IIR Information
NOTE eNOTE

29th Informatory Note on Refrigeration Technologies / November 2015

The Role of Refrigeration in the Global Economy

The IIR publishes Informatory Notes designed to meet the needs of decision-makers worldwide, on a regular basis. These notes summarize knowledge in key refrigeration-technology and refrigeration-application domains. Each note puts forward future priority developmental axes and provides IIR recommendations in this context.

The IIR estimates that the total number of refrigeration, air-conditioning and heat pump systems in operation worldwide is roughly 3 billion. Global annual sales of such equipment amount to roughly 300 billion USD. Almost 12 million people are employed worldwide in the refrigeration sector which consumes about 17% of the overall electricity used worldwide.

Statistical data presented in this new Informatory Note highlight the importance of the refrigeration sector which is expected to grow further in the coming years because of increasing cooling needs in numerous fields and global warming.

The refrigeration industry plays a major and increasing role in today's global economy, with significant contributions made in food, health, energy, and environmental domains which policy makers need to better take into account.

This Informatory Note was prepared by Didier Coulomb (Director General of the IIR), Jean-Luc Dupont (Head of the Scientific and Technical Information Department) and Audrey Pichard (Informatory Note writer), and was reviewed by several experts from IIR commissions.

INTERNATIONAL INSTITUTE OF REFRIGERATION
INSTITUT INTERNATIONAL DU FROID

www.iifiir.org | iif-iir@iifiir.org | #refrigeration

177, boulevard Malesherbes, 75017 PARIS – France
T: 33 (0) 1 42 27 32 35 – F: 33 (0) 1 47 63 17 98

The **International Institute of Refrigeration (IIR)** is the only independent, neutral intergovernmental science and technology based organization which promotes refrigeration knowledge and associated technologies that **improve the quality of life** in a cost effective and **environmentally sustainable manner**.

Key issues addressed by the IIR

- Food quality and safety
- Comfort in homes and commercial buildings
- Health products and services
- Low temperature and liquefied gas technologies
- Energy savings and energy efficiency
- Use of non-ozone depleting and low global warming refrigerants

IIR Network

- 58 member countries
- over 400 experts from 10 commissions
- 510 corporate and private members

IIR Activities

- Conferences
- Working Groups
- Research Projects
- Preparation of standards

IIR Publications

- **Fridoc**: a refrigeration database with 100,000 references
- **The International Journal of Refrigeration** (IJR): the best scientific journal in its field (Impact Factor 2.24)
- Newsletter, books and ebooks, Informatory Notes and Statements

Become a member!
Visit www.iifiir.org

En tant qu'organisation intergouvernementale, l'**Institut International du Froid (IIF)** est la seule organisation neutre et indépendante œuvrant dans le domaine du froid, au niveau international. L'une de ses préoccupations majeures consiste à promouvoir des technologies **indispensables à la vie**, **respectueuses de l'environnement** et **compatibles avec les impératifs économiques**.

Domaines de compétence de l'IIF

- Qualité et sécurité des produits alimentaires
- Confort dans les bâtiments résidentiels et commerciaux
- Produits et services de santé
- Technologies des très basses températures et de liquéfaction des gaz
- Efficacité énergétique et économie d'énergie
- Utilisation de frigorigènes à faible impact sur la couche d'ozone et sur le réchauffement planétaire

Réseau de l'IIF

- 58 pays membres dans le monde
- plus de 400 experts répartis dans 10 commissions
- 510 membres individuels et collectifs

Activités de l'IIF

- Conférences
- Groupes de travail
- Projets de recherche
- Préparation de normes

Publications de l'IIF

- **Fridoc** : base de données mondiale consacrée au froid comptant 100.000 références
- La **Revue Internationale du Froid** (RIF) : le meilleur journal scientifique dans son domaine (facteur d'impact 2.24)
- Newsletter, ouvrages et livres numériques, Notes d'information et Communiqués

Devenez membre !
Visitez www.iifiir.org

Introduction

For many people, refrigeration only means household refrigerators, refrigerated display cabinets in supermarkets, ice rinks and snowmaking systems. However, these applications are just the small visible fragment of the refrigeration industry which is present in countless sectors ranging from food industry to air conditioning, and plays a major role for healthcare, energy and the environment.

Economically speaking, the importance of refrigeration is paramount. The number of refrigeration-related jobs is increasing in both developed and developing countries. Refrigeration is vital for reducing post-harvest and post-slaughtering losses and in the preservation of food products. As refrigeration maintains food safety, nutritional and organoleptic qualities, it has become fundamental for the retail sector.

Along with refrigerators and freezers, air conditioners are now an essential part of our daily life.

Air conditioning plays a key-role in the economic and social development of warmer countries.

In the healthcare sector, refrigeration preserves pharmaceuticals and medicines, especially vaccines. New treatments, such as cryosurgery or cryotherapy, were developed due to ultra-low temperature technologies.

Refrigeration is employed in numerous manufacturing processes found in food and drink industries, chemistry, plastic processing, mechanical engineering and many other sectors.

Furthermore, refrigeration technology provides the basis for heat pumps to save energy and carbon emissions in all kinds of industrial and building applications.

Regarding energy, natural gas can be liquefied through cryocooling, making it easier and cheaper for transportation and storage.

Finally, refrigeration is at the heart of major scientific projects having a strategic nature, such as the CERN's Large Hadron Collider.

The refrigeration industry plays a major and increasing role in today's global economy, with significant contributions made in food, health, energy, and environmental domains which policy makers need to better understand and take into account.

This note summarizes basic statistical data illustrating the size, reach and role of the refrigeration sector. More economic data is available on the IIR's Web site (www.iifiir.org), in the "Refrigeration data" section.

The importance of refrigeration

1.1. Refrigeration economics

In order to illustrate the significance of the refrigeration sector, the IIR estimated the number of refrigeration systems in operation worldwide (based on published sources and own estimations resorting to partial data) as summarised in *Table 1*.

Table 1: *Number of refrigeration systems in operation worldwide per application*

Applications	Sectors	Equipment	Number of units in operation
Refrigeration and food (see § 2.1.)	Domestic refrigeration	Refrigerators and freezers	1.5 billion [1] [2]
	Commercial refrigeration	Commercial refrigeration equipment (including condensing units, stand-alone equipment and centralized systems)	90 million [1] [2]
	Refrigerated transport	Refrigerated vehicles (vans, trucks, semi-trailers or trailers)	4 million [3]
		Refrigerated containers (« reefers »)	1.2 million [2]
Air conditioning (see § 2.2.)	Air conditioners	Air-cooled systems	600 million [2] [4]
		Water chillers	2.8 million [2]
	Mobile air-conditioning systems	Air-conditioned vehicles (passenger cars, commercial vehicles and buses)	700 million [5]
Refrigeration and health (see § 2.3.)	Medicine	Magnetic Resonance Imaging (MRI) machines	25,000 [6]
Refrigeration in industry (see § 2.4.)	Liquefied Natural Gas (LNG)	LNG receiving terminals	110 [7]
		Liquefaction trains	92 [7]
		LNG tanker fleet (vessels)	421 [7]
Heat pumps (see § 2.5.)		Heat pumps (residential, commercial and industrial equipment, including reversible air-to-air air conditioners)	160 million [8] [9]
Leisure and sports (see § 2.6.)		Ice rinks	13,500 [10]

In the refrigerated storage (warehousing) sector, the overall volume of cold stores (refrigerated warehouses) around the globe is about 552 million m^3 [11].

Based on the above-mentioned figures, the IIR estimates that **the total number of refrigeration, air-conditioning and heat pump systems in operation worldwide is roughly 3 billion,** including 1.5 billion of domestic refrigerators.

Global annual sales of refrigeration, air-conditioning and heat-pump equipment amount to roughly 300 billion USD [4], more than the US automobile's industry annual sales [12].

For example, in Australia, the refrigeration industry is estimated to contribute about 1.7% to national GDP [13].

1.2. Refrigeration and employment

The socio-economic importance of refrigeration in today's world can be illustrated by means of employment data.

The IIR estimates that almost 12 million people are employed worldwide in the refrigeration sector, which means that almost 4 workers out of 1,000 have a job linked to the manufacturing, installation, maintenance and servicing of refrigeration equipment.

This ratio is even higher in countries, such as Australia, where around 173,000 people (1.5 % of the workforce) are employed in over 20,000 businesses operating in the refrigeration sector [13].

The refrigeration sector employs almost 12 million people worldwide.

In this field, the need for engineering and technical staff (e.g. installers and mechanics) increases due to the growing demand for refrigerating capacities, along with the unique skills required of refrigeration-related professions in the field of energy and environment.

In the US, employment of mechanics and installers in heating, refrigeration and air conditioning is projected to grow by 21% from 2012 to 2022, much faster than the average for all occupations (11%) [(14)].

1.3. Refrigeration and energy

Electricity consumption for refrigeration and air conditioning has been increasing over the last few years in both developed and in developing countries.

The refrigeration sector (including air conditioning) consumes about 17% of the overall electricity used worldwide. This IIR estimation is based on an analysis of fragmentary data about the sectorial electricity consumptions by various areas of the world.

This 17% share is all the more important given that the energy efficiency of refrigerated equipment is constantly progressing. It highlights the importance of the refrigeration sector which is expected to grow further in the coming years because of (i) increasing refrigeration demand in numerous sectors, and (ii) global warming.

Estimated growth in global electricity demand for cooling by 2030 could equate to three times the current generating capacity of the UK [(15)].

Chart 1: *Distribution of the global refrigeration sector's electricity consumption (%)*

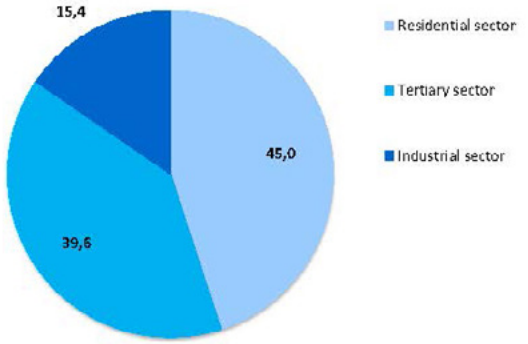
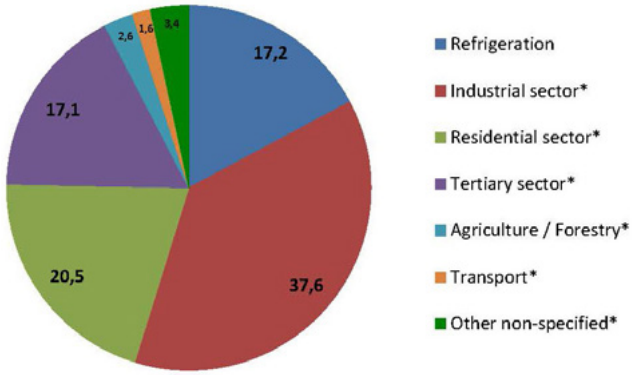


Chart 1 shows the distribution of the global refrigeration sector's electricity consumption between the residential, tertiary and industrial uses (as estimated by the IIR).

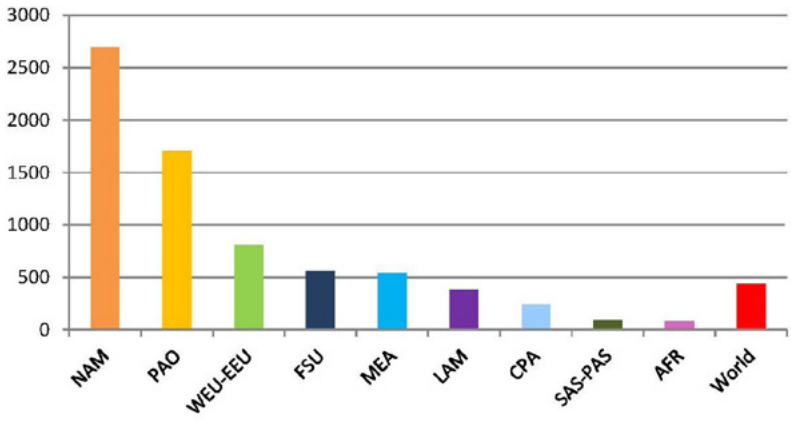
Chart 2: *Comparison of the global refrigeration sector's electricity consumption with that of other sectors (%)*



** Refrigeration sector consumption excluded*

Chart 2 compares this refrigeration-sector related electricity-consumption 17.2% with electricity consumption in other sectors, based on IEA data [(16)] and IIR estimations.

Chart 3: *Distribution of electricity consumption for refrigeration (kWh/year/capita) between world regions**



** According to IPCC definition of SRES World Regions* [17]

Chart 3 demonstrates differences in the refrigeration-sector electricity consumption regions with different development levels and climatic conditions.

Globally, 440 kWh/year/capita are spent for refrigeration purposes; however, this figure varies from 76 in Sub-Saharan Africa to 2,697 in North America.

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

1.4. Refrigeration and environment

The contribution of refrigeration to the environmental aspect of sustainable development might be illustrated through the indispensable role of refrigeration technologies for maintaining biodiversity by cryopreservation of genetic resources.

Refrigeration technologies are now being considered as a means to capture CO_2 from large power stations and industrial plants; they also enable the liquefaction of CO_2 for underground storage.

Refrigeration machines and heat pumps are among the environmentally-friendly technologies that may use renewable energy.

However, the adverse environmental effects of refrigeration must also be addressed. Around 20% of the global-warming impact of refrigeration systems are due to direct emissions (leakage) of fluorocarbons (CFCs, HCFCs and HFCs), while the remaining 80% are due to indirect emissions originating from the electricity production required to power the systems by fossil fuel power plants [4].

Hence, actions implemented by refrigeration stakeholders to fight global warming focus on two objectives:

- reduction in the direct emissions of fluorocarbons in the atmosphere through better containment of refrigerants, refrigerant-charge reduction, development of alternative refrigerants with negligible or no climate impact, development of alternative technologies that provide suitable alternatives to vapour compression, and training/certification of technicians.
- reduction in primary energy use by increasing energy efficiency of refrigerating plants.

Role and applications of refrigeration

2.1. Refrigeration and food

Refrigeration is crucial for the food sector because it ensures optimal preservation of perishable foodstuffs and provides consumers with safe and wholesome products.

However, the food cold chain is still insufficiently developed, especially in developing countries. Global food production comprises roughly one third of perishable products requiring refrigeration. In 2010, out of a total global food production (agricultural commodities, fish, meat products and dairy products) of 6,300 million tonnes, only about 400 million tonnes were preserved using refrigeration (in chilled and frozen state), whilst about 2,000 million tonnes required refrigerated processing [18] [19] [20].

A striking example is India where less than 4% of the country's fresh produce is transported under low-temperature conditions, as compared with over 90% in the UK [21].

This results in huge food waste and economic losses. **According to the IIR, the lack of a cold chain causes significant global food losses: up to almost 20% of the global food supply.** In developed countries, food losses from the absence of refrigeration account for nearly 9% of the total food production, and 23% on average in developing countries [20].

The FAO estimates that food production will have to increase globally by 70% (about 4,400 million tonnes) to feed an additional 2.3 billion people by 2050 [22] and refrigeration has a vital role to play in this context. Refrigeration can also make a significant contribution to addressing the issue of undernourishment, especially in the least-developed countries. **Setting up of cold chains for perishable foodstuffs, which are as extensive and reliable as those in industrialized countries, would enable developing countries to raise food supply by about 15% (i.e. about 250 million tonnes)** [20].

Continuous and ubiquitous refrigeration is necessary throughout the perishable food chain, from production to consumers.

In supermarkets, around 45% of the electric energy consumed is used by refrigeration equipment supplying cold to the display cabinets and the cold rooms for chilled and frozen food storage [23] [24]. It is inconceivable that small shops, restaurants, bars, and hotels could function without refrigeration equipment.

About 1.5 billion domestic refrigerators and freezers are in service worldwide [1] [2]. Based on the number of refrigerated appliances installed and their electricity consumption, the IIR estimates that domestic refrigerators and freezers consume almost 4% of global electricity.

However, energy efficiency in refrigerators has been increasing constantly, as highlighted by the qualitative evolution of the energy labels. The consumption of a typical household refrigerator dropped by around 65% within 15 years [25].

Consumers can only see a very small portion of the refrigerated equipment that constitutes the food cold chain. Refrigerated food processing, cold storage, refrigerated transport and distribution remain invisible for the costumer, but constitute other links that must be taken into account as they are key elements of the chain (along with the retail and household handling of chilled and frozen commodities).

In France, about 24 million tons of food products are processed each year by using refrigeration, while 40% of the food produce, i.e. 370 kg/capita, requires refrigeration [26].

Currently, there are about 4 million refrigerated vehicles in service worldwide, including vans, trucks, semi-trailers or trailers [3]. In Australia, 5.1 % [13] of road traffic is due to refrigerated trucks. However, to meet the entire food demand from emerging markets, e.g. Asia (led by China and India), the global refrigerated transport fleet may need to quadruple by 2025 [27].

Moreover, the area dedicated to cold storage in the world accounts for 552 million m^3 in 2014, with an increase of 20% over 2012 [(11)]. India has recently surpassed the US and has now the biggest cold-storage capacity in the world with 131 million m^3 [(11)].

The continuous advancement in freezing technologies permitted the fast development of attractive food markets for highly-demanded refrigerated products, such as frozen foods and ice creams. In the beginning of 2010s, the annual production of various frozen foodstuffs amounted to about 50 million tonnes (plus 20 million tonnes of ice cream and 30 million tonnes of fish) [(28)].

Annual consumption per capita of frozen food is about 50 kg in most advanced countries, such as the US, Ireland, UK, Sweden and Germany [(29) (30)].

Valued at USD 225 billion in 2012, the frozen-food market is expected to reach USD 294 billion by 2019 due to the very high growth rates expected in Brazil, China, India and Mexico [(31)].

Per-capita consumption of frozen food in the US is over 50 kg per year [(30)]

2.2. Air conditioning

Air conditioning is an essential part of the refrigeration sector. Its use is increasing for both human comfort and industrial processes (Information Technology, biotechnologies, etc.; see §2.4. *Refrigeration in industry*).

People feel comfortable within a certain temperature and humidity range and need a specific quantity of fresh air for breathing.

Hot areas and zones with high air humidity underwent remarkable economic development due to the introduction and expansion of air-conditioning technologies over the past 60 to 70 years.

Several independent studies reported that the quality of indoor air has a significant influence on the productivity of office workers [(32) (33)]. Inappropriate ambient temperatures impair work efficiency and may cause economic losses. In the UK, 15.7 billion euros are lost every year because of inadequate temperatures [(34)].

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 total electricity consumption in the US [(35)] and 40% in the Indian city of Mumbai [(36)].

Air-conditioning is growing dramatically in the world's emerging economies. For example, less than 1% of urban Chinese households owned an air conditioner in 1990, this number rose to almost 100% by 2009 [(37) (38)].

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%) [(39)].

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 [(40)].

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 [5].

2.3. Refrigeration and health

Refrigeration has a direct impact on human health through preservation of foods and pharmaceuticals, as well as through new low-temperature therapeutic techniques.

Refrigeration inhibits the development of bacteria and toxic pathogens therefore preventing foodborne diseases. Refrigeration dramatically reduces the need for chemical preservatives in food. Since 1930, thanks to cold-chain enabled food preservation, a 90% decrease in the number of stomach cancer cases was noticed, according to a study by the WHO [41].

Heat-sensitive health products, kept at a controlled temperature (particularly between 2°C and 8°C), experienced a tremendous market extension all over the world. The turnover of such products increases by more than 20% per year. While these medications represent only 2% of the total volume of medicines, their value approaches 15%. In 2011 in France, over 50% of the new pharmaceutical products approved for sale on the market needed to be preserved at 2-8°C [42].

Concerning vaccines, a particularly striking example is the role of refrigeration in the eradication of poliomyelitis. In 2013, the number of cases of poliomyelitis occurring worldwide was 416, i.e. almost a thousand times fewer than the 350,000 cases registered in 1988 [43].

Cryosurgery is an easy to use and relatively inexpensive technique which requires only fairly basic equipment. Cryoablation is used as a clinical treatment. Its ability to cure oesophageal cancer, for example, is proven to have a success rate for 70% of patients [44]. As for skin cancer, the healing rate reaches 99% [44].

Superconductivity – a phenomenon enabled by cryogenic technologies – is at the heart of Magnetic Resonance Imaging (MRI) scanners, helping to give doctors an unprecedented view of structures deeply within the human body. Most MRI machines use superconducting magnets to maintain strong, stable magnetic fields. MRI has a wide range of applications in medical diagnostics, while over 25,000 MRI scanners are in use worldwide [6].

Finally, the health benefits of air conditioning are also proven in hot weather – the number of deaths during hot weather dropped by 80% in the US since the 1950s [45].

2.4. Refrigeration in industry

Refrigeration is vital for the food (see § 2.1.), chemical, plastic and building industries, etc. Other advanced industries (such as electronic-data processing or biotechnologies) could not operate without refrigeration.

Air conditioning is not only important for human health and well-being, and work efficiency, but it also has a major influence in the industrial area, in particular in the high-tech sectors, including Information Technology (IT). While data centres are responsible for about 1.3% of global electricity consumption, 50% of this consumption is used for cooling the equipment [46].

New energy-related sectors such as gas liquefaction, are rapidly growing. World trade in liquefied natural gas (LNG) tripled since 1997, growing to 241.1 million tonnes of LNG in 2014, which constitutes 10% of global gas consumption [47]. In Japan (the world's largest importer of LNG) virtually all of the gas demand is met by LNG imports, with the exception of a very small portion of domestic production [48].

The Large Hadron Collider (LHC) – the world's largest and most powerful particle accelerator – uses a 27-kilometre ring of superconducting magnets maintained at-271.3°C thanks to superfluid helium to give access to the high energies needed to test fundamental theories of particle physics. The discovery of the Higgs boson in July 2012 is the first major result of LHC research [49].

LHC cryo-magnets © CERN

The International Thermonuclear Experimental Reactor (ITER), presently under construction, is a large magnetic device for plasma confinement aimed at demonstrating the feasibility of controlled thermonuclear fusion for electricity production. The machine uses very large superconducting magnets cooled at liquid helium temperature and cryopumps cooled by liquid nitrogen [50].

2.5. Heat pumps

Heat pumps are devices that use the refrigeration cycle for both heating and cooling. They have a unique role in the energy system of the future. No other technology can simultaneously provide for net primary energy savings, economic benefits to the users and reduced climate impact.

In heating mode, heat pumps are very energy-efficient since for each kW of electricity consumed, about 4 kW of thermal energy is generated. This corresponds to 300% of thermal efficiency, compared with about 70-80% for conventional gas/oil boilers [51].

Already installed heat pumps save today about 1% of the total global CO_2 emissions of over 32 billion tonnes [8] [52] [53]. Nevertheless, according to IEA, heat pumps could save 50% of the building sector's CO_2 emissions, and 5% of industrial-sector emissions. This means that nearly 8% of global emissions could be saved by heat pumps [8].

2.6. Leisure and sports

Ice rinks (about 13,500 worldwide [10]), artificial ski runs, bobsleigh, luge and skeleton tracks, and snowmaking machines, employing state-of-the-art refrigeration technologies, become increasingly popular.

For instance, Ski Dubaï resort owns 21 snowmaking systems which produce 30 tonnes of fresh snow everyday [54].

References

(1) UNEP, 2010 Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee. Retrieved March 19, 2015, from http://ozone.unep.org/Assessment_Panels/TEAP/Reports/RTOC/RTOC-Assessment-report-2010.pdf

(2) ADEME, AFCE, UNICLIMA, EReIE, Cemafroid, MINES ParisTech Armines. Alternatives to high GWP HFCs In Refrigeration and Air conditioning applications, December 2013. Retrieved October 15, 2015, from http://www.cemafroid.fr/doc_telechargement/Rapport_alternative_HFC_ENG.pdf

(3) IIR, 21st Informatory Note on Refrigerating Technologies "Sustainable Refrigerated Road Transport", December 2011. Retrieved May 20, 2015 from http://www.iifiir.org/userfiles/file/publications/notes/NoteTech_21_EN.pdf + IIR estimation

(4) IIR, Refrigeration drives sustainable development, 2007. http://www.iifiir.org/medias/medias.aspx?INSTANCE=exploitation&PORTAL_ID=portal_model_instance__News_dossiers_thematiques_en.xml&SYNCMENU=DOSSIER_THEMATIQUE&SETLANGUAGE=EN + IIR estimation

(5) IPCC/TEAP Special Report: Safeguarding the Ozone Layer and the Global Climate System. Chapter 6, Mobile Air Conditioning. Retrieved April 10, 2015 from https://www.ipcc.ch/pdf/special-reports/sroc/sroc06.pdf + IIR estimations

(6) Magnetic Resonance: A peer-reviewed critical introduction, 8th edition, January 2015. Retrieved April 10, 2015 from http://www.magnetic-resonance.org/ch/21-01.html

(7) GIIGNL, The LNG Industry, 2014. Retrieved October 21, 2015 from http://www.giignl.org/sites/default/files/PUBLIC_AREA/Publications/giignl_2015_annual_report.pdf

(8) IEA HPP, Heat pumps can cut global CO_2 emissions by nearly 8%. Retrieved April 13, 2015 from www.heatpumpcentre.org. IEA Heat Pump Programme, Heat Pump Centre, Order No. HPC-BR6

(9) Halozan H, Rieberer R. Energy-efficient heating and cooling systems for buildings, Bulletin of the IIR 2004-6. Retrieved May 20, 2015 from www.iifiir.org/clientBookline/service/reference.asp?INSTANCE=exploitation&OUTPUT=PORTAL&DOCID=I_IFD_REFDOC_2005-0975&DOCBASE=IFD_REFDOC_EN&SETLANGUAGE=EN + IIR estimations

(10) IIHF, Survey of players, 2014. Retrieved April 13, 2015 from http://www.iihf.com/de/iihf-home/the-iihf/survey-of-players/

(11) GCCA, 2014 IARW Global Cold Storage Capacity Report. Retrieved April 16, 2015, from http://www.gcca.org/resources/publications/white-papers-reports/global-cold-storage-capacity/

(12) SelectUSA, The Automotive Industry in the United States. Retrieved May 12, 2015 from http://selectusa.commerce.gov/industry-snapshots/automotive-industry-united-states

(13) Australian Government, Department of Environment, Cold hard facts 2: A study of the refrigeration and air conditioning industry in Australia, 2013. Retrieved April 15, 2015 from www.environment.gov.au/atmosphere/ozone/publications/cold-hard-facts-2.html

(14) United States Department of Labor, Bureau of Labor Statistics, Occupational Outlook Handbook, 2014-15 Edition, Heating, Air Conditioning, and Refrigeration Mechanics and Installers. Retrieved April 23, 2015 from http://www.bls.gov/ooh/installation-maintenance-and-repair/heating-air-conditioning-and-refrigeration-mechanics-and-installers.htm

(15) Carbon Trust, The Emerging Cold Economy, February 2015. Retrieved March 19, 2015 from http://www.carbontrust.com/media/619349/the-emerging-cold-economy.pdf

(16) IEA, Electricity/Heat in World in 2009. Retrieved March 19, 2015 from http://www.iea.org/statistics/topics/Electricity/

(17) IPCC, Appendix III: Definition of SRES World Region. Retrieved March 19, 2015 from http://www.ipcc.ch/ipccreports/sres/emission/index.php?idp=149

(18) FAO, Statistical Yearbook 2013, Part 3. Retrieved May 12, 2015 from http://www.fao.org/docrep/018/i3107e/i3107e03.pdf

(19) FAO, Global Food Losses and Food Waste, 2011. Retrieved May 12, 2015 from http://www.fao.org/ag/ags/ags-division/publications/publication/en/c/74045/

(20) IIR, 5th Informatory Note on Refrigeration and Food "The Role of Refrigeration in Worldwide Nutrition", June 2009, Retrieved May 20, 2015 from http://www.iifiir.org/userfiles/file/publications/notes/NoteFood_05_EN.pdf + IIR estimations

(21) Country: India's cold chain industry, US Commercial Service, Department of Commerce. Renie Subin, August 2011. Retrieved May 12, 2015 from http://www.academia.edu/5952490/Indias_Cold_Chain_Industry

(22) United Nations, World Economic and Social Survey 2013: Sustainable Development Challenges, United Nations publication. Retrieved May 12, 2015 from https://sustainabledevelopment.un.org/content/documents/2843WESS2013.pdf

(23) Schönenberger J. *et al.* Experience with ejectors implemented in a R744 booster system operating in a supermarket, 11th IIR Gustav Lorentzen Conference on Natural Refrigerants, Hangzhou, China, 2014. Retrieved May 20, 2015 from http://www.iifiir.org/clientBookline/service/reference.asp?INSTANCE=exploitation&OUTPUT=PORTAL&DOCID=IFD_REFDOC_0012281&DOCBASE=IFD_REFDOC_EN&SETLANGUAGE=EN

(24) Energy Star, Facility Type: Supermarkets and Grocery Stores, January 2008. Retrieved May 13, 2015 from http://www.energystar.gov/sites/default/files/buildings/tools/EPA_BUM_CH11_Supermarkets.pdf

(25) Mrzyglod M. *et al*. Aspects of Household Cooling Technology,15th International Refrigeration and Air Conditioning Conference at Purdue, July 2014. Retrieved May 20, 2015 from http://www.iifiir.org/clientBookline/service/reference.asp?INSTANCE=exploitation&OUTPUT=PORTAL&DOCID=IFD_REFDOC_0013513&DOCBASE=IFD_REFDOC_EN&SETLANGUAGE=EN

(26) Youbi-Idrissi M. Les applications du froid dans les IAA. Retrieved May 20, 2015 from http://www.iifiir.org/clientBookline/service/reference.asp?INSTANCE=EXPLOITATION&OUTPUT=PORTAL&DOCID=IFD_REFDOC_0012572&DOCBASE=IFD_REFDOC_EN&SETLANGUAGE=EN + IIR estimations

(27) University of Birmingham, The prospects for liquid air cold chains in India, December 2014. Retrieved March 20, 2015 from http://www.birmingham.ac.uk/Documents/news/The-prospects-for-liquid-air-cold-chains-in-India.pdf

(28) Fikiin KA. (2008). Emerging and Novel Freezing Processes – Chapter 5, In Frozen Food Science and Technology, Ed.: J.A. Evans, Blackwell Publishing (Oxford), 355 p.

(29) IIR News "Figuring out frozen food growth rates in Europe". Retrieved May 12, 2015 from http://www.iifiir.org/clientBookline/service/reference.asp?INSTANCE=EXPLOITATION&OUTPUT=PORTAL&DOCID=IFD_REFDOC_0006712&DOCBASE=IFD_REFDOC_EN&SETLANGUAGE=EN

(30) Interpack 2009, Burning Love for Frozen Food. Retrieved May 13, 2015 from Handbook of Frozen Food Processing and Packaging, Ed: Da-Wen Sun, Taylor & Francis Group, 2006

(31) Transparency Market Research, Frozen Food Market (Vegetables & Fruits, Potatoes, Ready-to-eat Meals, Meat, Fish/Seafood and Soups) - Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2013-2019, September 2013. Retrieved March 20, 2015 from http://www.prnewswire.com/news-releases/global-frozen-food-market-is-expected-to-reach-usd-29375-billion-by-2019-transparency-market-research-223101201.html

(32) Berkeley National Laboratory, Seppänen O, Fisk WJ, Lei QH. Effect of Temperature on Task Performance in Office Environment. Retrieved March 26, 2015 from https://indoor.lbl.gov/sites/all/files/lbnl-60946.pdf

(33) Kosonen R, Tan F. Energy and Buildings 36 (2004) 981-986, The effect of perceived indoor air quality on productivity loss. Retrieved March 26, 2015 from http://www.halton.com/dh/BQA6fsW31kborn6yUg-dKBNvx0mHXmaclst5mkKo0WKyJCn3DhBnxJenwibP7_zBqeKH8Hd-kCSP2Sc73yYqmso6shclXBaZGm2gBXYEujHGJKfb0cn2rgrnW_HOPrnUJxYaSZY3NwDpKJSNYSR_-1aj2mCwJtux2dti88CE/The_effect_of_perceived_indoor_air_quality_on_productivity_loss.pdf

(34) Sykes A. One Poll survey, March 2014. Retrieved April 14, 2015 from http://www.coolingpost.com/uk-news/hours-lost-from-poor-work-temperatures/

(35) US Energy Information Administration, 2009. Retrieved March 27, 2015 from http://www.eia.gov/todayinenergy/detail.cfm?id=12551

(36) The Guardian Environment Network, Climate risks heat up as world switches on to air conditioning. http://www.theguardian.com/environment/2012/jul/10/climate-heat-world-air-conditioning

(37) Berkeley National Laboratory, McNeil MA, Letschert VE. Future Air Conditioning Energy Consumption in Developing Countries and what can be done about it: The Potential of Efficiency in the Residential Sector. Retrieved March 27, 2015 from https://escholarship.org/uc/item/64f9r6wr

(38) Auffhammer M. Cooling China: The Weather Dependence of Air Conditioner Adoption, Front. Econ. China 2014, 9(1): 70-84. DOI 10.3868/s060-003-014-0005-5

(39) BSRIA, October 2014. Retrieved March 27, 2015 from http://www.iifiir.org/clientBookline/service/reference.asp?INSTANCE=EXPLOITATION&OUTPUT=PORTAL&DOCID=IFD_REFDOC_0012854&DOCBASE=IFD_REFDOC_EN&SETLANGUAGE=EN

(40) IPCC, Climate Change 2014: Impacts, Adaptation, and Vulnerability, Summary for Policy Makers, March 31, 2014. Retrieved March 27, 2015 from https://ipcc-wg2.gov/AR5/images/uploads/IPCC_WG2AR5_SPM_Approved.pdf

(41) WHO, 2008 World Cancer Report, Retrieved April 10, 2015 from, www.iarc.fr/en/publications/pdfs-online/wcr/2008/

(42) Boned M, Cavalier G. Evaluation of pharmacy cold chain, 2nd IIR International Conference on Sustainability and the Cold Chain, Paris, 2013. France. Retrieved May 20, 2015 from: http://www.iifiir.org/clientBookline/service/reference.asp?INSTANCE=exploitation&OUTPUT=PORTAL&DOCID=IFD_REFDOC_0007191&DOCBASE=IFD_REFDOC_EN&SETLANGUAGE=EN

(43) WHO, Poliomyelitis, Fact sheet N°114, October 2014. Retrieved April 10, 2015 from http://www.who.int/mediacentre/factsheets/fs114/en/

(44) Baust JG *et al*. Mechanisms of cryoablation: Clinical consequences on malignant tumors, Cryobiology, Volume 68, February 2014

(45) Barecca AI *et al*. Adapting to Climate Change: The Remarkable Decline in the U.S. Temperature-Mortality Relationship Over the 20th Century, Social Science Research Network. Retrieved April 10, 2015 from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2192245

(46) Koomey JG. Worldwide electricity used in data centers, Environmental Research Letters, 2008. Retrieved April 14, 2015 from http://iopscience.iop.org/1748-9326/3/3/034008/pdf/1748-9326_3_3_034008.pdf

(47) International Gas Union, World LNG Report- 2015 Edition, Retrieved June 22, 2015 from http://www.igu.org/sites/default/files/node-page-field_file/IGU-World%20LNG%20Report-2015%20Edition.pdf

(48) US Energy Information Administration, Japan full report, January 2015. Retrieved April 13, 2015 from http://www.eia.gov/countries/cab.cfm?fips=ja

(49) CERN, The Large Hadron Collider, Retrieved May 26, 2015 from http://home.web.cern.ch/topics/large-hadron-collider

(50) ITER: the world's largest Tokamak, Retrieved June 1, 2015 from http://www.iter.org/mach

(51) European Heat Pump Association, Key facts on heat pumps. Retrieved May 13, 2015 from http://www.ehpa.org/technology/key-facts-on-heat-pumps/

(52) Halozan H. Heat Pumps, Energy and Environment, Compressors 2009 Conference, 7th International Conference on Compressors and Coolants, Castá Papiernicka. Retrieved May 20, 2015 from http://www.iifiir.org/clientBookline/service/reference.asp?INSTANCE=exploitation&OUTPUT=PORTAL&-DOCID=I_IFD_REFDOC_2009-2502&DOCBASE=IFD_REFDOC_EN&SETLANGUAGE=EN

(53) US Energy Information Administration, International Energy Statistics. Retrieved April 22, 2015 from http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=90&pid=44&aid=8

(54) GEA Refrigeration, Refrigeration technology for top snow quality. Retrieved April 13, 2015 from http://www.gearefrigeration.com/en-uk/Markets/Leisure/indoor-ski/Pages/default.aspx

Informatory Notes on Refrigeration Technologies: Archives	Notes d'information de l'IIF sur les technologies du froid : Archives
12th Note: Fluorocarbons and global warming (July 1997)	**12e Note** : Fluorocarbures et effet de serre (juillet 1997)
13th Note: Standards for Flammable Refrigerants (December 1997)	**13e Note :** Normes applicables aux frigorigènes inflammables (décembre 1997)
14th Note: Reduction of emissions of refrigerants and containment in systems (May 1999)	**14e Note :** Réduction des émissions de fluides frigorigènes et confinement (mai 1999)
15th Note: Carbon dioxide as a Refrigerant (February 2000)	**15e Note :** L'utilisation du CO_2 comme frigorigène (février 2000)
16th Note: Refrigerated transport: progress achieved and challenges to be met (August 2003)	**16e Note :** Transport frigorifique : progrès et défis (août 2003)
17th Note: How to improve energy efficiency in refrigerating equipment (November 2003)	**17e Note :** Comment améliorer l'efficacité énergétique des équipements frigorifiques (novembre 2003)
18th Note: Evaporative Cooling and Legionella, A Risk which can be Prevented by Using Good Practices (February 2006)	**18e Note :** Refroidissement évaporatif et Legionella, un risque maîtrisable grâce à de bonnes pratiques (février 2006)
19th Note: Liquefied Natural Gas: Current Expansion and Perspectives (November 2006)	**19e Note :** Gaz Naturel Liquéfié : Expansion actuelle et défis (novembre 2006)
20th Note: Magnetic Refrigeration at Room Temperature (October 2007)	**20e Note** : Le froid magnétique à température ambiante (octobre 2007)
21st Note: Sustainable Refrigerated Road Transport (December 2011)	**21e Note :** Le transport frigorifique routier durable (décembre 2011)
22nd Note: Applications of Cryosurgery (July 2012)	**22e Note :** Les applications de la cryochirurgie (juillet 2012)
23rd Note: Risk Inherent in the Use of Counterfeit Refrigerants (November 2012)	**23e Note :** Risques liés à l'utilisation de fluides contrefaits (novembre 2012)
24th Note: Containment of Refrigerants within Refrigeration, Air Conditioning and Heat Pump Systems (January 2014)	**24e Note :** Confinement des frigorigènes dans les systèmes de froid, de conditionnement d'air et de pompes à chaleur (janvier 2014)
25th Note: Refrigerant Charge Reduction in Refrigerating Systems (May 2014)	**25e Note :** Réduction de la charge en frigorigène dans les systèmes frigorifiques (mai 2014)
26th Note: Overview of Regulations Restricting HFC Use, Focus on the EU F-Gas Regulation (January 2015)	**26e Note :** Tour d'horizon des règlementations limitant l'utilisation des HFC. Le point sur le Règlement F-gaz de l'UE (janvier 2015)
27th Note: Evaporative Cooling (January 2015)	**27e Note :** Le refroidissement évaporatif (janvier 2015)
28th Note: Qualification and Certification of Refrigeration Technicians (September 2015)	**28e Note :** Qualification et certification des techniciens du froid (septembre 2015)

- These Information Notes can be accessed at www.iifiir.org/Publications/Informatory Notes. The latest Informatory Note published is available to IIR Members only.
- Ces Notes d'Informations sont accessibles sur le site www.iifiir.org/Publications/Notes d'information. La dernière note d'information publiée est réservée aux membres de l'IIF.

Recommendations

The issues of food safety, health, energy and the environment make it quite clear that refrigeration is essential for mankind and must become a priority for governments in the sectors of industry, education and research.

It is necessary to advance training and qualification of staff in the refrigeration sector, but also to incite more young people to turn to promising refrigeration-related careers offering long-term perspectives.

No effort should be spared to help developing countries reach refrigeration capacities necessary to preserve food safety and human health. Investments in infrastructures should also be made in order to implement adequate equipment.

Energy efficiency in refrigeration equipment should be improved. This involves research and development in different renewable energy sources (solar, wind, geothermal, biogas, etc.), offering smart alternatives to the electrical grid when powering refrigeration plants. Refrigeration plays a substantial role in different energy storage technologies and may strongly enhance power grid sustainability.

The amount of high-GWP refrigerant emissions from refrigerating and air-conditioning installations must be reduced through leakage control, load reduction and use of alternative natural or synthetic low-GWP refrigerants.

Refrigeration-related research and development must be further stimulated and actively supported by national and international authorities, funding agencies, public and private industries in order to improve health, well-being, energy and environmental sustainability around the world.

International Institute of Refrigeration
Institut International du Froid