2009 BFRL Project Description

Project Title: Alternative Cooling Technologies

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BFRL Program: Healthy and Sustainable Buildings

Objective: To evaluate the measurement science needs for alternative cooling and heating technologies that could supplant vapor compression-based cooling and heating systems and offer significant energy savings.

Problem:

What is the problem? Energy usage for refrigeration and space cooling in residential and commercial in building the United States accounted for 25.8 % of total electrical energy use in buildings in 2005[1]. Almost all of this energy is consumed by vapor compression-based equipment, which has the dominant market position in space cooling and refrigeration. Additionally, vapor compression heat pumps are used for space heating, and they consume a significant share of the U.S. heating electrical consumption, which constitutes 8.1 % of total electrical energy use in buildings[1].

Within the last two decades two environmental impacts of vapor compression technology were recognized: the catalyzing function in the destruction of the stratospheric ozone layer and the trapping of infrared radiation contributing to global warming. These impacts, related to emissions of synthesized refrigerants, resulted in a phase-out of chlorine-containing refrigerants by the Montreal Protocol[2], and gave an impetus to regulatory considerations for partial phase-out of hydrofluorocarbon (HFC) refrigerants[3].

Vapor compression-based cooling and heating equipment is a technology which matured over a century of research and development. Considering the increasing environmental pressure to limit refrigerant options for vapor compression and the need to assess all technologies that move the Nation towards zero energy buildings, it is necessary to assess emerging cooling technologies[4,5].

Why is it hard to solve? Technical options for cooling and heating constitute a myriad of possibilities. As a first analysis, these options can be categorized by the form of the main energy input; mechanical (e.g., vapor compression), thermal (e.g., absorption or adsorption) and

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[1] 2007 *DOE Buildings Energy Data Book*, http://buildingsdatabook.eren.doe.gov/
[2] http://www.unep.org/OZONE/pdfs/Montreal-Protocol2000.pdf
[3] 2008 America's Climate Security Act, http://www.govtrack.us/congress/bill.xpd?bill=s110-2191
[4] ASHRAE Strategic Research Plan 2005-2015, Navigation for a Sustainable Future, http://www.ashrae.org/docLib/200641713376_347.pdf
[5] ARTI Research Road Map, http://www.arti-research.org/roadmap.php

electrical (e.g., thermoelectric or thermionic). They also can be analyzed within the context of different applications, e.g., cryogenics, refrigeration (low or high temperature), comfort cooling, comfort heating, process control, etc. Additionally, hybrid systems may offer advantages and should be considered as well. Consequently, the assessment of alternative cooling and heating options requires an in-depth evaluation of the state-of-the-art of different technologies, an identification of their application potentials and the development of breakthroughs required to bring about these various potentials.

How is it solved today, and by whom? A state-of-the-art assessment of alternative technologies is not available. The last comprehensive evaluation of not-in-kind cooling technologies was published in 1994[6]. This study did not identify a technology that could supplant vapor compression systems. A conference paper, published in 1997[7], also suggested a continuing dominance of vapor compression systems. Moreover, research papers on selected technologies studied within the last 10 years, e.g., magnetic refrigeration, give examples of performance at selected test conditions, but lack a comprehensive evaluation of competing technologies on equal bases[8].

Why NIST? This project is aligned with the BFRL mission by meeting the measurements science needs of the U.S. HVAC&R industry regarding emerging cooling technologies[5]. The project also is directly aligned with the BFRL competency of measurement science for building energy technologies and supports the strategic priority of Measurement Science for Net Zero Energy, High-Performance Buildings. BFRL has the expertise needed and long-standing tradition of supporting the US HVAC&R industry with research and dissemination of knowledge related to global issues of stratospheric ozone depletion and climate change: e.g., NIST organized and hosted the 1997 ASHRAE/NIST Conference entitled "Refrigerants for the 21st Century".

Approach:

What is the new technical idea? We will categorize different cooling technologies according to their main form of energy input and will systematically evaluate their potential for implementation as cooling systems or as devices for different applications. Also, we will consider potential benefits of the implementation of emerging technologies in hybrid systems where combining two technologies may offer a performance advantage. The study will establish the merits of competing technologies on equal bases, will identify the technological breakthroughs needed for their implementation, and will assess the effort needed and probability of overcoming the technological barriers. A systematic presentation of challenges and merits of different technical options will facilitate planning of innovative research at NIST and will provide industry with an understanding of the state-of-the-art of cooling technologies needed for their own research and development foci.

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[6] Fisher, S.K., Tomlinson, J.J., Hughes, P.J., 1994, "Energy and Global Warming Impacts of Not-In-Kind and Next Generation CFC and HCFC Alternatives", ORNL, Oak Ridge, TN.

[7] Crawford, J.G., 1997, "Heat Pump Technology on the Horizon", ASHRAE/NIST Refrigerant Conference: Refrigerants for the 21st Century, NIST, Gaithersburg, MD.

[8] Tagliafico, L.A., Scarpa, F., Canepa, F., Cirafici, S., 2006, "Performance analysis of a room temperature rotary magnet refrigerator for two different gadolinium compounds", Int. J. Refrig., 29 (8), 1307-1317.

Why can we succeed now? The regulatory curtailing of the use of HFC refrigerants in Europe and the partial HFC phase-out being considered in U.S. proposed regulation[3] directly increases industry's interest in non-conventional cooling technologies. Furthermore, it is important for ongoing and future discussions and in decision making to have a clear understanding of the potential of cooling options available outside the currently dominant HFC technologies.

What is the research plan? The study will begin with a literature review. Since the 1994 ORNL report[6] documented the state-of-the-art for different technologies that existed at the beginning of the 1990's, we will use the findings of this report as a general reference point. The extensive literature review and follow up interactions with the researchers will serve to establish the 2008 status of these technologies. The analyses performed during the study will seek to establish progress since the publication of the 1994 ORNL report, including the extent to which this progress has been demonstrated experimentally, to indentify the technical and economical factors barring market penetration of individual technologies, and to estimate the probability of these barriers being overcome in the next 10-20 years.

The product of this study will be a technical review paper which will document the landscape of different cooling options, will present their relative technical merits, and will evaluate their market viabilities.

Recent Results:

None. This is a new project.

Standards and Codes: None