NATURAL REFRIGERANTS IN HEAT PUMPS - A STUDY OF MARKET AND POLICY TRENDS IN THE EUROPEAN UNION AND NORTH AMERICA

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Abstract: The natural refrigerants carbon dioxide, ammonia and hydrocarbons are gaining traction in the global heating, ventilation, air-conditioning and refrigeration (HVAC&R) industry. However, although acknowledged as a viable alternative to hydrochlorofluoro-carbons (HCFCs) and hydrofluorocarbons (HFCs) in different applications, a range of barriers impede their more widespread use. At the international workshop "ATMOsphere 2010" representatives from the heat pump sector, non-governmental organisations, as well as legislators identified a range of concrete national/international barriers and solutions, covering the areas of technology & safety, legislation & standards, training & know-how, markets & marketing, funding & support, supply & availability, as well as psychology.

Building on these results, a global survey among industry experts was launched in February 2011 to verify barriers for natural refrigerants in HVAC&R sector. Preliminary results show (status: 31 March 2011) that the information level about natural refrigerants is unevenly distributed among the industry, and that training and psychology pose major barriers to a wider consideration of non-HFC refrigerant solutions. By August 2011, this data will result in a "guide to natural refrigerants" to provide quantitative and qualitative data about market shares, projections and scenarios, expectations from the industry and an evaluation of policy measures regarding their potential to support or delay the introduction of non-HFC solutions in heat pumps and beyond.

Key Words: natural refrigerants, carbon dioxide, ammonia, hydrocarbons, policy barriers, market size and expectations

1 INTRODUCTION

Natural refrigerants – including water and air, but mostly today still carbon dioxide (CO_2/R744), ammonia (NH_3/R717) and hydrocarbons (propane/R290, isobutane/R606a, propylene/R1270 etc.) – represent a technically viable alternative to traditional fluorinated gases in a growing range of applications in the global heating, cooling and refrigeration industry. Given that a rising number of international, supranational and national legislative acts restrict or ban the use of Ozone Depleting Substances (ODS) and high Global Warming Potential (GWP) gases - due to their known and unknown effects on atmospheric degradation, climate change, biodiversity loss, human health and safety, as well as their underrated economic and social costs – natural refrigerants have been capturing the attention of legislators and industry likewise. However, their use – with the exception of certain mainstream applications – remains minor as compared to synthetic (CFC, HCFC and HFC) alternatives. Despite a rising amount of scientific papers exploring the theoretical potential of natural refrigerant systems and components, the market share of CO_2, ammonia

and hydrocarbons in selected heating applications and world regions has been quantified only on an irregular basis (Antonsson and Hansen, 2010; Maté, 2010)

The international workshop "ATMOsphere 2010" – supported by the United Nations Environment Programme UNEP – was organised in September 2010 to define immediate challenges faced by industry and policy in encouraging the research on and the application of natural refrigerants as substitutes for CFCs/HCFCs currently in the process of being phased out in 147 countries (Atmosphere, 2010a). Participants from both developed and developing countries agreed that setting the course for future refrigerant choices will largely need to follow the "precautionary principle" in that scientific uncertainty about the effects of substances employed "shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation […] where there are threats of serious or irreversible damage […]". (Rio, 1992)

2 BARRIERS TO NATURAL REFRIGERANTS

In a global survey conducted among 200+ industry experts - representing 30 countries - from August to December 2010, the industry was asked to rank seven types of barriers in terms of significance for the adoption of natural refrigerants in their country (Atmosphere, 2010b). 32% of respondents stated "Safety & Technology" as the single most important barrier to their uptake, while 18% stated "Legislation" and 12% "Markets & Marketing" (Figure 1).[1] When weighing the single barriers in terms of their overall importance among the seven categories, "Safety & Technology" and "Legislation" remained at the top of the ranking, this time followed by "Training & Know-How" and "Supply & Availability" (Figure 2).[2] The most relevant finding from the conducted survey is that no single barrier impedes the use of natural refrigerants but that, demonstrated by the weighted responses, all seven barrier categories exert a similarly strong influence on the market adoption of CO_2, NH_3 and HCs, depending on the national context and in particular the country's situation as regards the phase-out of ODS and high GWP refrigerants.

Fig. 1: Most Important Barrier for Natural Refrigerants

(% of respondents)

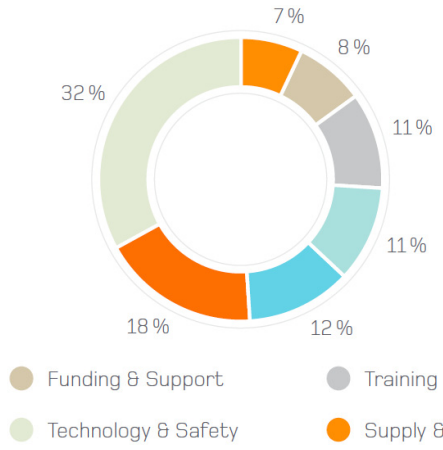
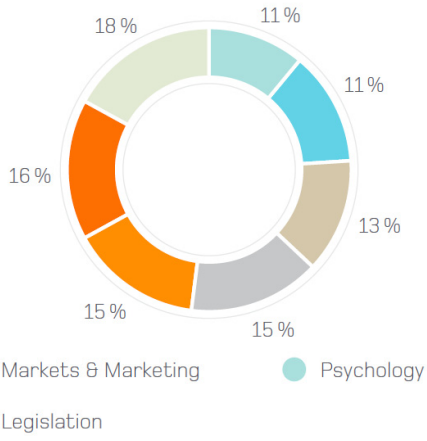


Fig. 2: Ranking of Barriers by Importance

(weighted responses)



Source: Atmosphere, 2010b

[1] Figure 1: Technology & Safety 32%, Legislation 18%, Markets & Marketing 12%, Psychology 11%, Training & Know-How 11%, Funding & Support 8%, Supply & Availability 7%

[2] Figure 2: Technology & Safety 18%, Legislation 16%, Supply & Availability 15%, Training & Know-How 15%, Funding & Support 13%, Markets & Marketing 11%, Psychology 11%

In the following, the three most important barriers and concrete solutions to overcome them, are elaborated more in detail:

2.1 Technology & Safety

Among the prevailing perceived barriers to a widespread use of ammonia, carbon dioxide and hydrocarbons in different world regions and heat pump applications, respondents consistently mentioned safety concerns, public perception/ misconceptions, and fear of high pressures/flammability. Solutions proposed to overcome shortcomings in this field include:

- the compilation of peer-reviewed safety guidelines that need to be endorsed by authoritative bodies and translated into national languages
- the accumulation and publication of risk analysis studies to focus on the technical nature of safety issues and proposed technical solutions
- the submission of natural refrigerant equipment by system manufacturers to standards and codes committees to base safety standards and codes on their evaluation
- the standardisation of refrigerant containers and their labelling to reduce the number of incidents resulting from their mishandling during charge / recharge processes
- the strengthening of regulatory bodies to ensure refrigerant purity
- the encouragement of third party testing / certification
- the application of minimal refrigerant charge technologies and the application of intelligence/electronics to systems
- the allowance of longer warranties for natural refrigerant equipment to reassure end-users about its durability and reliability
- the exploring of new opportunities for the applications of ammonia heat pumps (e.g. desalination of water) to ensure a wider deployment of the ammonia technology

More specifically, for ammonia used as a refrigerant in heat pump applications, the following barriers were identified as prevailing ones:

- the general misconception about ammonia as a refrigerant
- the small percentage of individuals in the industry that are involved in the development of ammonia heat pump solutions
- the perceived higher costs and a widespread “the business is too good to be true” scepticism

2.2 Legislation & Standards

Highly restrictive and prohibitive national and international standards, a lack of harmonised regulations pertaining to the use of natural refrigerants between different locations within the same region, and the manipulation of trade and safety standards for commercial ends, were mentioned as major barriers to the employment of HFC-free alternatives. Proposed solutions include:

- the drafting of permissions based on individual risk assessments
- the proper representation of natural refrigerants proponents (science, industry) in standardisation committees
- the review of outdated safety standards to reflect current state-of-the-art in safety capacities of natural refrigerant equipment
- the putting into place of rigorous controls to prevent the manipulation of standards
- the removal of regulations and trade barriers within a region that are redundant and not harmonised with the remainder of the region

Regarding major barriers identified for heat pumps using natural refrigerants, survey respondents and participants at the global workshop highlighted specifically the fact that U.S. legislation in the field of environmental protection would still lag several years behind that of Europe or Japan. This would especially be true for the use of CO_2 in domestic and commercial heat pump hot water heaters (HPHW) and dryers. (Atmosphere, 2010a) As a comparison, 14 Japanese corporations issued an industry agreement in March 2010 to engage in the active promotion of heat pumps, in particular of "Eco Cute" models using the natural refrigerant CO_2. As a result of active governmental support in collaboration with the heat pump manufacturing industry and utilities over the last decade, cumulative shipments of R744 HPHW in Japan had reached more than two million units by April 2010. A combination of extensive consumer information campaigns, tax incentives and purchase rebates, as well as the installation of show-rooms throughout the country was identified as a role model to follow to achieve high market penetration rates for natural refrigerants equipment in the industrial, commercial and residential heating sectors also beyond the borders of Japan. (JRAIA, 2010)

2.3 Training & Know-how

The lack of knowledge by manufacturers, contractors, installers, consultants, servicing companies, policy makers, ozone officers and consultants, and the related lack of information and training material were mentioned as major challenges in the category "training & know-how". Proposed solutions include:

- the set-up of trial equipment in local training institutes and in-house training centres for hands-on training of technicians and the provision of government support for implementing and extending existing independent training schemes
- the revision of university and technical schools' curricula to incorporate modules about the installation and maintenance of natural refrigerant installations
- the systematic forming of partnerships between regions/organisations with high expertise in natural refrigerant installations and those having no strong application basis yet
- the support for mobile trainers reaching out to installers and maintenance staff at their work place
- the training of Ozone Officers, consultants and technicians developing HCFC phase-out management plans (HPMP) in developing countries
- the introduction of certification schemes for technicians handling CO_2, ammonia, hydrocarbons
- the organisation of regional workshops and conferences to reach stakeholders at the local level (Atmosphere, 2010b)

3 GLOBAL HVAC&R INDUSTRY SURVEY 2011: FIRST RESULTS

From February to June 2011 a global survey among the HVAC&R industry - including component and system manufacturers, end-users, industry association bodies and engineering services providers – is being conducted to validate initial findings about major barriers to the uptake of natural refrigerants. The final results will be available in autumn 2011 in an attempt to be representative of the industry as a whole by including both organisations already active in natural refrigerants and those relying on the use of traditional synthetic refrigerant gases.

Conclusions and updated figures will be presented in a "guide to natural refrigerants". The digital publication will be an easy-to-access reference document to the global market for carbon dioxide (R744), ammonia (R717) and hydrocarbons (R290, R606a, R1270 etc.) as

alternatives to ODS and high GWP fluorinated gases in heating, cooling and refrigeration applications. It aims to illustrate, describe and, more importantly, quantify the market potential of natural refrigerants in selected world markets. Its first edition will focus on two world regions – North America and Europe – that provide 1) a high economic potential for the natural refrigerants business today and in the near future and 2) have a special role to play in scaling up energy conservation and greenhouse gas emissions reductions.

3.1 Survey Design

The survey was designed in an online format, directly accessible via several web platforms[3] and via individualised email invitations. Invitations were sent early February 2011 to more than 5,000 industry representatives directly and indirectly involved in the manufacturing, installation, maintenance or use of HVAC&R equipment. It is planned to also distribute the survey widely among members of leading industry associations. The questionnaire consists of a maximum of 28 questions, depending on which responses are chosen (question logic added).

It addresses the following issues, specifically for natural refrigerants:

- Level of Expertise/Information (individual respondent / HVAC&R industry overall / customers)
- Information Sources used (web, conference, trade shows, magazines, associations, training etc.)
- Products/Services (existing / planned)
- Main Markets & Adoption Potential (world region / national markets)
- Market Shares & Trends (per application / world region)
- Barriers and Strengths (per category)
- Business & Policy Climate

Respondents are also asked to indicate general information about organisation type, organisation size, main fields of activity, and their routes to market chosen.

3.2 Preliminary Results March 2011

By 31 March 2011, 568 respondents had fully or partially replied to the online questionnaire. The distribution of organisation type and their main fields of activity (multiple responses possible) is shown in Figure 3 and Figure 4, respectively (shecco, 2011):

[3] The survey is accessible on the following platforms (31 March 2011): http://www.shecco.com/survey.php ; http://www.ammonia21.com/survey.php; http://www.hydrocarbons21.com/survey.php ; http://www.r744.com/survey.php

Fig. 3: Organisation Type (total number of respondents)

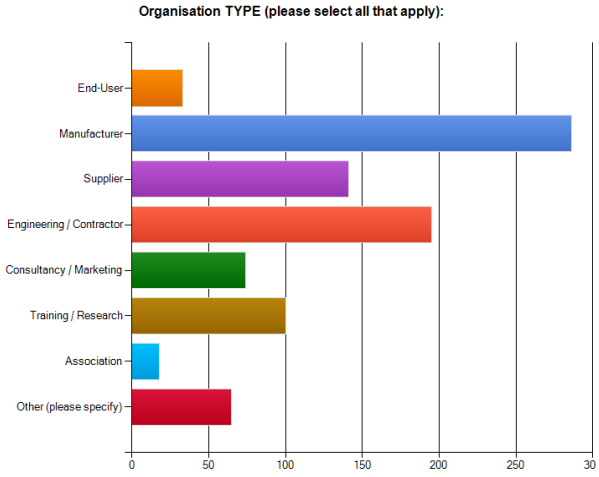
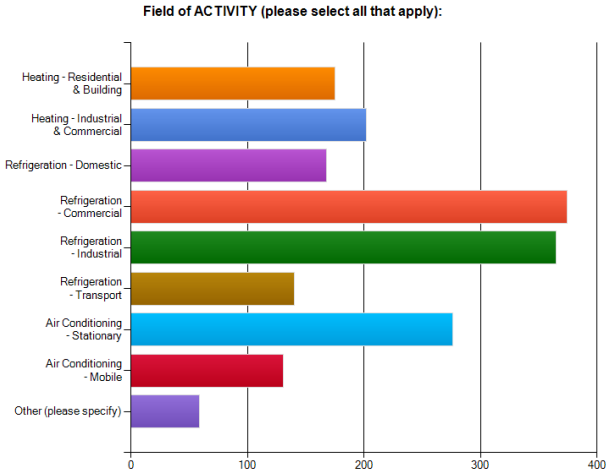


Fig. 4: Field of Activity (multiple responses possible)



Source: shecco, 2011

The level of knowledge about natural refrigerants varies greatly between the individual respondent (question: "How informed are you about Natural Refrigerants?) and the perceived awareness level for the HVAC&R industry overall (question: "How informed is the HVAC&R industry as a whole about Natural Refrigerants?). Figures 5 and 6 indicate that a majority of respondents (74.9%) believes to be informed or highly informed about natural refrigerants (61-100% information level). However, respondents also believe that only 26.0% of the HVAC&R industry as a whole has currently the same level of awareness (61-100%). Similarly low information levels are assumed for the respondents' customers, suggesting a wider need for awareness-rising measures for natural refrigerants within the HVAC&R industry and towards end-users.

Fig. 5: Information Level Individual Respondent (in % from total)

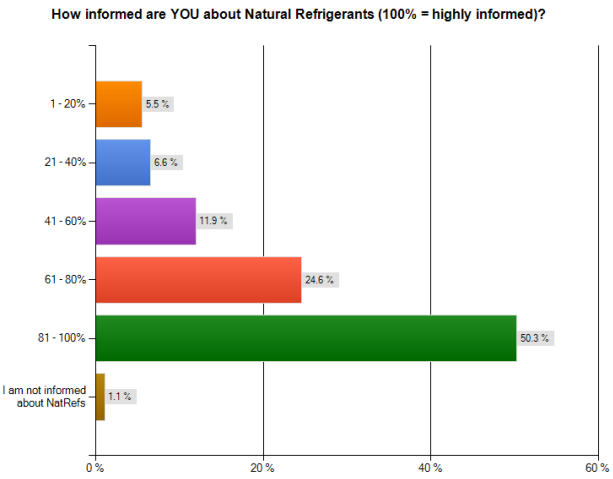
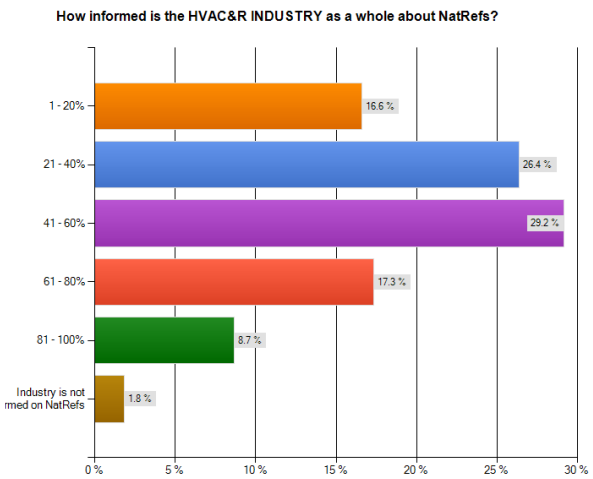


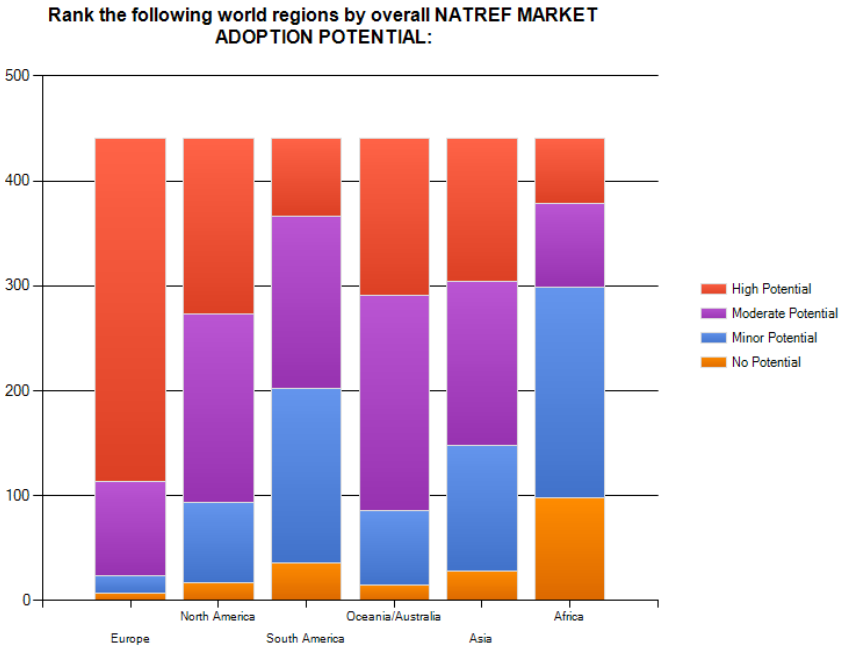
Fig. 6: Information Level HVAC&R Industry (in % from total)



Source: shecco, 2011

First responses to the question “Rank the following world regions by overall Natural Refrigerants Market Adoption Potential” show that Europe is the world region with the highest perceived market adoption potential for natural refrigerants (average value: 3.68 out of 4.0), followed by North America (3.13 out of 4.0) and Oceania/Australia (3.11 out of 4.0). Figure 7 shows the distribution of responses for the four provided response categories “No Potential”, “Minor Potential”, “Moderate Potential” and “High Potential”.

Fig. 7: Natural Refrigerant Market Adoption Potential per World Region (in % from total)



Source: shecco, 2011

First results indicate that the prevailing barriers (“strong barrier” and “very strong barrier”) for the wider uptake of natural refrigerants are seen in “Training & Know-How” (56.5%), “Technology & Safety” (49.9%) and “Psychology” (48.0%). However, given the short time span since the survey launch, these findings require more solid verification and analysis.

4 CONCLUSIONS

Studies on the market potential of natural refrigerants, as well as a global SWOT analysis for HFC-free solutions in a broader context have been limited. The present study aims to quantify the market for carbon dioxide, ammonia and hydrocarbon refrigerants at a global scale, and more specifically in the European Union and North America. Results obtained by June 2011 will build on preliminary findings from a first global survey conducted in 2010 to verify the most relevant barriers to the adoption of natural refrigerant solutions, and to elaborate on the perceived advantages of the latter in the context of changing national and international policy and business priorities.

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