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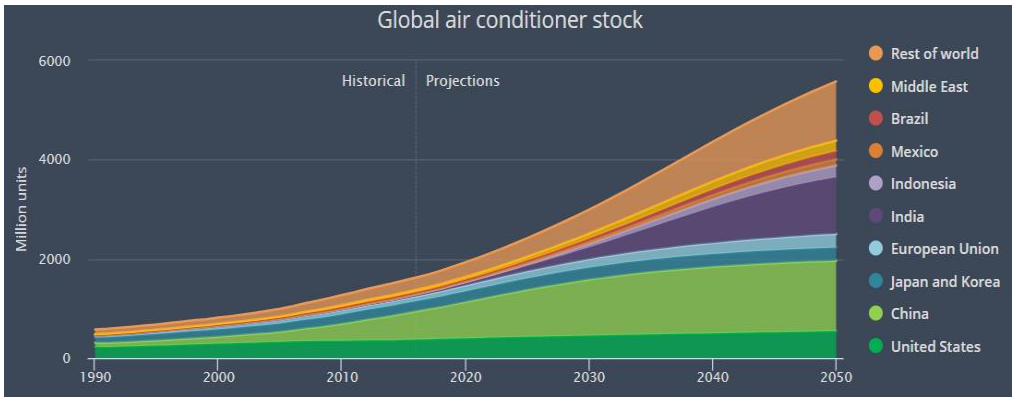
Challenges of Next-Generation Heat Pumps

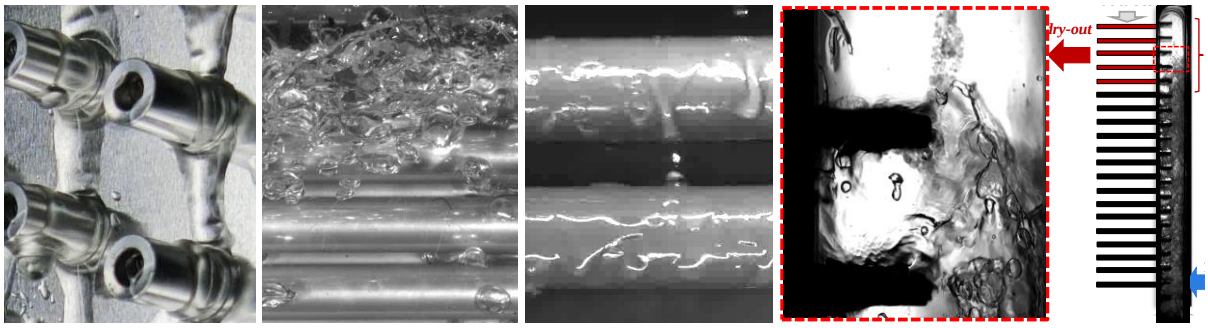
Abstract:

In the last three decades, from the Montreal Protocol (1987) to the Paris Agreement (2015), the ecological footprint of heating and refrigeration technologies has demanded a drastic reduction in greenhouse gases emissions and energy-saving strategies in order to cope with the sustainable development of this field. In this context, the development and spread of heat pump technology was cited as one of the most promising elements to reach the numerical targets of international protocols. This technology enables multidirectional heat transfer (cooling, heating, and temperature boosting) expanding the possibility of energy usage and provision, thus minimising energy waste.



https://www.iea.org/futureofcooling/

On the one hand, in terms of standard evaluation indexes, this technology has reached a performance level that is already approaching theoretical limitations, representing the potential for highly efficient operation. On the other hand, the actual operative conditions encountered are substantially different from those at which these indexes are evaluated. Therefore, the seasonal performance of operative systems is, in fact, substantially lower from their nominal efficiency. During real operation, subject to temperature and load variations, these systems often encounter complex interfacial phenomena that have not been conclusively clarified yet (such as phase changes, two-phase flow-pattern transitions, and film wetting).



In this respect, design and control methods have so far relied on trial-and-error procedures leading to nonoptimised operation.

This is evidence of the possibility for large energy savings provided that advanced modelling and control strategies, accounting for the actual complexity of the physical phenomena involved, can be used at an early predesign stage of thermal systems.

This presentation originates from the observation of the necessity for a solid theoretical background of this field, overviews the main scientific challenges to be overcome, and presents a hypothesis for achieving advanced modelling techniques.