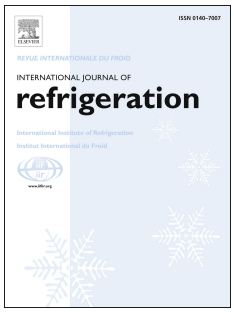
Accepted Manuscript



Present and future caloric refrigeration and heat-pump technologies

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PII: S0140-7007(15)00175-9

DOI: 10.1016/j.ijrefrig.2015.06.008

Reference: JIJR 3065

To appear in: *International Journal of Refrigeration*

Please cite this article as: Kitanovski, A., Plaznik, U., Tomc, U., Poredoš, A., Present and future caloric refrigeration and heat-pump technologies, *International Journal of Refrigeration* (2015), doi: 10.1016/j.ijrefrig.2015.06.008.

PRESENT AND FUTURE CALORIC REFRIGERATION AND HEAT-PUMP TECHNOLOGIES

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Keywords: solid-state physics, caloric material, magnetocaloric, electrocaloric, barocaloric, elastocaloric, energy conversion, refrigeration, heat pump, air conditioning

Abstract:

In recent years, several emerging technologies in the domain of solid-state physics have been investigated as serious alternatives for future refrigeration, heat pumping, air conditioning, or even power generation applications. These technologies relate to what is called caloric energy conversion, i.e., barocalorics, electrocalorics, magnetocalorics, and elastocalorics. Of these technologies, the greatest progress has been observed in the domain of magnetic refrigeration. However, in the recent few years, significant research efforts have also been made in the field of electrocaloric and elastocaloric refrigeration. Many of these technologies suggest the possibility for improvements in energy efficiency, compactness, noise level, as well as a reduction in environmental impacts, so it seems very probable that they will start to fill particular market niches as a replacement for vapor-compression technology in the future.

1. INTRODUCTION

The world's energy demands for refrigeration and air conditioning represent nearly 20% of the energy consumption. The major cooling technology, i.e., the vapor compression of a gas refrigerant, even though it is now mature, is characterized by a rather low exergy efficiency, especially for small devices. Despite the fact that other substances are being used to substitute for existing or already-abandoned harmful refrigerants, many of these are the subject of future prohibition. Moreover, several alternatives, such as the potential replacement of existing refrigerants in vapor compression, lead to lower energy efficiency or problems related to very high pressures, flammability, explosion hazards, etc.

In the past few years, many alternatives have been proposed by different technology-foresight studies. This articles focuses on the latest two. First, Brown and Domanski (2014) compared about 20 different technologies, from which they have emphasized the importance of magnetic (i.e., magnetocaloric) refrigeration, as being the alternative with the highest level of research activity and the best experimentally achieved exergy efficiency. However, they also noted that certain technical breakthroughs are required for most of the alternatives to become successful. They continued, that one should expect these alternatives to initially enter some specific market niches, and one should not expect the widespread displacement of vapor-compression technology in the near future.

The second study, performed by Goetzler et al. (2014), looked at the potential for energy savings and research opportunities for non-vapor-compression HVAC technologies. The authors of this comprehensive study selected 17 out of 20 identified viable technology options. They designated the remaining three technologies, i.e., the Bernoulli heat pump, the critical-flow refrigeration cycle, and electrocalorics as the early-stage technology options with missing demonstrations and information for a critical judgment and a comparison with vapor compression. Based on their analyses, they developed estimates for unit energy