Air conditioning environmental challenges

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Air conditioning is part of our comfort in our buildings. It is however also necessary in many various uses and the technology is basically the same as the refrigeration technologies. These technologies face two important challenges, reduction of energy consumption and reduction of refrigerant emissions. The International Institute of Refrigeration aims to reduce these environmental impacts.

Keywords: air conditioning, energy consumption, refrigerants, hydrofluorocarbons, global warming.

REHVA, the Federation of European Heating, Ventilation and Air Conditioning Associations and **IIR**, the International Institute of Refrigeration have a partnership agreement to promote progress and expansion of knowledge and to disseminate information on refrigeration and air conditioning technology. Both partners agreed to act in close cooperation of matters of mutual interest such as: journals, books, newsletters, congresses and conferences.

REHVA
Federation of European Heating, Ventilation and Air Conditioning Associations

Air conditioning is necessary for life

Air conditioning is largely used in buildings, in houses as well as in commercial buildings. It is also largely used for industry purposes, since the temperature is a magnitude and a key variable in physics, chemistry and biology. It characterizes the state of matter and liquid, solid and gaseous phases. It thus drives to applications for which the size of the materials shall be particularly stable such as information technologies and nanotechnologies or datacenters. It is also vital to all living beings (biotechnologies industry …).

It is similar to other refrigeration uses, in:

- Cryogenics (petrochemical refining, steel industry, space industry, nuclear fusion…)
- Medicine and health products (cryosurgery, anesthesia, scanners, vaccines…)
- Food industry and the cold chain
- Energy sector (including heat pumps, LNG, hydrogen…)
- Environment (including carbon capture and storage), public works, leisure activities…

Everybody can understand the need of refrigeration for the preservation of food and its vital necessity. Less people know that air conditioning is also useful for health. For instance:

- a recent MIT study showed mortality during hot days (temperatures higher than 32°C) decreased by 80% between 1900–1959 and 1960–2004 in the US: "The adoption of residential air-conditioning explains essentially the entire decline in the temperature-mortality relationship" (1).
- Air conditioning is expected to play an increasing role in the context of climate change and increase of ambient temperatures. IPCC estimates that energy demand for residential air conditioning in summer is projected to increase over 13-fold between 2000 and 2050 and over 30-fold by 2100, under its reference climate change scenario (2).
- According to another study, in the United Kingdom, 15.7 billion Euros are lost every year because of inadequate temperatures (3).

Refrigeration and air conditioning are a major energy consumer

Refrigeration, including air conditioning, represents more than 17% of global electricity consumption (4). And this figure increases. Refrigeration issues are clearly linked with electricity issues, which are:

- Global warming because of CO_2 emissions (electricity production depending on fossil fuels): we need to take into account the TEWI (Total Equivalent Warming Impact), and the LCCP (Life Cycle Climate Performance) of the refrigerating equipment.
- The price of electricity will increase in a long term perspective (new sources of energy have higher costs).
- There is a lack of power infrastructures, particularly in developing countries.

Overall system solutions (district cooling, trigeneration…) should certainly be developed and we need to review the coefficients of performance of the systems as we did for heat pumps. There are new regulations on energy and on buildings in Europe, the USA or Japan with new constraints on energy and thus new constraints on refrigeration systems, and probably everywhere in the future.

New sources of energy can be used, such as solar energy. Even if the coefficient of performance of solar equipment is still relatively low and if investment costs can be high, some systems are already in place and many experiments and research programmes are ongoing.

In any case, changing a system because of refrigerant issues must take into account potential reductions in energy consumption: both issues are linked.

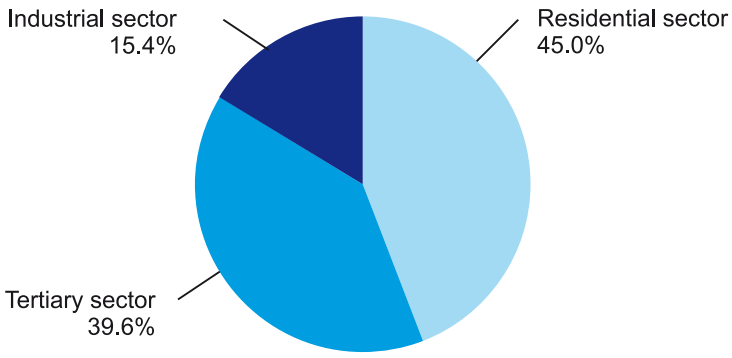

Chart 1 shows IIR estimations of the global distribution of the refrigeration sector's electricity consumption between the residential, tertiary and industrial uses.

Chart 1: Global distribution of the refrigeration sector electricity consumption.

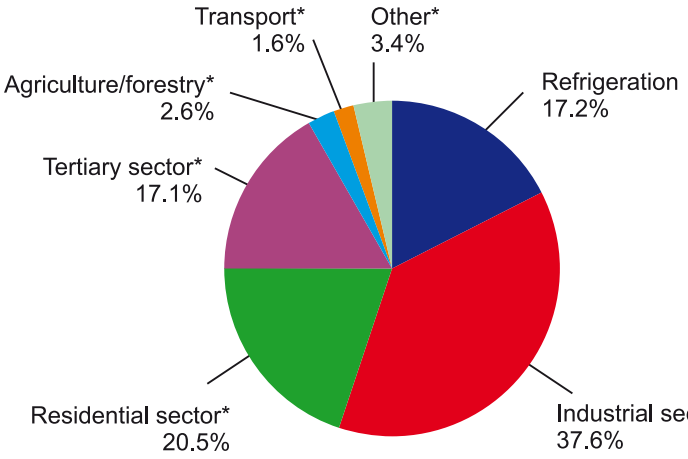

Chart 2 compares this refrigeration sector related electricity consumption ratio of 17% with electricity-consumption ratios in other sectors: industrial, residential and tertiary (refrigeration-sector consumption excluded), agriculture/forestry, transport and other non-specified sectors, based on IEA data [15] and IIR estimations.

Chart 2: Comparison of the refrigeration sector electricity consumption with that of other sectors.

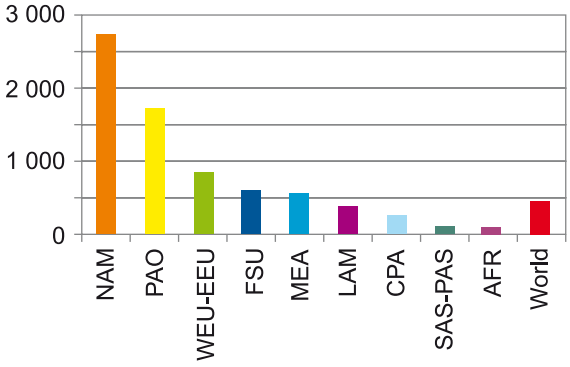

Chart 3 demonstrates regional differences in refrigeration sector electricity consumption, depending especially on development levels and climatic conditions.

NAM: North America
PAO: Pacific OECD
WEU-EEU: Western, Central and Eastern Europe
FSU: Independent states of the former Soviet Union
MEA: Middle East and North Africa
LAM: Latin America and the Caribbean
CPA: Centrally planned Asia and China
SAS-PAS: South Asia – Other Pacific Asia
AFR: Sub-Saharan Africa

Chart 3: Distribution of electricity consumption for refrigeration (kWh/year/capita) between the world regions (According to IPCC definition of SRES World Regions)

Air-conditioning penetration is expanding quickly. As a whole, it is responsible for around 5% of global electricity consumption, according to IIR estimations. This ratio varies widely from one country to another, depending on the local climate and the development level. While air conditioning is almost absent in the least developed countries, it accounts for about 14% of the total electricity consumption in the US (5) and 40% in the Indian city of Mumbai (6).

Air-conditioning is dramatically growing in the world's emerging economies. For example, less than 1% of urban Chinese households owned an air conditioner in 1990, while this number rose to almost 100% by 2009 (7,8).

The value of the world market of air conditioners was 72.3 billion Euros in 2012, corresponding to 128.5 million air-conditioning units sold. This value is predicted to reach about 82 billion Euros by 2017 (+13.4%) (9).

Furthermore, air conditioning is expected to play an increasing role in the context of climate change and the associated increase of ambient temperatures. IPCC estimates that energy demand for residential air conditioning in the summer is projected to increase over 13-fold between 2000 and 2050 and over 30-fold by 2100, under its reference climate change scenario (10).

Mobile air conditioning is expanding at an even higher pace since most new vehicles currently sold are air-conditioned. There are currently about 700 million mobile air-conditioning units in vehicles and buses worldwide (11).

The impact of refrigerants on the environment

Vapour-compression systems will remain predominant in the short and medium term and thus we will require more refrigerants in the future.

Because of their impact on the stratospheric ozone layer, Chlorofluorocarbons (CFCs) and Hydrochlorofluorocarbons (HCFCs) are included in the Montreal Protocol and each country (whether developed or developing) had to build phase-out plans. Hopefully this issue will soon be behind us, apart from the bank issue (refrigerants in existing equipment to be destroyed in the future). However, the main issue of phase-out plans is the kind of refrigerating equipment which is used to replace old equipment.

There are alternative refrigerants:

- Hydrofluorocarbons (HFCs), including Hydrofluoroolefins (HFOs) have no impact on the ozone layer but they have an impact on global warming (they are included in the Rio Convention and the Kyoto Protocol)
- Natural refrigerants (ammonia, CO_2, hydrocarbons, water, air) have a very low impact on global warming.
- Mixtures, combinations (cascades, secondary fluids) are being developed in order to meet the various requirements.

HFCs currently represent less than 1% of CO_2 eq emissions. In 2050, they will represent 7-45% (more likely 7%) of CO_2 equivalent emissions.

HFCs emissions in 2050 could offset the achievements of the Montreal Protocol related to the phase-out of CFCs.

Two international discussions are underway simultaneously and the challenge is to link them.

The Montreal Protocol

The Montreal Protocol is clearly a success, since CFCs were phased out and HCFCs are gradually being phased out. Its tools were efficient: gradual phase-out within about 20 years for developed countries, 30 years for developing countries, which gives the industry time to adapt and maintain existing equipment which has an average lifespan of about 20 years; replacement refrigerants which are well identified and allowing drop-in solutions in general; UNEP correspondents (ozone officers) in each country, who are in contact with ministries and the industry in the country and have to report to UNEP each year; funding via a dedicated fund for developing countries in order to help them to finance refrigerant projects replacement. Soon these tools will no longer be necessary because of the success of the Protocol.

HFCs have the same applications as CFCs and HCFCs and the above-mentioned tools could also be efficient for phasing out or phasing down HFCs. HFCs only concern particular sectors and their impact on lifestyles is invisible, compared to CO_2 emissions which directly concern housing and transport. Constraints on them would only directly concern a few industrial associations.

Moreover, the lifespan of HFCs is much lower than that of CO_2. A phase-down of HFC emissions would therefore have rapid positive consequences, even if such consequences would exert a more limited impact on the climate than a reduction in CO_2 emissions, and would not address the climate change issue in the long term.

The Rio Convention and the Kyoto Protocol

The Rio Convention established the need to reduce emissions of greenhouse gases in order to mitigate climate change. HFCs are included, as well as CO_2, CH4… The Kyoto Protocol, signed in 1997, obliged developed countries to reduce CO_2 equivalent emissions with objectives, country by country, and to financially help projects in developing countries. The Kyoto Protocol ended in 2012. It was decided in 2012 to continue the same kind of commitments until 2020; however, only Europe and Australia agreed to sign a commitment this time, representing less than 15% of global greenhouse gas emissions.

The aim is to reduce emissions by 50% in 2050 compared to 1990 on average and to reduce emissions by 80% for developed countries in order to stay within a limit of +2°C (temperature rise) in 2050. In Copenhagen (2010), the European Union confirmed its commitment to reduce emissions by 20% in 2020; the USA to reduce emissions by 4% in 2020 (compared with 1990); China, India and Brazil only agreed to reductions compared with their GDPs (e.g. China: –40%/GDP).

Since 2010, new negotiations have started. The aim is to obtain new commitments for the year 2030 in Paris, during the United Nations Conference on climate change, in December 2015. Countries will have to present their commitment proposals before November 2015, before the final negotiations in Paris.

The current negotiations on HFCs

The European Union (EU) adopted a Mobile Air Conditioning (MAC) Directive and a Fluorinated Gas regulation (F-gas) in 2006. According to the MAC Directive, new cars are progressively being equipped with systems using refrigerants with a GWP under 150 for air-conditioning. According to the 2006 F-gas regulation, staff shall be trained and certified, companies shall be certified in order to use fluorinated gases in all fixed equipment, in order to reduce leakage. In addition, various EU member countries implemented taxes on HFCs.

In 2014, the EU adopted a new F-gas regulation, completing the first one. As of January 2015, quotas are given to companies selling HFCs; these quotas will be reduced by up to 21% of the initial level. And HFCs with the highest GWPs will be progressively forbidden in various applications (12).

This new regulation is in line with the North American and Micronesia amendment proposals to the Montreal Protocol. Since 2009, these countries try to impose a phase down of HFCs: 15% of an initial level in 2033 for developed countries and 15% of that level in 2043 for developing countries.

The key negotiation is the Paris 2015 United Nations Conference on climate change: an amendment to the Montreal Protocol on HFCs needs to be previously adopted by the UN Convention on climate change and the next one is now that one. Because of that agenda and the new position of the European Union, negotiations accelerate in 2015. The EU, North America,

Islands states and India proposed in April 2015 new amendments to the Montreal Protocol which are more flexible for developing countries. Negotiations will continue until the next UN Conferences on the Montreal Protocol which will take place in Paris in July 2015 and then in Dubai, United Arab Emirates, in November 2015, just before the UN Conference in Paris.

A phase down of high global warming refrigerants will very probably take place in the near future with or without an international agreement in climate change in 2015. HCFs must not be replaced by high GWP HFCs which will progressively disappear, region by region, for most applications. Alternative solutions are needed. IIR works with UNEP on these solutions, including for hot climate countries, thanks to the PRAHA project and various conferences and meetings.

Solutions exist

Many solutions have already been developed in order to face these challenges: eco-design, ecolabelling in order to reduce the energy consumption; reducing leakage, reducing the refrigerant charge, choosing a lower GWP refrigerant, particularly natural refrigerants in order to reduce refrigerant emissions; developing not-in-kind technologies (solar refrigeration, evaporative cooling …). The International Institute of Refrigeration proposes these solutions, thanks to its publications and conferences (see www.iifiir.org).

Changes will rapidly occur since the goals are clear: 2030 is the deadline for the current commitments of the European Union, both for its general reduction of greenhouse gases emissions and for its phase down of HFCs. 2030 is tomorrow for industrial investments as well as domestic investments. Training and information are needed. The IIR is a REHVA partner and is at your service. ■

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