Proceedings of the 15th International Green Energy Conference
IGEC2023-341~347 (invited)
July 10-13, 2023, Glasgow, UK

Special Session: Energy for Buildings

Session Description:

To achieve the carbon reduction goal, great efforts have been made worldwide. In the world rapidly growing its wind and solar power generation. Especially in the UK, 80% carbon emission reduction from power generation has been achieved compared with 10 years ago. However, carbon emission from buildings is almost unchanged. Domestic space heating and hot water demand contributes to 40% of the total carbon emissions. The actions must be taken to decarbonize building. This special session is aimed at presenting the latest decarbonizing energy technologies and energies used in buildings, ranging from components to systems, and from modeling, simulations and analyses to experimental investigations.

Session Organizer:

Shuli Liu (Beijing University of Technology)

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Topic 1: A study of an indirect expansion solar-assisted air source heat pump with hybrid thermal energy storage for space heating in North China: efficient-economic-environmental analysis

Shuli Liu
School of Mechanical Engineering, Beijing Institute of Technology, China,
shuli.liu@bit.edu.cn

Abstract: The insufficient heating capacity and low coefficient of performance have always been obstacles that inhibit the application of air source heat pump (ASHP) systems in cold regions. This study proposes an indirect expansion solar-assisted air source heat pump (IX-SAASHP) system to improve the heating performance of ASHP. The IX-SAASHP consists of solar collectors, a hybrid thermal energy storage tank, and a dual-source heat pump. An optimized switching method is proposed to tackle the refrigerant redistribution problem for the dual-source heat pump. An experiment is carried out to study the thermodynamic performance of the IX-SAASHP system. The experimental results indicate that the average COP of solar heat pump mode is increased by 50.0% compared with air source heat pump mode due to the higher evaporating temperature. Based on the experimental results, an efficient-economic-environmental analysis of the IX-SAASHP system for space heating is conducted in six northern cities in China. The IX-SAASHP system has the highest annual average COP of 2.53 in Jinan and realizes the shortest payback period of 5.1 and 5.7 years in Xining and Harbin. In the north region, it is practical to set a subsidy on the additional initial cost to promote the IX-SAASHP system. Applying the IX-SAASHP system in the northwest region is suitable for its better energy and economic performance. The analysis result indicates that the IX-SAASHP system shows great significance for decarbonizing the space heating system in the northeast region.

Keywords: Solar energy; Solar-assisted air source heat pump; Control method; Efficient-economic-environmental analysis.

Shuli Liu is Professor in the School of Mechanical Engineering, Beijing Institute of Technology, China, with about 20 years research experience. She aims to integrate the key strands of: application of renewable energy and sustainable technology; PCM thermal energy storage and Thermal chemical energy storage; building energy performance (materials, construction and lifecycle, etc.) and low carbon behaviors of occupiers and operators, to achieve a smart, Eco home for the future. She has been involved in 13 research projects funded by NSFC, EPSRC, KTP, and industry partners such as Tata Steel, Triton Shower and Orbit House Group Ltd, etc. over £1.7 million. Shuli has over 100 journal and conference publications. She is CIBSE member and fellow of higher education academy, UK. Shuli is also member of World Society of Sustainable Energy Technologies, UK and IBPSA, England.

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Topic 2: Multi-level scale-up research on distributed clean building heating using heat thermal storage of PCM and solar energy

Kongxiang Fei
Energy and Environment Engineering College, Hebei University of Technology, China
xfkong@hebut.edu.cn

Abstract: Solar energy coupled with electric heat storage is a promising energy saving technology for distributed building heating. Energy saving performance of this technology used in buildings has been widely investigated by prototype-scale experiments and numerical assessments. However, the commercial and economic feasibility of this technology during the operational phase of a real building have not been proven yet. In this report, the discussion is based on a comprehensive techno-economic analysis of the electric heat storage system coupled with solar energy installed in a three-story office building (2000 m^2 heating area) in Tianjin, China. The electric heat storage system with the heat storage capacity of 1274.8 MJ was installed on the first floor of the building. The solar collector system with a total heat collection area of 160 m^2 was installed on the roof of the building. Meanwhile, the long short-term memory was used to predict the heat gain of solar collector in order to adjust the quantity of storage heat of storage device. The results indicated that the prepared storage medium possessed an excellent thermal property with a total heat storage capacity of 448.8 kJ/kg within 50–150 °C. The average thermal efficiency of vacuum tube solar collector was 51.3%, its heat gain per square meter per day was 6.5 MJ. The use of the solar radiation prediction model stabilized thermal efficiency of heat storage reservoir at 95.8%. The specific operational cost of this system within an entire heating season was 15.6 RMB/m^2/season. Distribute clean building heating (DCBH) system can save up to 61% of heating cost compared to the centralized heating. The results showed a great application potential of combination of electric heat storage and solar energy based on solar energy prediction for the heat dispatch of distributed building heating.

Keywords: Distribute clean building heating; Solar energy; Electric heat storage; Model predictive control; Phase change material;

Prof. Xiangfei Kong acquired his doctoral degree from Tianjin University in 2013. He commenced his career in the same year at Hebei University of Technology. He's Assistant Dean of Energy and Environment Engineering College, Head of the Department of Heating, Ventilation and Air-conditioning and the principal of national first-class major. His study mainly covers efficient building thermal energy storage and research on corresponding primary application. In order to fulfill building energy conservation, technologies like phase change material, low-grade thermal energy reservation and foundation of building thermal environment etc. have been thoroughly investigated. As an essential technique route, building energy conservation works for national strategic aim on carbon peaking and carbon neutrality. Being selected as one of the world wide Top 2 % scientists, Prof. Kong has published over 120 sophisticated academic papers. Among which, he's first/correspond author to 72 of them (61 articles rated Q1), ESI Hot Paper (0.1 %) 1, ESI Most Cited papers (1 %) 2. There are more than 1900 citations (most cited paper: 177 citations) of his papers. With the H-index of 23, he coedited Phase Change Materials. He has obtained/filed 40 national patents, 5 software copyrights and 2 transformation and application of patented achievements. Dr. Kong has edited/coedited 5 technical standards. He has won three provincial and ministerial second prizes, including the second Prize of Tianjin Technology Invention (Sequence 2) and the second Prize of Huaxia Construction Science and Technology (Sequence 2). In addition, he has won the China Xiangjiang Scholars Award Program. He is the executive director and member of Expert Committee of Tianjin Building Energy Supply Technology Engineering Center, Secretary of International Society for Built Environment (ISBE), member of China Green Building and Energy Conservation Committee, member of Science and Technology Service Expert Committee of China Higher Education Association.

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Topic 3: Energy and Environmental Assessment of a Shared Workspace in UK Educational Buildings During the Winter Season

Thara Al-Mindeel, Mahroo Eftekhari, Eftychia Spentzou
School of Architecture, Civil and Building Engineering, Loughborough University Loughborough LE11 3TU
T.Al-Mindeel@lboro.ac.uk; m.m.eftekhari@lboro.ac.uk ; e.spentzou@lboro.ac.uk

Abstract: Meeting the indoor environment's health, comfort, and energy reduction requirements is necessary for creating a sustainable built environment. However, achieving thermal comfort, indoor air quality (IAQ), and energy consumption goals appear to be more challenging in shared open area working environments. In this study, energy consumption and environmental conditions of an educational building were assessed during the winter season to investigate the effects of shared working spaces on energy consumption, thermal comfort and IAQ targets. Therefore, a long-term field measurement was conducted using a combination of objective and subjective approaches. Occupant surveys coupled with in situ measurements of energy consumption, indoor temperature, relative humidity, and carbon dioxide concentration levels were performed to provide a comprehensive evaluation of the workspace. The findings of the study provide further insights into on the potential implications of a shared working environment for optimizing energy consumption, thermal comfort, and IAQ.

Keywords: Energy consumption, Thermal comfort, Indoor air quality, field study, educational building, shared workspace, winter season, occupant surveys.

Mahroo Eftekhari CEng DPhil FCIBSE MASHRAE MInstR SFHEA- Professor and course director for MSc in Low Energy Building Services Engineering at Loughborough University. She has a long-term interest in developing control systems, fuzzy logic, Model Predictive Controller MPC, developing software for airport and strategies for buildings in order to reduce energy consumption while providing thermal comfort and improving occupant's well-being. She has a sustained record of application for research funding from a wide range of funding bodies and industrial partners, mainly Tata Steel, Vexo and Mitsubishi R&D. The EPG and direct funding from Tata Steel have resulted in setting up Building & Industrial services Pipework Academy (BISPA www.bispa.org). This is a unique national centre of excellence for delivering CPD courses in Building Information Modelling (BIM) and pipework systems. Interactive rigs have been designed and built in the Civil laboratories and were launched by Loughborough University's Vice Chancellor and the CIBSE president in July 2016.

Eftychia Spentzou DipArchEng MSc PhD PGCAP FHEA ARB Architect
Lecturer in Architecture and Design Management
Her research combines her architectural background with modelling expertise (computational fluid dynamics (CFD) and dynamic thermal modelling (DTM)) and has demonstrated approaches to increase resilience of the existing building stock, deliver sustainable development, and provide solutions to fuel poverty. Eftychia's research spans the relationship between visionary architecture, sustainability and vernacular practices and the interactions between humans and the built environment.

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Topic 4: A solar powered PCM heat exchanger to stabilize indoor temperature for winters in Pakistan

Abdur Rehman Mazhar*, Aurang Zaib, Muhammed Inshal, Tariq Talha
College of Electrical & Mechanical Engineering; National University of Sciences & Technology; Pakistan
**arehman.mazhar@ceme.nust.edu.pk*

Abstract: Winters in northern Pakistan consist of warm daytime temperatures followed by cold subzero nighttime temperatures. The disparity between indoor temperatures of buildings during the different times of the day without heating can be as high as 20°C. Additionally, there is an abundance of solar irradiation during most of the season. To minimize this disparity and stabilize indoor temperatures by harnessing solar irradiation a PCM based heat exchanger has been experimentally developed and tested. A solar thermal collector heats water to about 50-55°C during the daytime to charge about 7kg of paraffin wax with a phase change temperature of 45°C. This heat exchanger with water as the heat transfer fluid is embedded in a cubical insulated room about 3 feet in dimensions. During the nighttime heat is extracted from this heat exchanger into this insulated room using both free and forced convection. Furthermore, during Pakistani winters the indoor air lacks water vapor with relative humidities dropping to as low as 30-40%. The effects of maintaining indoor humidity levels to 80% are investigated by evaporating liquid water in the form of latent heat transfer from the room in conjunction to the discharging of the PCM based heat exchanger. Results show that forced convection whilst charging during the day providing sensible heat gains to the room with consistent humidity providing latent heat losses from the room to enable the best solution to stabilize indoor air temperatures to as low as 5°C.

Dr. Abdur Rehman Mazhar, is an Assistant Professor and the head of the PhD program in Mechanical Engineering at the National University of Sciences & Technology Pakistan. He completed his PhD from Coventry University, UK in 2019 with expertise in energy, renewables and thermofluids. Prior to this he completed his MSc in Power Engineering from TU Munich in Germany with a research thesis at Fraunhofer ISE. Dr. Abdur Rehman Mazhar is a young researcher involved in many promising research ventures. Over the span of just four years, he has published more than 20 articles in high-impact factor journals. At the same time, he has about 6 years of teaching experience in Pakistan and the UK at both undergraduate and postgraduate levels. He is also supervising several post and undergraduate students in their final year thesis.

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Topic 5: Experimental investigation of natural ventilation characteristics of a solar chimney coupled with earth-air heat exchanger (SCEAHE) system in summer and winter

Yongcai Li
School of Civil Engineering, Chongqing University, Chongqing,
yongcail85@163.com

Abstract: The coupled effect of the solar chimney (SC) and earth-air heat exchanger (EAHE), as a pure passive system, is expected to generate natural ventilation with a cooling/heating potential. This study aimed to experimentally evaluate the natural ventilation characteristics of SCEAHE system in both summer and winter. The results showed that under the regulation of SCEAHE system, indoor air temperatures below 29 °C accounted for 78.6% of the total 168 h in summer, whereas indoor air temperatures above 5 °C accounted for 77.4% during the winter. The driving force for nocturnal ventilation was generated by the coupled effect of the thermal mass and subsoil in summer, whereas the same was generated by only the subsoil in winter. This shift in buoyancy forces ensured continuous nocturnal natural ventilation for an annual cycle. The continuous and periodic airflow rates varying from 56.5 to 291.5 m^3/h, and from 90.9 to 388.8 m^3/h were observed during the summer and winter, respectively. Therefore, the SCEAHE system was able to provide continuous natural ventilation, even under the cloudy weather condition. In addition, the average thermal efficiency of the system was 0.61 in the summer, while the average value was 0.86 in the winter.

Keywords: Solar chimney; Earth-air heat exchanger; Natural ventilation; Summer and winter Experimental study

Dr. Li is now an Associate Professor at the School of Civil Engineering of Chongqing University, China. In 2014, he graduated from the doctoral degree of architectural and civil engineering at Coventry University, UK. His research interests include building ventilation, low carbon technology, and building energy conservation. Dr. Li has been involved in over 20 research projects, and has published over 60 journal and conference papers. Dr. Li is also the peer reviewer for more than 15 high quality journals.

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Topic 6: Experimental investigation of Earth-air ventilation system ventilation systems in low-energy buildings

Abdullahi Ahmed*[1], Mohammed Fadl, Shuli Liu[2]
[1]School of Engineering, Technology and Design, Canterbury Christ Church University, Canterbury, CT1 1QU.
[2]School of Mechanical Engineering, Beijing Institute of Technology, Beijing 100081, China
*Email. Abdullahi.ahmed@canterbury.ac.uk

Abstract: Low-energy ventilation plays a critical role in achieving low/net zero energy buildings. Buildings require ventilation to provide healthy indoor air quality and to remove pollutants, moisture, and odors. However, traditional ventilation systems consume significant amounts of energy to condition the incoming air to the desired temperature and humidity levels. Low-energy ventilation systems, on the other hand, use less energy to provide fresh air and can help to reduce the overall energy consumption of the building. One type of low-energy ventilation system is an earth-air heat exchanger (EAHE), which uses buried pipes to precondition the incoming air by exchanging heat with the surrounding soil. This approach can significantly reduce the energy required to heat or cool the ventilation air, as the soil maintains a relatively stable temperature throughout the year. This paper presents an experimental investigation of an earth-air heat exchanger (EAHE) for low-energy ventilation in low-energy buildings. The EAHE system consists of a buried horizontal pipe that preconditions the incoming ventilation air by exchanging heat with the surrounding soil. The study aims to evaluate the effectiveness of the EAHE system in terms of its thermal performance and energy savings potential. The experimental setup consists of a building integrated EAHE system, which is connected to a building's mechanical ventilation and heat recovery system. The system is designed to simulate typical residential conditions and is subjected to varying outdoor temperatures and air-flow rates. The performance of the EAHE system is evaluated by measuring the air and soil temperature of the incoming and outgoing air streams, as well as the energy consumption of the ventilation unit. The experimental results indicate that the EAHE system is capable of significantly reducing the temperature and humidity of the incoming air stream during hot and humid conditions, and increasing it during cold and dry conditions. The system is found to be effective in reducing peak inlet air temperature by up to 10 K and increasing winter inlet air temperature by up 7K, reducing the energy consumption of the ventilation unit by up to 30% compared to conventional ventilation systems.

Dr Abdullahi Ahmed is a Chartered Building Services Engineer (CIBSE) with over 15 years academic and professional practice in Building Services Engineering and Sustainability Design. Dr Ahmed is the Director for Engineering and Built Environment at Canterbury Christ Church University. Hold a PhD in low-energy systems modelling. He is active member of CIBSE as a member of the course accreditation panel, CIBSE membership reviewer and planning/scientific committee of CIBSE Technical Symposium. He is principal investigator and project manager for several multi-disciplinary and multi-partner research projects. He received and managed research funding from local and international funding agencies relating to projects in circular economy, micro-grid, district scale low-energy renovation and building performance evaluation. He was Keynote and invited speaker for several national and international events and workshops across Europe, Middle East, and Africa. Dr Ahmed Supervised and examined innovative PhD research projects in areas of Energy, climate change and built environment sustainability and resilience.

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Topic 7: Heat Storage and the Discharge Performance of a Phase Change Material (PCM) Storage Tank

Juan Zhao
School of Urban Planning and Municipal Engineering, Xi'an Polytechnic University, Xi'an
juanzhao@xpu.edu.cn

Abstract: The application of phase change hot water storage tanks to solar thermal utilization systems has certain research significance and broad engineering application prospects. In order to improve the utilization rate of solar energy, the goal should be to maximize the accumulation of solar radiation and release heat within a specified time, and combine various influencing factors to find the optimal structure and operating parameters of the phase change unit. This study proposes a new method for capacity design of phase change heat storage tank, establishes a mathematical model of phase change heat storage unit, uses MATLAB to establish a dynamic simulation model, sets an ideal time period to complete the phase change process, and discusses the optimal size, design the supply and return water temperature and flow range. In the design of the phase change thermal storage unit, the melting/solidification time can be set according to the actual demand, and on this basis, the ideal range of the above variable parameters can be found, and the optimized design can be further carried out. When screening variable intervals, it is also necessary to consider that the temperature of the inlet and outlet of the water body should not be close to boiling, and the size of the phase change plate should not be too thin to be difficult to process or not strong enough. In view of the obvious decline in heat transfer capacity in the later stage of the phase change process, it is sufficient for the phase change ratio to reach 0.9 within a specified period of time. According to the above principles, the multi-variable optimization dynamic simulation based on the target interval is completed, and the ideal interval of each variable factor in the demand time period is obtained. This optimization idea provides an optimization method and design path that are more in line with actual needs for phase change hot water storage tanks.

Key words: phase change heat storage unit, solar heat utilization, interval optimization, multi-factor optimization

Dr. Zhao is now an Associate Professor at the School of Urban Planning and Municipal Engineering in Xi'an Polytechnic University. She acquired her doctoral degree from Chongqing University, and worked as a post-doctoral research fellow at Southwest Jiaotong University. She focuses her research on the renewable energy applications and PCMs. Dr. Zhao has been led or participated 10 research projects including National Natural Science Foundation of China, and has published over 20 scientific papers.