

WORLD GUIDE TO LOW-CHARGE AMMONIA

PART II

AMMONIA21

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World Guide to Low-Charge Ammonia

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WELCOME MESSAGE



Klára Zolcer Skačánová

Manager, Market Development, shecco
Lead Author

The use of low-charge ammonia has emerged as one of the key trends in the industrial refrigeration industry in the last few years. Moreover, the technological developments have opened up opportunities for ammonia beyond its traditional market.

The aim of this report is to identify the underlying trends for low-charge ammonia technology in different parts of the world. The report is being released in three parts. The first part focused on some of the key characteristics of ammonia as a refrigerant and outlined the ongoing efforts to define the term “low-charge ammonia”.

This second part of the “Guide to Low-Charge Ammonia” is divided into two chapters. The first chapter provides an overview of a variety of applications where low-charge ammonia technology is already in use today with real-life examples from around the world. The applications vary from cold storage and other industrial refrigeration applications where ammonia has traditionally been used, to supermarkets and air conditioning, where low-charge ammonia is believed to hold a huge potential in view of the growing regulatory restrictions on chemical refrigerants.

The next chapter in part two of the report highlights some of the key global regulations and standards governing the use of ammonia as a refrigerant. The focus is on those that create new opportunities for low-charge ammonia technology, either by imposing stricter rules on (traditional) ammonia technology with a high charge or by regulating the use of HCFCs and HFCs. Policy is traditionally among the most important drivers when it comes to shifting to new technologies and it is no different for low-charge ammonia systems.

The third and final part of the report will zoom in on the key trends for low-charge ammonia technology, looking at its advantages, drivers and major challenges in today's market. It will compare developments in different world regions, with focus on North America, Europe, Japan and Australia. Moreover, gathering data through analysis of a survey, interviews with key experts it will outline the future opportunities and perspectives for low-charge ammonia systems.

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An aerial photograph showing a dense, vibrant green forest on the left side of the frame, which meets a dark blue lake on the right. The forest is composed of many tall, thin trees with lush green foliage. The lake's surface is dark and reflects the surrounding environment, with some lily pads visible near the shoreline. The text 'ABOUT THIS GUIDE' is overlaid in large, white, bold, sans-serif capital letters on the left side of the image, partially covering the forest.

ABOUT THIS GUIDE



Introduction

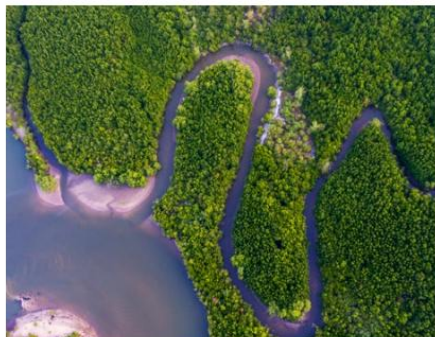
The use of ammonia as a refrigerant goes back 150 years - it is the only refrigerant that has been uninterruptedly used throughout all these years. This is especially thanks to its excellent thermodynamic properties ensuring good energy efficiency performance as well as ammonia's abundance and ease of use.

Ammonia's major drawback - toxicity - has been addressed through design to prevent any leaks. Nevertheless as a result of several major incidents the industry has focused the development efforts on reducing ammonia charge in systems as the most effective measure to improve safety of ammonia-based technologies. In the recent years the development of low-charge ammonia systems has taken a centre stage, disturbing the traditional ammonia refrigeration industry in a positive way.

Today a growing number of manufacturers offer systems that use as little as 20g/kW ammonia charge without compromising the system efficiency, but actually further improving it.

This report zooms in on the recent market and technology developments, identifies key trends, challenges and future progress across different geographical regions.

A SHORT OVERVIEW



CHAPTER 1: Ammonia as a Refrigerant

This chapter provides a short introduction into ammonia as a refrigerant. It takes a look at the characteristics of this molecule, its behaviour as a refrigerant, its role and history in the refrigeration industry.

READ IN PART I

CHAPTER 2: What is 'low-charge ammonia'?

This chapter seeks to identify what is meant by 'low-charge ammonia', using industry feedback and know-how, and looks at issues of defining a technology that is relatively new in the industrial refrigeration sector. It also provides overview of key types of the technology.

READ IN PART I

CHAPTER 3: Applications of low-charge ammonia

This chapter delves into the applications for low-charge ammonia technology from its beginnings in traditional ammonia refrigeration, such as in cold storage, food processing and logistic facilities, to its forays into HVAC and the pharmaceutical industry.

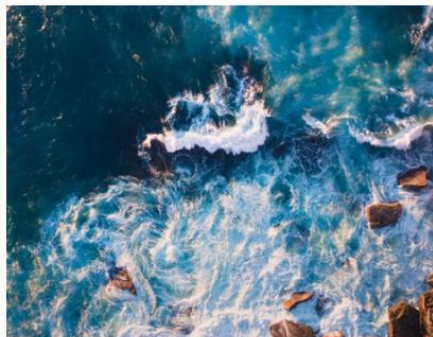
READ ON PAGE 10



CHAPTER 4: **Regulations and standards**

The use of ammonia as a refrigerant is regulated in most of the world due to its risk to human health. This chapter looks at how regulations and standards on high charges of ammonia could offer opportunities for lower-charged technology.

READ ON PAGE 20



CHAPTER 5: **Low-charge ammonia today**

In this chapter, the current market for low-charge ammonia systems and applications is looked at in detail. It identifies the key trends and challenges in different world regions.

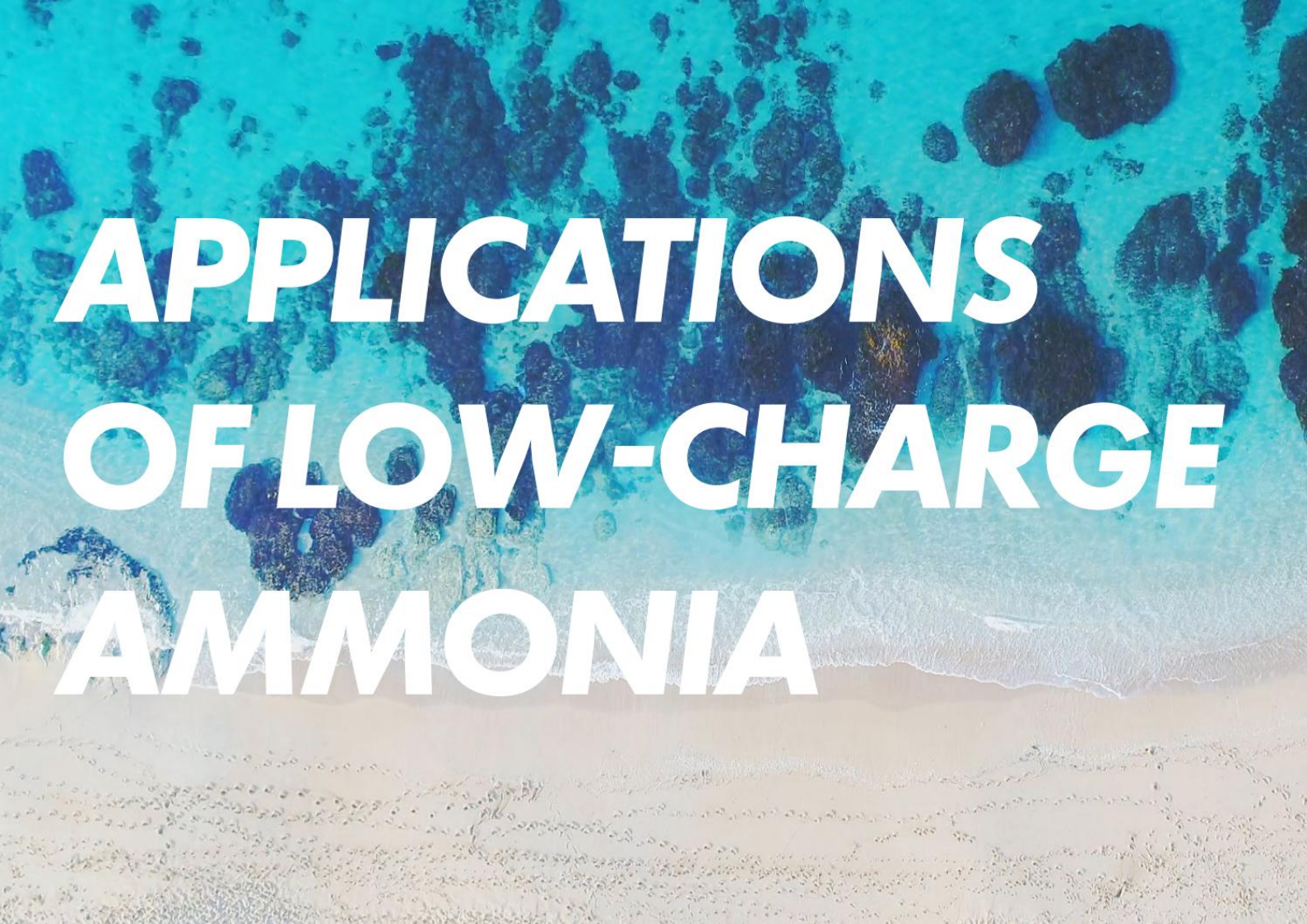
COMING SOON



CHAPTER 6: **Future of low-charge ammonia**

Based on interviews, research, surveys and the market today this chapter anticipates the market potential for low-charge technology in the world, its future uses and the next steps that will need to be taken to make this technology successful.

COMING SOON



APPLICATIONS OF LOW-CHARGE AMMONIA

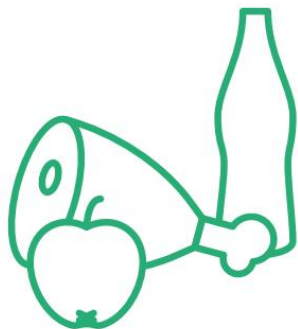


An overview

Low-charge ammonia technology has been deployed in a variety of applications across the world for many years. From food processing and data centres to pharmaceutical facilities, supermarkets, and even commercial air conditioning applications.

The following pages showcase examples of installations using different types of low-charge ammonia systems across the world, categorized by type of application.

FOOD CHAIN



FOOD & DRINK PROCESSING

Meat processing

Belgian retailer Colruyt Fine Food's meat processing facility, located in Buizingen, near the Belgian capital Brussels, uses a CO₂ subcritical system with an ammonia refrigeration and heat pump system. The facility was opened in September 2016. The Belgian employers' organisation Agoria awarded the "Factory of the Future" award to the Fine Food meat processing facility for its use of green technology.

lowa-based meat processor Western Liberty opened a cold storage facility in Illinois in 2015. It is equipped with an ammonia system using 7,500lbs [3,402kg] of refrigerant to cool the 253,360ft² [23,538m²] facility. The ammonia charge supports a capacity of 928TR [3,267kW] with a ratio of approximately 8.1 lbs/TR [1.04kg/kW]. Liberty Cold Storage is keeping the stick-built, central-engine-room format traditionally used by industrial operators, but employs a direct expansion (DX) evaporator for both medium- and low-temperature applications.

Fish processing (on-shore and off-shore)

Seafood processor Neptune Foods is one of a growing number of industrial refrigeration end users installing low-charge ammonia packaged units, in a major break from traditional refrigeration technology. Neptune Foods operates a seafood storage facility in an old Chicken of the Sea cannery right on the waterfront at San Pedro Bay (U.S.). The fish is stored in a 30,000ft² [2,700m²] freezer at minus 4°F [minus 20°C] before being shipped to market overseas. Neptune Foods operates two low-charge ammonia freezer units that reside outside the building next to the freezer room. Each unit requires only 20 lbs [9kg] of ammonia to generate 40TR [141kW]. In total, the system's 0.5lbs/TR [0.06kg/kW] makes it one of the lowest-charge industrial refrigeration systems in the world.

An HCFC-22 freezing system in Greenlandic vessel, "The Polar Princess", was retrofitted with 12 vertical plate freezers using an ammonia/CO₂ cascade freezing system. back in June 2015. It is capable of freezing 200 tons of fish a day. The ammonia/CO₂ freezing system consists of three ammonia screw compressors and five CO₂ reciprocating compressors. On the low temperature side, CO₂ helps to maintain freezing at a constant temperature.

Fruits and vegetable processing

An ammonia/CO₂ fluid solution was commissioned in 2007 for a sophisticated high-rise fruit distribution centre near the port of Rotterdam, in the Netherlands. The building is 66ft [20m] high and can store 12,500 pallets, spread over 15 individually controlled temperature compartments. The unique design for the NH₃/CO₂ pump-system was implemented with all 100 evaporators providing a 852TR [3,000kW] refrigeration capacity.

Other food and drink processing

Shepherd's Processed Eggs, Spanish Fork, Utah, which processes about one million eggs per day for fresh, hard-boiled and pasteurized liquid-egg products, installed a low-charge ammonia DX system at its 10,000ft² [900m²] facility. This was in contrast to its other facilities, which run condensing units using HCFC and HFC refrigerants. The plant consists of a freezer room with two blast freezers at -15°F, -25°F [-26°C, -32°C] saturation suction and two large egg-cooler rooms at 38°F [3°C]. The total ammonia charge is only 400lbs or 3lbs/TR [182kg or 0.43kg/kW], compared to what would have been a pumped ammonia charge of 5,000lbs [2,273kg]. The first cost of the system was USD125,000 less than a pumped ammonia system, and USD180,000 less than an HFC-507 system, with lower operating and maintenance costs.

Slovakian dairy company Milsy a.s. has installed a cooling system that runs on the rarely-used refrigerant R723, a mixture of 60% ammonia (R717) and 40% dimethyl ether (RE170), which has a GWP of eight. The system provides a cooling power of 141kW [40.1TR] and a heating power of 187kW [53.2TR]. The dairy, which produces 100,000 liters [26,417 gallons] of milk per day, uses the system to cool down production and storage areas to 4°C [39.2°F]; waste heat is used for 2m³ [70.63ft³] of domestic hot water, the cloak room, a 420 m² [4,5201ft²] dining room and defrosting. The energy efficiency of the R723 system is 40% better than the considered HFC solution according to the system manufacturer.

Turner Dairy, a member of Prairie Farms, operates a milk and juice processing plant in Memphis, Tennessee (U.S.). The dairy installed four low-charge ammonia packaged units – two 35°F [1.7°C] penthouse coolers and two process cooling chillers – to replace an outdated ammonia refrigeration system. The total charge of the four units is 960lbs or 2.1lbs/TR [435kg or 0.27kg/kW], which is 1/10th the charge of what the system would have had in a conventional expansion system. The chillers use secondary glycol to do process cooling (for ingredient tanks and pasteurizers), eliminating ammonia from the process area. The penthouse units also confine ammonia to the roof. Cooling to the new warehouse and existing plant is done via ducted air supplied to separate rooms.

An ammonia/CO₂ refrigeration system was installed at a candy manufacturing facility in Irvine, California (U.S.). A study funded by Southern California Edison (SCE) on the energy performance of the system shows the system consumes 32% less energy than baseline R507A equipment running in the same facility.



WINERIES & BREWERIES

Winery

The Sirromet Winery in Australia replaced its existing R22 chiller with two screw compressors using ammonia refrigerant. The plant chills the Alcool LF secondary heat exchange fluid, which is reticulated in a closed loop throughout the winery. By using an evaporative condenser, lower condensing pressures are achieved in comparison to an air-cooled system. This results in a lower compressor compression ratio with reduced energy costs for every kW of refrigeration. Based on Sirromet's average medium load run-time, the theoretical estimated cost-saving of electricity for the new ammonia chiller is up to 32% per annum.

Brewery

Refrigeration is the biggest energy load in a brewery. Craft brewery Stone & Wood, New South Wales, Australia, installed a centralized ammonia plant in 2017. The 298TR [1,050kW] welded-plate heat exchanger package provides glycol chilling. It is fitted with an oversized surge drum and heat exchanger frame, allowing future for an upgrade of 597TR [2.1MW] including a second screw compressor and condenser. The 298TR [1,050kW] ammonia screw compressor is fitted inside a 20ft shipping container with sound attenuation, ammonia detection, ventilation system, lighting, and full access doors on three sides. The total ammonia charge is 1,320lbs [600kg], leading to a specific charge of 4.43lbs/TR [0.57kg/kW].

FOOD STORAGE & DISTRIBUTION

Cold storage



An Australian transport depot installed a low-charge, two-stage, central-style ammonia system at its plant in Brisbane. The refrigerated volume is around 45,000m³ [1,588,950ft³]. It is a direct expansion system (DX), both on the low-temperature side and the medium-temperature side. This means that there are no ammonia pumps. The low- and medium-temperature capacities are 194/192kW [55.11/54.55TR] respectively, with future expansion to 284/241kW [80.68/68.47TR].

A rooftop, ultra-low-charge ammonia refrigeration system was installed at KPAC General Cold Storage in California (U.S.). The system powers an 82,000ft² [7,380m²] building with a total ammonia charge of 15-30lbs [7-14kg] per unit. Compared to the conventional HCFC-22-based system used before, KPAC General Cold Storage benefitted from a volume of space increased by 30% thanks to smaller size of the equipment, as well as a 30% decrease in energy costs.

Yokahama Reito Co., Ltd., one of Japan's leading food distribution and cold storage companies, has installed an ammonia/CO₂ packaged refrigeration system in Saitama, Japan, for the Satte Logistics Facility. The facility is a three-story, reinforced concrete building with a total floor area of about 204,833ft² [18,435m²]. Four ammonia/CO₂ units service a total refrigerated storage capacity of about 93,033ft³ [8,373m³]. Frozen goods are stored at a temperature of -13°F [-25°C].

The first sub-critical heavy duty ammonia/CO₂ cascade refrigeration system for a cold storage application in the Philippines was installed in April 2016 for Allforward Warehousing Inc. The system provides cooling for storage of up to 6,000 MT of canning-grade whole tuna and tuna loins, at 25°C [77°F] below room temperature.

Logistics and distribution centres

In March 2018, Lidl opened a new ammonia/CO₂ logistics centre for fruit in the Netherlands. The cold-storage facility will supply 78 national and regional Lidl distribution centres with fruit from the southern Dutch port town. The 26,900ft² [25,000m²] centre is to serve as a space to ripen bananas and other fruit like mangoes and avocados. It also functions as a European hub for frozen products. The ammonia/CO₂ booster installation has a capacity of 711TR [2.5MW].

A Carrefour distribution centre in Buenos Aires, Argentina opted for an ammonia/CO₂ system. The safe low-charge ammonia system is in the machine room. No ammonia is in the evaporators. The cold room has no need for CO₂ compressors and only requires a CO₂ pump for the brine/CO₂ system.



SUPERMARKETS

In 2015, U.S.-based retailer Piggly Wiggly installed an NH_3/CO_2 refrigeration system in a supermarket in Columbus, Georgia. The retailer recorded energy savings averaging 33% over a 13-month period (October 2015 – October 2016) compared to another store in La Granda, Georgia using HFC-407A. The Piggly Wiggly store uses an ultra-low charge of ammonia (53lbs, or 0.76lbs/TR [25kg or 0.09kg/kW]), which is confined to the roof in the ammonia rack. Besides the refrigeration system the new store was equipped with a number of other energy-saving elements, including LED lights, skylights, occupancy and daylight controls, doors on display cases, and heat reclaim for hot water. However, the NH_3/CO_2 system, accounting for 60% of the store's electricity consumption, was by far the most impactful on efficiency.

In California, food retailer Raley's decided to make an ammonia/ CO_2 overfeed system the choice for its first natural installation. The California-based chain of 123 stores has decided to implement a rooftop ammonia/ CO_2 refrigeration system in a new Sacramento store. The technology - ammonia DX with liquid-overfeed CO_2 and no CO_2 compressors - differs from the ammonia/ CO_2 cascade system typically used. The retailer's version includes: DX ammonia; direct-drive compressors in a two-stage configuration; liquid-overfeed CO_2 for low- and medium-temperature cases and AC; water-cooled condensing and heat reclaim with plate heat exchangers; and a total ammonia charge of approximately 120lbs [55kg].

A family-owned Delhaize middle-size store in Belgium was equipped with a 110kW ammonia/ CO_2 system, leading to energy savings of around 40%. For this store with a sales area of 800m², an ammonia/glycol loop is used for the medium temperature refrigeration, ammonia being confined to the machine room and glycol circulating in the store. CO_2 is used for low temperature refrigeration, and the heat rejected by the CO_2 condensers is recovered. 40kg of ammonia are used and confined to the machine room with a total cooling capacity of 110kW; this leads to a specific ammonia charge of only 40g/kW.

INDUSTRY, SPECIAL APPLICATIONS & SPORTS



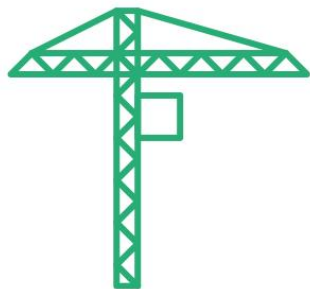
INDUSTRIAL / CHEMICAL PROCESSING

Sylvan Pty Ltd, New South Wales, Australia uses an ammonia-glycol chiller for cooling of nutrients used for mushroom production. A DX system was installed, in combination with a dry cooler to provide the heat rejection. Compared to HFC-134a, the coefficient of performance (COP) could be increased by 39% (from 3.78 to 5.25). At approximately 2,500 full-load hours and with 20AUD/kWh, an annual saving of AUD10,670 was achieved. The chiller was designed as compact as possible, resulting in a charge of 10.78lbs [4.9kg] for 30TR [106kW] cooling capacity, which represents 0.36lbs/TR [0.05 kg/kW].



PHARMACEUTICAL PROCESSES & LABORATORIES

Pharmaceutical company Roche installed a refrigeration package system using about 0.12kg/kW [1lb/TR] in one of its facilities in Puerto Rico. The refrigerant is confined to the packaged refrigeration system, and does not reach operation spaces. The whole system was factory-built and ready to operate when it was delivered to the site. Ready-to-operate packages allow simultaneous construction of the site foundation and equipment.



CONSTRUCTION

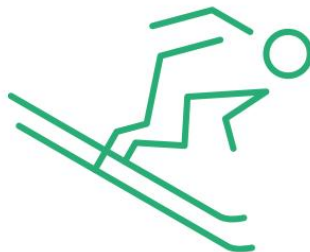
Japanese Chemical Grouting Co., Ltd., specializes in construction projects across Japan for buildings, dams, slopes and soil cleansing, and decontamination. It installed an ammonia/CO₂ industrial refrigeration system for an underground tunnel construction in 2017. The company claims the new system achieved 40% savings in energy consumption compared to the traditional HCFC-22-based system originally installed. This particular project dealt with soil freezing during the construction of an underground tunnel in a metropolitan area in Japan. The project began in January 2017 and was completed in March 2017. One of the biggest benefits the company saw by using the ammonia/CO₂ system was the reduction of the project's run time by 40% (39 days). The system's compact size greatly simplified the disassembly and removal process. Improved performance ranked among the other benefits.



ICE RINKS

At the Covent Garden Market Rotary Rink, an outdoor ice rink in London, Ontario (Canada) installed a low-charge (65lbs [30kg]) ammonia/glycol system, which is owned and managed by the City of London, Ontario. The ice rink was installed in November 2017, as a replacement for an 18-year-old system with 700lbs [318kg] of HCFC-22 refrigerant. The system includes four "smart" products, two 50HP compressors, one chiller and one plate-and-frame condenser. According to the London Free Press, the system cost USD450,000.

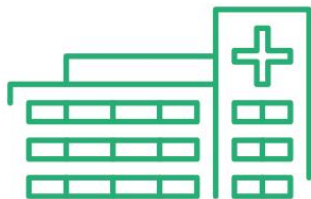
Great Britain's (Team GB) wheelchair curling team, as well as its Olympic curling team, skate on a low-charge ammonia-based ice rink. The system is installed at the U.K.'s first National Curling Academy (NCA) in Stirling, Scotland since Summer 2017 when it opened, in addition to other ice rinks in Scotland. It uses an air-cooled chiller package that uses ammonia in-directly with a refrigerant charge of just 1.39lbs/TR [0.18kg/kW].



SKI SLOPES

In Milton Keynes, England, the 558ft [170m] long Snozone ski slope was equipped with two 102TR [360kW] ammonia-glycol chillers. The ammonia charge per chiller is 187lbs [85kg], and its specific charge is 1.83lbs/TR [0.24kg/kW]. The concentration of glycol was reduced compared to the former installation with HFC-404A. A security fence was built around the system. Together with some other improvements in the system design, the energy consumption could be reduced by approximately 50%.

CITY & BUILDINGS



HOSPITALS

Uzbekistan's first low-charge ammonia air-conditioning (AC) system, installed between 2016 and 2017, is running at the Republican Research Center for Emergency Medicine (RRCEM) – an emergency hospital and research facility in Tashkent. The UN Development Programme (UNDP) Uzbekistan and the Global Environment Facility (GEF), a public-private NGO, funded 61% of the total USD512,000 cost of the equipment, while the remainder (39%) was contributed by RRCEM. Two outdated chillers on HCFC-22 in the centralised air-conditioning system were replaced with low-charge ammonia chillers. A total of 482TR [1,695kW] of cooling is provided by the two chillers, running in tandem, with just 176lbs [80kg] of ammonia charge to provide air conditioning to 250,000 patients and 2,600 employees annually.



OFFICE BUILDINGS

Two HCFC-22-based air-conditioning systems in a local Council administration building in South East Queensland, Australia, were replaced by an ammonia-based, central air-conditioning installation. The new system comprises two identical water-cooled, low-charge water chilling units employing ammonia. The combined refrigeration capacity of the two units is approximately 341TR [1,200kW]. Each chiller is fitted with a shell-and-tube type discharge gas desuperheater. These heat exchangers recover heat from the discharge gas leaving the compressors prior to the gas entering the condensers. In the future, the heat recovered will be used for heating hot water and for various other purposes, yet to be determined by the Council.



OTHER BUILDINGS

Low-charge ammonia chillers are being used to safely provide air conditioning for a bakery in a populated area of Portland, Ore. The bakery plant uses three low-charge-ammonia chillers, each at 300TR [1,055kW] and 450lbs [204kg] of ammonia (1.5lbs/TR [0.19kg/kW]), which received jurisdictional acceptance. They have four levels of ammonia release prevention, three levels of leak detection, and fresh air dilution. Each chiller has a TEWI (total equivalent warming impact) that is 32% less than that of a water-cooled HFC-507 unit.

A low-charge ammonia packaged chiller is providing air conditioning at a Campbell Soup plant in Ohio. The chiller/air handler delivers comfort cooling to a labeling and packaging section of the building where the red-and-white labels are applied to soup cans – and where a cool environment is needed to ensure proper adherence of the

labels to cans. Using a flooded plate heat exchanger, 450lbs [204 kg] of ammonia in the chiller cools a glycol solution to 44°F [6.7°C], and the glycol is piped to an air handler in the building, where the air is cooled to about 65°F [18.3°C].

A major U.S. retailer installed low-charge DX ammonia chillers to provide air conditioning in office space at about 10 warehouse locations. The rooftop chiller is designed with only 1lb/TR [0.13kg/kW] of ammonia, which is confined to the unit; it pumps chilled water to an air handling unit, which delivers cool air to the office space. The typical chiller contains about 100lbs [45kg] of ammonia and employs a variable frequency drive (VFD) screw compressor and electronically commutated motor (ECM) motors. The AC chillers are replacement units for HCFC-22 systems using 180-220lbs [82-100kg] of refrigerant.



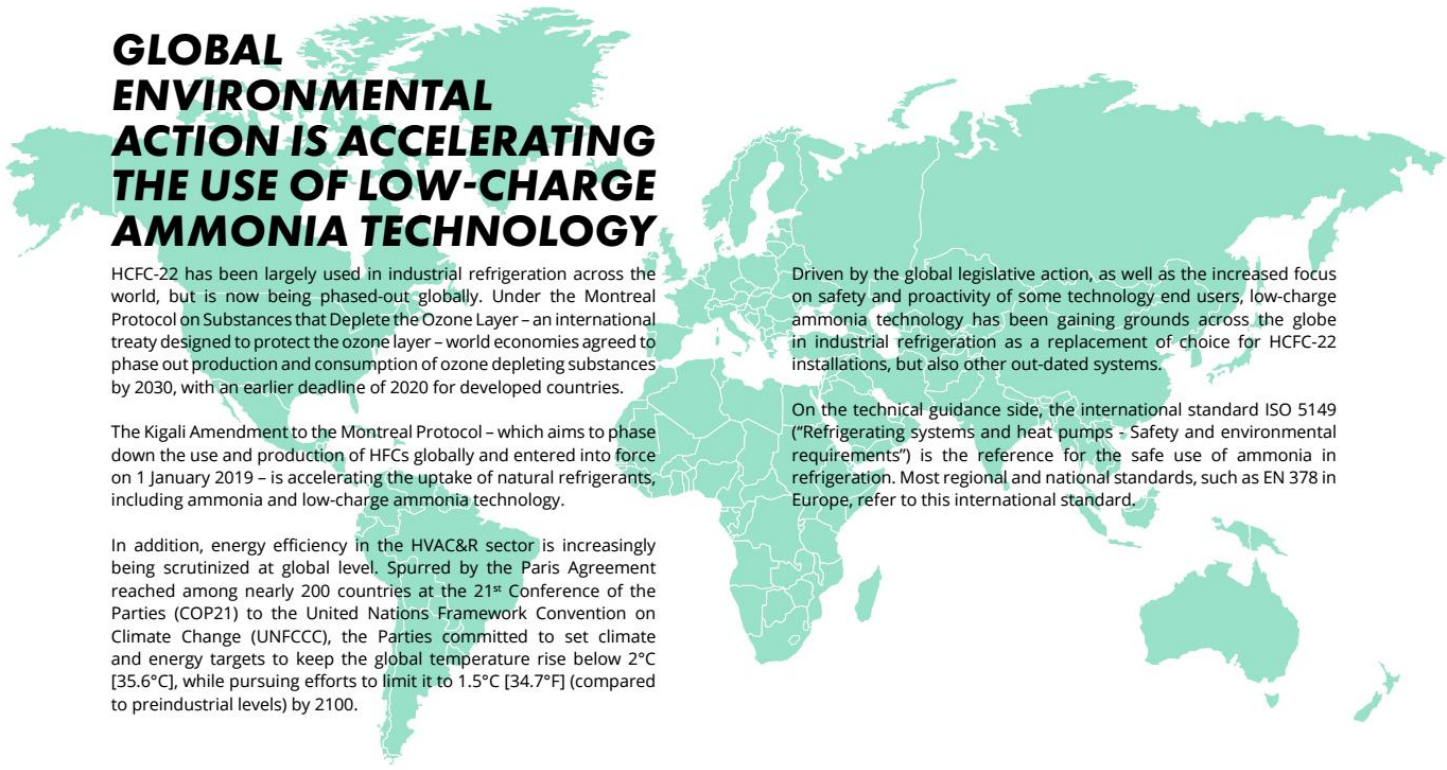
REGULATIONS AND STANDARDS



An overview

This chapter provides the regulatory framework governing the use of ammonia as a refrigerant around the world.

The use of traditional ammonia systems requires additional regulatory requirements in most countries, due to the refrigerant's classification as a hazardous and caustic fluid in its concentrated form. Those regulatory requirements are usually based on the charge of ammonia, requiring more stringent rules the larger the system is. Therefore, low-charge ammonia systems usually benefit from lighter controls.



GLOBAL ENVIRONMENTAL ACTION IS ACCELERATING THE USE OF LOW-CHARGE AMMONIA TECHNOLOGY

HCFC-22 has been largely used in industrial refrigeration across the world, but is now being phased-out globally. Under the Montreal Protocol on Substances that Deplete the Ozone Layer – an international treaty designed to protect the ozone layer – world economies agreed to phase out production and consumption of ozone depleting substances by 2030, with an earlier deadline of 2020 for developed countries.

The Kigali Amendment to the Montreal Protocol – which aims to phase down the use and production of HFCs globally and entered into force on 1 January 2019 – is accelerating the uptake of natural refrigerants, including ammonia and low-charge ammonia technology.

In addition, energy efficiency in the HVAC&R sector is increasingly being scrutinized at global level. Spurred by the Paris Agreement reached among nearly 200 countries at the 21st Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC), the Parties committed to set climate and energy targets to keep the global temperature rise below 2°C [35.6°C], while pursuing efforts to limit it to 1.5°C [34.7°F] (compared to preindustrial levels) by 2100.

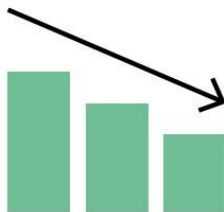
Driven by the global legislative action, as well as the increased focus on safety and proactivity of some technology end users, low-charge ammonia technology has been gaining grounds across the globe in industrial refrigeration as a replacement of choice for HCFC-22 installations, but also other out-dated systems.

On the technical guidance side, the international standard ISO 5149 ("Refrigerating systems and heat pumps – Safety and environmental requirements") is the reference for the safe use of ammonia in refrigeration. Most regional and national standards, such as EN 378 in Europe, refer to this international standard.

SURVEY: KEY POLICY DRIVERS FOR THE UPTAKE OF LOW-CHARGE AMMONIA



Bans on HFCs with high global warming potential (high GWP)



Gradual phase down of HFCs



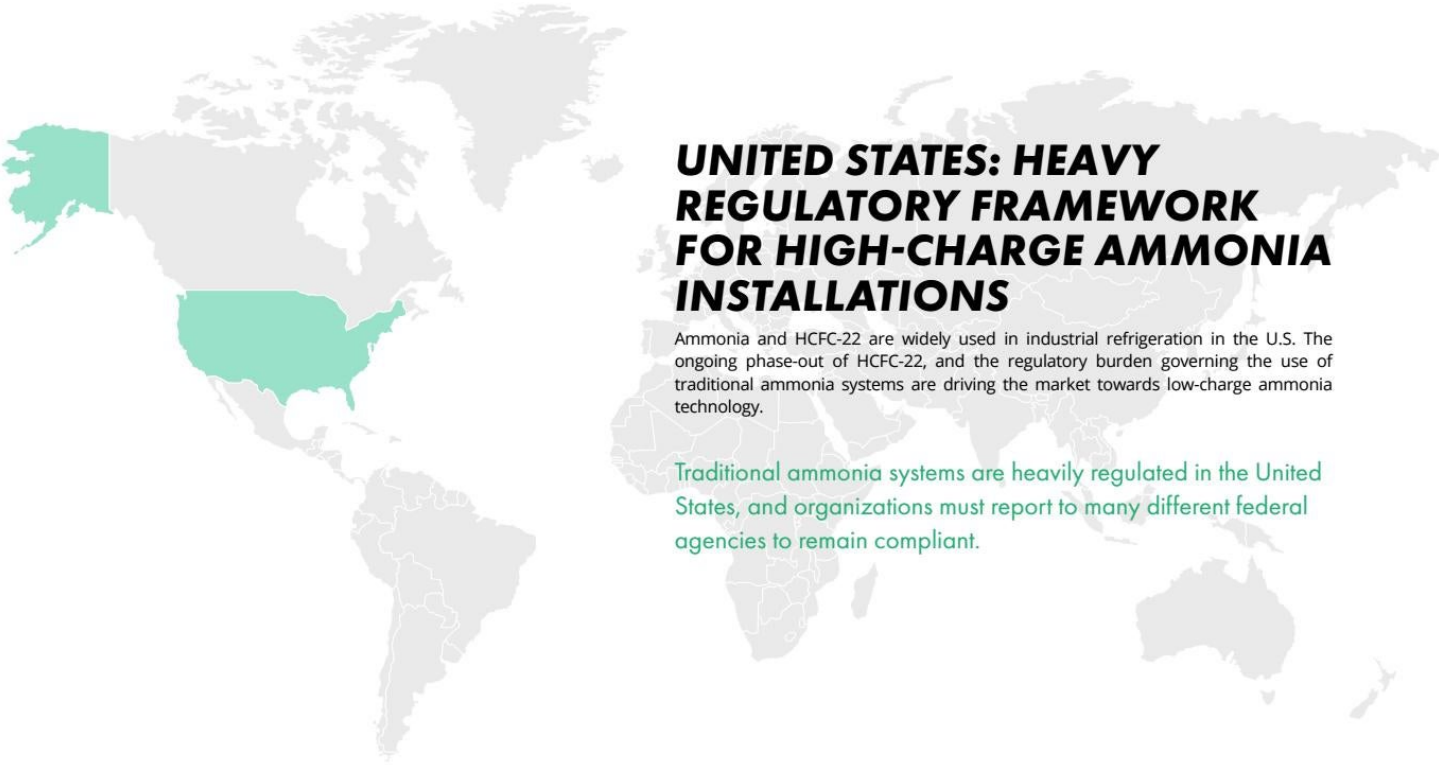
Financial incentives for energy efficient installations



Minimum energy efficiency requirements

Policy is traditionally among the most important drivers when it comes to shifting to new technologies and it is no different in case of low-charge ammonia systems. shecco asked industry experts in a global survey about the most effective policy measures for the uptake of low-charge ammonia technology. The findings from more than 800 respondents indicate that different types of measures play an important role and the effectiveness might depend on the regional circumstances and other factors. While all listed types of policy measures ranked similarly on scale of importance, bans on HFCs with high global warming potential received slightly more votes than others.

Number of respondents: 815



UNITED STATES: HEAVY REGULATORY FRAMEWORK FOR HIGH-CHARGE AMMONIA INSTALLATIONS

Ammonia and HCFC-22 are widely used in industrial refrigeration in the U.S. The ongoing phase-out of HCFC-22, and the regulatory burden governing the use of traditional ammonia systems are driving the market towards low-charge ammonia technology.

Traditional ammonia systems are heavily regulated in the United States, and organizations must report to many different federal agencies to remain compliant.

Azanechiller 2.0

Ultra-efficient, Low-charge ammonia chillers



Flatbed Condenser

Stainless steel tube condenser for long life. Full perimeter maintenance access.

Variable Speed Fans

EC variable speed fans with Axitop diffusers (option) for low fan power and improved air flow.

Stainless Steel Control Panel

Allen-Bradley PLC control provides optimized performance based on ambient temperature and cooling load. Touch screen HMI, remote access, and condition based monitoring are available through broadband.

Compressor

Standard variable speed, reciprocating compressor(s) provide linear capacity, extended compressor life, and COPs approaching 11.9 at part load.

Single or twin compressor options available.

Heat Exchanger

Fully welded plate and shell heat exchanger. High integrity design, giving low refrigerant charge and minimizes risk of leakage.

Drive Motor

VFD NEMA Premium Efficiency IE3 drive motor with flange mounting to ensure accurate alignment.

Heat Recovery

Optional heat recovery from ammonia hot gas system.

World-leading manufacturers of low charge ammonia refrigeration solutions.

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Standard cooling capacities from 40 to 340 TR and fluid temperatures from 10°F to 50°F

Due to its toxicity, ammonia installations are regulated more strictly and additional requirements might apply. These additional requirements are not necessarily an obstacle, but they can present a large burden to manufacturers and facilities. The use of low-charge ammonia technology allows facility owners to avoid or reduce the regulatory requirements detailed below, as they do not pass the charge threshold enabling authorities to enforce the regulations.

Following the commitments under the Montreal Protocol, the U.S. Environmental Protection Agency (U.S. EPA) regulations issued **under Section 601-607 of the Clean Air Act** gradually phase out the production and import of ozone-depleting substances (ODS), including HCFC-22 from 1 January 2010 until 1 January 2030. The next step in the phase-out process will be on 1 January 2020, with a planned 99.5% reduction of the production and import of HCFC-22. As existing HCFC-22 equipment is reaching its end of life, ammonia-based systems are well positioned to be taken up as replacement technologies.

U.S.: REGULATORY OVERVIEW

At federal level, systems with **ammonia charges above 10,000lbs [4,536kg]** may be subject to:

- **OSHA Standard “Process Safety Management of Highly Hazardous Chemicals” (PSM):** The minimum requirements for compliance are for a plant to develop, implement and maintain 14 elements listed in the PSM Program, such as the development of standard operating procedures including safe work practices, appropriate training for contractors and personnel, as well as reporting audit requirements to certify the plant complies with PSM rules.
- **The EPA “Risk Management Program for Chemical Accidental Release Prevention” (RMP):** The focus of the RMP regulation is to prevent accidental chemical releases and minimize their impact. Ammonia refrigeration facilities must comply with additional requirements detailed in the *Supplemental Risk Management Program Guidance for Ammonia Refrigeration Facilities*. EPA’s RMP duties apply to all ammonia refrigeration systems containing 10,000lbs [4,536kg] or above.
- **The Emergency Planning and Community Right to Know Act (EPCRA) Section 313, pursuant to the Homeland Security Appropriations Act of 2007:** EPCRA Section 313 sets reporting requirements to the EPA. The EPCRA also requires that facilities that are subject to Section 313 liaise with their Local Emergency Planning Committee and their State Emergency Response Commission.
- **Chemical Facilities Anti-Terrorism Standards implemented pursuant to the Homeland Security Appropriations Act of 2007:** Facility owners must report to the Department of Homeland Security (DHS) the total mass quantity of ammonia within the system and the physical state, temperature, and pressure as it exists in the vessel(s) downstream of the condenser(s).

TYPICALLY, FACILITIES USING LOW-CHARGE AMMONIA EQUIPMENT ARE NOT SUBJECT TO **PSM** AND **RMP** REQUIREMENTS

Facilities using low-charge ammonia equipment are typically not subject to OSHA's PSM and EPA's RMP requirements as their ammonia charge is less than 10,000lbs [4,536kg]. However, irrespective of the ammonia amount being used, employers are subject to both **OSHA** and **EPA's General Duty Clause**. Both OSHA and EPA can apply their General Duty Clauses to ensure employers provide a workplace free from recognized hazards.



Traditional ammonia installations
(≥ 10,000 lbs charge)



Low-charge ammonia installations

IIAR CREATES GUIDELINES FOR LOW-CHARGE AMMONIA

In response to the growing demand for low-charge ammonia installations, which end users increasingly recognize as an effective way to reduce the regulatory burden, the International Institute of Ammonia Refrigeration (IIAR) has developed guidelines to help users safely install, operate and maintain ammonia refrigeration systems that use a charge of 500lbs [226.8kg] or less (and under 100lbs [45.5kg] in the next step).

These guidelines, called “Ammonia Refrigeration Management – Low Charge (ARM-LC)”, are a scaled-down version of the ARM guidelines the IIAR had previously issued for ammonia systems using charges of between 500lbs [226.8kg] and 10,000lbs [4,536kg].

The overarching goal of the ARM-LC guidelines is to help end users comply with the General Duty Clause of the Occupational Safety and Health Act, which requires that a place of employment be “free from recognized hazards.”

Under the guidelines, contractors that install low-charge ammonia systems will still be responsible for training their on-site employees, although the training would be significantly less intensive than for large, industrial facilities that use bigger ammonia charges. Training of employees should revolve around a few key areas, including the safety hazards of ammonia, monitoring the system and steps to take in emergency.

The ARM-LC guidelines recommend an audit of the system every five years.

CALIFORNIA IMPOSES STRICTER MEASURES ON AMMONIA

California is particularly stringent on the use of ammonia in refrigeration compared to the federal regulations. The **California Accidental Release Prevention (CALARP)** sets a threshold quantity limit for anhydrous ammonia at 500lbs [226.8kg], compared to the 10,000lbs [4,536kg] limit at federal level.

Facilities based in California must be inspected by the Administrative Agency every three years, while an updated Refrigerant Management Program (RMP) must be submitted to the Administrative Agency every five years. The facility also must do a compliance audit once every five years at least, and the RMP must contain two release scenarios in case of an accident.

The stringent requirements on ammonia installations in California are the key driver behind the increased uptake of innovative low-charge ammonia systems compared to other U.S. States.

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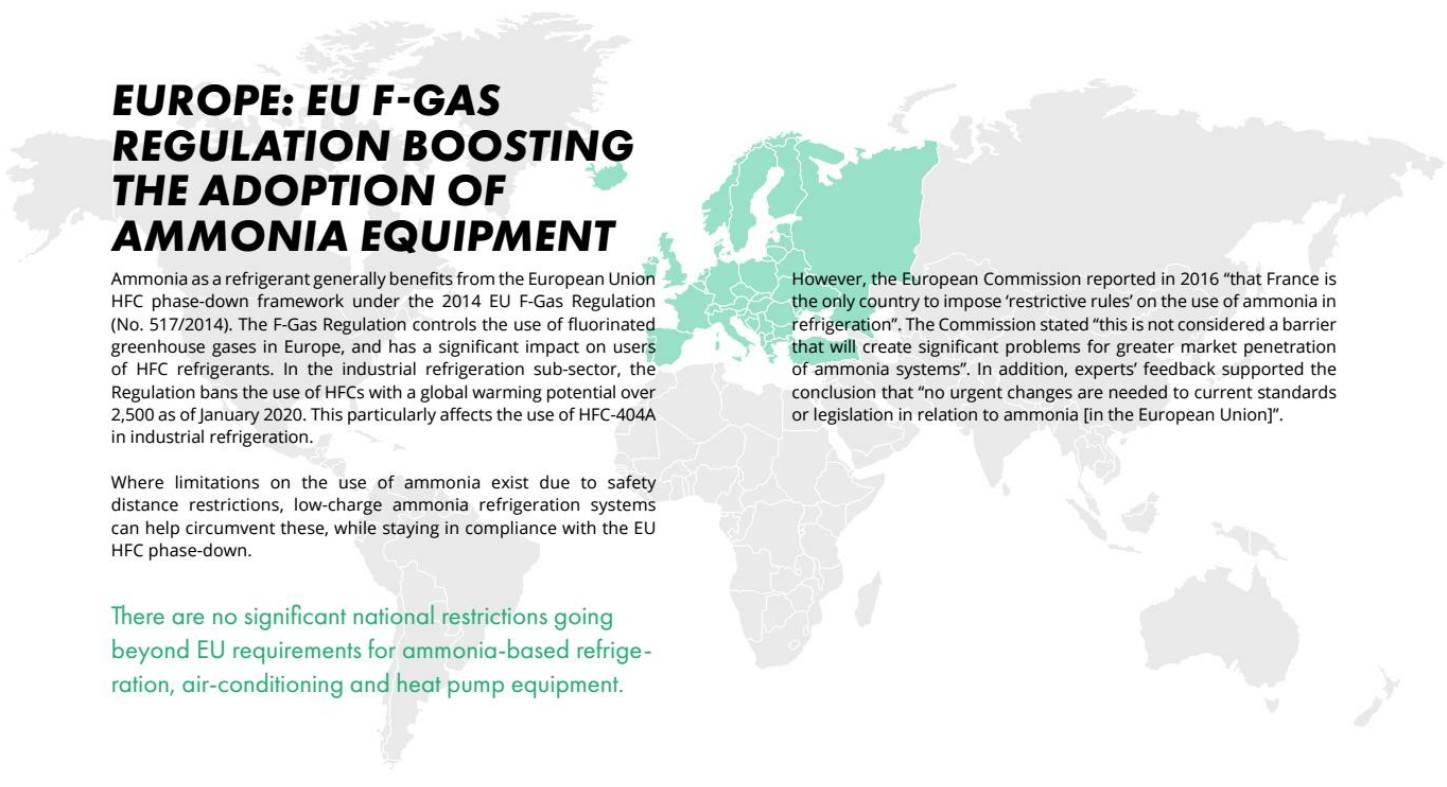
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EUROPE: EU F-GAS REGULATION BOOSTING THE ADOPTION OF AMMONIA EQUIPMENT

Ammonia as a refrigerant generally benefits from the European Union HFC phase-down framework under the 2014 EU F-Gas Regulation (No. 517/2014). The F-Gas Regulation controls the use of fluorinated greenhouse gases in Europe, and has a significant impact on users of HFC refrigerants. In the industrial refrigeration sub-sector, the Regulation bans the use of HFCs with a global warming potential over 2,500 as of January 2020. This particularly affects the use of HFC-404A in industrial refrigeration.

Where limitations on the use of ammonia exist due to safety distance restrictions, low-charge ammonia refrigeration systems can help circumvent these, while staying in compliance with the EU HFC phase-down.

There are no significant national restrictions going beyond EU requirements for ammonia-based refrigeration, air-conditioning and heat pump equipment.

However, the European Commission reported in 2016 “that France is the only country to impose ‘restrictive rules’ on the use of ammonia in refrigeration”. The Commission stated “this is not considered a barrier that will create significant problems for greater market penetration of ammonia systems”. In addition, experts’ feedback supported the conclusion that “no urgent changes are needed to current standards or legislation in relation to ammonia [in the European Union]”.

EU: REGULATORY OVERVIEW

The specific legislation and regulatory requirements applied in the European Union for the safe use of ammonia as a refrigerant are detailed below.

Companies operating in the European Union and using or producing ammonia-based commercial and industrial refrigeration equipment must comply with the **ATEX Equipment Directive** (ATEX/94/EC). ATEX/94/EC may apply to systems installed in facilities or locations that contain potentially explosive environments. Locations for “standard” ammonia-based refrigeration systems are “normally” not classified as hazardous areas. Ammonia is classified as a non-flammable refrigerant – under ATEX requirements.

In addition, ammonia systems must be installed in compliance with the **ATEX Workplace Directive** (ATEX 99/92/ED). This regulation requires Hazardous Area Classification (HAC) to be carried out where there may be a risk of explosion due to the presence of flammable substances in the form of gases, vapours, mist of dust – including ammonia. The regulation also requires that to ensure safe operation, any equipment (both electrical and non-electrical) used in a classified area falls within the scope of the regulation and must therefore be suitable for use in the respective zone.

Area classification is carried out by reference to codes. **Standard EN 60079-10** (Explosive atmospheres) establishes a quantitative method to identify sources of release of flammable gas, vapour or mist. EN 60079 is harmonized with the ATEX Directive. The standard covers electrical systems used in potentially explosive atmospheres, and establishes three different categories of environments that present certain dangers when using electrical equipment. EN 60079 also sets technical requirements for electrical equipment used in these environments.

Standard EN 378 (Refrigerating Systems and heat pumps – Safety and environmental requirements) applies to nearly all refrigeration systems within all European Union member states. The Standard includes specific provisions related to ammonia use as a refrigerant, including leak monitoring. EN 378 states that leaks and other faults in the system must be remedied immediately by a qualified person.

All refrigeration and air conditioning systems must comply with the requirements of the **EU Pressure Equipment Directive (PED)** (97/23/EC). For most systems, this means manufacturers must identify the maximum system pressure (PS) of their equipment, ensure all components are suitable for PS and adequately protected, identify the hazard category the equipment falls into, ensure materials are up to the correct standard and traceable, ensure brazers and welders are qualified and work to an appropriate standard, pressure test the system correctly, and CE mark the system if necessary. Under Article 9 of the PED, ammonia is considered a group 1 fluid, due to its toxicity and flammability.

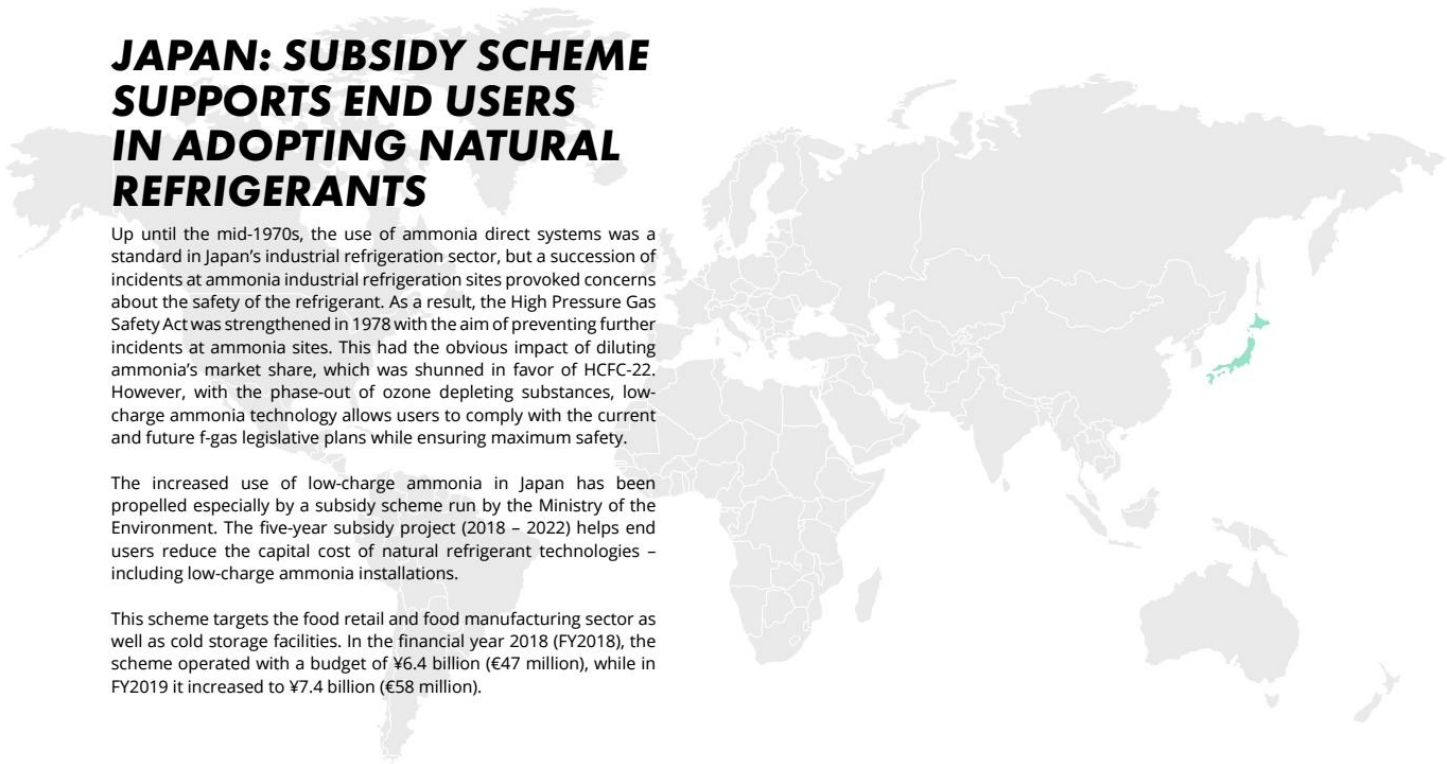
FRANCE: SPECIFIC REQUIREMENTS FOR AMMONIA-BASED INSTALLATIONS

In France, facilities using ammonia-based systems with a charge from 150kg to 1.5 tons are subject to mandatory reporting and periodic inspections by approved organisations (Article L. 512-11 of the French Environment Code).

Users intending to equip their site with a refrigeration system or systems whose total charge is greater than to 1.5 tons of ammonia require authorization from the prefecture (which represents the French state in each of France's regional *départements*) before they can do so.

The European Union recognizes that French legislation represents a barrier for a wider uptake of ammonia-based technology in the country. French trade unions have been advocating for an administrative easing to encourage the use of ammonia in industrial refrigeration even before the adoption of the EU F-Gas Regulation.

However, ammonia installations in France are often eligible for an Energy Saving Certificate (CEE), thanks to the heat recovery offered by these technologies. CEE is an energy-efficiency bonus issued by the state that finances energy efficiency-related works.



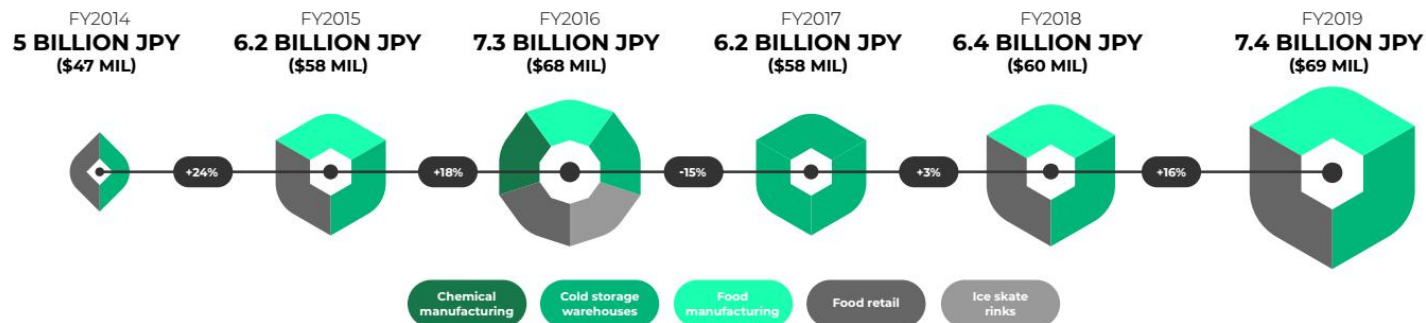
JAPAN: SUBSIDY SCHEME SUPPORTS END USERS IN ADOPTING NATURAL REFRIGERANTS

Up until the mid-1970s, the use of ammonia direct systems was a standard in Japan's industrial refrigeration sector, but a succession of incidents at ammonia industrial refrigeration sites provoked concerns about the safety of the refrigerant. As a result, the High Pressure Gas Safety Act was strengthened in 1978 with the aim of preventing further incidents at ammonia sites. This had the obvious impact of diluting ammonia's market share, which was shunned in favor of HCFC-22. However, with the phase-out of ozone depleting substances, low-charge ammonia technology allows users to comply with the current and future f-gas legislative plans while ensuring maximum safety.

The increased use of low-charge ammonia in Japan has been propelled especially by a subsidy scheme run by the Ministry of the Environment. The five-year subsidy project (2018 – 2022) helps end users reduce the capital cost of natural refrigerant technologies – including low-charge ammonia installations.

This scheme targets the food retail and food manufacturing sector as well as cold storage facilities. In the financial year 2018 (FY2018), the scheme operated with a budget of ¥6.4 billion (€47 million), while in FY2019 it increased to ¥7.4 billion (€58 million).

JAPAN'S SUBSIDY PROGRAM DRIVING UPTAKE OF LOW-CHARGE AMMONIA IN INDUSTRIAL APPLICATIONS



JAPAN: REGULATORY OVERVIEW

Some key regulations and standards in Japan relevant for the use of ammonia as a refrigerant are described below.

The **Chemical Substances Control Law** mandates evaluation, monitoring and reporting of certain hazardous properties of chemical substances that are intended to be manufactured or imported to Japan, including ammonia.

Ammonia-based HVAC&R equipment must comply with the **High Pressure Gas Safety Act**. The Act applies to stationary applications, such as air conditioning and refrigeration. The act regulates the alignment of facilities and equipment with technical regulations, the preparation of guidelines for safe administration by the operators, and the allocation of qualified personnel.

Equipment using ammonia is also regulated by the **Offensive Odour Control Law**. Each Japanese prefecture is responsible under the Act to define how and where the control of odorous substances would be enforced.

The **Poisonous And Deleterious Substances Control Act** controls the production, import, sale, storage, transportation and display of toxic substances for non-medical purpose, including ammonia. The Act sets safety requirements in the production, handling, transport and disposal of ammonia.

Standard **JIS B 8612** (Commercial Refrigeration Cabinets) specifies materials and appropriate usage for refrigerated display cases for food retail applications, including ammonia-based equipment.

AUSTRALIA: HFC PHASE-DOWN ACCELERATING ADOPTION OF LOW-CHARGE AMMONIA TECHNOLOGY

Australia's HFC phase-down began on 1 January 2018. The country is aiming to reduce its HFC consumption by 85% by 2036 in line with obligations under the Kigali Amendment to the Montreal Protocol. This will be achieved by gradually reducing the maximum permitted amount of bulk HFC imports.

As legislation drives the industry away from high-GWP refrigerants, there is potential for further growth of low-charge ammonia equipment replacing HFC-based equipment in an estimated 100,000 refrigerated warehouses.

AUSTRALIA: REGULATORY OVERVIEW

Under **Australian work health and safety laws**, workplaces with ammonia-based refrigeration systems must have a documented emergency plan in place.

The Australian government provides an online **Occupier's Guide to Emergency Planning** assisting users in preparing and implementing an emergency plan for ammonia-based refrigeration systems. Emergency planning guidance for all hazardous industries is also provided online in **Emergency Planning: A Guideline for Hazardous Industry**.

In addition, a **Workplace Health and Safety Queensland (WHSQ) Safety tool** for ammonia refrigeration safety (which included an audit checklist and supporting reference material) is currently being updated¹. The tool will raise awareness of the hazards and risk control measures and provides additional educational and training material about ammonia safety in the industrial refrigeration industry.

The Australian technical standard of reference for ammonia-based refrigeration systems is **AS/NZS 5149:2016**, which refers to the international standard ISO 5149.

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CHINA: ADHERENCE TO SAFETY STANDARDS KEY TO AMMONIA'S FUTURE

China is currently in the process of phasing out the use and production of HCFCs, giving low-charge ammonia a competitive edge as a replacement of choice for HCFC-22 in industrial refrigeration. By 2015, China had already achieved its preliminary policy objective of reducing HCFC consumption by 10% by 2015. Total phase out of HCFC use and production in China is planned for 2040.

In addition, the government's support for energy efficiency and technology development to maintain the country's competitive edge in the world market, in the industrial sector, could lead to a much greater use of natural refrigerants in China, both by manufacturers and end users.

Ammonia has been used in industrial applications for more than 60 years. However, it has gained a certain level of attention among the Chinese public and government, especially due to two fatal accidents that occurred in 2013. This, in turn, has resulted in strict regulation of the refrigerant in the Chinese market, including blacklisting of ammonia by local governments. Nevertheless, under the increasing pressure to phase out synthetic refrigerants, safe use of ammonia is a clear priority that China needs to address.

Increased focus on safety standards and practices combined with more training of technicians would be key to the return of ammonia use in the country. The Chinese Association of Refrigeration is driving efforts for creating and enforcing proper design and operational standards that guarantee safety when working with ammonia systems.

The safe use of ammonia in China is regulated by a set of safety standards. The adoption of the **Safety Code for Cold Stores (GB28009-2011)** at the end of 2012, paved the way for the safe use of ammonia as a refrigerant in China's cold storage infrastructure. The standard sets out detailed safety rules and principles for cold storage design, construction, operation and maintenance management. It applies to both direct and indirect refrigeration systems using

ammonia and fluorinated refrigerants (HFCs and HCFCs) and includes detailed rules regarding safety management for the machinery room, refrigeration equipment and systems, refrigerating compressors and other auxiliary refrigeration equipment.

In addition, according to China's code for **Design of Cold Stores (GB50072-2010)**, which has recently been under revision, facility owners must carry out regular system maintenance to ensure the refrigeration system is in good condition and minimize the risk of ammonia leaks.

The growing restrictions imposed on ammonia use, revisions of safety standards and involvement of leading industry groups, are expected to create suitable market conditions for accelerated adoption of low-charge ammonia solutions, which have already seen rapid development over the past ten years in China.

"If the end users can show the government that, though ammonia use does entail legitimate safety concerns, they can be easily managed with proper standards and training, then progress in China can be made," said Jin Ma, Deputy Director of the Cold Storage and Cold Processing Committee at the Chinese Association of Refrigeration

"If the end users can show the government that, though ammonia use does entail legitimate safety concerns, they can be easily managed with proper standards and training, then progress in China can be made."
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Get in touch with shecco's market development team to learn more about the market for natural refrigerants or find out how we can help you in gathering market intelligence and proactively building your business with our tailored market development services, to get your technology faster to market.

Email us at
research@shecco.com

Talk to us on the phone
shecco Europe +32 2 230 3700
shecco America +1 (347) 763-7043
shecco Japan +81-3-4243-7095

Our mailing address
shecco Europe
Rue Royale 15, 1000 Brussels,
Belgium

shecco Japan
Global Business Hub Tokyo,
Otemachi Financial City Grand Cube 3F
Otemachi 1-9-2, Chiyoda-ku, Tokyo, 100-0004

shecco America
81 Prospect St, Brooklyn,
NY 11201

sheccoMarketDevelopment 

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