Annex 53

Advanced Cooling/Refrigeration Technologies

By 2050 a huge increase in buildings energy demand for cooling and refrigeration is expected. To address this challenge there is a need for global action on research, development, and demonstration for advanced heat pumping technology solutions. To help minimize the long term energy demand growth, the availability of higher-efficiency and low–global warming potential (GWP) heat pumping technologies is essential.

Key Findings

Annex participants investigated over a dozen different technology approaches for future air-conditioning and refrigeration (AC&R) systems. These included advances to the time-proven vapor compression (VC) cycle, electrochemical compression, absorption and adsorption, and others based on nontraditional cycles including several caloric cycles. Technology Readiness Levels (TRL) ranged from about 2 to 5 for nontraditional options and up to 8 for advanced VC options investigated by Annex work period end.

1. An advanced VC AC system was a Grand Winner of the Global Cooling Prize competition. Cost reduction work is ongoing.
2. Adding a pressure exchanger to a transcritical CO2 system demonstrated coefficient of performance (COP) improvements up to 27% in a supermarket field test.
3. Electrochemical NH3 compressor tests showed isentropic efficiencies monotonically increasing with pressure ratio in contrast with VC compressors, which exhibit a peak efficiency and then a decrease at higher pressure ratios.
4. A heat–driven elastocaloric system projected to have a COP greater than those of state-of-the-art single-effect absorption chillers and photovoltaic-driven electric ACs (Figure 1).
5. A proposed electrocaloric HP device using a novel high-entropy polymer achieved a COP of ~80% of Carnot.
6. Heat pipe–coupled magnetocaloric (MC) technology tests demonstrated a cooling power density of 12.5 W/g of MC working material.
7. Power density of MC devices can match that of commercially available VC compressors up to about 500 W cooling capacity.
8. A prototype of a two-stage absorption thermal energy storage system that can operate with extremely low charging temperatures (~50°C) was developed.
9. Plastic adsorber material can potentially achieve adsorber mass reduction of 50% to 65% compared to aluminum with similar performance.
10. Simulation of ideal membrane heat pumps showed potential seasonal performance factor >8.

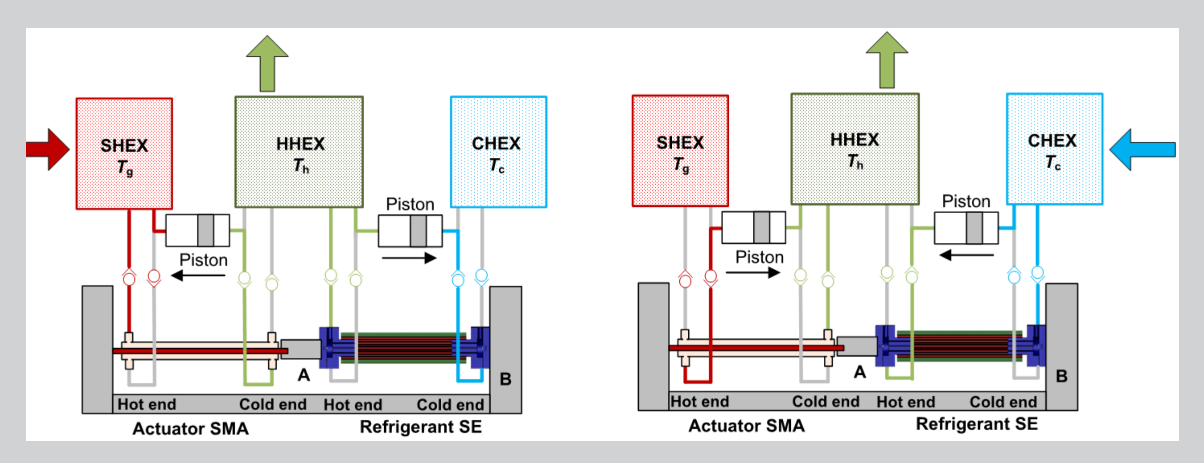

Figure 1: Heat-driven elastocaloric cooling system. (Left) Heating shape memory alloy (SMA) actuator and loading super elastic (SE) refrigerant. (Right) Cooling actuator and unloading refrigerant.

Figure 2: Two possible future paths for refrigeration and AC systems (courtesy of Navigant Consulting, Inc.; source: US Department of Energy Building Technologies Office, Emerging Technologies Program).

Background

AC&R systems account for a large share of current global energy consumption with the demand expected to increase sharply over the next 30-50 years. The adoption of AC in developed countries increased rapidly in the twentieth century, and the twenty-first century is expected to see increased adoption in developing countries—especially those with hotter climates and large, growing populations, such as India, China, Brazil, and Middle Eastern and African nations. The IEA projects that by 2050, AC energy consumption levels will increase by 4.3× over the 2010 levels for non-Organisation for Economic Co-operation and Development (OECD) countries vs. only 1.5× for OECD countries.

Technologies of interest follow two distinct paths: those based on the traditional vapor compression (VC) system and those based on nontraditional cooling approaches (Figure 2). VC may continue to be widely used but, to the extent that it continues to use nonzero GWP refrigerants it will remain vulnerable to further international refrigerant restrictions. Nontraditional technologies (e.g., caloric or other types) are not subject to this challenge because they do not rely on refrigerants in the traditional sense. However, all the nontraditional technologies being investigated still require additional development before they can significantly affect the market.

Objectives

Further the development of advanced (higher efficiency and lower GHG emission) AC&R focused heat pump technologies and promote their deployment to minimize or reduce the projected major growth in AC&R energy demand anticipated in the coming decades.

Further information

Contact person:	Operating Agents were Prof. Reinhard Radermacher raderm@umd.edu from University of Maryland and Van Baxter baxtervd@ornl.gov from Oak Ridge National Laboratory, the USA.
Participating countries:	China, Germany, Italy, South Korea, and USA
Publications:	Final report of Annex 53 and Executive Summary of Annex 53, available at https://heatpumpingtechnologies.org/publications/
Internet:	https://heatpumpingtechnologies.org/annex53/