Next-Generation Nature-Inspired Variable Capacity Evaporators for Low-GWP Blended Refrigerants

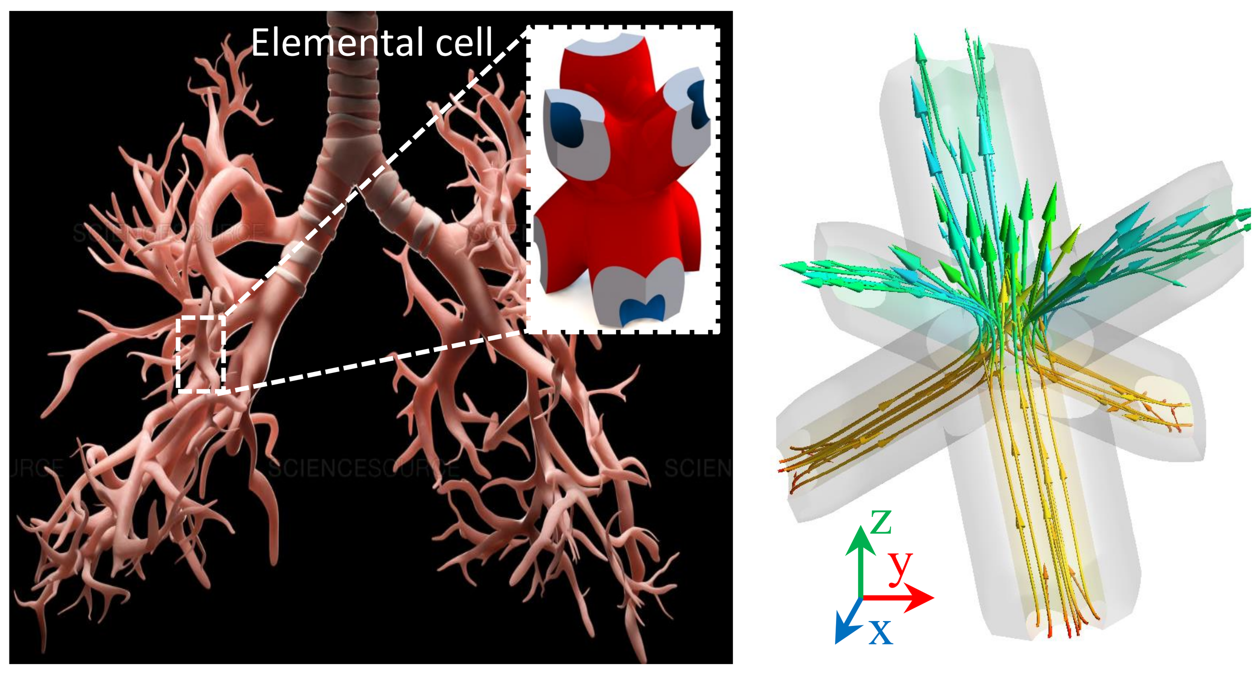
Department of Mechanical and Aerospace Engineering, North Carolina State University, Raleigh, NC, 27606, USA
Building Technologies Research and Integration Center, Oak Ridge National Laboratory, One Bethel Valley Road, Oak Ridge, TN, 37831, USA
Carrier Global Corporation, Nashville, TN , 37211, USA

Motivation

- Existing evaporators cannot effectively respond to partial cooling loads, as they have passive designs with fixed heat transfer topologies and flow distribution pathways. This results in two-phase flow mal-distribution at reduced off-design refrigerant flow rates associated with part AC loads (a long-standing issue). The two-phase flow mal-distribution issue is particularly aggravated for zeotropic blended refrigerants with high-temperature glides.
- In current evaporator designs, the mixture of liquid and vapor from the expansion valve flows through long, large-diameter tubes in the evaporator section. While a large-diameter evaporator tube works fine for pure refrigerants, its two-phase performance can be substantially degraded for low-GWP zeotropic refrigerant mixtures due to fractionation.

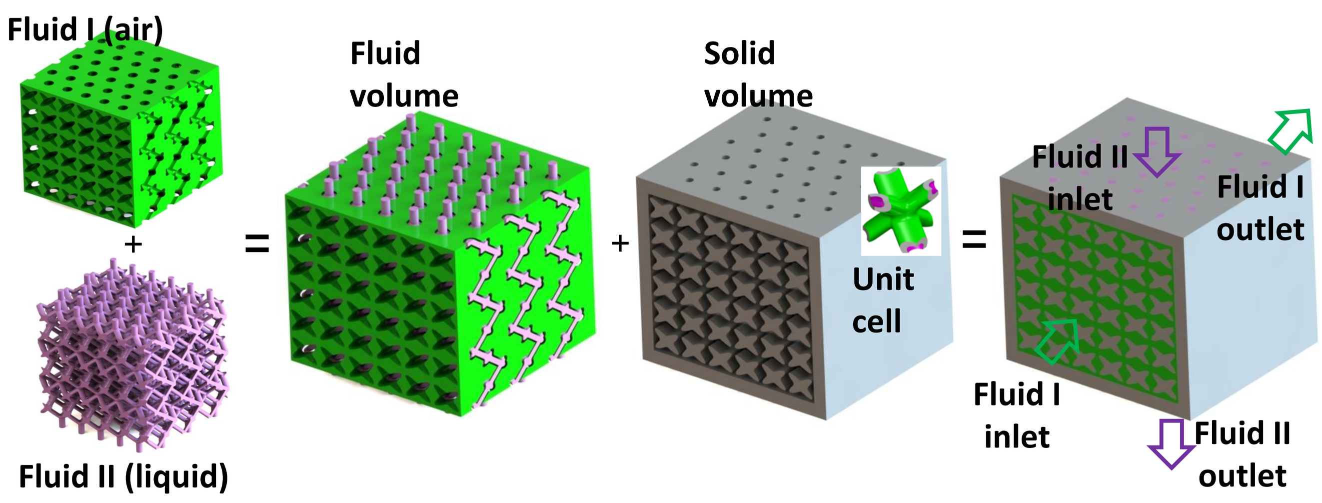
Approach

- The conceptual design of the proposed evaporator topology is inspired by the alveolus architecture of lungs, demonstrating an augmented volumetric flow distribution.
- At the heart of the evaporator, there is an elemental cell connecting three converging inlet pathways and then branching them out into three diverging outlet channels. This allows the evolution of two bi-continuous refrigerant and air arteries.

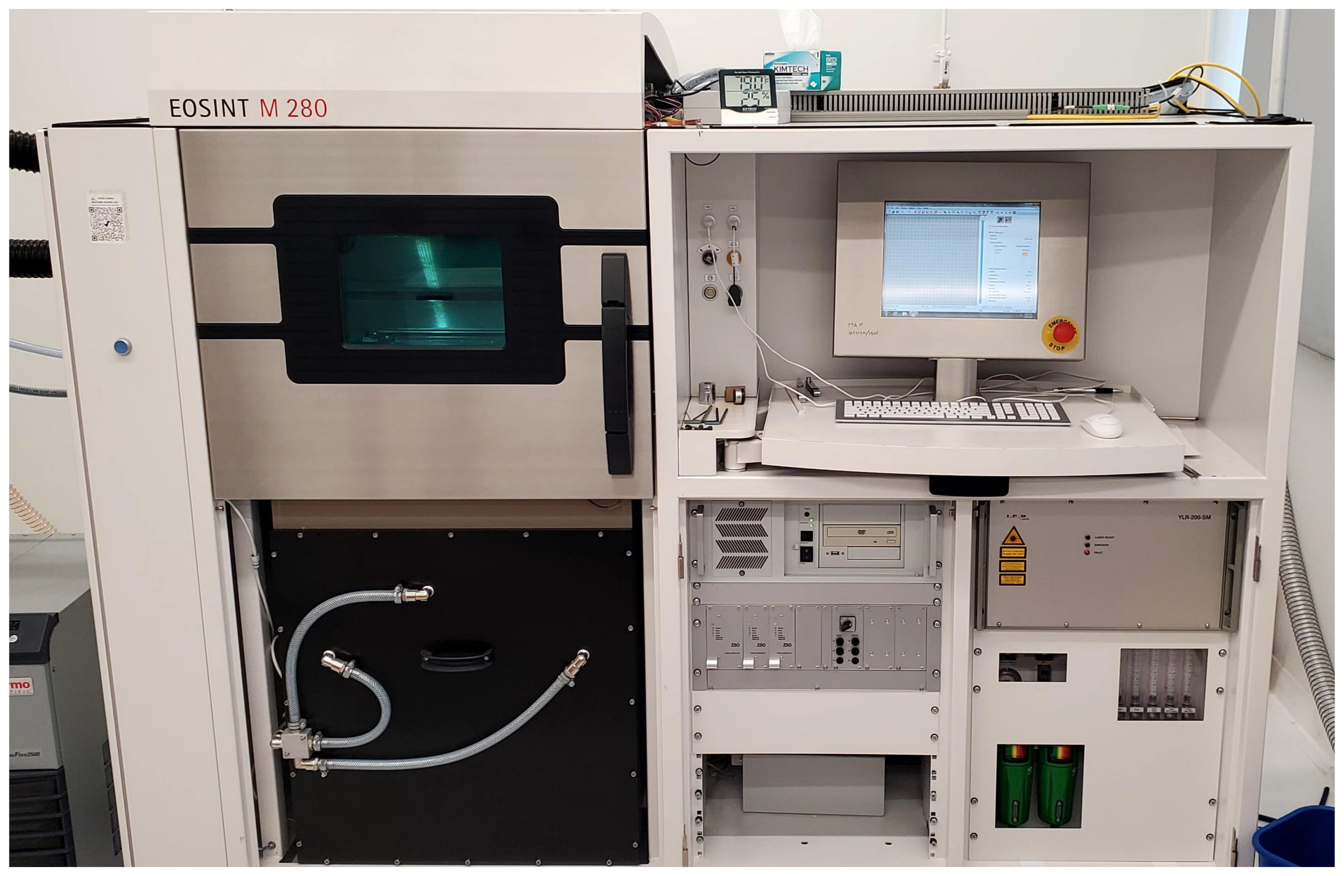


- The first artery evenly distributes a refrigerant blend through the second artery carrying the supply air to the conditioned space. Therefore, the two refrigerant and air arteries are highly intertwined, which allows an augmented thermal exchange between two streams flowing at reduced pressure drop penalties.
- The continuous splitting and mixing of the refrigerant flow artery prevent the stratification of a zeotropic refrigerant blend (i.e., accumulation of the liquid refrigerant with the least volatility at the evaporator's heated surface).

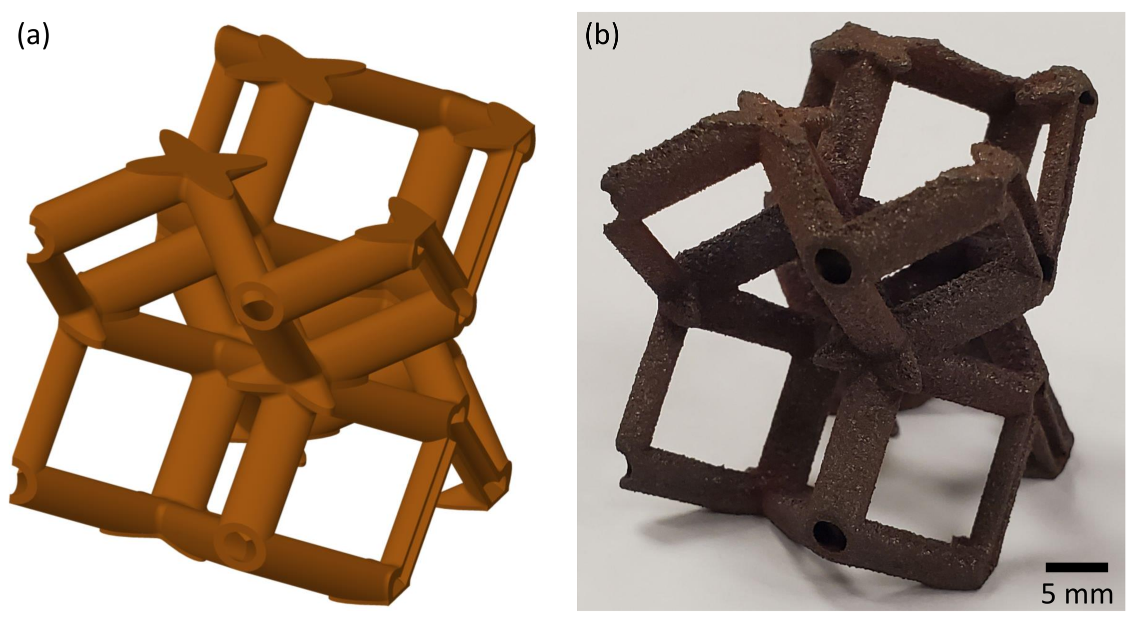
Design and manufacturing



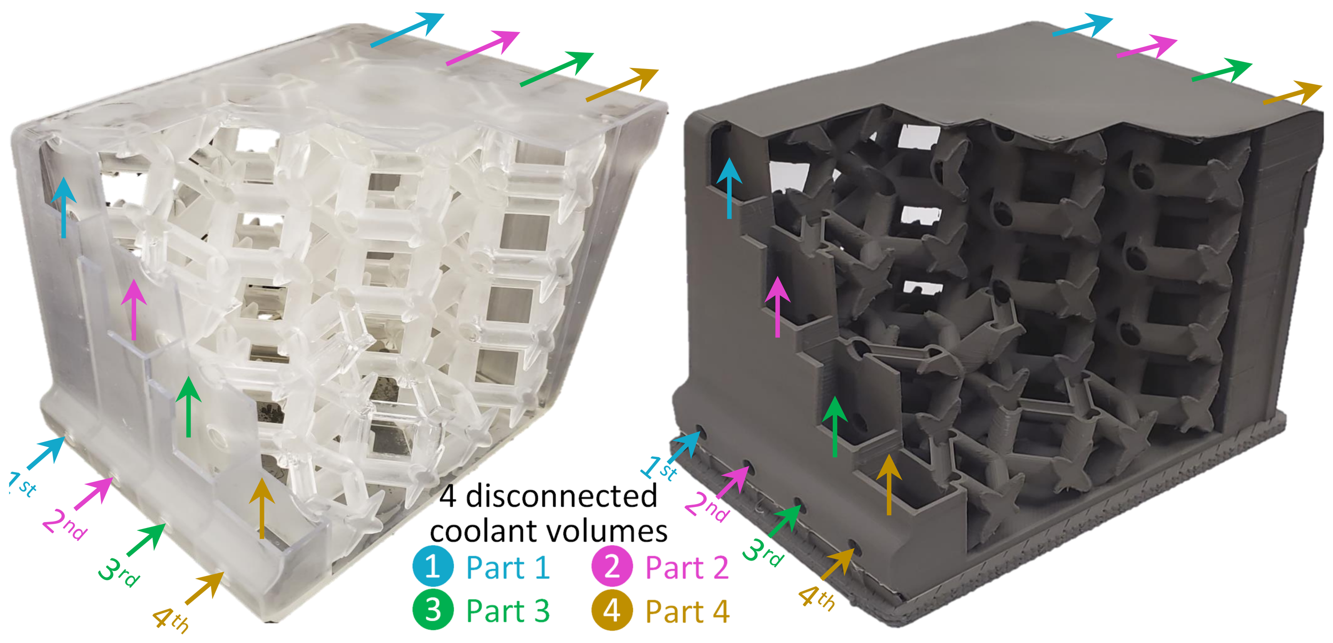
Conceptual exploded view of evaporator



Copper 3D printing with DMLS EOSINT M280

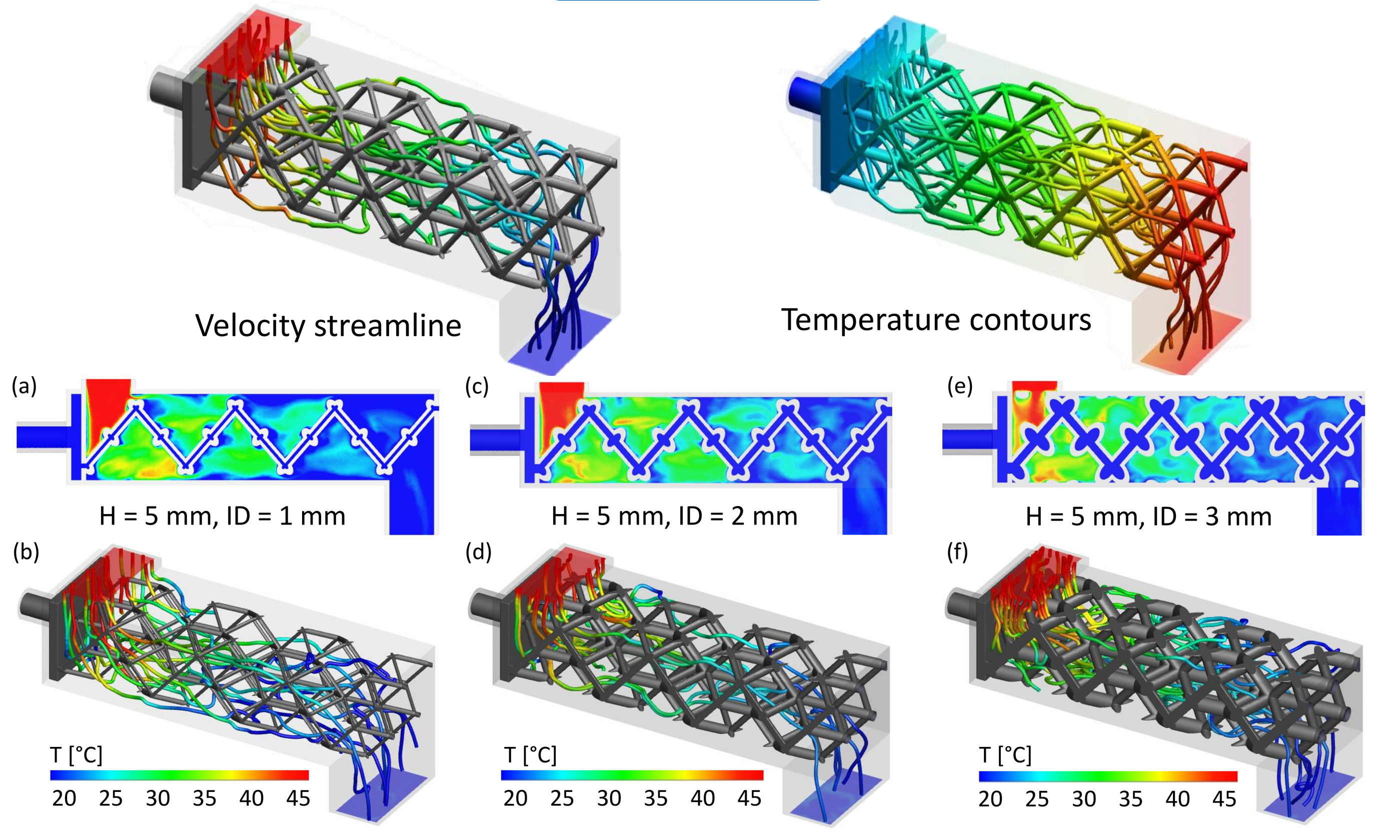


Exploring copper 3D printing space at cell scale

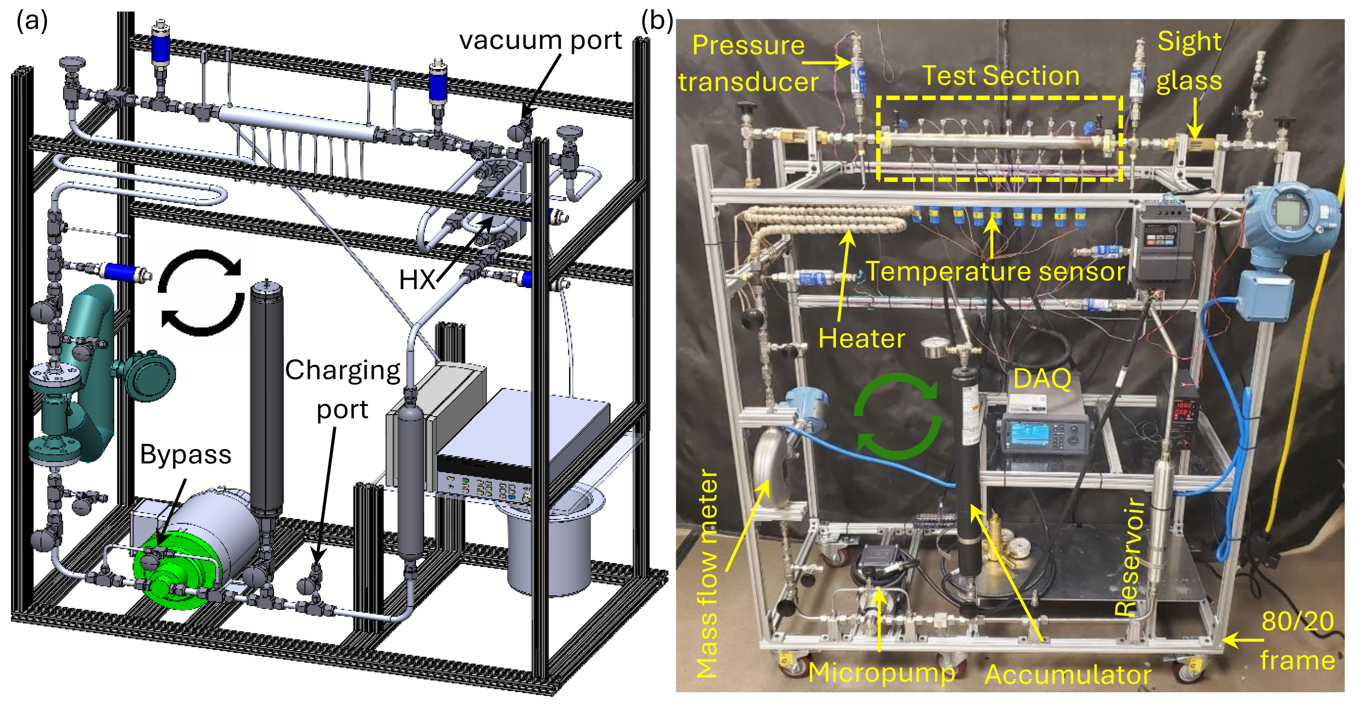


3D-printed lung-inspired evaporator modules

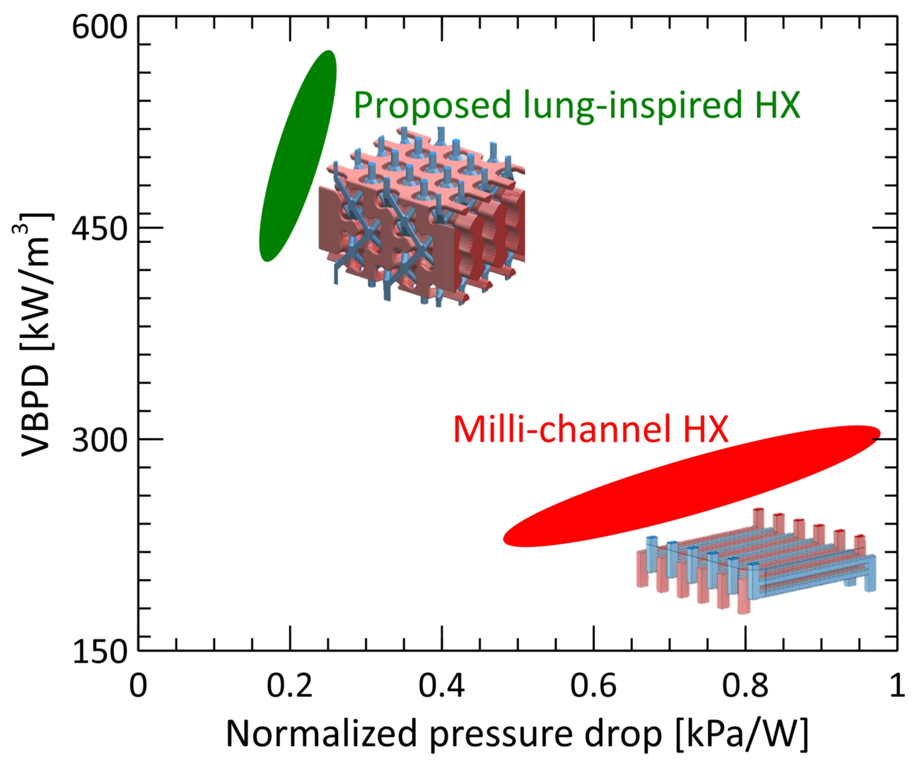
Results



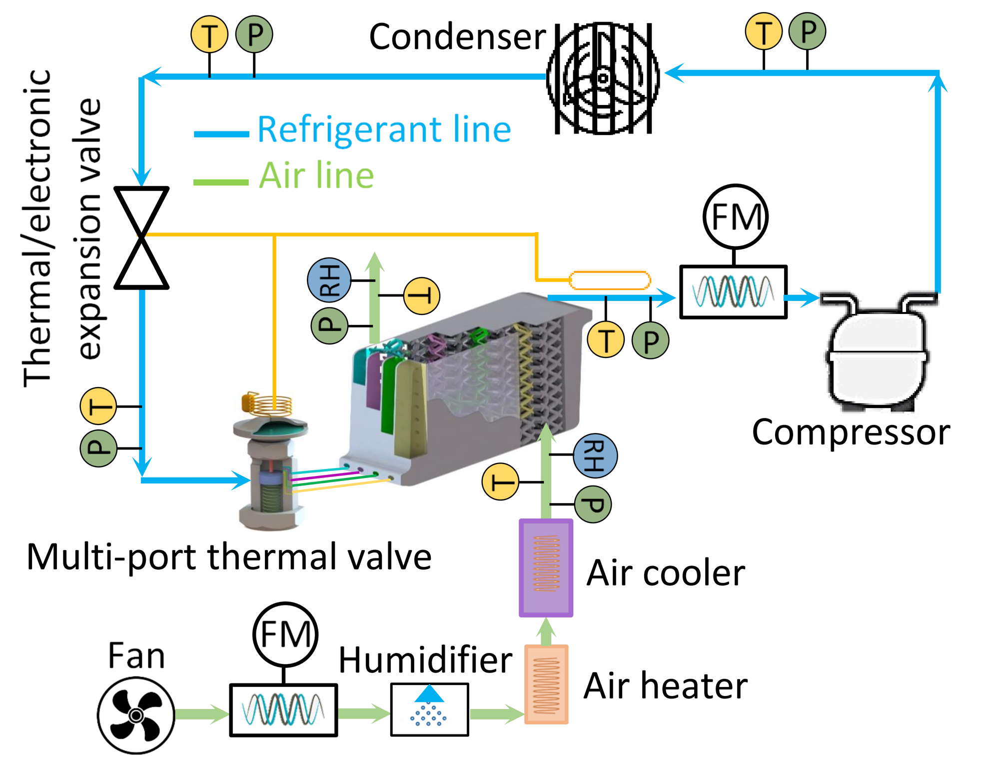
Detailed CFD simulations for optimal lung-inspired evaporates



Experimental evaluation of lung-inspired evaporates



Next steps: Cu 3D printing of full-scale lung-inspired evaporators, dedicated two-phase refrigerant performance testing, and integration into a heat pump system and performance testing



Acknowledgments: This research is sponsored by the US Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under the Building Technology Office Award Number DEEE0010909.