frontiers | Frontiers in Energy Research

TYPE Editorial
PUBLISHED 16 August 2022
DOI 10.3389/fenrg.2022.993093

OPEN ACCESS

EDITED AND REVIEWED BY
Ellen B. Stechel,
Arizona State University, United States

*CORRESPONDENCE
Wen Su,
suwenzn@csu.edu.cn

SPECIALTY SECTION
This article was submitted to Process and Energy Systems Engineering, a section of the journal Frontiers in Energy Research

RECEIVED 13 July 2022
ACCEPTED 20 July 2022
PUBLISHED 16 August 2022

CITATION
Li X, Su W, Xu W, Dai B, Li J and Li L (2022), Editorial: CO_2-based energy systems for cooling, heating, and power. *Front. Energy Res.* 10:993093. doi: 10.3389/fenrg.2022.993093

Editorial: CO_2-based energy systems for cooling, heating, and power

Xiaoya Li[1], Wen Su[2]*, Weicong Xu[3], Baomin Dai[4], Jian Li[5] and Liang Li[6]

[1]School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore, Singapore, [2]School of Energy Science and Engineering, Central South University, Changsha, China, [3]School of Mechanical Engineering, Tianjin University, Tianjin, China, [4]School of Mechanical Engineering, Tianjin University of Commerce, Tianjin, China, [5]Department of Energy and Power Engineering, Tsinghua University, Beijing, China, [6]School of Physics, Engineering and Computer Science, University of Hertfordshire, Hatfield, United Kingdom

KEYWORDS

CO_2, CO_2-based mixture, power cycle, refrigeration /heating, combined cycle

Editorial on the Research Topic
CO_2 -based energy systems for cooling, heating, and power

As a natural working fluid, carbon dioxide (CO_2, R744) has attracted the widest attention for the next-generation energy systems to tackle climate change due to its extraordinary thermophysical properties and environmental friendliness of zero ODP, low GWP (~1), non-toxicity, and non-flammability. These targeted applications include both the standalone refrigeration systems, heat pumps, and the power generation systems, and the cogeneration systems by integrating the cooling, and/or heating, and/or power subsystems to meet various demands. Despite the ongoing research from academia and industry, there are indeed, theoretically and technically, remaining challenges that slow down the advancement of such applications and need to be solved. There is always a tradeoff between the efficiency improvement and the cost reduction. Besides, the development of the key components is still somewhat weak, such as the high-temperature CO_2 compressor, highly efficient CO_2 expander especially at a power scale of several and several tens kilowatt, compact gas cooler and gas heater, which requires dedicated structure design and material evolution. Moreover, the cooling of CO_2 working fluid is very challenging owing to its near ambient critical temperature (31.1°C), which leads to working fluid exploration by CO_2-based mixture or blends. Due to these limitations, at present, the CO_2-based energy systems are seldomly demonstrated and there is a lack of experimental study to identify their potential. This topic explores the thermo-economic analysis of the CO_2-based standalone and cogeneration energy systems for cooling, heating and power, experimental investigation on the systems and the key components of such systems, and other relevant advanced energy systems. It concludes with six peer-reviewed journal papers to promote research, sharing and development.

10.3389/fenrg.2022.993093

We have collected two papers on thermodynamic analysis for single energy output systems. Li et al. focused on the vapor compression heat pump technology for vehicle cabin heating, with particular attention to the CO_2-based mixture working fluids screening. Thermodynamic performance was analyzed under various operation conditions for both the subcritical and transcritical cycles. It was found that the subcritical cycle with CO_2/R32 (50/50, mass fraction) produces the highest coefficient of performance (COP). Que et al. investigated power generation systems by simultaneously harvesting solar and geothermal energy. A novel energy-to-electricity combined system was proposed with a topping recompression supercritical carbon dioxide (sCO_2) Brayton cycle and a bottoming organic flash cycle (OFC). Key parameters were analyzed and optimized with the objective of energy and exergy performance for different configurations of sCO_2 cycle (recompression/regenerative) and various working fluids (R245ca, R123, MM, and R601a) for the OFC cycle. This work obtained high energy efficiency of ~26% and identified the potential components for further optimization.

We have collected one paper on thermo-economic analysis on the cogeneration energy systems. Yu et al. compared four CO_2 power and cooling combined systems in terms of the energy, exergy and economic performances. Multi-objective optimization by NSGA-II algorithm was conducted. These four systems represented the main coupling approaches of such cogeneration systems by component sharing, additional component introduction (ejector), and process modification (multi-stage compression). Among them, the system sharing the low-temperature recuperator and gas cooler was the best considering the power generation, cooling capacity, efficiency, and the total cost.

We have collected one paper on the experimental study on the heat pump system. Dai and Qin constructed an air source transcritical CO_2 heat pump test apparatus and carried out a series of experiments at various compressor frequencies, ambient temperatures, and discharge pressures. The heating performance and the water outlet temperature were analyzed. Based on the test data, a theoretical model by the Buckingham PI method was proposed, which is able to predict the water outlet temperature at a high accuracy for such systems with different sizes.

We have collected one paper on the key component investigation, specifically the CO_2 expander. With the aim at replacing the throttling valve in the household air conditioners, Wang et al. concentrated on the CO_2 rotor expanders with small capacity. A fully enclosed double-cylinder CO_2 rotor expander was designed with a detailed illustration on the working mechanism and theoretical modelling to identify the losses associated to the expansion process (friction, leakage, and other) and address the factors that affect the expander efficiency. Optimal structure design was suggested, which provides theoretical support for the design and manufacture of expander.

We have collected one paper on the advanced energy systems. Instead of adopting CO_2 as working fluid to realize energy conversion, Zhang et al. turned to solar-driven carbon dioxide reduction technology. Techno-economic performance was evaluated for two devices: photovoltaic-biased photoelectrocatalysis (PV-PEC) and photovoltaic-powered electrocatalysis (PV-EC). A novel light management was proposed by the reflective-spectrum-splitting configuration, which enabled the use of high-efficiency opaque perovskite PV cells and boosted the solar-to-chemical energy conversion efficiency of PV-PEC CO_2 reduction reaction to 8%, double the state-of-the-art efficiency.

This research topic could not be made without the authors' contributions. We hope that this issue sheds light on various frontiers related to CO_2-based energy systems for cooling, heating, and power and adds the credits to the effort in solving the current challenges in these fields.

Author contributions

XL and WS wrote the draft. All authors listed have revised the work and approved it for publication.

Acknowledgments

WS acknowledges the support by the National Natural Science Foundation of China (Grant No. 52106037) and Natural Science Foundation of Hunan Province, China (Grant No. 2021JJ40755).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note