International Journal of Sustainable Built Environment (2012) 1, 85–101

Gulf Organisation for Research and Development

International Journal of Sustainable Built Environment

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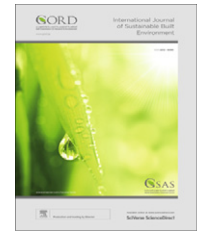

Review

Status of not-in-kind refrigeration technologies for household space conditioning, water heating and food refrigeration

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Received 2 February 2012; accepted 19 July 2012

Abstract

This paper presents a review of the next generation not-in-kind technologies to replace conventional vapor compression refrigeration technology for household applications. Such technologies are sought to provide energy savings or other environmental benefits for space conditioning, water heating and refrigeration for domestic use. These alternative technologies include: thermoacoustic refrigeration, thermoelectric refrigeration, thermotunneling, magnetic refrigeration, Stirling cycle refrigeration, pulse tube refrigeration, Malone cycle refrigeration, absorption refrigeration, adsorption refrigeration, and compressor driven metal hydride heat pumps. Furthermore, heat pump water heating and integrated heat pump systems are also discussed due to their significant energy saving potential for water heating and space conditioning in households. The paper provides a snapshot of the future R&D needs for each of the technologies along with the associated barriers. Both thermoelectric and magnetic technologies look relatively attractive due to recent developments in the materials and prototypes being manufactured.

Keywords: Efficiency; Thermoacoustics; Thermoelectricity; Stirling; Magnetic refrigerator

Contents

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Peer review under responsibility of The Gulf Organisation for Research and Development.

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2212-6090
http://dx.doi.org/10.1016/j.ijsbe.2012.07.003

Nomenclature

AMRR	active magnetic regenerative refrigeration
CCHP	combined cooling heating and power
CD-MHHP	compressor driven metal hydride heat pumps
COP	coefficient of performance
HX	heat exchanger
HPWH	heat pump water heater
i	electric current [A]
IHPS	integrated heat pump system
K	thermal conductivity [$Wm^{-1} K^{-1}$]
MCE	magneto caloric effect
NIK	not-in-kind
PTR	pulse tube refrigerator
Q	heat transfer rate [W]
T	temperature [K]
VS	variable speed
Z	figure of merit

Greek symbols

α	seebeck coefficient [VK^{-1}]
Δ	difference
ρ	electrical resistivity [Ω-m]

Subscripts

C	cold
H	hot
adiabatic	adiabatic process
L	low temperature
R	room temperature

1. Introduction

The vapor compression refrigeration has remained practically a predominant technology for well over 100 years. The fundamental principle is to use liquid–vapor and vapor–liquid phase transitions to transfer heat from a low temperature state to a higher temperature state. It is desirable to have these phase transitions occur at room temperature. The ideal refrigerant for the vapor compression systems should be non-toxic, noncorrosive, efficient, cost effective and more importantly environmentally benign. There is a general trend of increasing demand for heating, cooling and refrigeration services world-wide. This will eventually lead to the increase in related CO_2 emissions. This trend could be alleviated by the performance enhancement of current heat pumping technologies and/or the development of new energy efficient technologies. In this context, the current paper reviews emerging not-in-kind technologies (NIK) that offer the potential for significant energy savings and environmental benefits compared to existing technologies. In addition, the status of emerging technologies that are useful in a household, including space conditioning, water heating and refrigeration, are discussed.

There have been a few integrated reviews of alternative technologies in the open literature. Fischer et al. (1994) presented one of the earliest and most comprehensive summaries of not-in-kind technologies. This was then updated by Fischer and Labinov (2000) with emphasis on economic impact and potential commercialization. Lately there has been a flurry of activity (Radermacher et al., 2007; Dieckmann et al., 2007) in this area, where Navigant Consulting Inc. (2009) provided an overview of some of the alternative technologies targeting energy savings for commercial refrigeration applications. This was followed by a report from Brown et al. (2010) that assessed the prospects of thermoelectric, thermionic, thermotunneling, thermoacoustic and magnetic refrigeration for space cooling and food