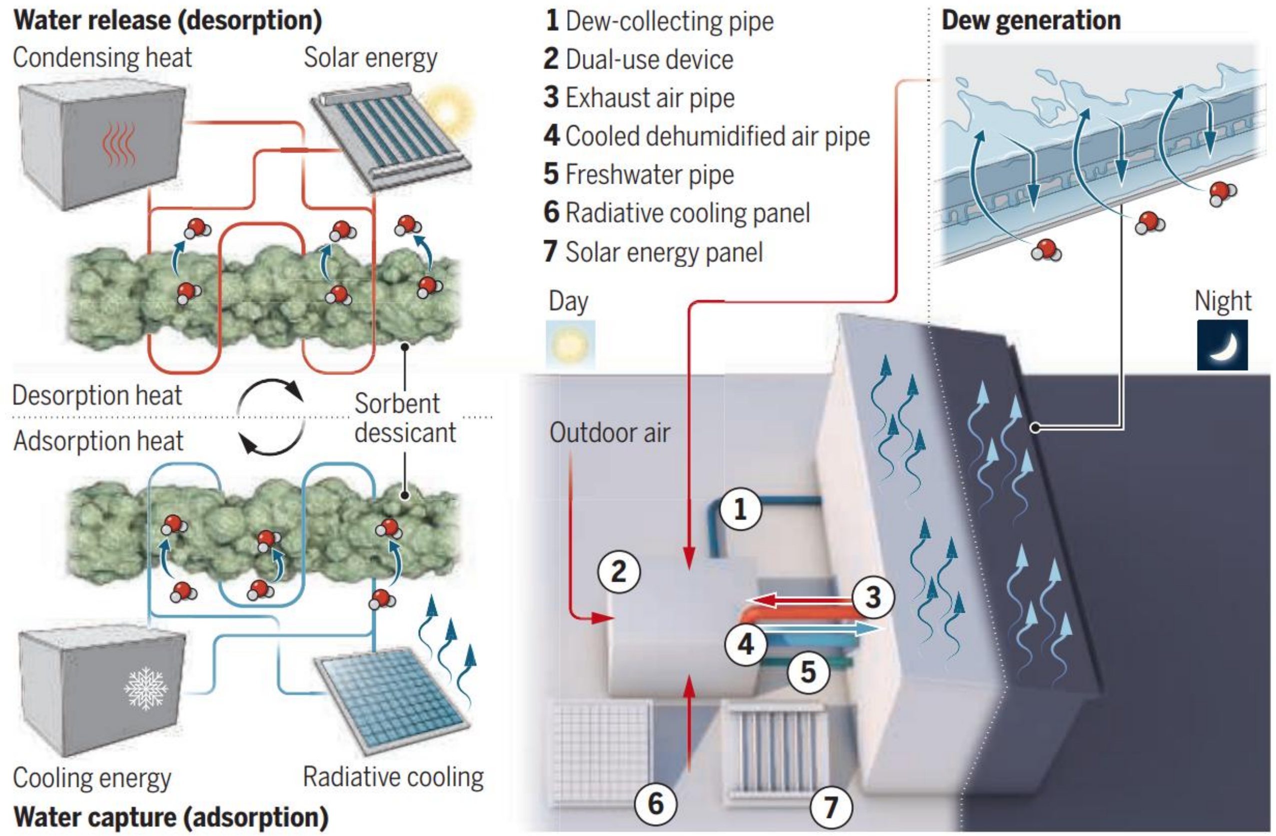
❑ Simulation results



Propose a robust method of energy assessment, identify scope of application for AWH technologies, outline materials and operational parameters choice guidelines

DH3: Dual-use devices for sustainable cooling and AWH

Science: Sustainable cooling with water generation. 2023, 380, 458-459.



Primož Poredoš
First author

Presented scientific concept for efficient cooling with atmospheric water generation using a dual-use device, with desiccant-coated heat pump, radiative sky cooling and solar energy.

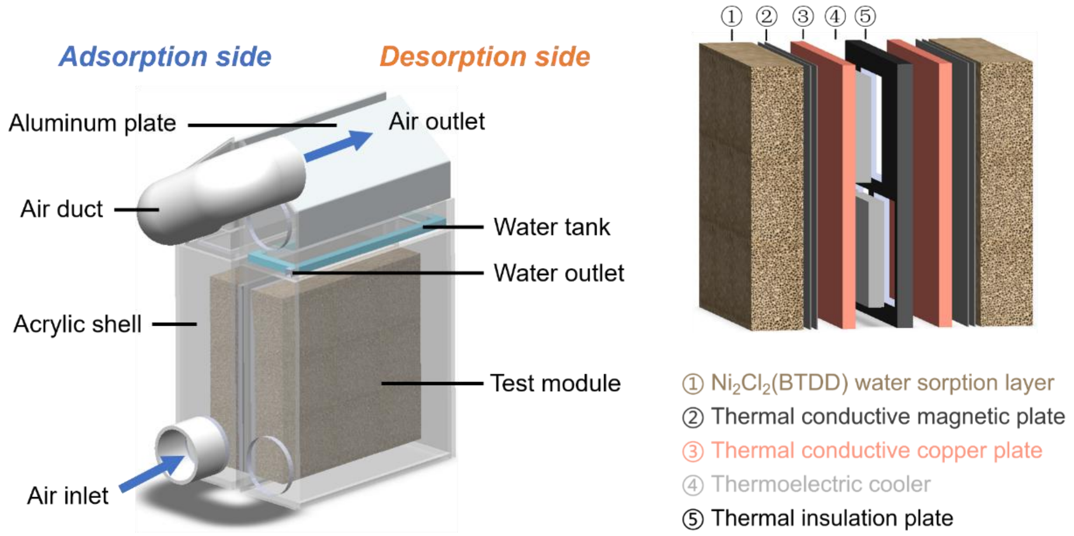
DH4: Dual-functional humidity pump for continuous AWH

Nano Energy： Continuous atmospheric water production coupled with humidity regulation enabled by a MOF-based humidity pump. 2024, 125, 109596.

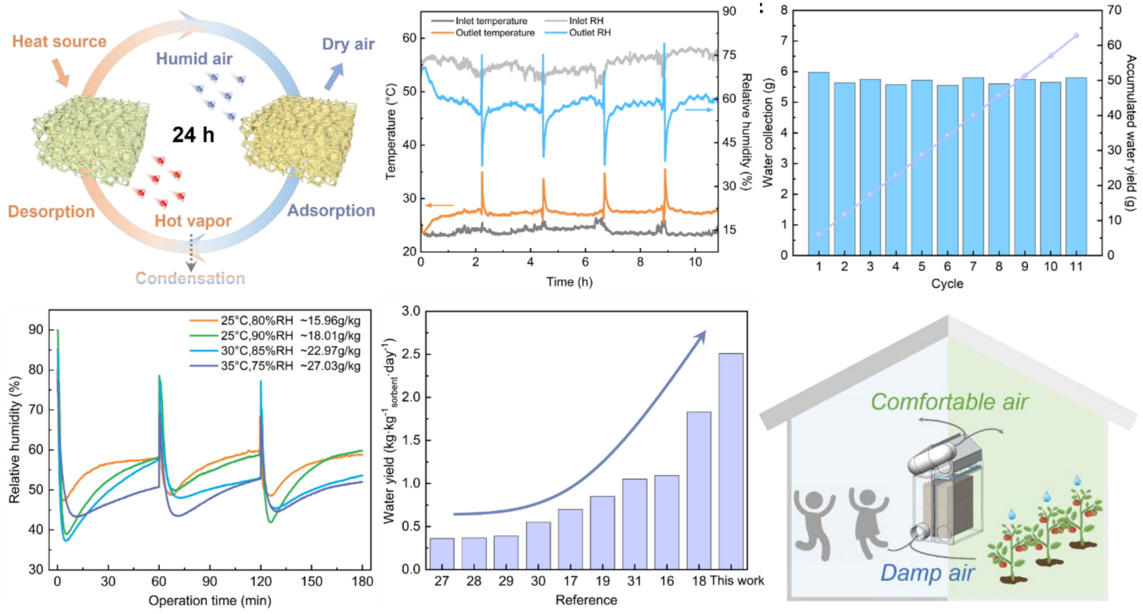
Zhihui Chen

First author

❑ MOF-based rapid cycling



❑ Continuous AWH & humidity regulation



Developed a TEC-based rapid-cycling design， realizing a bifunctional coupling of continuous AWH and humidity regulation and achieving a high water yield of 2510 mL kg^{-1} day^{-1}

Research Focus of ITEWA Team

04. Energy Storage

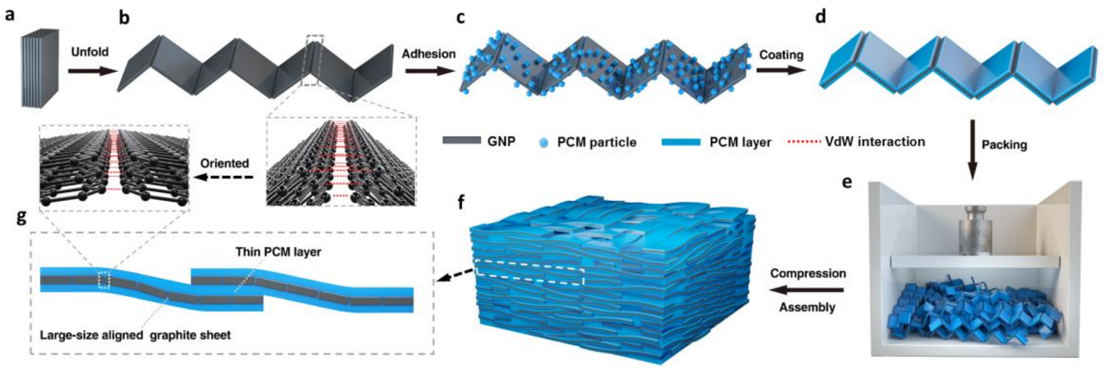
What we have done? **0-1** and **1-100** in Energy-Water-Air-Food nexus.

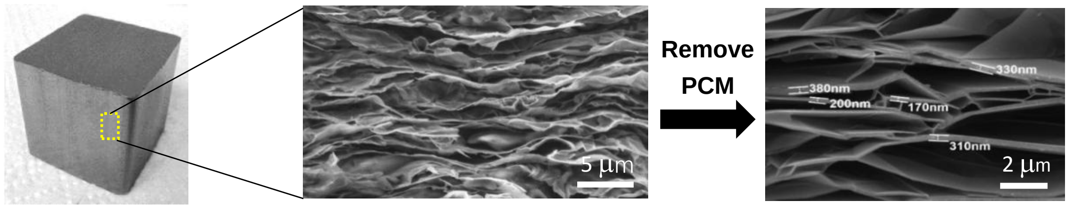
ES1: Large-size oriented graphite sheet for high-power-density phase-change latent heat storage

First author

Advanced Materials: High-performance thermally conductive phase change composites by large-size oriented graphite sheets for scalable thermal energy harvesting. 2019, 31, 1905099. **(ESI highly cited paper)**

❑ Constructing thermally conductive network





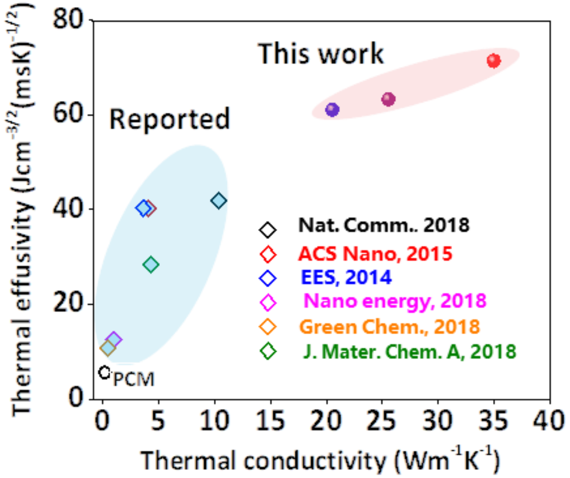
Composite block (30x30x30 mm)

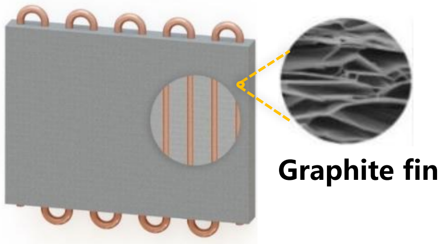
Aligned large-size graphite nanosheet

Nanosheet framework

❑ High-power latent heat storage device/system

High thermal conductivity & high thermal effusivity





Modular heat storage unit

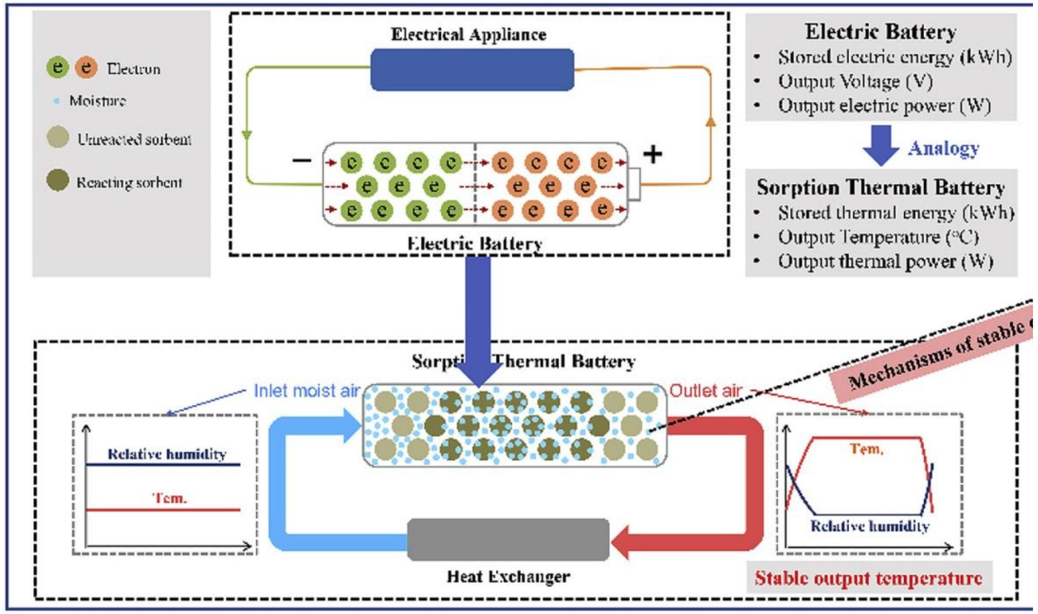
Developed a novel method to prepare thermally conductive phase-change composites and high-power LHS device, realizing record high *K* enhancement, 2~6 times higher than previous reports

ES2: Air humidity assisted sorption thermal battery

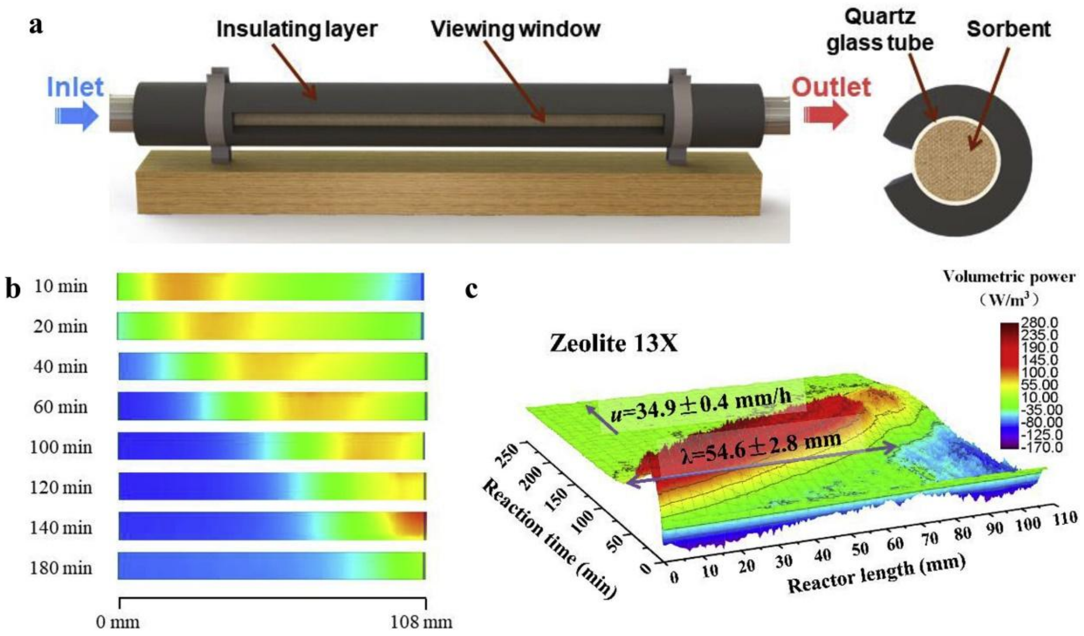
First author
Yannan Zhang

Energy Storage Materials: Air humidity assisted sorption thermal battery governed by reaction wave model. 2020, 27: 9-16.

❑ Working principle



❑ "Reaction wave" model



Build "reaction wave" model, provide design criterion for obtaining stable output

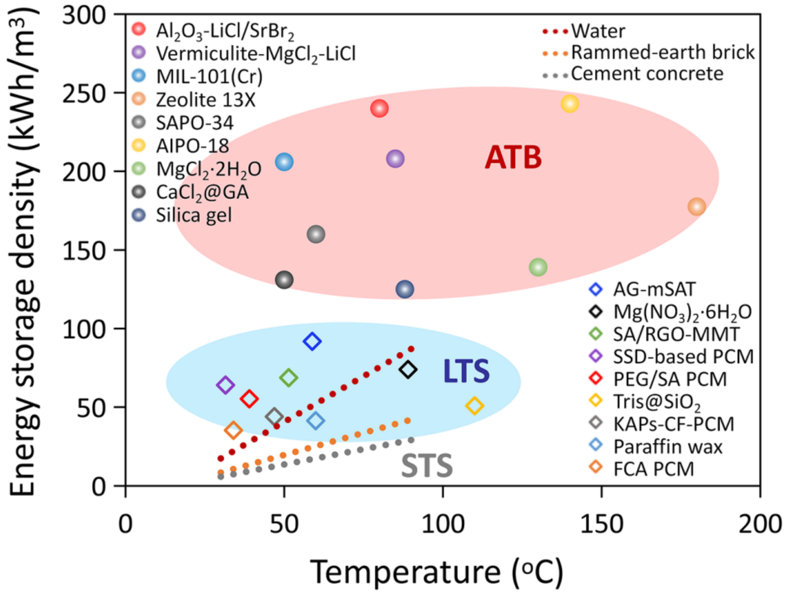
Warm up air from 20 °C to 38.1 °C for 5.51 h, obtain storage density of 240 kWh/m^3

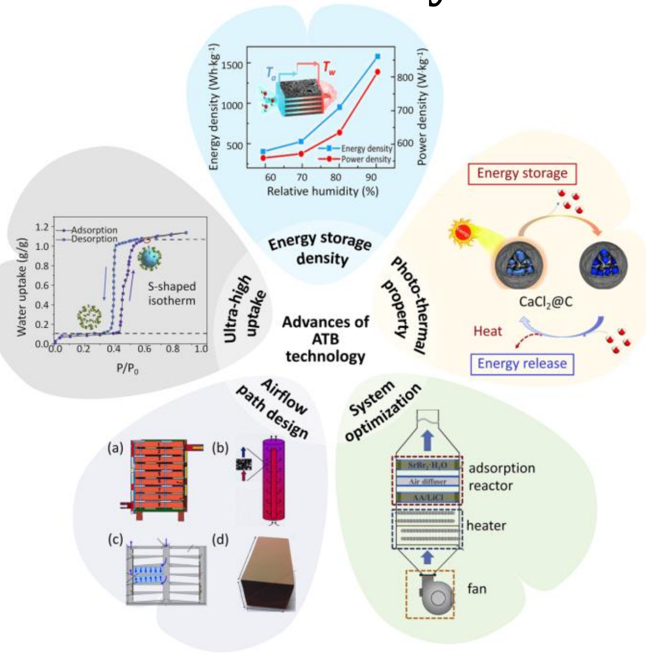
ES3: Adsorption thermal battery for day and night heating

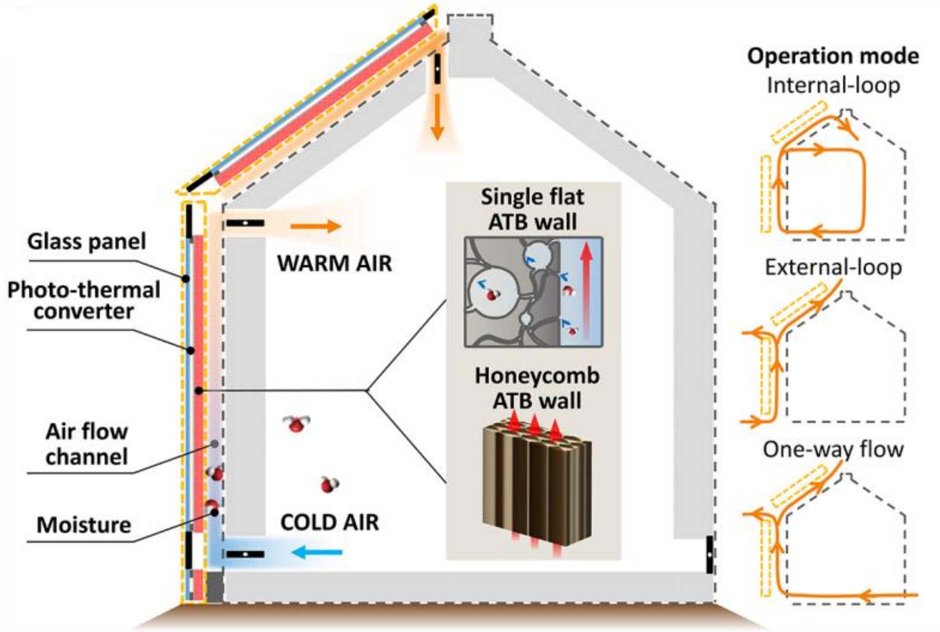
Cell Reports Physical Science: Passive day and night heating for zero energy buildings with solar-based adsorption thermal battery, 2021, 2(9), 100578.

First author

❑ High energy density ATB ❑ Material-device-system advances ❑ Solar ATB for space heating







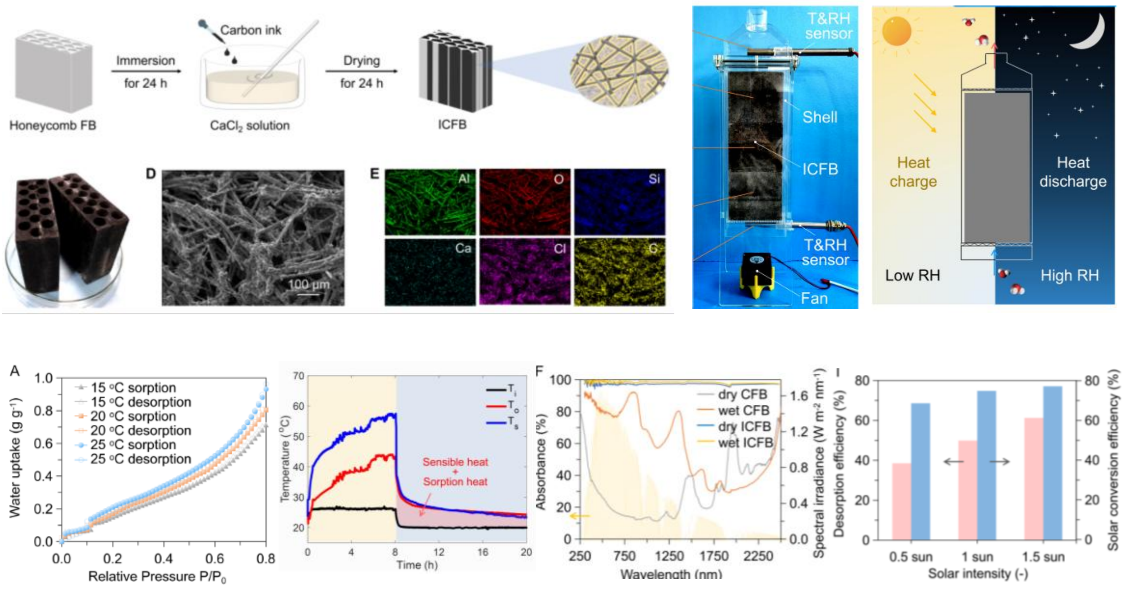
Proposed a building envelope concept of solar ATB wall with ultrahigh energy storage dnesity , enabling day & night heating, near-zero energy consumption, and controlable thermal comfort

ES4: Solar ATB for day & night heating in low-carbon scenario

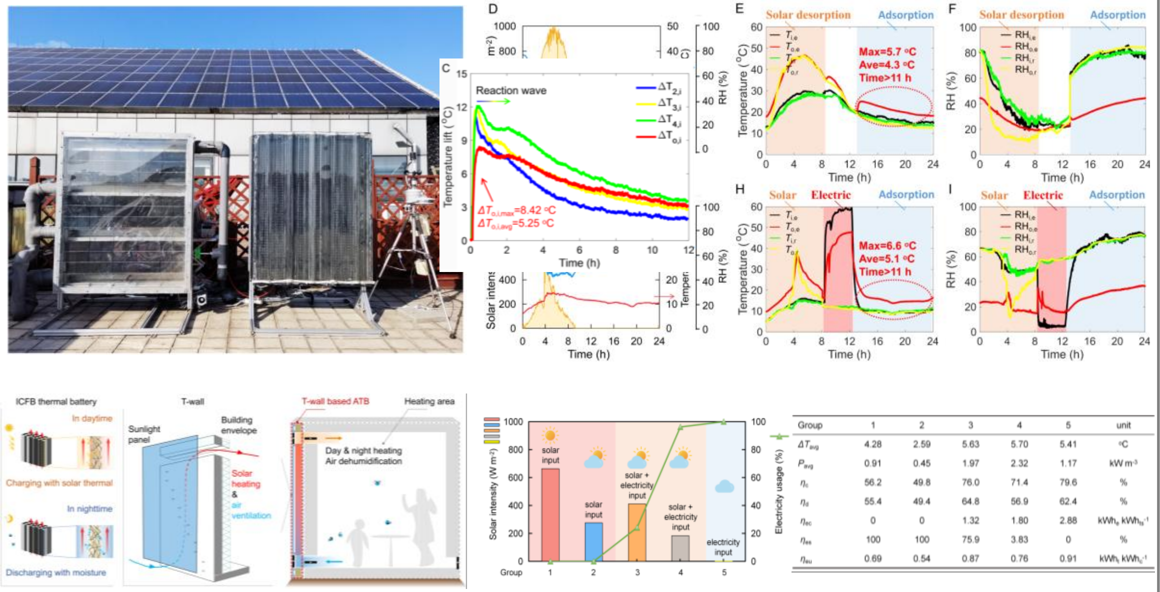
First author

Energy & Environmental Science: Scalable solar-based adsorption thermal battery for day and night heating in low-carbon scenario, 2024, DOI: 10.1039/D3EE03519K.

❑ Design and performance of ATB reactor



❑ Scalable solar-based ATB wall apparatus



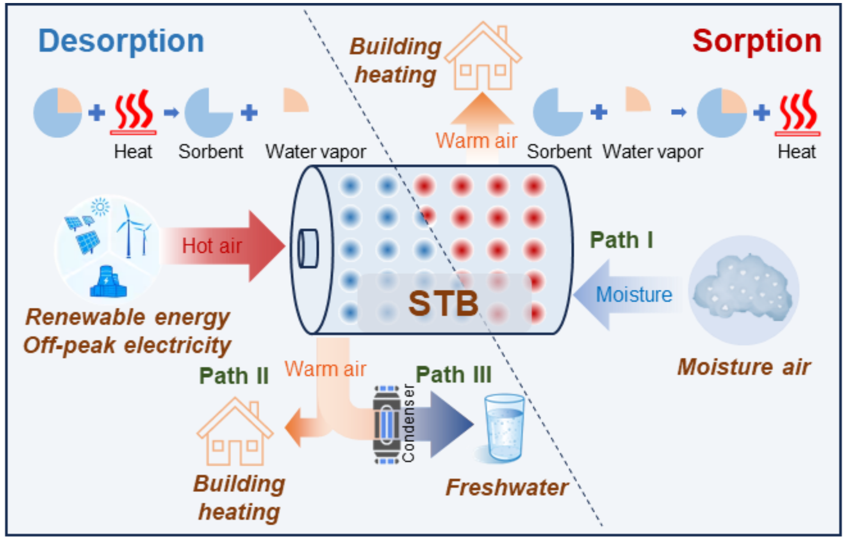
Developed a novel solar ATB wall system, realizing 24-hour effective heat delivery for low-carbon building heating, and an energy consumption reduction by 54.2% compared to electric heating

ES5: Polyzwitterionic gel for harvesting energy and water from air

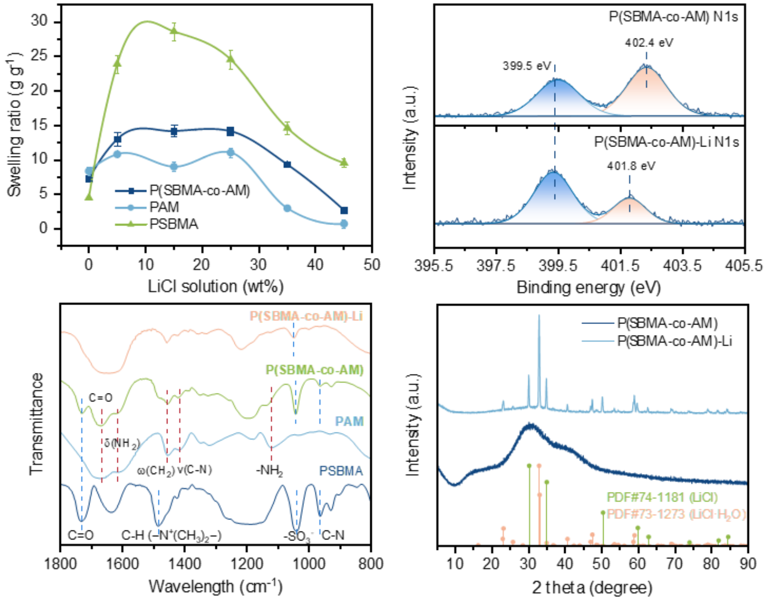
ACS Energy Letters: Harvesting Thermal Energy and Freshwater from Air through Sorption Thermal Battery Enabled by Polyzwitterionic Gel. 2023, 8, 12, 5184–5191

He Shan
First author

❑ Water and energy harvesting modes



❑ Polyzwitterionic hydrogel



Leveraging the adjustable swelling of polyzwitterionic hydrogels in salt solutions to create high-performance gel for efficient water and energy harvesting from air.

Research Focus of ITEWA Team

05. Thermal & Humidity Management for Solar Greenhouse & Crop Yield Increase

What we have done? **0-1** and **1-100** in Energy-Water-Air-Food nexus.

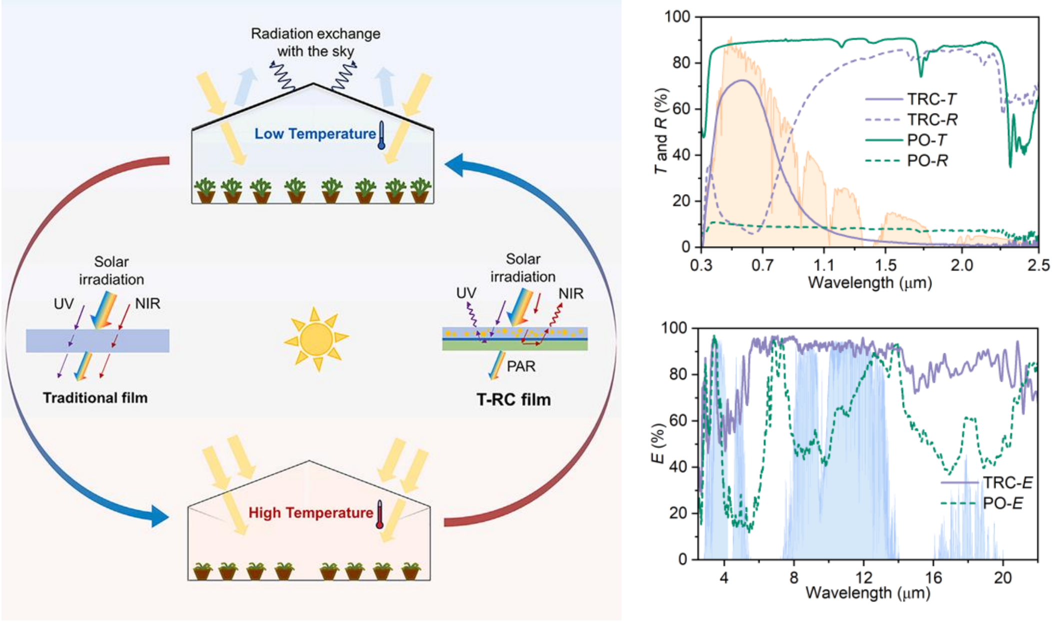
GH1: Transparent RC film for greenhouse cooling

Cell Reports Physical Science： Eliminating greenhouse heat stress with transparent radiative cooling film. 2023, 4, 101539.

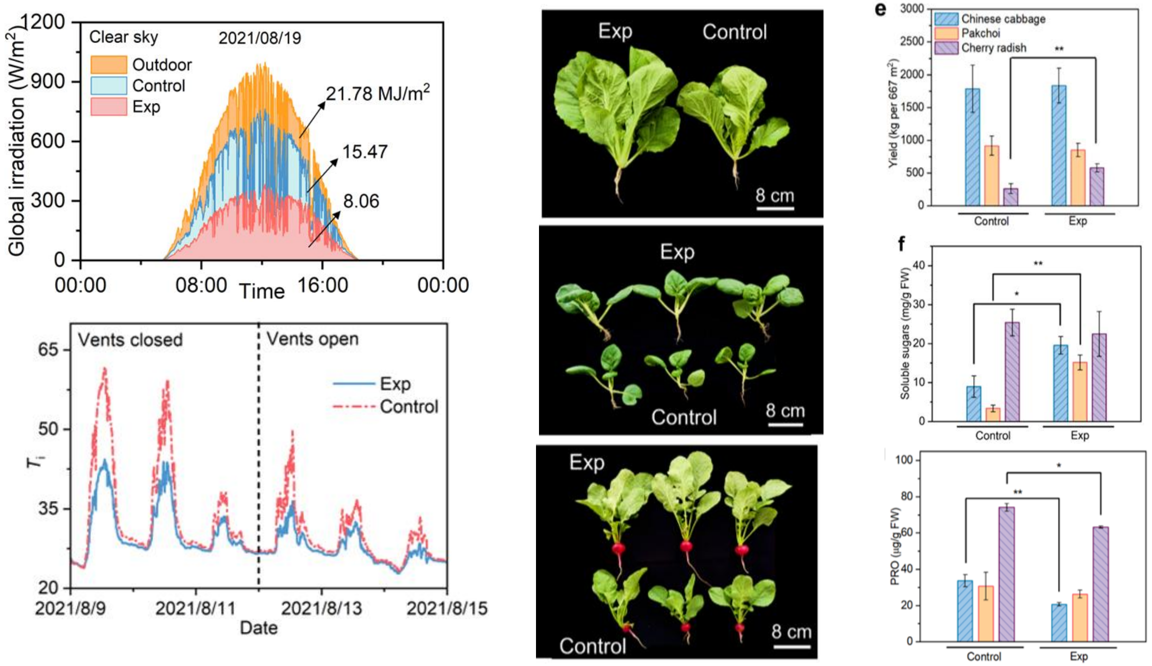

Co-first author Hao Zou

Co-first author Chenxi Wang

❑ High PAR transmittance T-RC film



❑ Increase crop yield and quality with 0 energy



Developed a transparent RC film is as covering material for greenhouses, realizing excellent cooling effect of 18.6ºC with 20% crop yield promotion

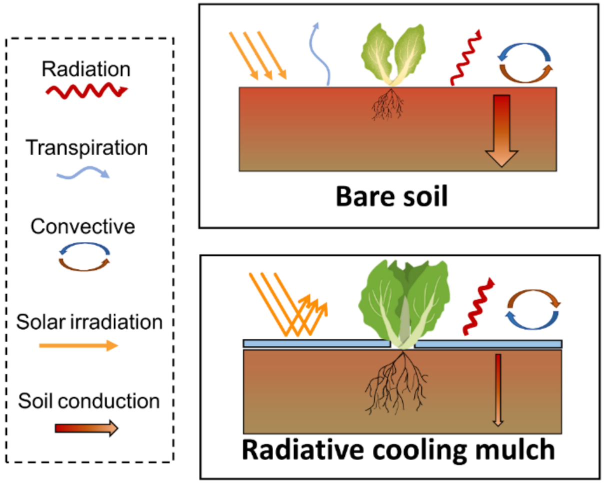
GH2: Radiative cooling mulch for Food-Water-Energy Nexus

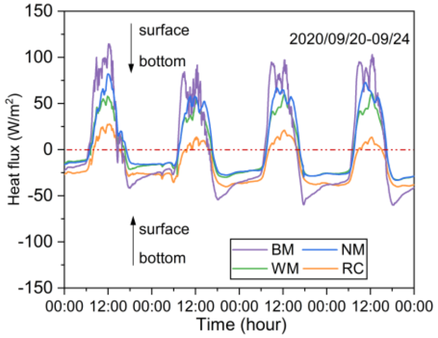
Chenxi Wang
First author

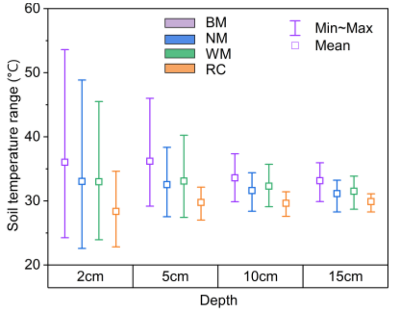
Hao Zou
Co-author

Nexus: Enhancing food production in hot climates through radiative cooling mulch: A nexus approach. 2024, 100002.

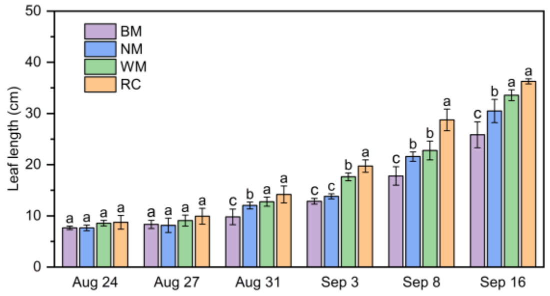
❑ Soil thermal regime under radiative cooling mulch

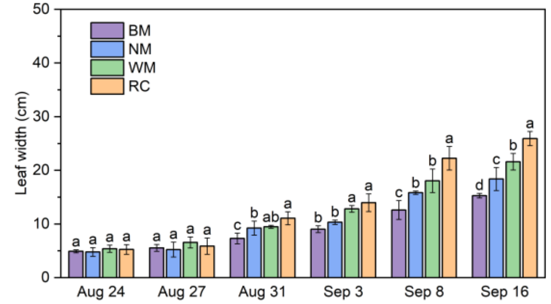






❑ Yield promotion in the field test





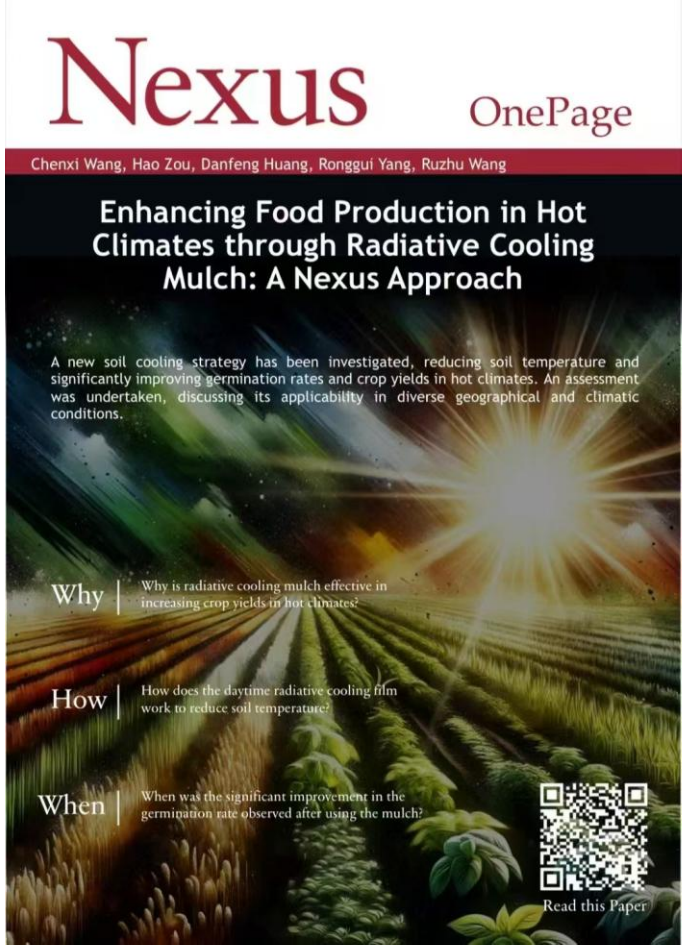
Developed a soil cooling strategy based on the radiative cooling mulch, effectively alleviating heat stress in hot climates, promoting corps growth, reducing soil evaporation, increasing Chinese Cabbage yield by 127.4%

GH2: Radiative cooling mulch for Food-Water-Energy Nexus

First author

Co-author

***Nexus*:** Enhancing food production in hot climates through radiative cooling mulch: A nexus approach. 2024, 100002.



Cover & 1st Paper

Nexus

Nexus Journal

Verified email at polyu.edu.hk

FOLLOW

TITLE	CITED BY	YEAR
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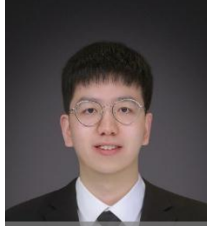
Worth of prior knowledge for enhancing deep learning H Xu, Y Chen, D Zhang Nexus 1 (1)	31	2024
Advancements and Challenges in Wireless Power Transfer: A Comprehensive Review Z Liu, T Li, S Li, CC Mi Nexus 1 (2)	21	2024
Enhancing food production in hot climates through radiative cooling mulch: A nexus approach C Wang, H Zou, D Huang, R Yang, R Wang Nexus 1 (1)	19	2024

Now, 20 citations

(Screenshot from April 14th)

GH3: Integrating Rooftop Agriculture and Atmospheric Water Harvesting for Water-Food Production

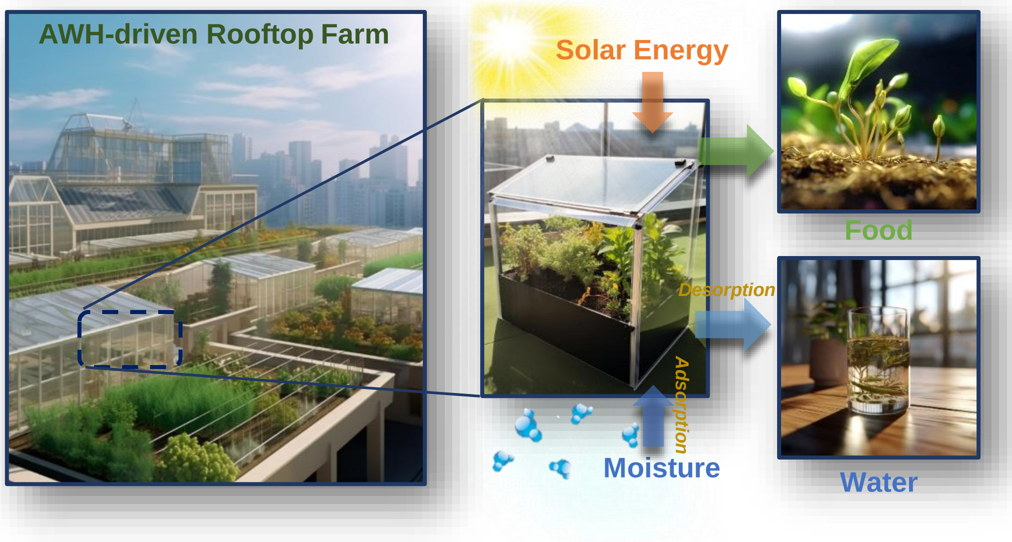


He Shan

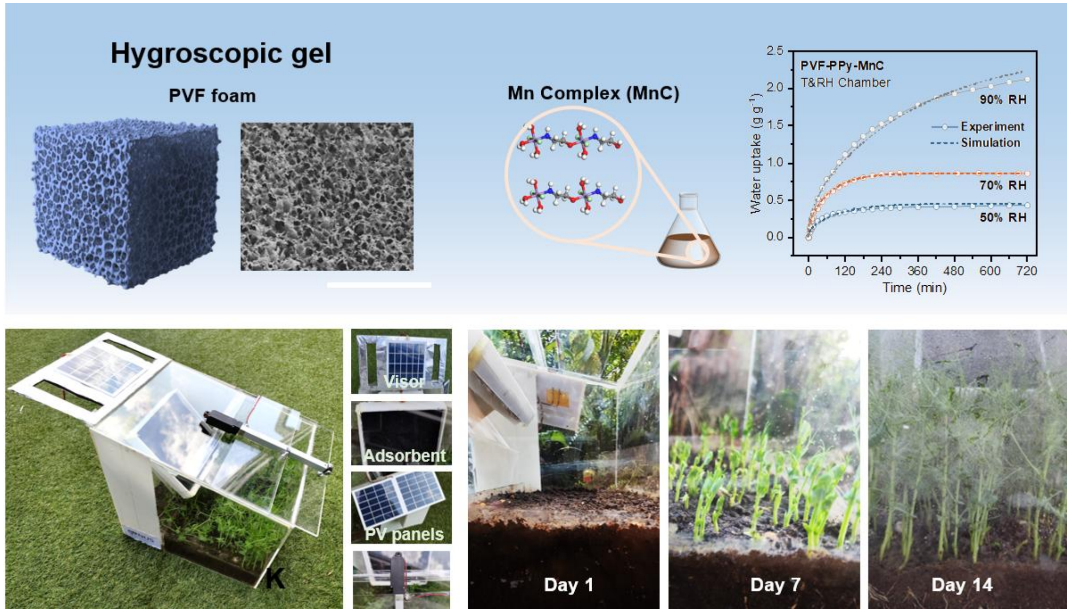
First author

Adv. Func. Mat.: Integrating Rooftop Agriculture and Atmospheric Water Harvesting for Water-Food Production Based on Hygroscopic Manganese Complex. 2024, 2402839.

❑ Implementation of the atmospheric water-irrigated rooftop farm



❑ Water harvesting enabled by the hydrogel



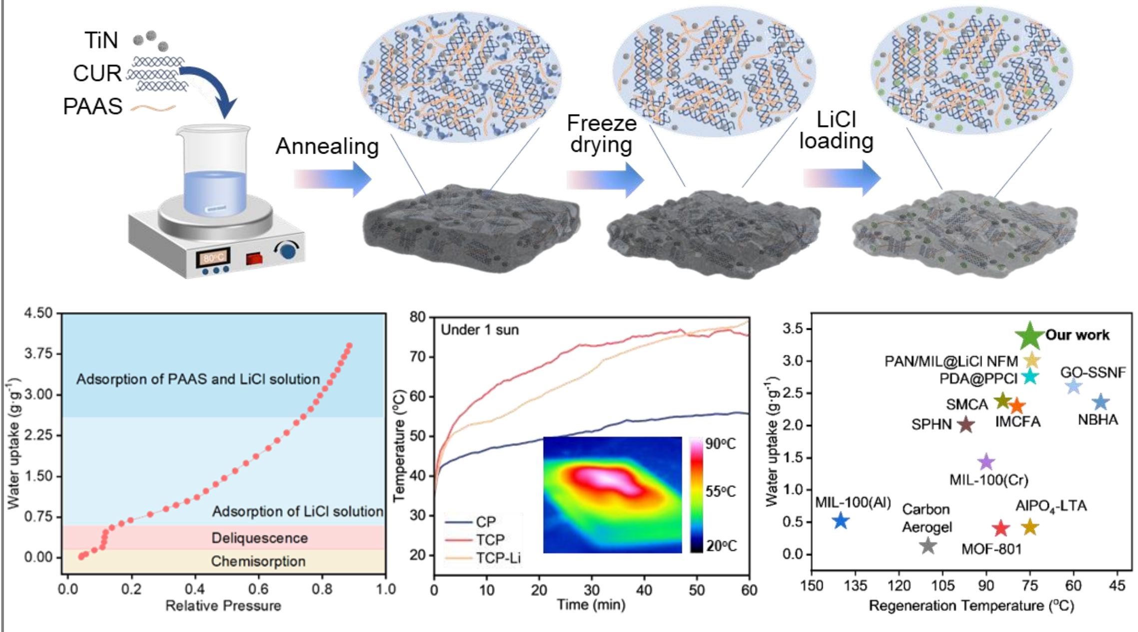
Coupling AWH with rooftop farming for precision irrigation offers a novel solution for joint urban food-water production. In a 14-day autonomous trial, it yielded 879.9 g/m² of water and 1.28 kg/m² of food, fostering sustainable city development.

GH4: Solar-driven hygroscopic gel for irrigation recycling in greenhouse

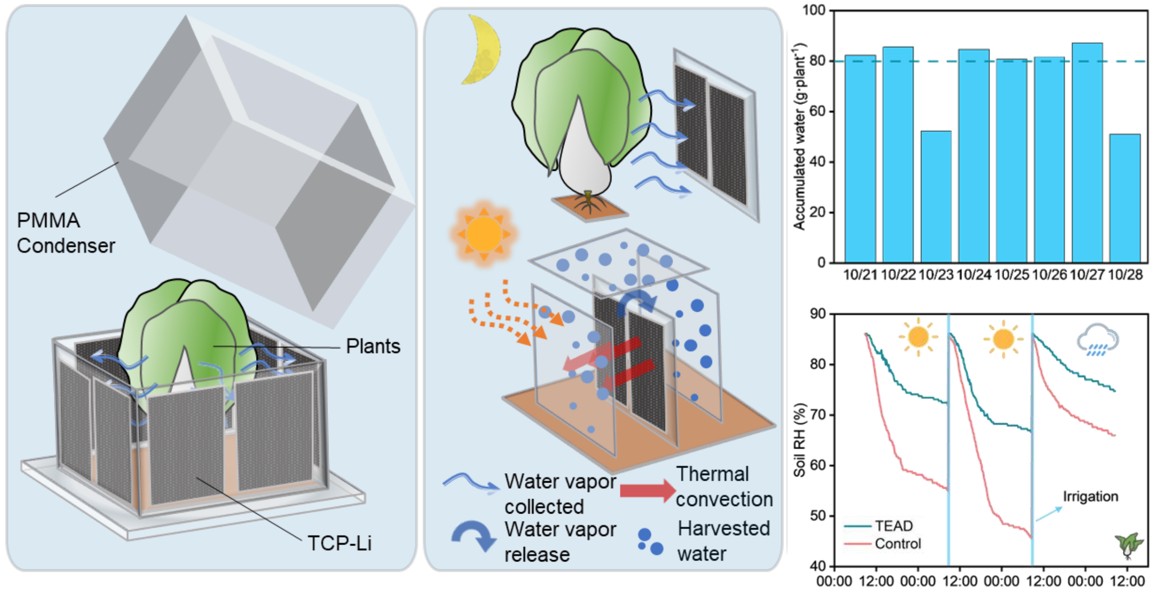
First author

Nature Water: Solar-driven Scalable Hygroscopic Gel for Passive Plant Transpiration and Soil Evaporation Water Recycling. 2024, 2: 663-673.

❑ TiN-PAAS-Curdlan composite hydrogel



❑ Transpiration & evaporation adsorption device



Developed a hygroscopic porous gel and a transpiration & evaporation adsorption device,

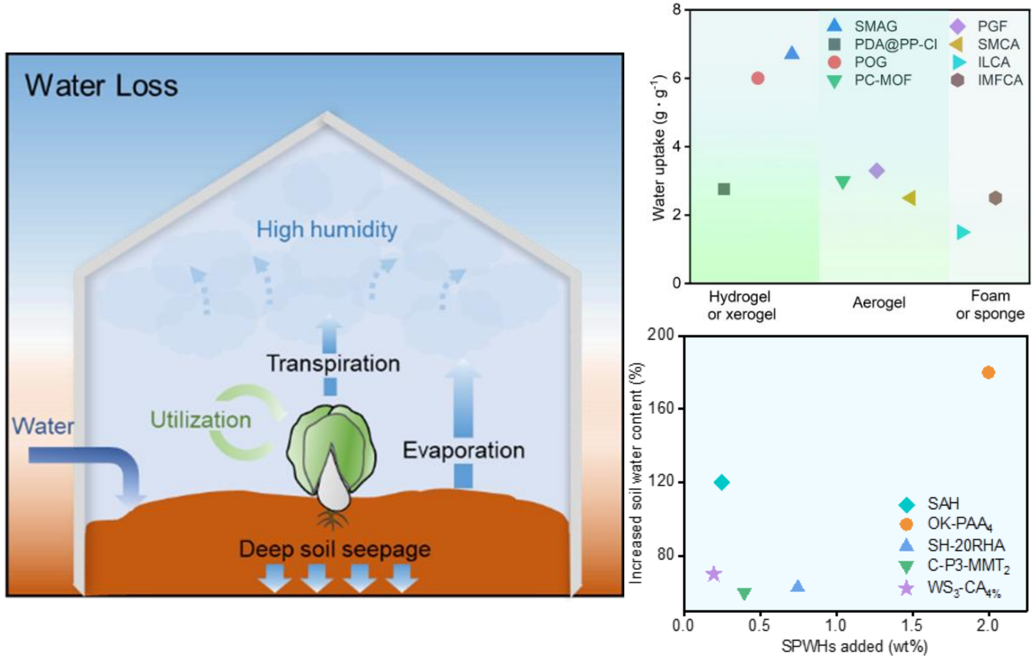
realizing high water productivity up to 1.8 $L/m^2/day$ and water-saving effect of 44.9%

GH5: A Nexus Approach to Greenhouse Water Supply

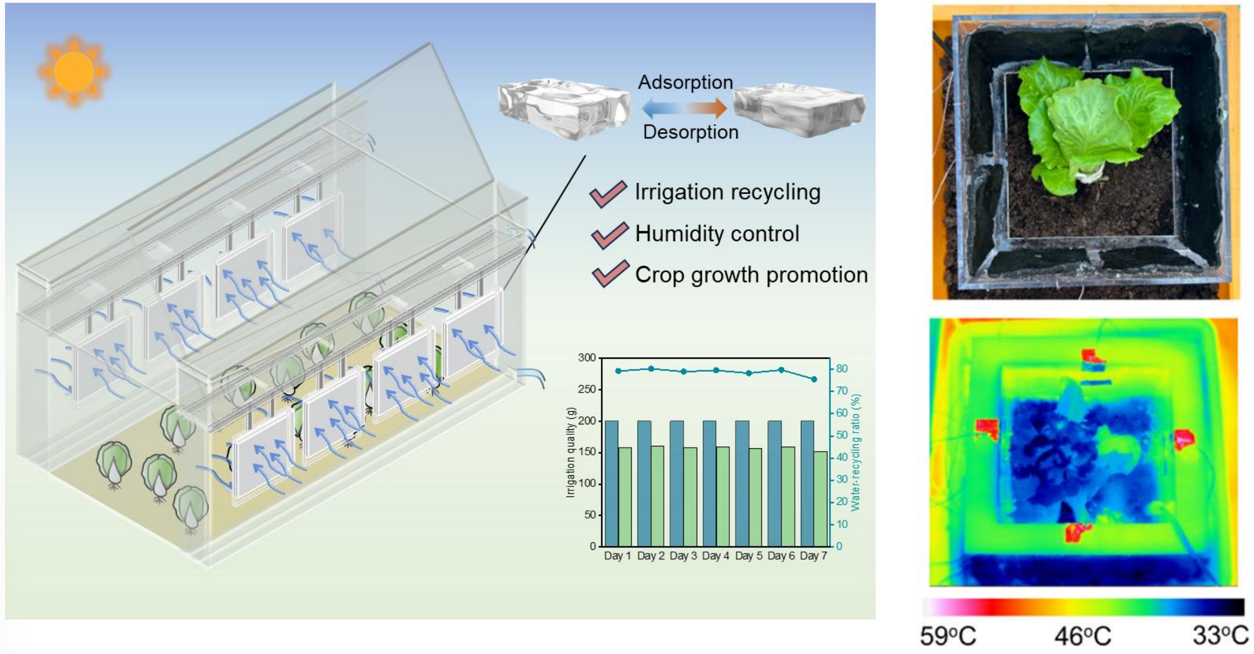
Hao Zou
Reporter

This afternoon oral session (16:00 at BC301): A Nexus Approach to Greenhouse Water Supply Utilizing Sorption-Based Atmospheric Water Harvesting.

❑ Exploration of greenhouse water-saving technology



❑ Greenhouses sustainable water management via SAWH



Developed a nexus strategy for greenhouses sustainable water management via SAWH, recycle the wasted water inside the greenhouse by adsorption-desorption cycle.

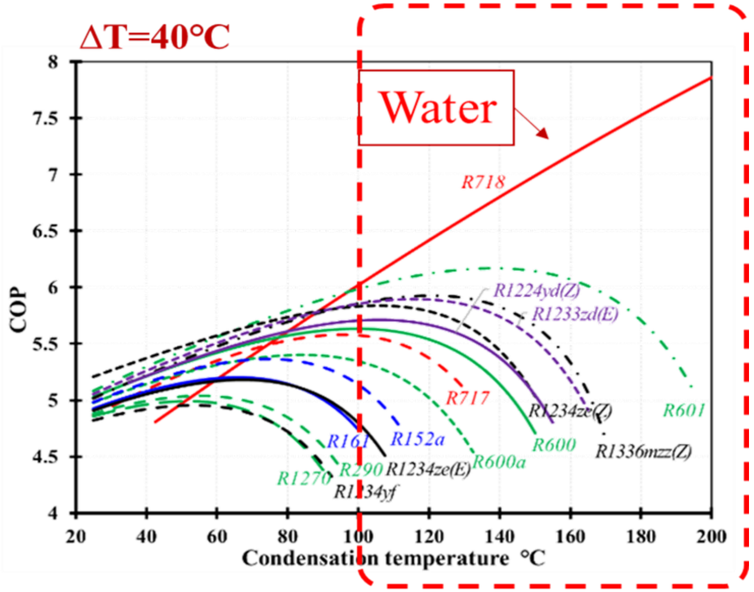
Research Focus of ITEWA Team

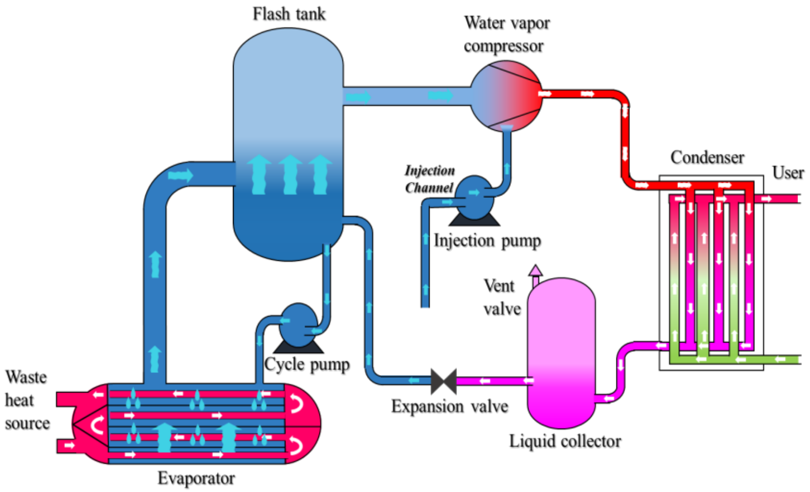
06. Heat Pump Incremental Thermal Storage & Energy Quality Control

What we have done? **0-1** and **1-100** in Energy-Water-Air-Food nexus.

HP1: Water vapor high-temperature heat pump: Utilize industrial waste

High-temperature heat pump with water as refrigerant capable of outputting 120-150℃ high temperature, with system efficiency higher than others





Performance	Te=82.9 ℃;Tc=115.0 ℃	Te=80.4 ℃;Tc=120.5 ℃	Te=81.4 ℃;Tc=130.5 ℃
Heating capacity (kw)	260.12	211.07	199.58
Power consumption (kw)	45.61	46.84	57.1
COP	5.7	4.51	3.49

HP1:Water vapor high-temperature heat pump: Utilize industrial waste

High-temperature heat pump with water as refrigerant capable of outputting 120-150℃ high temperature, with system efficiency higher than others

First place in the Best Student Paper at the 25th International Refrigeration Conference (Montreal, Canada, August 2019), with related achievements incubated at Shanghai Nuotong New Energy Technology Co., Ltd

Heating capacity (kw)	260.12		
Power consumption (kw)	45.61		
COP	5.7	4.51	3.49

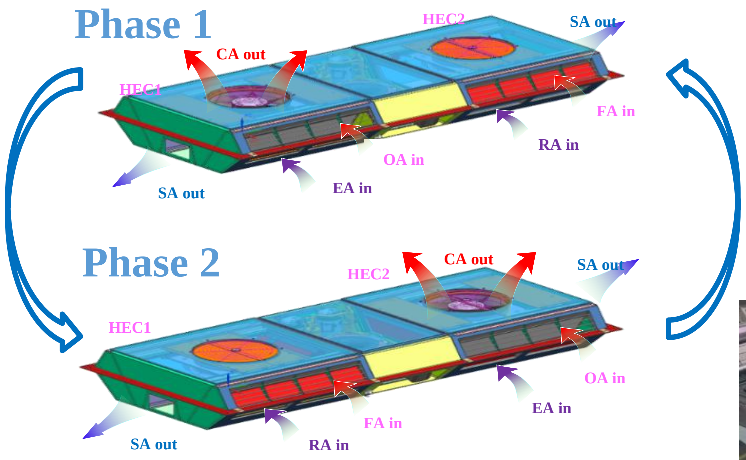
HP2: DCHE-based system designed for high-speed rail

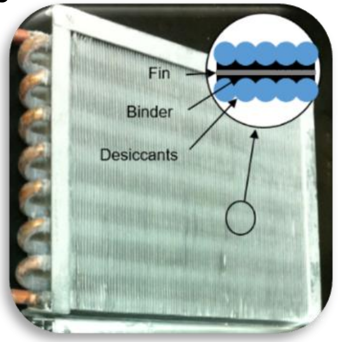

Zhao Shao　Zhenggen Wang

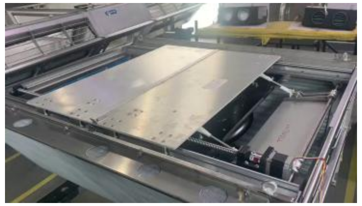
First author

***Energy*:** Highly efficient desiccant-coated heat exchanger-based heat pump to decarbonize rail transportation. 2023, 271, 127014.

❑Application of DCHE technology in train

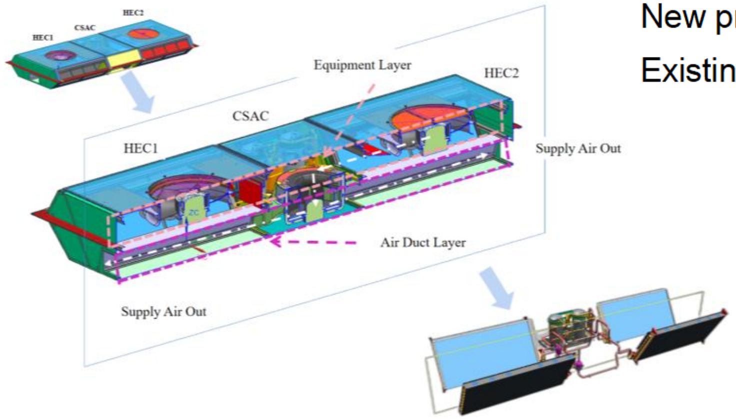


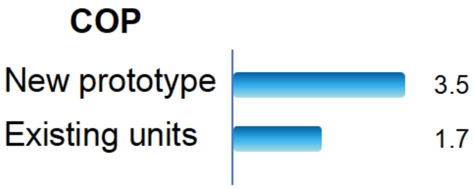




Technology transfer

❑Doubled COP under railway standard conditions





Awarded 1st Prize IIR Best Student Paper Competition

The engineering prototype achieved a doubled COP compared to existing units. Technology transfer to *Jinxin Merak*, a leading company in rail HVAC systems

HP2: DCHE-based system designed for high-speed rail


Zhao Shao


Zhenggen Wang

First author

***Energy*:** Highly efficient desiccant-coated heat exchanger-based heat pump to decarbonize rail transportation. 2023, 271, 127014.

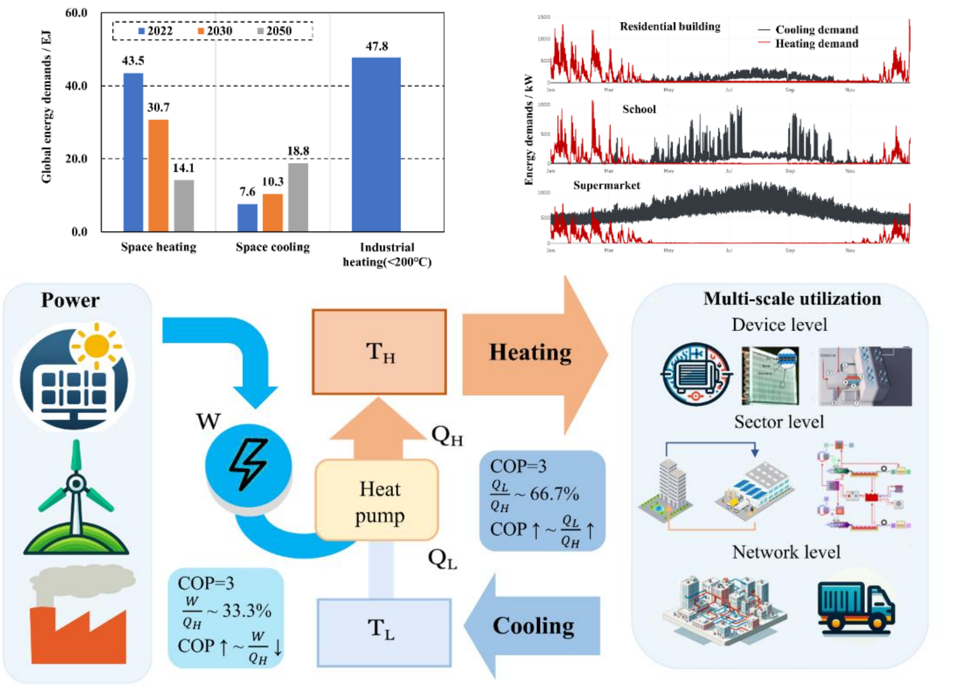
First place in the Best Student Thesis of the 26th International University of Refrigeration (Paris, France, August 2023)

HP3: Heat pumps as a sustainable bridge for global heating and cooling at multi-scale

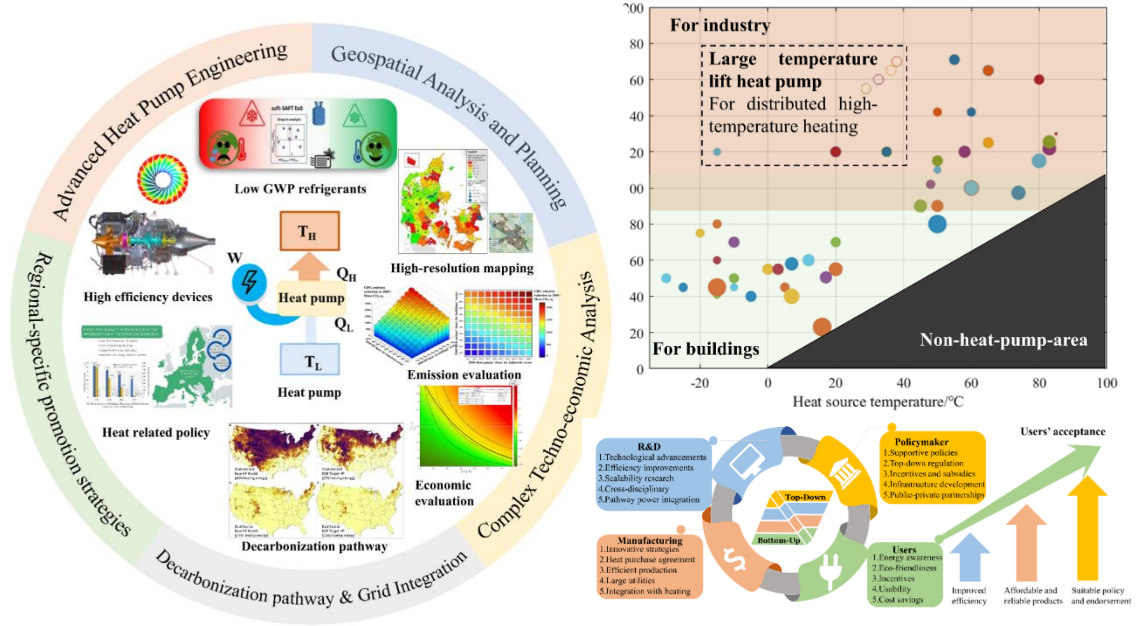
Hongzhi Yan
First author

Energy & Environmental Science: Heat pumps as a sustainable bridge for global heating and cooling at multi-scale. 2024:10.1039.D3EE04246D (Hongzhi Yan, …. , Ruzhu Wang*)

❑ Multi-scale, cross-regional strategy



❑ Interdisciplinary research approach and multi-sector collaboration



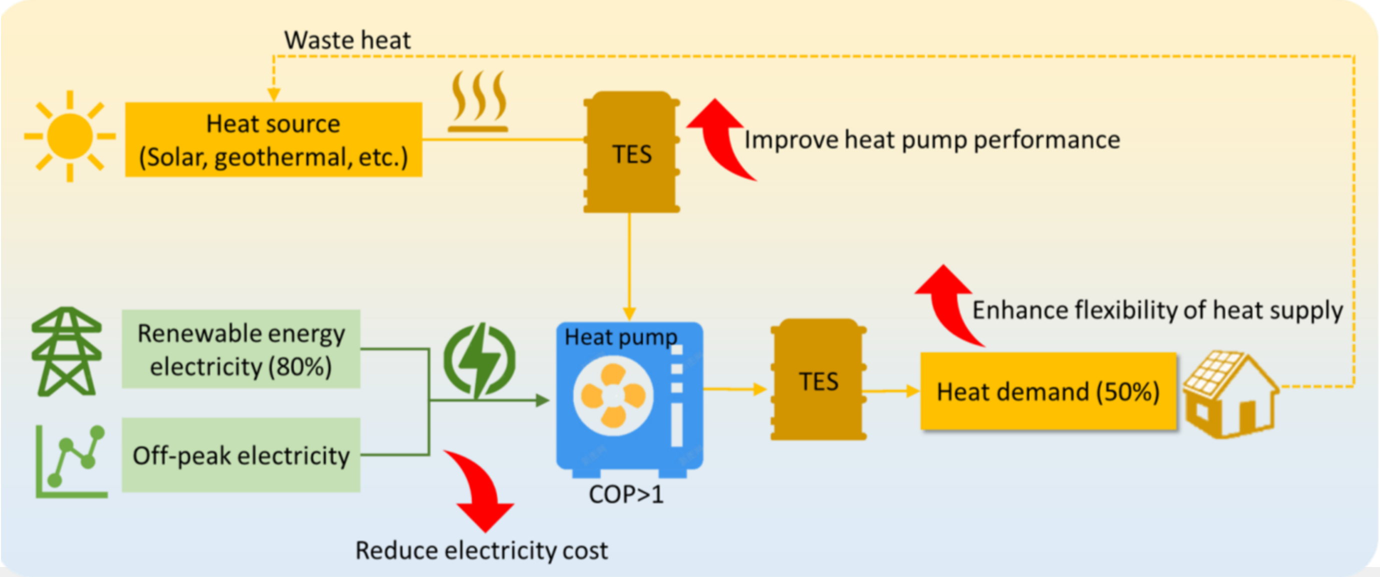
Explored the potential of heat pumps in global heating and cooling, proposed a multi-scale, cross-region strategy for heat pumps, established the interdisciplinary research approach and multi-sector collaboration mode for sustainable cooling&heating energy utilization

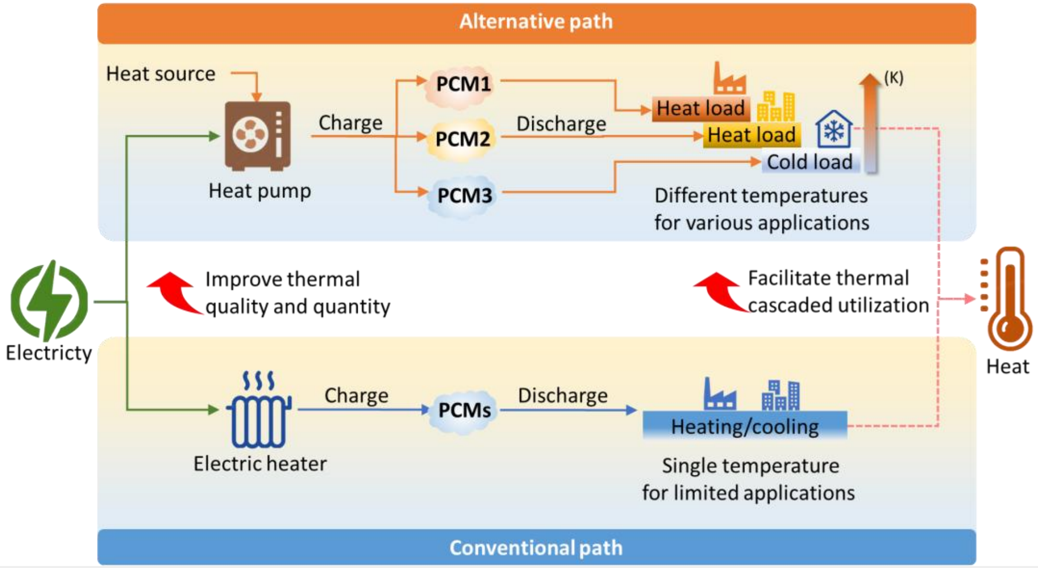
HP4: Heat pump integrated with latent heat energy storage

Baoshan XIE
First author

Energy & Environmental Science: Xie B., Du S., Wang R.Z.*, et al.. Heat pump integrated with latent heat energy storage. 17, 6943 – 6973 (2024).

Renewable energy electricity / **Off-peak electricity on time-of-use tariffs** → **Heat pump +latent heat storage** → **Increase quality** / **Improve quantity** → **Heat cascaded utilization**





Summarized the coupling principle, heat matching mechanism, and heat cascaded utilization methods of the heat pump-latent heat storage integrated system, and clarifying the technical principle and prospects of the integrated system based on phase change material in terms of "Scalable Thermal Energy Storage and Conversion Regulation System".

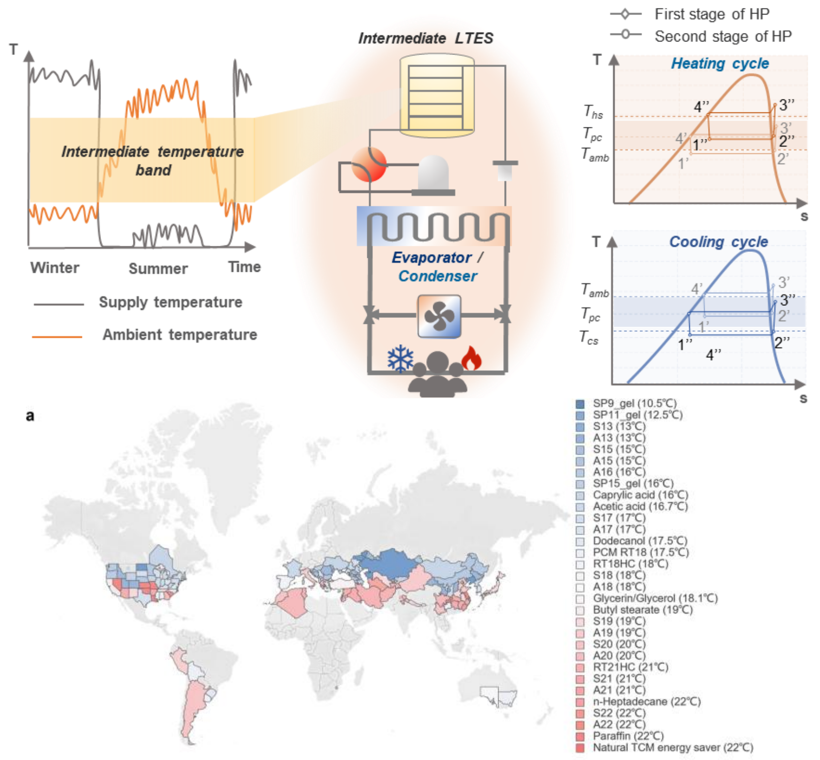
HP5: Intermediate thermal storage for both heating and cooling

Xiaoxue Kou

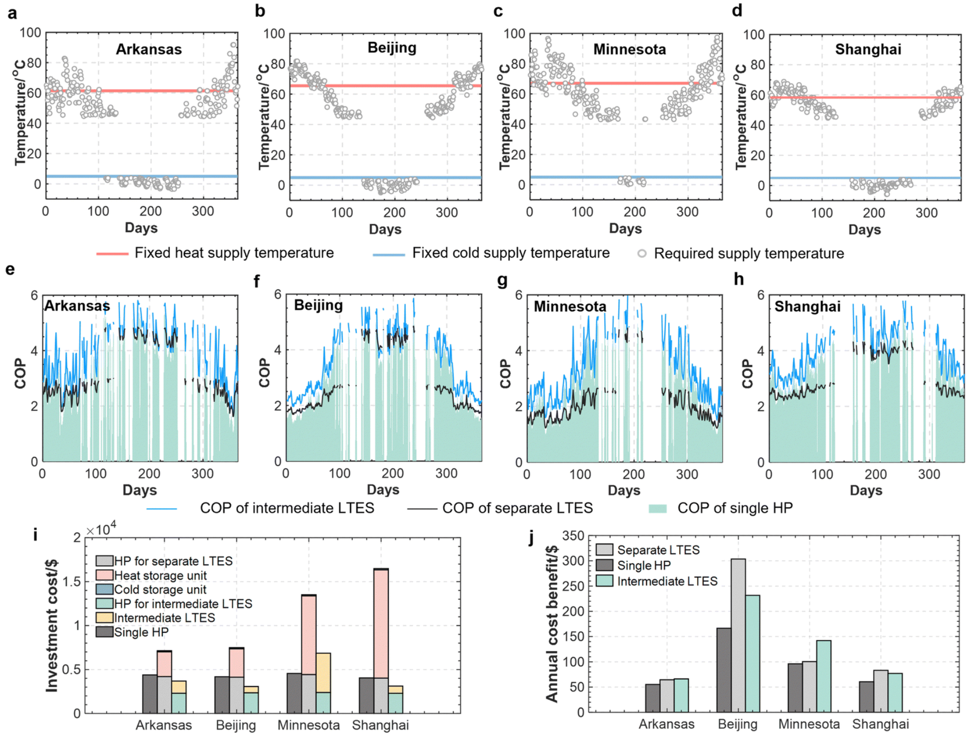
First author

***Energy & Environmental Science*：** Fewer temperature ties: scalable integration and broad selection of phase change materials for both heating and cooling. 2025, https://doi.org/10.1039/D4EE04223A.

☐ Intermediate thermal storage system & application potential



☐ Performance evaluation in typical regions



Developed an intermediate thermal energy storage solution, matching the optimal materials for 51 countries and 95 subnational regions worldwide. The energy efficiency in typical areas is improved by 11.73-21.99%.

HP6: Heat Pumps Integrating Direct Air Capture Processes

Bingyao Ge
First author

Applied Energy: Innovative Process Integrating High Temperature Heat Pump and Direct Air Capture. 2024, https://doi.org/10.1016/j.apenergy.2023.122229

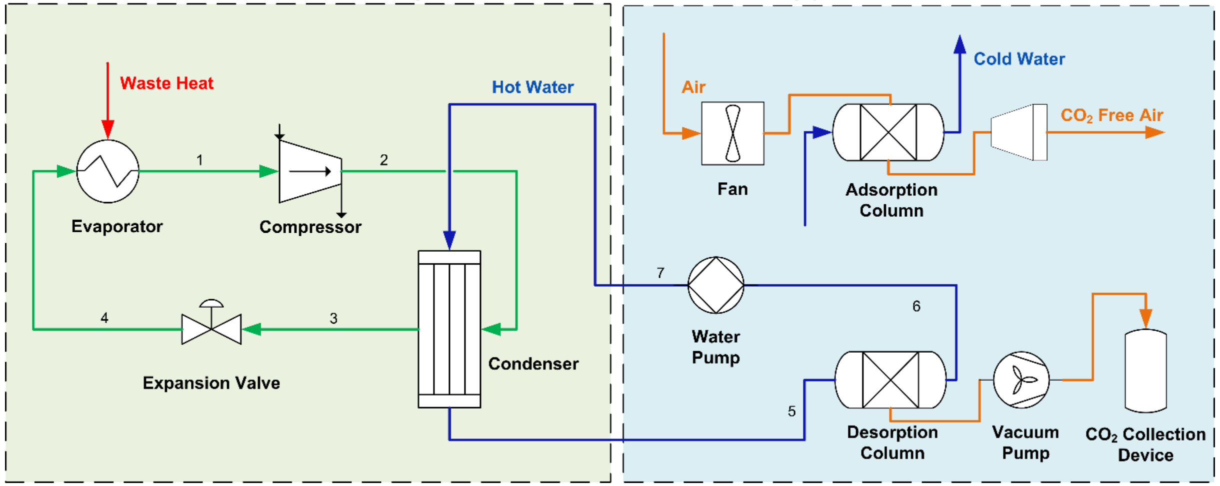


Figure 1. The flowsheet of simple DAC with **Heat Pump system** (H-DAC)

Table1. Energy consumption analysis of H-DAC and I-DAC system

Components	boiler	chiller	fan	vacuum	compressor	pump	Total ($GJ\ t_{CO_2}^{-1}$)
I-DAC	0	0	0.46	0.50	1.81	0	2.77
H-DAC	0	0.60	0.46	0.50	1.965	0.004	3.53

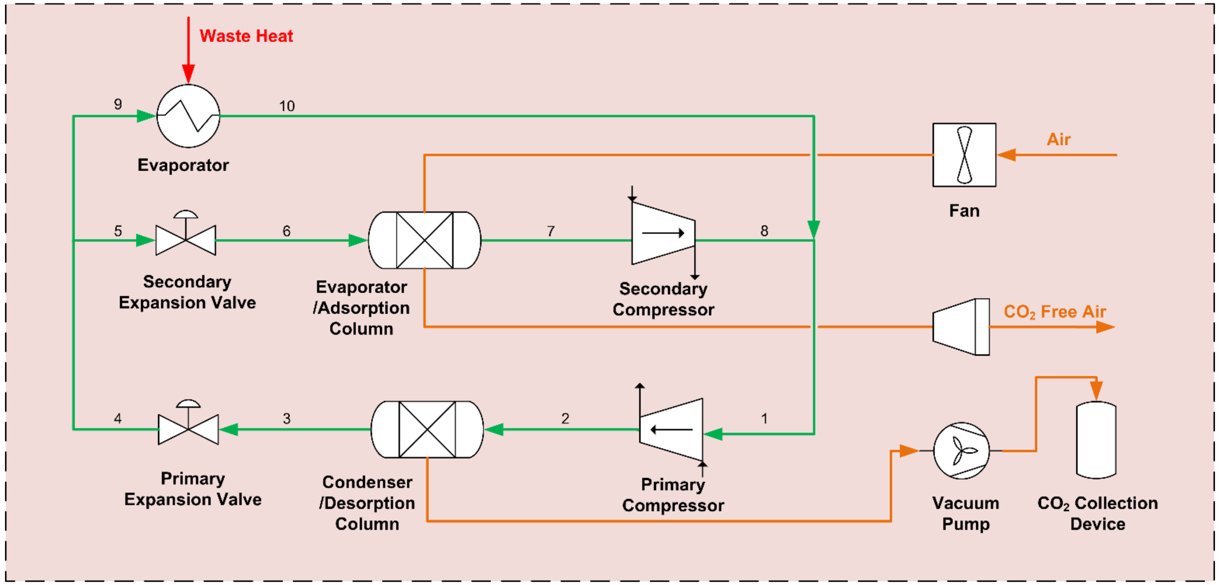
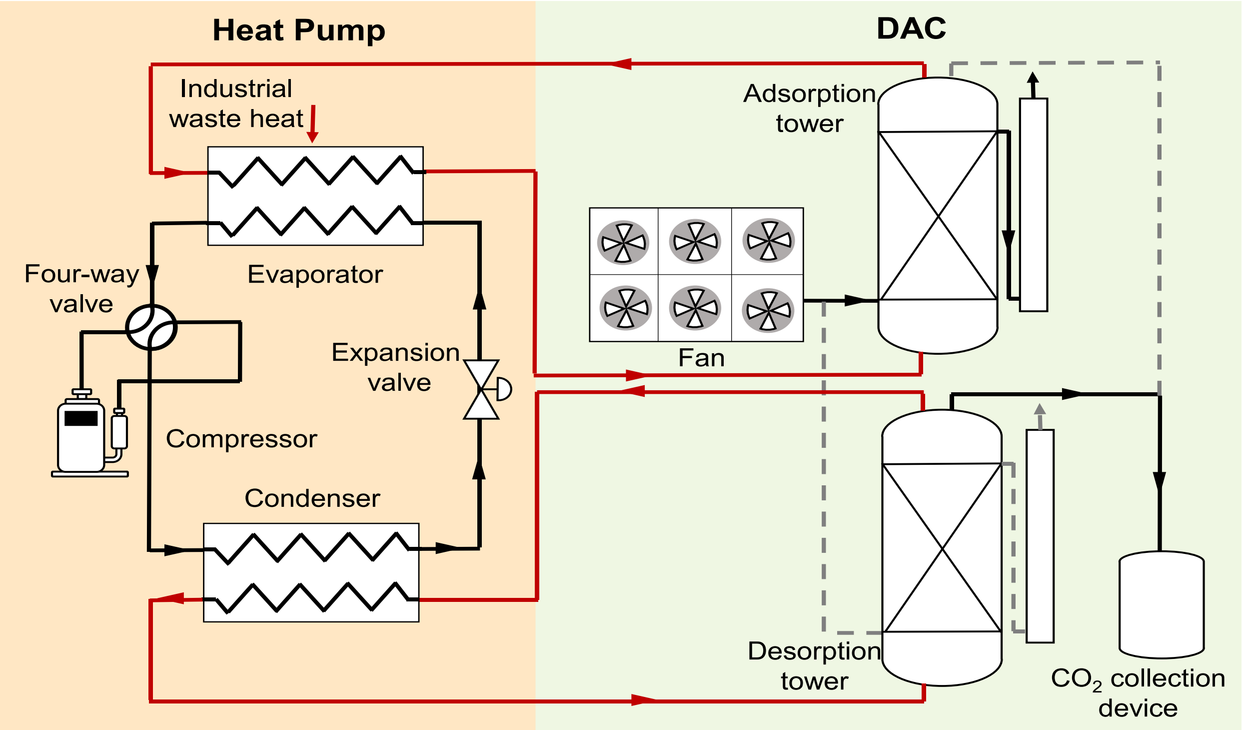


Figure 2. The flowsheet of deeply integrated DAC with heat pump **system** (I-DAC)

The combination of heat pump and DAC system offers a substantial reduction in thermal energy consumption, the deep thermal integration led to the reducing energy consumption by 69.5%.

Heat Pumps Integrated DAC demonstration-CarbonBox

600tons/year CO2 capture from air



Kou X, Wang R*, Du S, Xu Z, Zhu X. Heat pump assists in energy transition: Challenges and approaches. DeCarbon 2023:100033. https://doi.org/10.1016/j.decarb.2023.100033.

Zhu, X.; Xie, W.;…; O'Hare, D.; Li, J.; Ge, T.*; Wang, R.*, Recent advances in direct air capture by adsorption. Chem. Soc. Rev. 2022, 51 (15), 6574-6651.

Research Focus of ITEWA Team

07. Solar-based Desalination

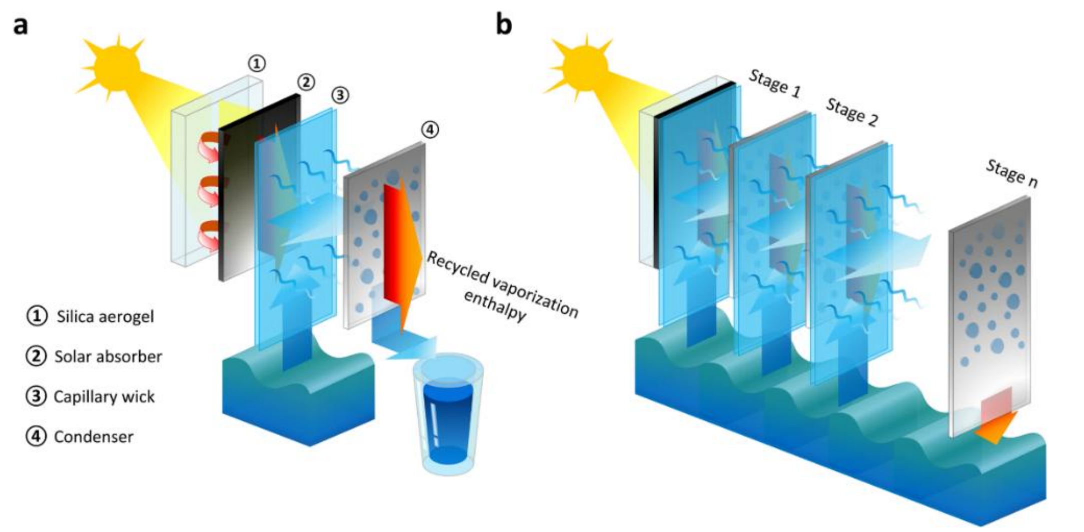
What we have done? **0-1** and **1-100** in Energy-Water-Air-Food nexus.

SD1: Ultrahigh-efficiency multistage solar desalination

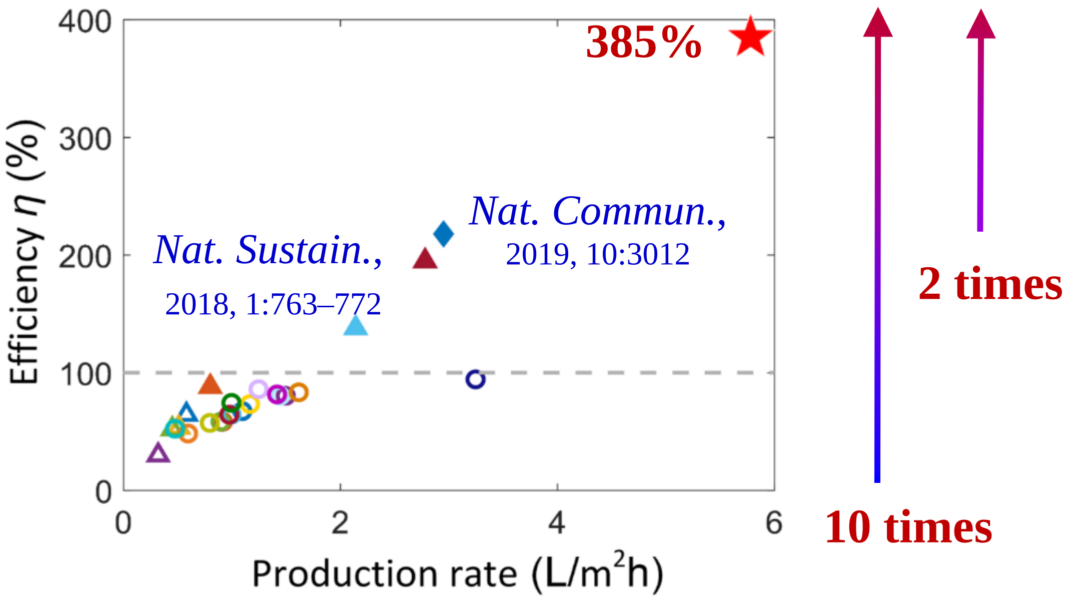
Energy & Environmental Science: Ultrahigh-efficiency desalination via a thermally-localized multistage solar still. 2020, 13, 830-839.

Zhenyuan Xu
First author

❑ Thermally-localized multistage solar still



❑ Distillation performance enhancement



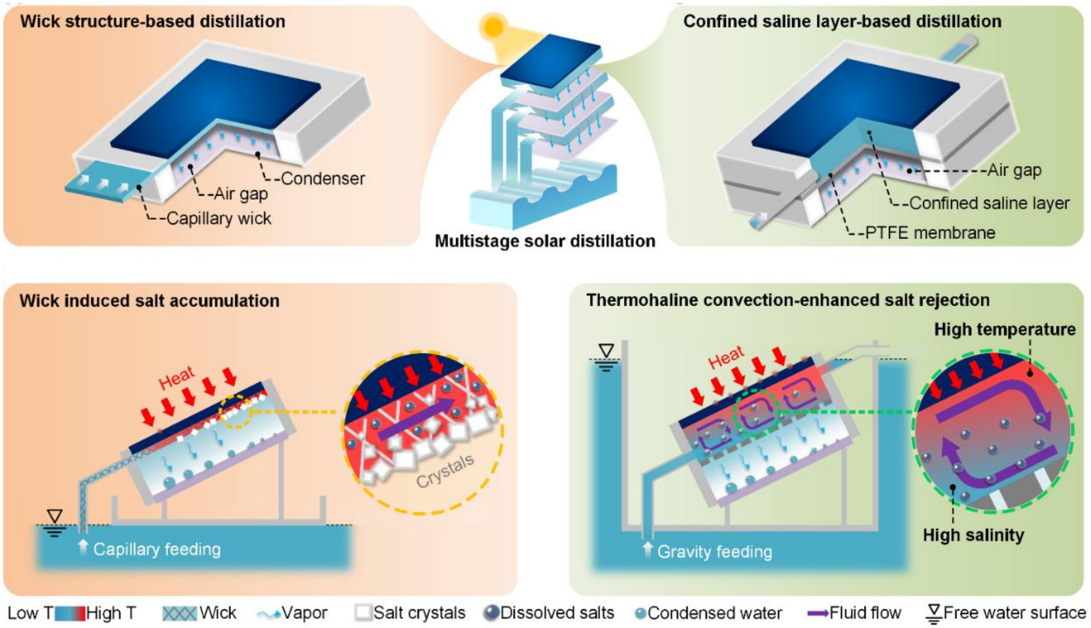
With thermally-localized multistage solar still, 385% solar GOR and 5.78 L m^{-2} h^{-1} production rate were demonstrated, which is 2 times higher than previous record (Top MIT research stories 2020).

SD2: Hypersaline desalination *via* thermohaline convection

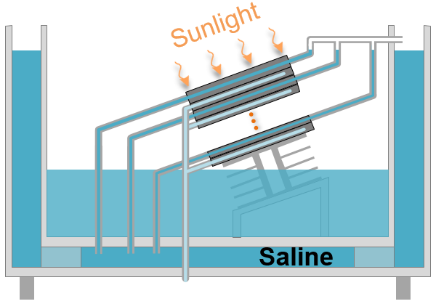
Jintong Gao
First author

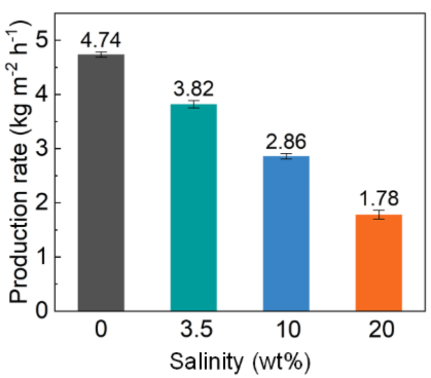
Joule: Extreme salt-resisting multistage solar distillation with thermohaline convection. 2023, 7, 1-17.

❑ Mechanism of thermohaline convection



❑ Solar-driven multistage TSMD device





Enhanced salt rejection and heat transfer by initiating thermohaline convection,

realizing stable water productivity of 1.78 kg m^{-2} h^{-1} with 20 wt% hypersaline brine

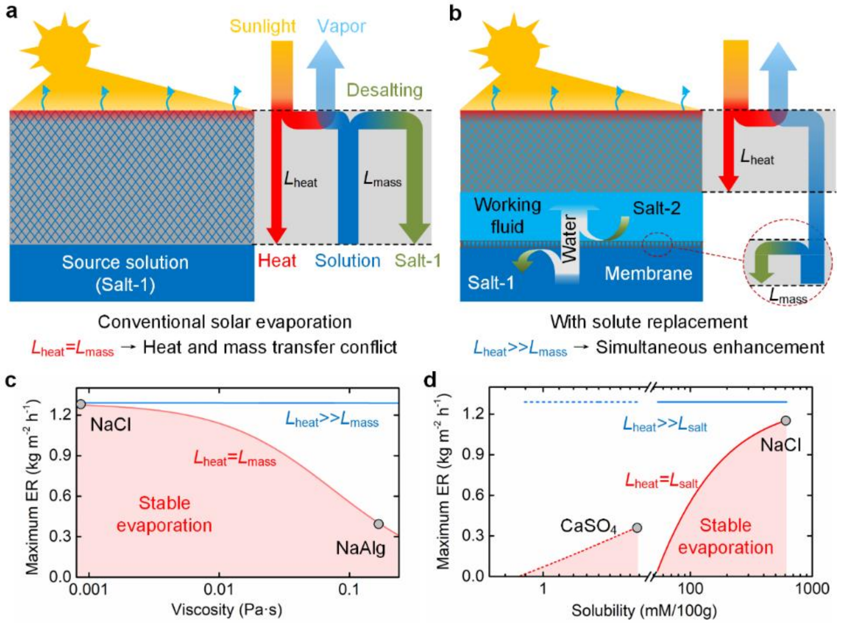
SD3: Solar evaporation towards real-world applications

Zhenyuan Xu

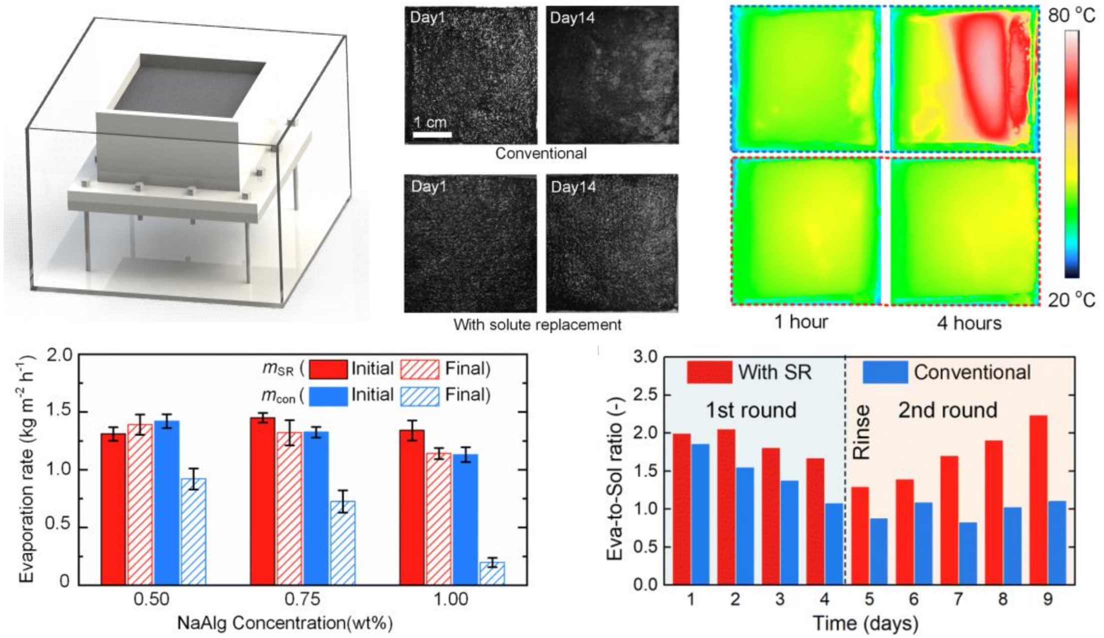
First author

Energy & Environmental Science: Solar evaporation with solute replacement towards real-world applications. 2023, 16, 5325-5338.

❑ Solute replacement strategy



❑ Evaporation performance enhancement

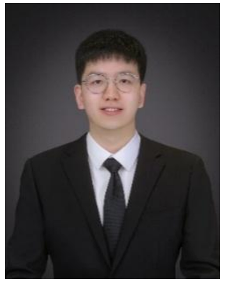


Developing solar evaporation with solute replacement, realizing fouling free when treating $CaSO_4$ solution, and 478% performance enhancement when treating NaAlg solution

SD4: Thermally-pressurized distillation for high water production rate

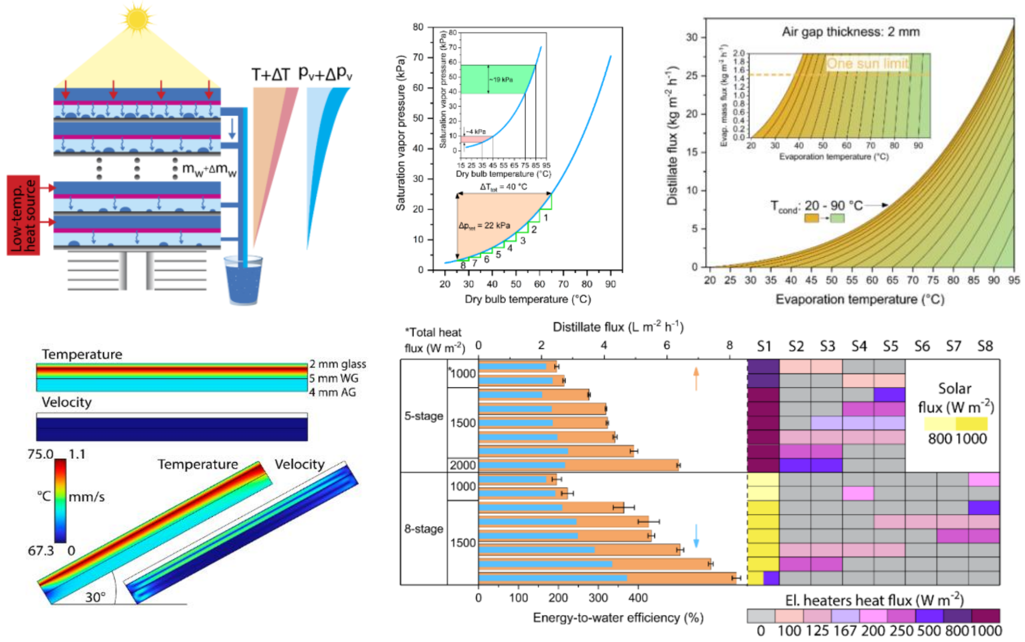
Nature Communications: Ultra-high freshwater production in multistage solar membrane distillation via waste heat injection to condenser. 2024, 15, 7890.



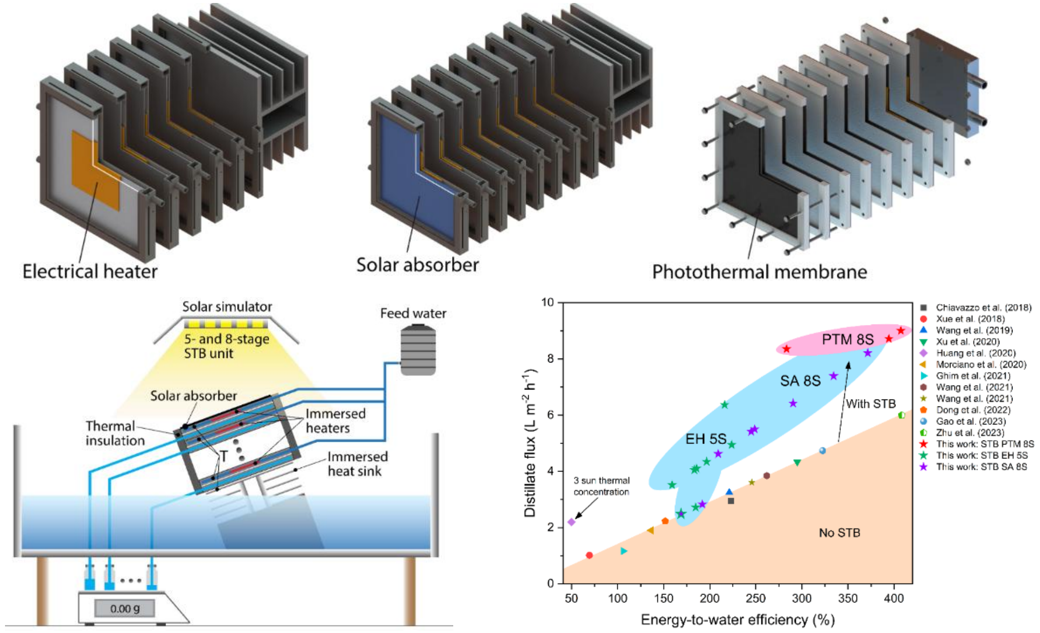


Primož Poredoš, Jintong Gao, He Shan

❑ Mechanism analysis



❑ Multistage MD and performance



Proposed a pressurization strategy to increase the vapor flux of membrane distillation,

realizing total distillate flux over 9.0 L m^{-2} h^{-1} and per-stage distillate flux up to 1.13 L m^{-2} h^{-1}

Contents

Gains widespread attention

中国科学家开发出通过“出汗”散热的涂层材料

2020-01-23 14:03 来源：新华社 【字体：大 中 小】 打印

新华社华盛顿1月22日电（记者 周舟）电子产品通常使用风扇来降温，但这种方法噪音大、耗能多且不适用于手机等小型电子产品。中国科学家团队近日开发出一种电子产品的散热涂层，能像出汗一样实现散热。

Science News *from research organi*

Coating helps electronics stay cool by sweating

Date: January 22, 2020
Source: Cell Press
Summary: Mammals sweat to regulate body temperature, and researchers are exploring whe our phones could do the same. The authors present a coating for electronics that releases water vapor to dissipate heat from running devices -- a new thermal management method that could prevent electronics from overheating and keep th cooler compared to existing strategies.
Share:

能源化工 2020年2月26日 星期三
编辑 / 李惠钰 校对 / 何工劳 Tel:(010)62580710 E-mail:hyli@stimes.cn
中国科学报 3

层层传“热”：海水淡化效率倍增

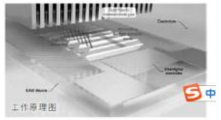
■本报见习记者 韩扬眉

系统正在 MIT 进行测试。

便携小型“随处可用”

常见系统热量损失效率低

■百叶窗



工作原理图

“迷你”超声波装

Top MIT research stories of 2020

The year's popular research stories include astronomical firsts, scientific breakthroughs, and engineering milestones addressing Covid-19 and other global problems.

MIT News Office
December 22, 2020

Science News *from research organizations*

Harvesting water from air with solar power

Atmospheric water harvester provides water to arid communities using hygroscopic gel and salts

Date: December 5, 2023
Source: American Institute of Physics
Summary: Researchers have developed a promising new solar-powered atmospheric water harvesting technology that could help provide enough drinking water for people to survive in difficult, dryland areas: They synthesized a super hygroscopic gel capable of absorbing and retaining an unparalleled amount of water. One kilogram of dry gel could adsorb 1.18 kilograms of water in arid atmospheric environments and up to 6.4 kilograms in humid atmospheric environments. This hygroscopic gel was simple and inexpensive to prepare and would consequently be suitable for

Breaking *this hour*

- Polymers That Can Kill Bacteria
- Evaluating Truthfulness Ups Belief in Fake News
- Using AI, a New Class of Antibiotics
- How Jellyfish Regenerate Tentacles in Days
- How Did the Universe Begin?
- Reindeer Sleep While Chewing Their Cud
- Light Color and Internal Clock
- Insect Defense Strategies in the Cretaceous
- Neolithic Farmers

ScienceDaily
Your source for the latest research news
Follow: Subscribe:
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Science News *from research organizations*

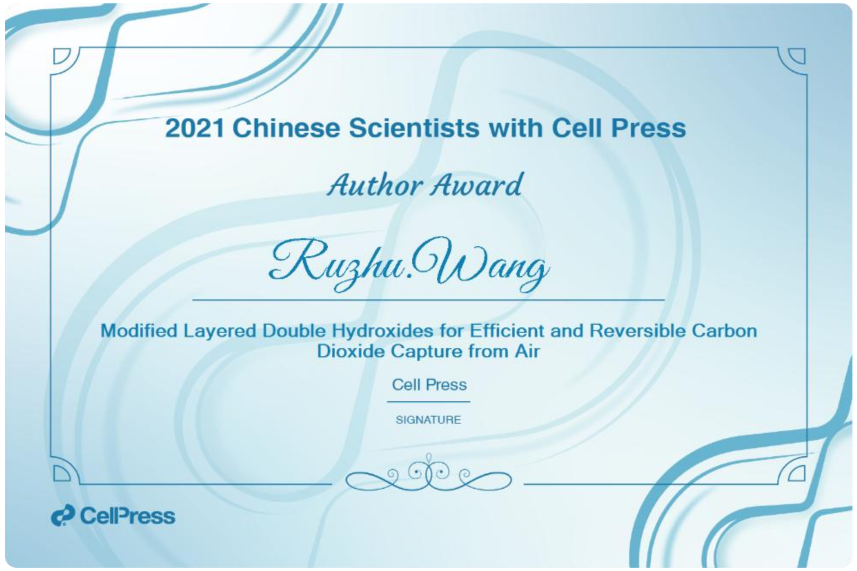
Desalination system could produce freshwater that is cheaper than tap water

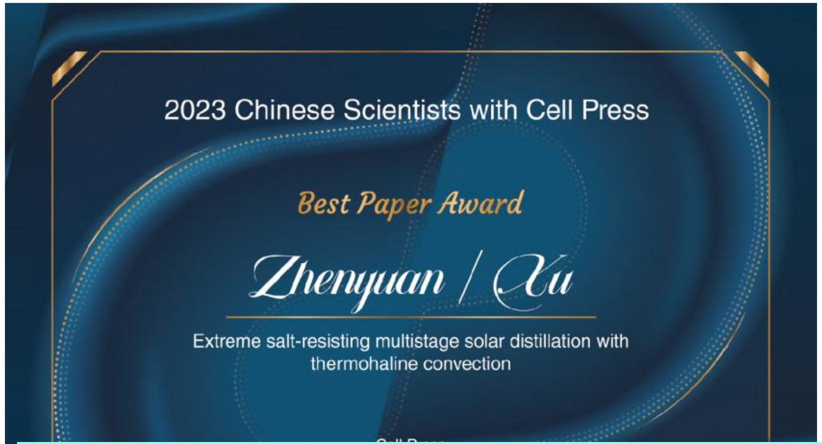
Date: September 27, 2023
Source: Massachusetts Institute of Technology
Summary: Researchers have designed a new solar desalination system that takes in saltwater and heats it with natural sunlight. The system flushes out accumulated salt, so replacement parts aren't needed often, meaning the system could potentially produce drinking water at a rate and price that is cheaper than tap water.
Share:

Breaking *this hour*

- Polymers That Can Kill Bacteria
- Evaluating Truthfulness Ups Belief in Fake News
- Using AI, a New Class of Antibiotics
- How Jellyfish Regenerate Tentacles in Days
- How Did the Universe Begin?
- Reindeer Sleep While Chewing Their Cud
- Light Color and Internal Clock

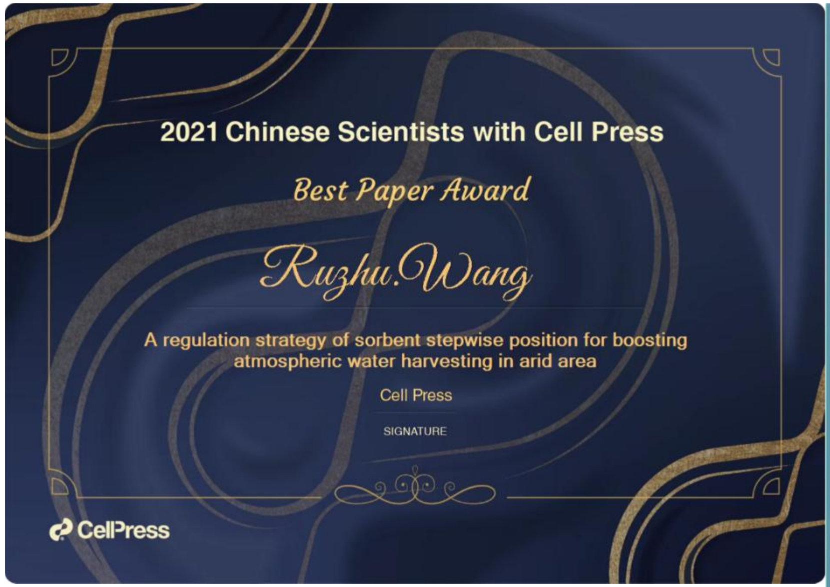
Chinese Scientists with Cell Press Best Paper Award 2020/2021/2022/2023/2024

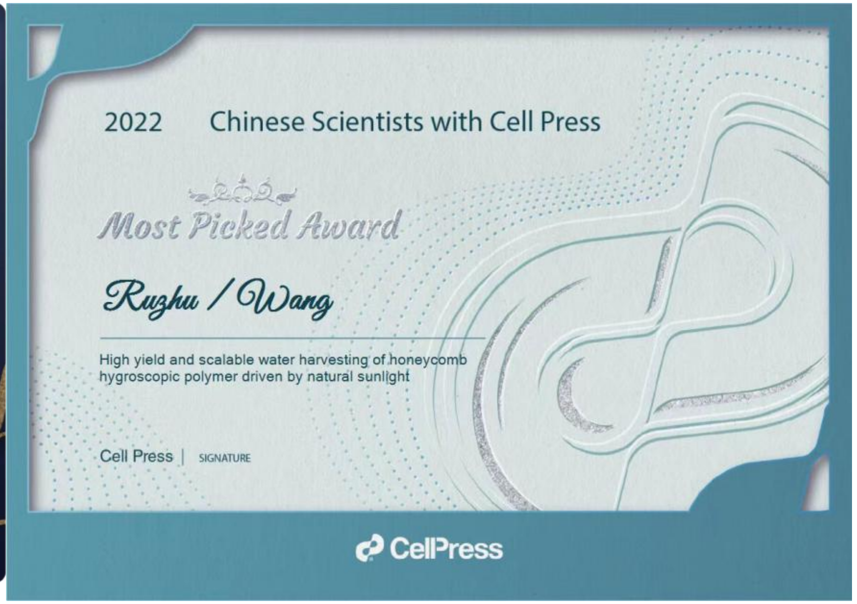




2023 Chinese Scientists with Cell Press Best Paper Award

(Ten Papers in Sustainable Development)





2023 Chinese Scientists with Cell Press Best Paper Award

(Ten Papers in the Field of Materials Science)

Published Top Papers by ITEWA (2018-2023)

NO.	Journal	Year of Publication	Volume and Pages	Impact Factor (2022)	ESI Highly Cited Paper (Until 2023)
1	Science	2023	380, 458-459	**56.9**	
2	Nature Review Materials	2023	-	**83.5**	
3	Nature Energy	2023	8, 226-227	**56.7**	
4	Nature Water	2023	1, 971-981	**-**	
5	Chemical Society Reviews	2022	51, 6574-6651	**46.2**	🏆
6	Joule	2018	8, 1452-1475	**39.8**	🏆
7	Joule	2019	6, 1427–1436	**39.8**	
8	Joule	2020	2, 435-447	**39.8**	🏆
9	Joule	2021	7, 1678-1703	**39.8**	🏆
10	Joule	2022	7, 1390-1393	**39.8**	
11	Joule	2023	10, 2274-2290	**39.8**	
12	Energy & Environmental Science	2020	13, 830-839	**32.5**	🏆
13	Energy & Environmental Science	2021	14, 5979-5994	**32.5**	🔥 🏆
14	Energy & Environmental Science	2022	15, 4867-4871	**32.5**	
15	Energy & Environmental Science	2022	15, 3223-3235	**32.5**	
16	Energy & Environmental Science	2023	16, 5325-5338	**32.5**	
17	Energy & Environmental Science	2023	-	**32.5**	
18	Energy & Environmental Science	2023	-	**32.5**	
19	Nature Communications	2022	13,193	**16.6**	
20	Nature Communications	2022	13, 5406	**16.6**	
21	Nature Communications	2022	13, 6771	**16.6**	
22	Nature Communications	2023	14, 8060	**16.6**	
23	Advanced Materials	2019	31, 1905099	**29.4**	🏆
24	Advanced Materials	2023	2210957	**29.4**	
25	Advanced Materials	2023	2302038	**29.4**	
26	Advanced Materials	2023	2310177	**29.4**	
27	Angew. Chem. Int. Edit.	2020	59, 5202-5210.	**16.6**	🏆
28	ACS Energy Letters	2021	6, 1795-1802	**22.0**	
29	ACS Energy Letters	2023	8,1921-1928	**22.0**	
30	ACS Energy Letters	2023	8, 5184–5191	**22.0**	
31	Matter	2021	4, 3385-3399	**18.9**	
32	Matter	2022	5, 2487–2490	**18.9**	
33	Matter	2023	6, 19–22	**18.9**	
34	Matter	2023	6, 2490–2493	**18.9**	
35	Advanced Functional Materials	2021	2105267	**19.0**	
36	ACS Nano	2022	16, 11473–11482	**17.1**	
37	ACS Central Science	2020	6, 1542-1554.	**18.2**	
38	Device	2023	1, 100054	**-**	
39	Device	2023	1, 100016	**-**	
40	Device	2023	1, 100122	**-**	
41	Device	2023	1, 100065	**-**	
42	Device	2023	1, 100058	**-**	
43	Science Bulletin	2023	68, 1493-1496	**18.9**	
44	Science Bulletin	2023	-	**18.9**	
45	Nano Energy	2021	84, 105946	**17.6**	🏆
46	Nano Energy	2021	85, 105977	**17.6**	
47	Nano Energy	2021	89, 106338	**17.6**	🏆
48	Nano Energy	2021	90, 106642	**17.6**	
49	Energy Storage Materials	2020	27, 9–16	**20.4**	
50	Energy Storage Materials	2020	27, 352–369	**20.4**	
51	Energy Storage Materials	2021	42, 380–417	**20.4**	🏆
52	Energy Storage Materials	2022	54, 794-821	**20.4**	
53	Energy Storage Materials	2023	57, 205-227	**20.4**	
54	Applied Physics Reviews	2023	10, 041413	**15.0**	
55	Applied Physics Reviews	2023	10, 041409	**15.0**	
56	Advanced Science	2022	9, 2204508	**15.1**	
57	Advanced Science	2022	9, 2204724	**15.1**	
58	ACS Materials Letters	2020	2, 471-477	**11.4**	
59	ACS Materials Letters	2023	5, 2019-2027	**11.4**	
60	Renew. Sust. Energ. Rev.	2020	121, 109712	**15.9**	
61	Renew. Sust. Energ. Rev.	2020	123, 109748	**15.9**	
62	Renew. Sust. Energ. Rev.	2020	124, 109791	**15.9**	
63	Renew. Sust. Energ. Rev.	2021	137, 110651	**15.9**	
64	Renew. Sust. Energ. Rev.	2021	141, 110802	**15.9**	
65	Renew. Sust. Energ. Rev.	2021	145, 111026	**15.9**	
66	Renew. Sust. Energ. Rev.	2022	157, 112015	**15.9**	
67	Renew. Sust. Energ. Rev.	2022	161, 112106	**15.9**	
68	Renew. Sust. Energ. Rev.	2022	169, 112890	**15.9**	
69	Renew. Sust. Energ. Rev.	2023	182, 113373	**15.9**	
70	Chemical Engineering Journal	2021	410, 128322	**15.1**	
71	Chemical Engineering Journal	2021	425, 131409	**15.1**	
72	Chemical Engineering Journal	2022	450, 137958	**15.1**	
73	Chemical Engineering Journal	2023	452, 139116	**15.1**	
74	Water Research	2021	198, 117154	**12.8**	
75	Water Research	2022	211, 118029	**12.8**	
76	Small	2022	18, 2105647	**13.3**	
77	Small Structures	2023	4, 2300055	**15.9**	
78	Engineering	2023	23, 13-18	**12.8**	
79	Resour. Conserv. Recy.	2022	185, 106521	**13.2**	
80	J Materials Chemistry A	2020	8, 16421-16428	**11.9**	
81	J Materials Chemistry A	2020	8, 20011-20020	**11.9**	🏆
82	J Materials Chemistry A	2022	10, 22853-22895	**11.9**	
83	J Materials Chemistry A	2022	10, 6576-6586	**11.9**	
84	ACS Materials Au	2023	3, 43-54	**-**	
85	ACS Appl. Mater. Inter.	2021	13, 19200-19210	**9.5**	
86	Cell Reports Physical Science	2021	2, 100484	**8.9**	
87	Cell Reports Physical Science	2021	2, 100561	**8.9**	
88	Cell Reports Physical Science	2021	2, 100578	**8.9**	
89	Cell Reports Physical Science	2021	2, 100664	**8.9**	
90	Cell Reports Physical Science	2022	3, 100954	**8.9**	
91	Cell Reports Physical Science	2023	4, 101278	**8.9**	
92	Cell Reports Physical Science	2023	4, 101539	**8.9**	
93	Cell Reports Physical Science	2023	4, 101517	**8.9**	
94	Cell Reports Physical Science	2023	4, 101554	**8.9**	

Exploring Groundbreaking Basic Research from 0 to 1

April 2024: ITEWA Laboratory

Science 1、Nature Research Journals 12

50+ publications in IF>15 journals

April 2024: Expansion of Laboratory Space

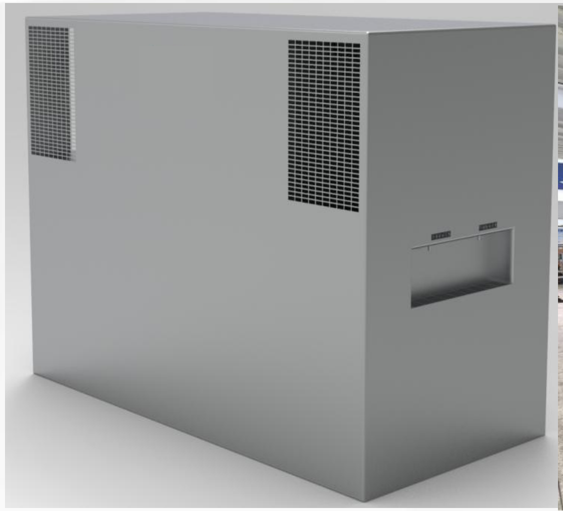
GEL204

Peripheral Lab Setups and Measurement Tools

AWH commercialization (AtmosWell, GE Water+SJTU)

AWH commercialization (AtmosWell, GE Water+SJTU)

- Market requirements: 10L, 20L, 50L, 100L, 500L, 1000L/day (condensing units for RH>=40%)
- Market requirements: 1L, 10L, 50L, 100L/day (Sorption units, for RH=20~50%)



Heat exchanger design and system installation

Typical 1 ton/day AWH product

Solar Sorption AWH

More R&D is going on

AWH commercialization (AtmosWell)

Expected for large scale commercialization

Residential/business 20L/day **Public service (solar PV+Battery+AWH+Clean Water)**

AWH commercialization (AtmosWell)

Expected for large scale commercialization

Residential/business 20L/day

Public serv

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Commentary

Approaching thermodynamic boundaries and targeting market players for commercial atmospheric water harvesting

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Prof. Ruzhu Wang is a chair professor at Shanghai Jiao Tong University and has served as director of the Institute of Refrigeration and Cryogenics for three decades. He is also editor-in-chief of *Energy*. His research focuses on the energy-water-air nexus, green building energy systems, and heat pumps. He has received three Chinese National Research Awards and numerous prestigious international honors, including the IIR Gustav Lorentzen Medal, the IEA Rittinger International Heat Pump Award, and the Global Energy Prize in 2023.

Introduction

One-third of the world's population lacks reliable access to clean water, particularly in remote and low-income regions. Atmospheric water harvesting (AWH) offers a solution by capturing the abundant yet dispersed atmosphere moisture and converting it into drinkable water anytime and anywhere.[1] Recent scientific breakthroughs, notably in material science and energy efficiency, have extended AWH viability to lower humidity environments and reduced energy consumption to economically feasible levels, moving the technology beyond laboratory demonstrations toward practical implementation. This technological maturation is driving significant academic and industrial engagement, including the formation of numerous startups aiming to commercialize AWH systems.

This commentary examines the current state of the AWH market to provide transparency for decision-makers and investors navigating this fast-evolving field. We analyze the diverse technological approaches adopted by leading players, quantify their reported water production yields and energy consumptions, and evaluate the potential for future technological advancements through heat pump platforms by examining their thermodynamic limits. Additionally, we assess the market opportunity for AWH to supplement or even replace conventional centralized water infrastructure. By synthesizing technical performance with commercial realities, we aim to guide stakeholders in collectively accelerating the adoption of AWH as a transformative solution for global water access.

Rethinking AWH as an energy-water thermodynamic system

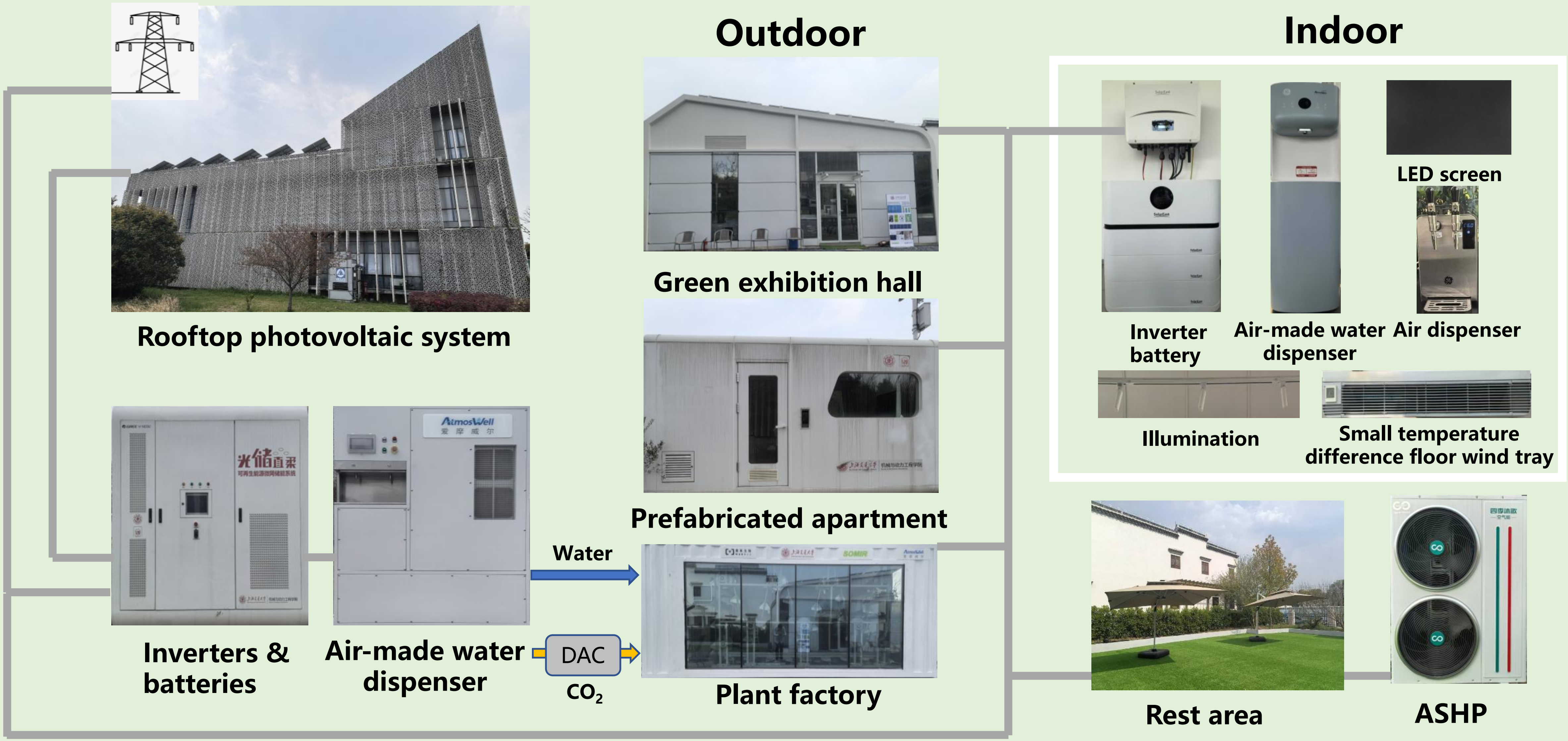
AWH should be understood as an energy-water conversion pathway focused on balancing yield, efficiency, and scalability. Its transition from lab innovation to commercial application requires understanding AWH as both a thermodynamically constrained process and a practical market solution. Rather than advancing technologies in isolation, we evaluate existing players to define energy boundaries and accelerate practical deployments.

From a thermodynamic standpoint, all AWH systems convert energy into liquid water by separating vapor from air. The minimum theoretical work for reversible water extraction from unsaturated air is defined by the change in Gibbs free energy:

$$E_{min} = -RT_{amb}\ln(\alpha_w) \quad \text{(Equation 1)}$$

where α_w denotes the water activity, which equals the relative humidity (RH) of moist air in thermodynamic equilibrium, T_{amb} is ambient temperature, and R is the specific gas constant for water vapor. This theoretical work sets the minimum energy requirement for an ideal thermodynamic cycle, which, for example, is 46 $Wh \cdot L^{-1}$ at 30% RH and 25°C (see Note S1 and Figures S1 and S2). This value increases exponentially as RH decreases, reflecting the increasing difficulty of extracting water from drier air. However, in practice, this minimum work is never feasible because practical

ITEWA Park


Outdoor
Indoor
Rooftop photovoltaic system
Green exhibition hall
Prefabricated apartment
Plant factory
Inverters & batteries
Air-made water dispenser
Water
DAC
CO_2
LED screen
Inverter battery
Air-made water dispenser
Air dispenser
Illumination
Small temperature difference floor wind tray
Rest area
ASHP

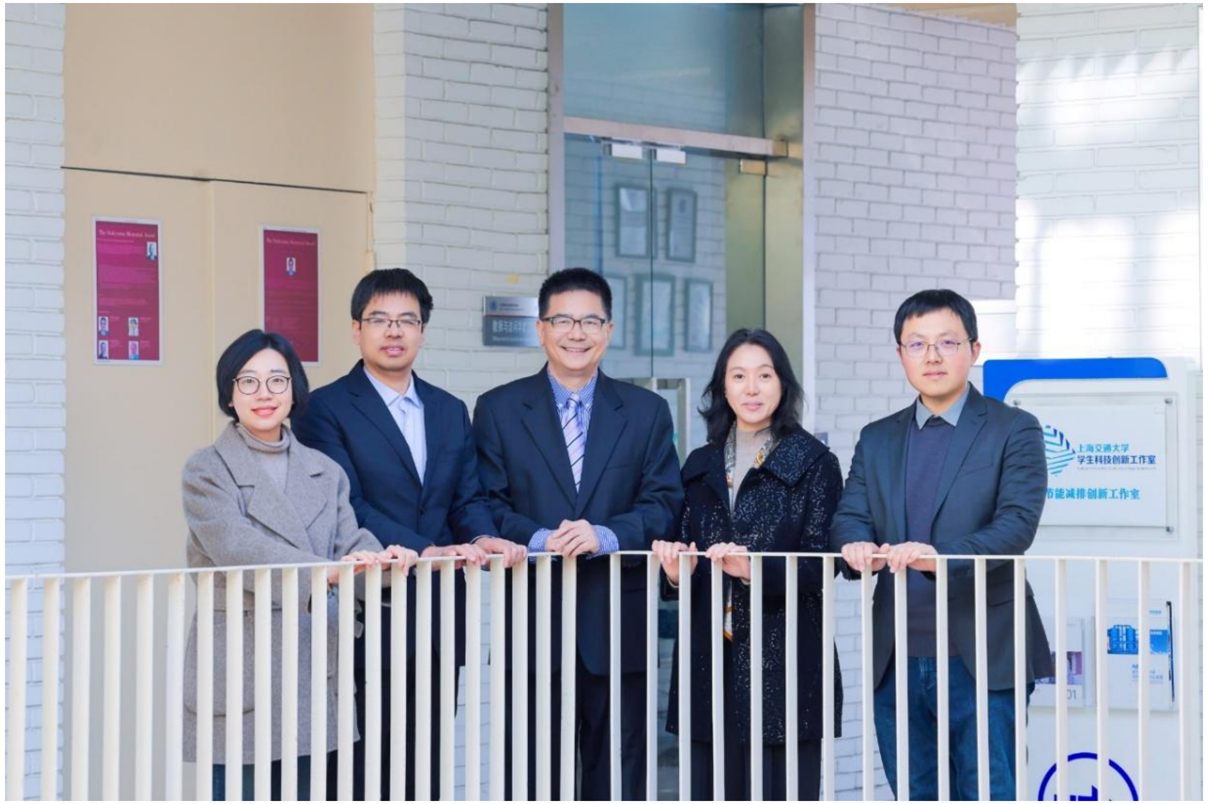
2020 ITEWA Team

2021 ITEWA Team Faculty Members:

Ruzhu Wang;
Tingxian Li;
Tianshu Ge;
Zhenyuan Xu;
Xuncan Zhu

Dual-focused Research (0~1 & 1~100) helps Academic Team Development

- NSFC Innovative Research Group with Excellence (2021)
- NSFC Major Program (Newly Approved in 2022)
- Shanghai Leading Talent Program of Eastern Talent Plan (2023)
- Faculty Selected into National-Level Talents



My research group (all faculty members & research staffs)

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Concluding Remarks

Energy-water-air-food: a nexus approach

- Understanding 0-to-1 and 1-to-100 Paradigms
- Inspire young researchers
- Team work
- Excel in Pioneering Innovations from 0 to 1 while Scaling Up from 1 to 100

Concluding Remarks

Thanks and welcome to Shanghai!