WSSET
World Society of Sustainable Energy Technologies

NEWSLETTER

Volume 15 | Issue 3 | September 2023

Note to articles

The second article (page 3) in this newsletter is based on the research that won the **Best Paper Award at SET2023.**
The next four articles are based on research that won the prestigious **WSSET Innovation Awards**.
More details of these can be found on page 8.

SET2023 | Nottingham | UK

SET2023, the 20th SET conference, was held in Nottingham on the 15-17 August 2023. 300 abstracts were submitted by authors from 50 countries; 200 delegates attended presenting 112 papers and 69 posters.

Ten Keynote Speakers introduced their research ranging from the journey to Net Zero Cities to microplastic and nanoplastic pollution; conversion of waste to energy and resource; from digital twins for decarbonisation to energy transition; from a flat-panel ground heat exchanger to mini grids; from multi-functional application of BIPV/T system to solar driven heating and cooling system; and the development of wake and yaw-control simulation models for optimized wind power generation.

Delegates were surprised by the appearance of the infamous Robin Hood who regaled them with tales of his life in Sherwood Forest, whilst the Gala Dinner was enlivened first by an ABBA tribute band followed by the carnival band Can Samba, and friend!

With four parallel sessions, delegates could choose from an array of topics covering energy technology & renewables; energy storage & conversion; low carbon buildings; architecture & sustainable cities; and policies & management.

Prof Saffa Riffat and the SET2023 Organising Team would like to extend their deepest thanks to the three sponsors: Zafer Ure from PCM Products Ltd.; Michael Farnsworth from Stormsaver Ltd. and Prof Terry Payne who sponsored the registration of fees of 15 post graduate delegates.

SET2024 will be in Shanghai, China
More information to follow!

Volume 15 | Issue 3 | September 2023

Smart all-in-one window with integration of PV vacuum glazing and window frame heat recovery ventilation system

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This is a brief introduction article for introduction of the technologies produced in the EU H2020 SureFit Project.

Poor glazing insulation and natural window ventilation represent an average of 15% and 35% primary energy consumption in most of residential and commercial buildings, which is crucial in energy conservation for net zero energy target in 2050. Natural ventilation by opening windows is the most common in residential and commercial buildings, with approximately 35% additional primary energy consumption. Due to the fondness for daylighting and the broad view, architects prefer using large windows, glass curtain walls, and the skylight in modern architecture, such as the conservatory. However, the wide use of glass leads to a critical energy issue. A large surface area lets both daylight and heat pass through and causes a significant variation of the indoor temperature since standard glass has worse heat insulation and preservation abilities than other building materials. It increases the energy consumption of air conditioning for both heating and cooling.

The smart all-in-one window systems integrated with frame is shown in Figure 1 with alternative horizontal and vertical install positions, including a window heat recovery system and PV vacuum glazing system. Window heat recovery system is heat exchangers coupled to building windows frame that enable to exchange heat between exhausted and supplied air during the building ventilation. This is accomplished by ultra-quiet axial fan with adjustable air speeds varied from 10 m3/h to 60 m3/h. One being installed at the supply air side and another at the exhaust air outlet. The PV-Vacuum glazing is used for glass area to provide renewable electricity with battery storage and solar controller to support the power need of window heat recovery and indoor lighting. The electrical configuration of connection between PV-VG and Window heat recovery is shown in Figure 2. The renewable generated electricity by PV vacuum glazing is stored in the battery through the DC to AC convert inside the solar controller. When required by the operation of the window heat recovery unit, the battery will supply the electricity to support the window heat recovery through the conversion of solar controller.

Therefore, the heat recovery effectiveness is calculated according to the validated model with indoor and outdoor temperature differences varied from 5 to 40 ℃ and ventilation rate varied from 10 to 60 m3/h. The calculation results of different heat recovery effectiveness of the prototypes are shown in Figure 3. The PV vacuum glazing generate the electricity and stored in the battery to supply the window heat recovery ventilation when required. And the glazing insulation achieves U-value of 0.5 W/m2K with glazing solar to electricity conversion efficiency of 5.28% with light transparency of 50%. In addition, the window heat recovery unit using the heat pipe as high thermal conducting method with heat recovery efficiency between 74%-94% with variation of ventilation rate between 10-60m3/h.

The smart all-in-one window system, integrating window heat recovery and PV vacuum glazing (PV-VG), presents a promising solution for enhancing building energy efficiency and sustainability. The window heat recovery system efficiently exchanges heat between exhausted and supplied air during building ventilation, enabling year-round thermal comfort. The PV-VG provides both renewable electricity generation and high-efficiency thermal insulation, reducing heat loss while allowing visible light to pass through. In a case study of a 1940s' masonry semi-detached house, the smart all-in-one window significantly reduced total annual energy consumption of the room by 15.3%, resulting in improved indoor air quality and substantial cost savings in energy bills. The payback period for the investment was calculated at 7 years, confirming its economic feasibility. Overall, the smart all-in-one window system offers a cost-effective and sustainable approach to enhance building energy efficiency, indoor comfort, and renewable electricity generation. Its successful integration of window heat recovery and PV-VG technologies makes it a promising candidate for widespread implementation in buildings to promote energy conservation and reduce environmental impact.

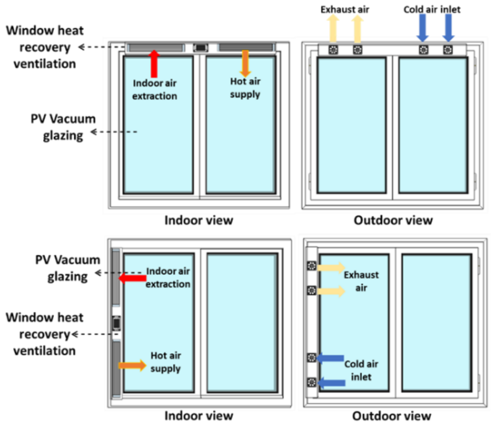

Figure 1: Smart all-in-one window system integrated with frame (winter example) (a:horizontal install, b:vertical install).

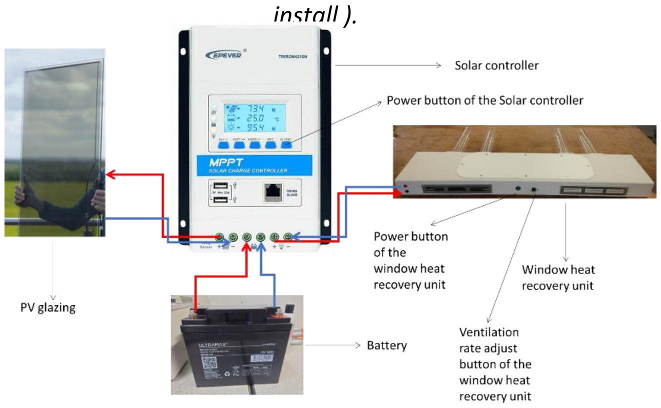

Figure 2: Electrical configuration of connection between PV-VG and Window heat recovery

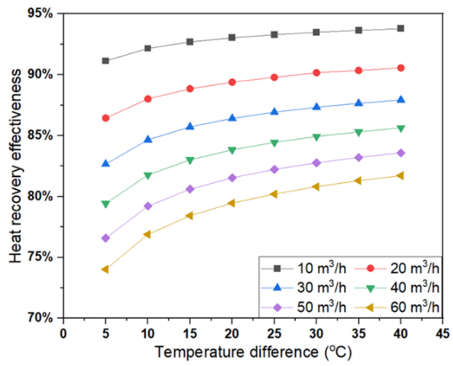

Figure 3: Heat recovery effectiveness of the prototypes under different operation conditions

Volume 15 | Issue 3 | September 2023

Machine learning applications in data centre cooling performance optimisation and forecasting: A review

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As one of the signatories of The Paris Agreement, the UK's legally binding requirement is to reach net zero emissions by 2050, and its commitment under the Paris agreement is to cut emissions by 68% by 2030 [1]. Over the past decade, data centres (DCs) have evolved into a critical infra-structure that underpins daily lives of individuals and leading Information and communication technology (ICT) companies, like Google, facilitating remote data services for diverse needs including cloud services, social media, etc., which makes the number of hyperscale DCs globally is doubled from 2015 to 2021 (Figure 1) [2]. And this have turned data centres into a rapidly growing industry.

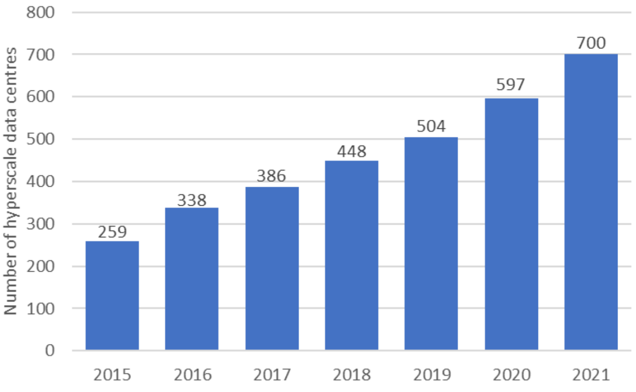

Figure 1: Hyperscale data centres worldwide 2021

In 2022, DCs accounted for 1% of global electricity consumption, while in the UK, this figure further increases to 2.5% [3]. Even though the IT system attributes primarily to a DC's total power consumption, depending on different cooling techniques (air, liquid, and free cooling), the cooling system alone can make up 30% to 40% of the energy consumption (Figure 2) [3]. It is critical to use efficient cooling methods and control strategies for DCs.

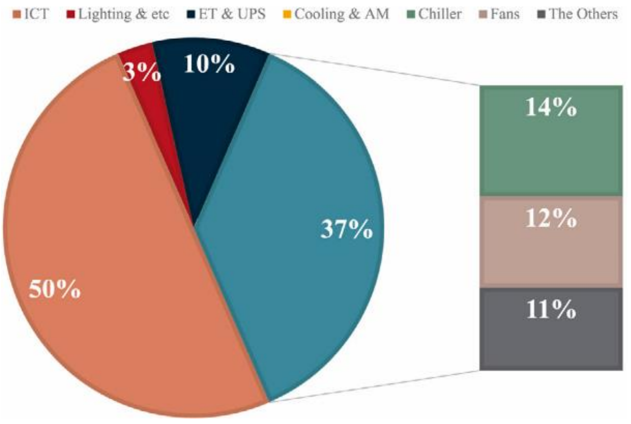

Figure 2: Power consumption breakdown of a DC [3]

To meet the cooling demand of DCs, preliminary modelling is required during the designing stage [4]. While due to the dynamics natural of DCs cooling system, it often results in inadequate optimisation and inaccurate forecasting of cooling performance which require hand-tuning for specific devices [5]. In this case, machine learning technique fundamentally outperform conventional modelling as it only learns and derives from the massive data collected from the desired system. Combining machine learning technique with energy-efficient DC cooling can achieve energy saving for up to 26.6% [6], 15% [7], and 72% [8] for air, liquid and dew-point cooling (DPC) techniques respectively, which makes integrating machine learning into DC cooling systems, especially DPC, a promising research area.

This review paper focuses on the development of machine learning applications in DC's control strategy optimisation and long-term performance forecasting from 2000 to 2022. Existing literatures are categorized based on seven criteria, while five machine learning based optimisation strategies and six forecasting methods are firstly introduced, followed by jointly optimizing approaches with IT system. Based on above analysis, the discussion and conclusions are focused on the comparations of DC cooling systems, the limitations of physical engineering modelling and machine learning technologies, the present and future trend of machine learning applications in DC sector. The findings of this review can act as a steppingstone for scholars, researchers, and policy makers in related fields.

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Volume 15 | Issue 3 | September 2023

Solar2Water – A Decentralized water solution

Dr Muhammad Wakil Shahzad

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According to the United Nations, one in three people worldwide still live without access to safe drinking water, sanitation and hygiene services, a problem which is only worsening with climate change, conflicts and population growth. This lack of access to water leaves communities across the globe exposed to water- and sanitation-related diseases, with over 800,000 people estimated to die each year from diarrhoea alone as a result of unsafe drinking-water, sanitation and hand hygiene.

We, at Northumbria's Department of Mechanical and Construction Engineering, have been developing pioneering solutions to help tackle water scarcity. Our latest project has seen the creation of 'Solar2Water', an innovative water production unit, which uses solar energy to extract moisture from the air and turn it into clean, safe drinking water.

The patented Solar2Water system overcomes the operational limitations of conventional atmospheric water generators, with major advantages including that it can produce a constant amount of water, regardless of the outside air humidity and that it generates double the amount of water using the same amount of energy. Running on solar energy alone, the unit features two solar panels, which, once unfolded, begin harnessing energy from the sun to kick-start water production.

A battery system that stores energy during the day and releases it at night enables 24-hour operation, producing water for daily usage. No training or experience is required to use the system and its robust mechanical build means it can be operated in any environment. This allows Solar2Water to be deployed quickly and easily to any location, such as disaster zones, field hospitals, offices, refugee camps, army camps and remote communities where there is no grid connection or water availability nearby. It is a water neutral system – it can produce water without the need for a body of water.

This technology could be game-changing in helping to achieve sustainable water supplies in under-developed areas and will help to progress two of the UN's Sustainable Development Goals – Zero Hunger and Clean Water and Sanitation for all.

This project has received initial funding from Northumbria University to demonstrate the Solar2Water concept. Following the successful development of the prototype unit in the lab, Solar2Water project was granted Proof-of-Concept funding from Northern Accelerator, an exciting collaboration between the North East's universities, creating real-world impact from world-leading research, commercialising innovation and boosting the region's economy.

For more information, visit the following websites:
https://www.northumbria.ac.uk/about-us/news-events/news/new-portable-system-produces-drinking-water-from-just-air-and-sunlight/

https://www.pv-magazine.com/2023/06/08/new-portable-system-uses-pv-to-produce-drinkable-water-from-air-moisture/

Figure 1: Dr Muhammad Wakil Shahzad (left) and his team from Northumbria University

Volume 15 | Issue 3 | September 2023

Design, production and thermo-dynamic analysis of solar energy supported, nanofluid integrated thermoelectric vaccine cabinet

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Thermoelectric coolers work silently and vibration-free, do not contain any moving parts, are suitable for automation, have a long life and a compact structure. Thanks to these advantages, they have a wide range of uses, from in-car refrigerators to organ and drug transport boxes. They consist of P-type and N-type semiconductors placed between two ceramic plates. These semiconductors are connected electrically in series and thermally in parallel to form a circuit, and if current is applied to this circuit, one of the ceramic plate surfaces begins to cool and the other begins to heat up. This phenomenon is called the Peltier effect, and thermoelectric coolers are also specifically called Peltier. The most important advantage of thermoelectric coolers compared to conventional cooling systems is that they do not contain large, space-consuming, and noisy parts. However, the coefficient of efficiency (COP) values of thermoelectric coolers is low. This situation limits the usage areas of thermoelectric cooling applications.

A cooling cabinet was produced using 6mm thick XPS insulation material with dimensions 20cm wide, 30cm long and 20cm in depth. These dimensions were determined by considering that the cabinet was designed for portable applications. The designed and manufactured cooling cabinet consisted of four sections: injector section, ampoule for injection section, battery and inverter section, and circulation pump and fan section. The system was designed to have a capacity of 100 ampoules for injection and 100 injectors. The appearance of the vaccine cabinet is shown in Figure 1.

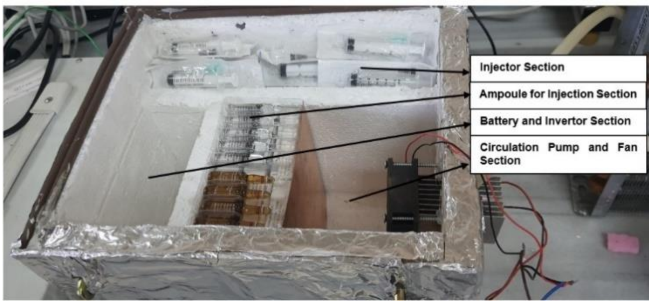

Figure 1: Schematic description of vaccine cabinet

A PV panel was placed on the upper surface of the vaccine cabinet in order to benefit from solar energy, thus ensuring energy efficiency. In order to store the electrical power obtained from the PV panel, a battery was located at the bottom of the cabinet. An aluminium heatsink and a fan were used on the cold side of the Peltier placed against the side surface of the vaccine Cabinet. A liquid-cooled block was used on the hot side of the Peltier and an aluminium heatsink used on the other surface of this block to further accelerate the heat dissipation. A small circulation pump was located under the Peltier section to circulate the refrigerant. 2% by mass of Al2O3-TiO2-SiO2-Water nanofluid was used as the refrigerant in the system. During the experimental studies, vaccine cabinet temperature, cold and hot heatsink temperatures, outdoor temperature and refrigerant temperature were observed. The schematic representation of the experimental setup is shown in Figure 2. During the experiment, 9 volts was applied to the system by means of a regulated power supply, and it was observed that the system drew 7 amps of current.

Figure 2: Schematic description of experimental setup

During the experiments, the time when the cabin temperature converged to 4°C, which was the refrigerator cabinet temperature, was taken into account as the test period. After about an hour, it was observed that the indoor temperature reached equilibrium around 4°C. At the end of this period, the cold heatsink temperature was observed to be in the range of 1-2°C, and the hot heatsink temperature was approximately 22°C. Obtained results are shown in Figure 3.

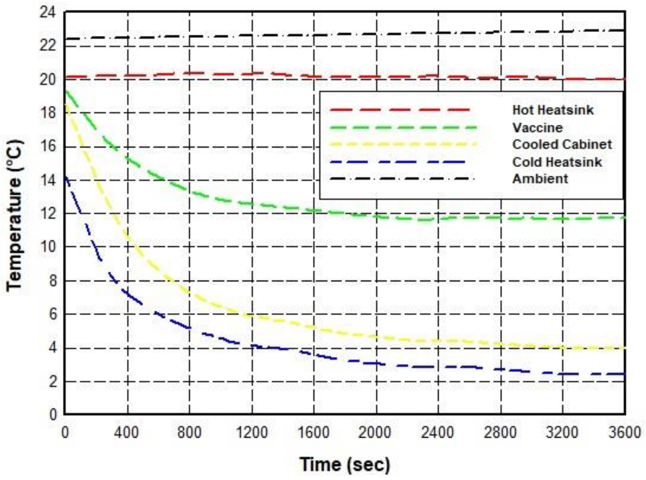

Figure 3: Experimental results

The average COP value of the system was calculated as 0.51 and shown in Figure 4.

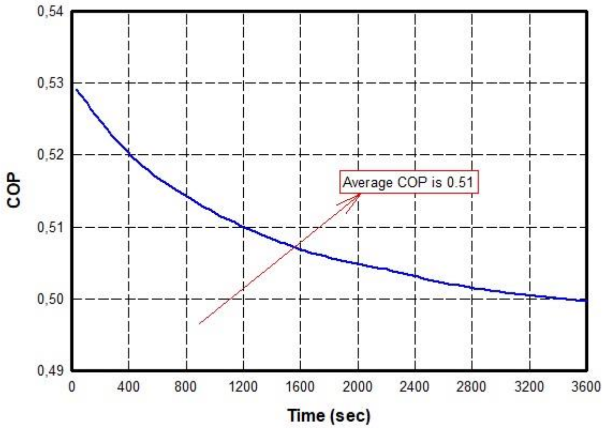

Figure 4: COP values of the system

Volume 15 | Issue 3 | September 2023

Efficient energy harvesting from the sun and universe

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The hot sun (~5800K) and the cold universe (~3K) are the ultimate heat source and heat sink for the Earth, which can be regarded as huge renewable resources for clean heat and cool harvesting. For solar energy harvesting, many efforts have been devoted to highly efficient solar thermal conversion, relying on the solar absorber. Recently, the use of the cold universe as the heat sink of the earth by radiative cooling has much attention due to that passive cooling can be achieved by pumping terrestrial waste heat into the cold universe, mainly relying on the atmospheric window (i.e., 8-13μm). However, most of the current solar thermal and radiative cooling approaches are static and monofunctional, which can only provide heating or cooling respectively under sunlight or darkness. To solve this issue, we propose a smart strategy for the dynamic combination of daytime solar thermal and nighttime radiative cooling.

As reported in our previous work [1], We designed and fabricated an Al2O3/VO2/Al2O3/Al multilayer smart coating, which has high solar absorptivity and dynamic emissivity changing from broadband low emissivity at high-temperature conditions to the selective high emissivity within the atmospheric window at low-temperature conditions. Coupled with a vacuum system with ultra-low heat loss, considerable solar heating and radiative cooling is achieved. Thermal modeling also shows that the heat and cool energy gains of the system with the proposed coating are 78% and 103% higher than those of the reference system that combines static and monofunctional solar thermal absorber and radiative cooler.

Figure 1: Al2O3/VO2/Al2O3/Al multilayer smart coating and its excellent diurnal solar heating and nocturnal radiative cooling performance.

Very recently, we developed a new multilayer smart coating with broadband emissivity modulation [2]. The coating consists of four layers of Al2O3, VO2, SiO2, and Al, and the two-step thermal oxidation method was applied to prepare the VO2 layer. Optical measurement shows that the new coating exhibits excellent solar absorption of over 0.85 and a broadband infrared emissivity modulation from 0.21 for solar thermal mode to 0.75 for radiative cooling mode. Interestingly, the critical temperatures of the VO2 film prepared by the two-step thermal oxidation method are about ∼58.4 and 49.2 °C for the heating and cooling processes, which is lower than that of classical VO2 film, behaving as a good feature under low solar irradiance conditions. In addition, the experimental demonstration shows that this coating can be heated to 95°C during the day and shows a sub-ambient cooling at night with a temperature drop of 5°C and a maximal cooling power of nearly 60 W·m-2. In summary, this work opens new possibilities for continuously efficient energy harvesting utilizing the sun and the universe, contributing to the carbon neutrality of society.

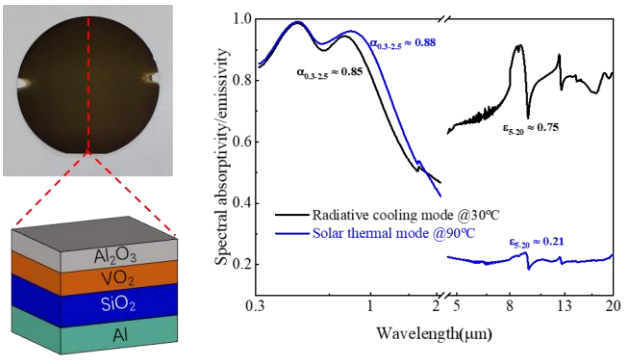

Figure 2: Al2O3/VO2/SiO2/Al multilayer smart coating and its broadband emissivity modulation property

Notes: The above works were published in *Proceedings of the National Academy of Sciences* and *ACS Nano*, please find the details from the full papers that can be found at:

https://doi.org/10.1073/pnas.2120557119

https://doi.org/10.1021/acsnano.3c01755

Reference:

[1] Ao X, Li B, Zhao B, et al. Self-adaptive integration of photothermal and radiative cooling for continuous energy harvesting from the sun and outer space. Proceedings of the National Academy of Sciences, 2022, 119(17): e2120557119.

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Volume 15 | Issue 3 | September 2023

An innovative self-powering house: the PV/T driven hybrid system for efficient power, heating, and cooling solutions

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The PV/T driven hybrid system for efficient power, heating, and cooling solutions (PV/T-PHC) is designed to optimize the utilization of solar energy for power, heating and cooling. The PV/T component combines photovoltaic (PV) and solar thermal systems, creating a single integrated component that generates both electricity and heat. During the day, when solar radiation is available, the electricity generated by the PV/T module drives the inverter compressor in the refrigeration/heat pump cycle, while the heat produced by the PV/T system is stored in a water tank to meet the heat demand of users. In this project, the following aspects have been investigated:

1. PV/T high-performance PV/T development: optimizing solar energy utilization

Maximizing solar energy utilization efficiency is the focus of the PV/T-PHC system, where the PV/T system directly drives the inverter compressor. Through investigating the connection between temperature and thermal stress in PV/T modules, innovative processing technology and structural design are optimized to enhance durability and stability. By understanding the dynamic response relationship between the output characteristics of the PV/T system and the inverter characteristics of the compressor, a dynamic control mechanism is formulated for the PV direct-driven inverter compressor, optimizing the energy matching connection between the PV/T system and the inverter compressor [1].

Figure 1: High performance PV/T collector

2. PV direct-driven refrigeration/heat pump system: dynamic conversion of energy

The research on PV direct-driven refrigeration/heat pump systems has focused on clarifying the dynamic variation of state parameters of the refrigerant in the thermodynamic cycle driven by a DC inverter compressor, as shown in Figure 2. A dynamic mathematical model has been established to clarify the dynamic conversion mechanism of light-heat-electricity-cold in the PV/T-PHC system, optimizing energy conversion efficiency and operational stability. This research contributes to the development of more efficient and reliable PV/T-PHC systems for air conditioning and cooling applications, with implications for system design, operation, and control, and advancement of sustainable and energy-efficient technologies in the field [2].

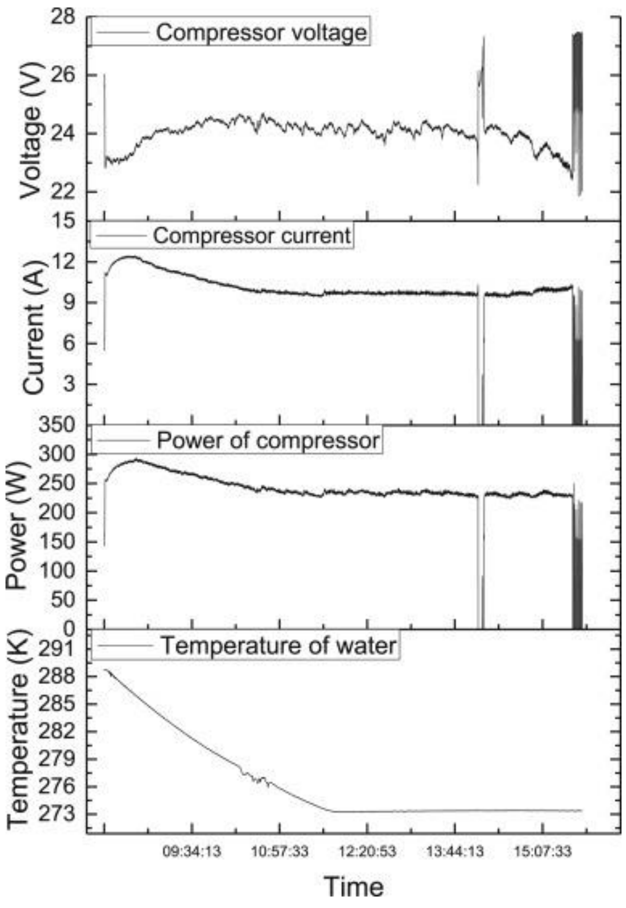

Figure 2: The variation of voltage, current and power of compressor and temperature of water along with the time.

3. Building-integrated demonstration and operation strategy: meeting user's demand

A building-integrated PV/T-PHC demonstration system was built to study the dynamic relationship between the demand-side load and the output characteristics (cooling, heating, and electricity) of the PV/T-PHC system, as shown in Figure 3. This research helped formulate a control strategy based on demand-side response to meet the user's demand for cooling, heating, and electricity. The goal is to develop an efficient and user-centric approach for building-integrated PV/T-PHC system operation, ensuring optimal performance and satisfaction[3].

Cont.

Volume 15 | Issue 3 | September 2023

Cont.

Figure 3: A domestic house using PV/T-PHC

References:

[1] Han K, Ji J, Cai J, et al. Experimental and numerical investigation on a novel photovoltaic direct-driven ice storage air-conditioning system[J]. Renewable Energy, 2021, 172: 514-528.

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[3] Cai J, Zhou H, Xu L, et al. Energy and exergy analysis of a novel solar-air composite source multi-functional heat pump[J]. Renewable Energy, 2021.

7th WSSET Innovation Award Winners

This year, there were 19 submissions to the WSSET Innovation Awards with projects ranging from an innovative self-powering house: a PV/T driven hybrid system for efficient power, heating, and cooling solutions, to Solar2Water: a decentralized water solution for remote communities. The lucky winners were announced at the SET2023 Gala Dinner and details are below. Look out for details of the next awards, the 8th WSSET Innovation Awards, which will be launched in the next newsletter in the autumn.

Jingyong Cai, Shanghai University of Electric Power
Entry: An innovative self-powering house: The PV/T driven hybrid system for efficient power, heating, and cooling solutions

Muhammad Wakil Shahzad, Northumbria University
Entry: Solar2Water-A decentralized water solution for remote communities

Qiliang Wang, The Hong Kong Polytechnic University
Entry: A novel spectral heat transfer model with innovative optimization strategies based on spectral selectivity regulation and structure design

Professor Ji Jie from University of Science and Technology of China receiving the award on behalf of Bin Zhao (from the same university)
Entry: Self-adaptive photothermal and radiative cooling for efficient energy harvesting from the sun and outer space

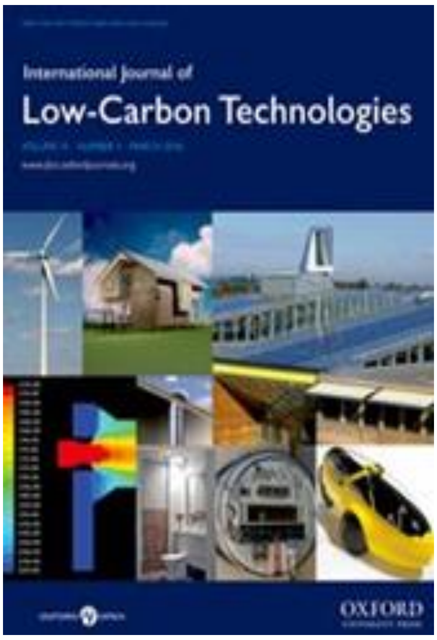
Pinar Mert Cuce, Recep Tayyip Erdogan University
Entry: Design, production and thermodynamic analysis of concentrated solar powered T-TEG

Cagri Kutlu, University of Nottingham
Entry: Innovative Heat storage tank: Efficient heat storage and delivery system for zero/low-carbon domestic hot water and space heating

Volume 15 | Issue 3 | September 2023

Photos and full coverage of SET2023 can be found on: www.set2023.org/photogallery/

Thank you for coming to SET2023
from the organising team!



WSSET exclusive offer – IJLCT

The International Journal of Low-Carbon Technologies (IJLCT) is an Open Access SCI Journal published by Oxford University Press. In 2022, IJLCT's CiteScore increased to 1.8 putting the journal into the 68th percentile in the category of Architecture, which means we're currently ranked #44 out of 138 journals in this field on SCOPUS. IJLCT offers a 20% discount to the APC (article processing charge) for WSSET members wishing to publish a paper in IJLCT (open access). This will cost WSSET members £915 (€1099) as opposed to the full charge of £1144 (€1373). Authors will need to state that they are WSSET members when paying.

Please visit www.ijlct.oxfordjournals.org to submit your articles.

WSSET exclusive offer - FCE

Future Cities and Environment (FCE) is a fully open access journal published by]u[Ubiquity Press and indexed with SCOPUS (CiteScore of 1.9 for 2021) as well as with other indexes. FCE maintains a low APC of £575 for OA publications and in conjunction with WSSET offer a £25 discount for WSSET members. Authors should declare their membership details in their cover letter and follow the author guidelines for their submissions.

Please visit www.futurecitiesandenvironment.com to read FCE articles and submit your own.

Volume 15 | Issue 3 | September 2023

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Thanks

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Whether you would like to get more involved or contribute financially, please get in touch with us at: secretary@wsset.org

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Contributing to WSSET newsletters and e-bulletins

All WSSET members are kindly invited to submit articles for publication in future WSSET newsletters. Articles can be on a range of topics surrounding the word of sustainable energy technologies. With nearly 2000 members, the WSSET newsletter provides a great opportunity to publicise new ideas, technologies or products – all free of charge!

Articles should be no more than 400-500 words and one or two photographs would be very much appreciated. Submissions should be emailed to secretary@wsset.org

Furthermore please contact secretary@wsset.org regarding any conferences, seminars or symposiums relating to topics of sustainable energy technologies that you wish to be advertised in the newsletter.

Once again, thank you for your continued support to WSSET.