SUMMER 2017

ACCELERATE

ADVANCING HVAC&R NATURALLY

AUSTRALIA & NZ

GREENER FOOD STORAGE p.24

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Electricity cost savings by switching from old fashioned Freon to low charge NH_3 refrigeration systems will, in most cases, return the investment in 5 to 6 years.

Towards a homegrown sustainable future

— by Andrew Williams

As governments in Australia and New Zealand prepare to translate the ambitions of the Kigali Amendment to the Montreal Protocol into deliverable HFC phase-down strategies at home, the summer edition of *Accelerate Australia & NZ* sheds light on how proponents of natural refrigerant solutions at home and abroad are already helping companies to wean themselves off harmful chemicals.

Many of the solutions that will deliver the transition are already out there – with more on the way. Local vendors like Scantec and international firms like Mayekawa and Hillphoenix are competing to equip Australian and New Zealand industry with the HVAC&R solutions that will help deliver the post-Kigali new world order (p.40).

Strathbrook is one of the homegrown companies showing how it's done. The industrial refrigeration firm is banking on natural refrigerant technologies to deliver efficiency and sustainability goals for customers across Australia. For this issue, *Accelerate Australia & NZ* met Strathbrook co-owner Ian Wilson on the premises of F. Mayer Imports to hear how natural refrigerants are helping the food importer and wholesaler to reduce its carbon footprint (p.24).

Australia and New Zealand have both made commitments under the Kigali agreement to slash HFC emissions by 85% by 2036. To deliver on this timetable, the Australian government must amend existing legislation by the end of 2017. New Zealand, meanwhile, plans to extend its Synthetic Greenhouse Gas Levy to HFCs imported as components in formulated polyol (p.16).

Further afield, California's national leadership on environmental issues in the United States – never more important given January's change of administration in Washington, D.C. – includes its latest plan to reduce emissions of HFCs (p.56).

This evolution in policy is being matched by a widening market for natural refrigerant-based systems worldwide. Ice rinks are an exciting growth area. Ammonia has long been the refrigerant of choice for ice rink installers, yet it is facing growing competition from another natural refrigerant – CO_2 (p.34).

In the US, cold storage operator Henningsen is demonstrating how ammonia charges can be reduced dramatically without compromising on system performance (p.18). Features on ejectors (p.48) and heat pumps in the energy market (p.52) add to this summer edition of *Accelerate Australia & NZ*.

As the HVAC&R industry gears up for Refrigeration 2017 in Melbourne, the coming months look set to be a once-in-a-generation opportunity for industry to choose natural refrigerant technologies as market-ready replacements for climate-damaging HFC systems. We look forward to accompanying you on this journey!

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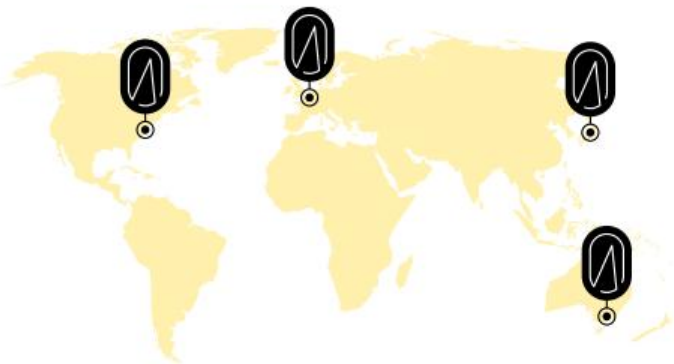
ACCELERATE

ADVANCING HVAC&R NATURALLY AUSTRALIA & NZ

ABOUT *ACCELERATE AUSTRALIA & NZ*

Brought to you by shecco, the worldwide experts in natural refrigerant news, *Accelerate Australia & NZ* is the first quarterly news magazine written for and about the most progressive business leaders working with natural refrigerant solutions in all HVAC&R sectors.

http://accelerateaunz.com/



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POLICY

OPINION

EVENTS GUIDE

February 2017 / March 2017

01 23 February, Singapore, Malaysia
Datacloud Asia 2017
www: http://www.datacloudAsia.com/
twitter: @datacloudAsia
#DatacloudAsia #Singapore #datacenter

02 23 February, Bankstown, Australia
RACCA's Future Gas Info Night
www: http://racca.asn.au/industry-topics/events

03 23-25 February, Delhi, India
ACREX 2017
www: http://www.acrex.in/

04 27 February, Hanoi, Vietnam
2017 3rd International Conference on Environment and Renewable Energy (ICERE 2017)
www: http://www.icere.org/

05 2-5 March, Bangkok, Thalland
Food Pack Asia 2017
www: http://www.foodpackthailand.com/

06 8-10 March, Bangkok, Thailand
SETA
www: https://www.seta.asia/

07 9-11 March, Bali, Indonesia
BALI ALLPACK INDONESIA 2017
www: http://10times.com/allpack-indonesia-bali

08 13-15 March, Beijing, China
ICETEEPC 2017
www: http://bioleagues.com/conference/ICETEEPC-conferences/

09 16-19 March, Jakarta, Indonesia
MEGABUILD Indonesia
www: http://www.megabuild.co.id/
twitter: @MegaBuildExpo

10 22-24 March, Manila, Philippines
Renewable Energy and Energy Efficiency Exhibition
www: http://www.renergyphilippines.com/

11 24-26 March, Sydney, Australia
The Home Show
www: http://www.sydneyhomeshow.com.au/

12 24-26 March, Addington, Australia
Christchurch Home Show
www: http://www.canterburyhomeshow.co.nz/

13 27-28 March, Melbourne, Australia
AIRAH Refrigeration 2017
www: http://www.airah.org.au/AIRAH/Navigation/Events2/AIRAHConferences/2017/Refrigeration_2017_Conference/Refrigeration_2017_Conference.aspx
twitter: @AIRAHnews

14 29-30 March, Sydney, Australia
TOTAL FACILITIES EXPO
www: http://www.totalfacilities.com.au/
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15 29-31 March, Ho Chi Minh City, Vietnam
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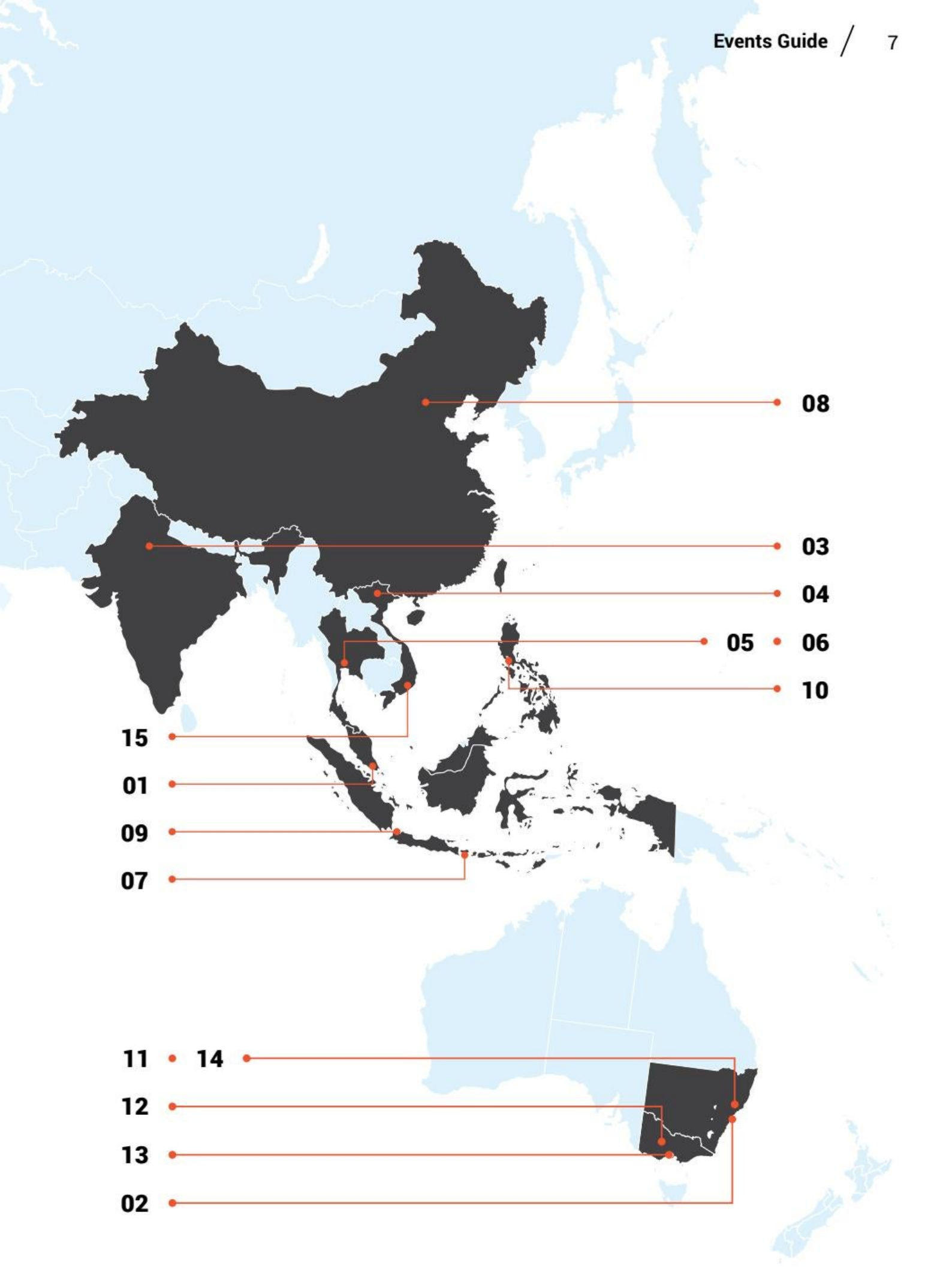
08
03
04
05
06
10
15
01
09
07
11
14
12
13
02

EVENTS GUIDE

April 2017

01 5-8 April, Jakarta, Indonesia
Food & Hotel Indonesia 2017
www: http://foodhotelindonesia.com/

02 12-14 April, Shanghai, China
China Refrigeration Expo 2017
www: http://www.chinaexhibition.com/Official_Site/11-8651-CRH_2017_-_CHINA_REFRIGERATION_2017.html

03 14-16 April, Guangzhou, China
AAC China Guangzhou
www: http://www.84t.cn/

04 20-22 April, Xi'an, China
China International Heating & Building
www: http://www.cnhe.com.cn/en/index/

05 24-26 April, Kuala Lumpur, Malaysia
7th International Conference on Environment and Industrial Innovation (ICEII 2017)
www: http://www.iceii.org/

06 25-27 April, Ho Chi Minh City, Vietnam
Food & Hotel Vietnam 2017
www: http://www.foodnhotelvietnam.com/

07 26-29 April, Shanghai, China
Expo Build China
www: http://www.hdeexpo.com/en-us/sectors/hotel-building/ecobuild

08 27-29 April, Bangkok, Thailand
Asia Cold Chain Show 2017
www: http://www.asiacoldchainshow.com/
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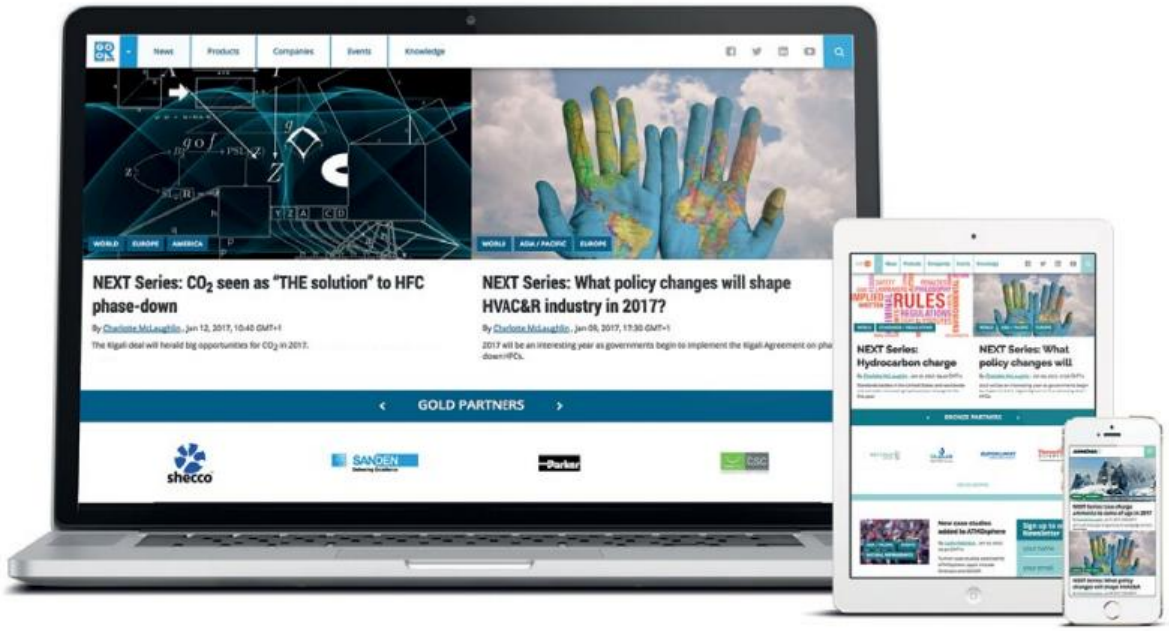

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KIGALI: *What's in it for* ***natural refrigerants?***

The Kigali amendment is a step in the right direction, but the details don't pack a hard enough punch.

The Kigali amendment agreed in October 2016 is the first change to the Montreal Protocol on ozone-depleting substances in the past decade. Though a great leap forward in the fight against climate change, the amendment nonetheless falls short of the high level of ambition boasted about in the run-up to the meeting.

An ambitious HFC phase-down – the low-hanging fruit of climate change mitigation – could prevent up to 0.5°C of global warming by 2100, bringing the world closer to its ambition of reducing overall warming by 1.5°C.

Many hail the Kigali deal as a step in the right direction. Initial reactions from governments, industry and NGOs were supportive. The EU's commissioner for climate action and energy, Miguel Arias Cañete, declared the deal "a huge win for the climate," arguing that it will help the world to stick to the promise made in last year's Paris Agreement to slash half a degree off the median global temperature rise by the end of the century.

These ambitions will only be realised with a far more stringent agreement.

The pace of the Kigali HFC phase-down is slow – almost too slow. The deal does not place enough emphasis on the opportunity to leapfrog HFCs in favour of new natural refrigerant-based technologies that are cost effective, energy efficient and readily available.

Given the technology solutions available today, developed countries could achieve their phase-down of 15% of their baseline far more quickly than by 2036, the date agreed in Kigali.

For developing countries, the deadlines are even looser. The baseline years taken as reference for the phase-down are far into the future, allowing for increased use of HFCs before the eventual freeze and reduction. Split into two groups, they will only start freezing HFC use in 2024 or 2028, achieving the phase-down in 2045 or 2047 respectively.

The Kigali text recognises the need "to avoid transitions from hydrochlorofluorocarbons to high-GWP hydrofluorocarbons" but still offers flexibility if alternatives cannot be found. Necessity is the best stimulant for innovation, but the amendment is weak on necessity.

A lawyer by training, ***Ermenegilda Boccabella*** *is the public affairs campaigner at shecco and represented the company at the Kigali negotiations. shecco is the publisher of Accelerate Australia & NZ.*

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WE'RE STUCK WITH THIS FOR A WHILE

The amendment is inflexible yet will be operational for a long time. It will be difficult to change, with future alterations likely to require new decision texts rather than becoming part of the Montreal Protocol itself.

The most inflexibility can be found in the list of substances, which currently includes 19 known one-compound saturated HFCs. HFCs used in heating, air conditioning and refrigeration tend to be blends of these. Adding new substances to the list may take years. This is a problem – the list is not exhaustive, leaving substances such as unsaturated HFCs (so-called HFOs) on the market.

The HFC phase-down is measured in CO_2 equivalent (GWP x kg of refrigerant), leaving the door open for the chemical industry to push new HFO-HFC blends onto the market whose GWP is still rather high. This will reduce industry's incentive to shift away from HFCs. Adopting intermediary solutions would come at a high price for end users.

'LOW' GWP MIGHT LEAD US TO ACID RAIN

The decision text fails to define high and low GWP, allowing substances that are comparatively noxious greenhouse gases to fall through the cracks and be classified as low GWP.

More worrying still is the risk of industry making another historic mistake. The decade since the Protocol was last amended has been the hottest on record. Temperatures are expected to keep rising. After damaging the ozone layer and warming the planet with CFCs and HCFCs, a new generation of fluorinated refrigerants are not only still on the table: their use is likely to grow.

The Kigali deal allows unsaturated synthetic substances to be considered 'low GWP' and therefore widely used as alternatives. Despite their lower GWP than HFCs, they break down in the atmosphere into trifluoroacetic acid, creating acid rain. Will we wake up in 10 years' time lamenting the damage done again? Or finally learn from past mistakes and avoid creating new problems when trying to fix existing ones?

EXEMPTIONS

The decision text fails to tackle the 'high ambient exemptions' issue. It allows countries where ambient temperatures are high to apply for exemptions from the HFC phase-down. What's more, as the world gets warmer, more countries will become eligible for high ambient exemptions. The Kigali amendment fails to address this.

There is no reason for countries not to act. Innovation is quickly eroding arguments that high ambient temperatures compromise technological efficiency. Come 2032, the parameters will be entirely different.

NO SILVER BULLET

The Kigali amendment will deliver a global phase-down of HFCs. It also put the HVAC&R sector back in the global and mass media spotlight. Yet it is no silver bullet for the harmful effects of synthetic refrigerants.

The amendment was expected to be far more aggressive, saving us from the dangers of a two-degree rise in average global temperature. Phasing in refrigerants that will need to be phased out again is irresponsible when viable alternatives are already available on the market.

The decision text mentions 'zero GWP' alternatives but does not specifically name natural refrigerants. Natural refrigerants are the only genuinely sustainable solution. It is up to innovators to improve technological efficiency, legislators to create better standards, and educators to provide comprehensive training. These are the priorities that international negotiations must focus on. EB

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AUSTRALIA & NZ IN BRIEF

TRAINING

CO_2 TRAINING ON-THE-GO WITH DANFOSS

Leading CO_2 system supplier Danfoss has launched a new Mobile Training Unit, equipped with CO_2 technology and interactive learning modules.

The container classroom is designed to respond to growing industry demand for training on CO_2 refrigeration systems worldwide.

The unit's first stop was Danfoss' US headquarters in Baltimore, Maryland on 10 January 2017. The company hopes to display the unit at the ATMOsphere Australia conference in Sydney on 2 May, while Thailand is also on the mobile unit's itinerary.

The company's goal is to launch several training containers that can serve its primary markets in North America, Europe, and Asia.

The growing popularity of CO_2 refrigeration systems is increasing the need for technicians who are properly trained for its different uses. "Our mobile training unit will go a long way to promoting the benefits of CO_2," said Hans Ole Matthiesen, Segment Marketing Director (Food Retail) at Danfoss.

Eda Isaksson

TRENDS

COLD LOGIC, COOPERS BREWING WITH AMMONIA

Adelaide-based Coopers Brewery has commissioned an ammonia refrigeration plant for its new malting facility under a AU $3.5 million contract struck with local refrigeration company Cold Logic.

The much-loved Australian brewer, known for its pale ales, expects to open the new plant in Regency Park in late 2017. The facility will boast a water chilling system to circulate five million litres of water every day for the purposes of temperature regulation.

"The new plant will guarantee the long-term supply of high-quality malt for our future growth," said Coopers Managing Director Tim Cooper.

Cold Logic partner Eddie Lane said his firm had played an instrumental role in the design and installation of the new refrigeration plant. "Typically, refrigeration makes up 40-60% of a brewery's energy use. We are passionate about helping Coopers to overcome higher energy costs and improve their efficiencies," he said.

Andrew Williams

TRAINING

ARC TO REVIEW CERTIFICATE II QUALIFICATION

The Australian Refrigeration Council (ARC) Board has initiated a review of the competencies related to the Certificate II qualification. The goal is to review proficiency standards for the restricted heat pump – split systems – installation and decommissioning licence.

Kevin O'Shea, an ARC board chairperson and president of RACCA (Refrigeration and Air Conditioning Contractors Association of Australia), believes this review is long overdue.

"[It] will identify if the training competencies still meet the requirements of the scope of works permitted by the restricted licence. The dynamic nature of the industry gives rise to the need for qualifications which underpin licence types to remain relevant and appropriate," he said.

ARC CEO Glenn Evans stressed the importance of adhering to licence restrictions due to the summer months being a busy time of the year for the industry.

"Summer is the business end of the year for our sector, so let's make it a safe, legal and prosperous one for industry and consumers alike."

James Ranson

TRENDS

CHILE INSTALLS FIRST CO_2 TRANSCRITICAL SYSTEM

A transcritical CO_2 refrigeration system has been installed in a Jumbo supermarket in the city of Valdivia, Chile. It is Chile's first instance of transcritical CO_2 refrigeration, according to Claudia Paratori, a coordinator in the Chilean Ministry of Environment's Ozone Unit.

The 5,300 m^2 store, which opened on 12 January, was built to the highest standards in sustainability. It includes 100% LED lighting and an integrated building energy management system, alongside the CO_2-only refrigeration system.

The project was implemented by the Ministry of Environment's Ozone Unit and was funded by the Climate and Clean Air Coalition (CCAC).

Paratori said this was an opportunity to promote the technology, eliminate HCFCs and minimise the use of HFC-based systems in the country.

"This project will connect the different actors in the cold chain supermarket sector, promote the adoption of this technology, and help minimise the introduction of HFC-based systems in Chile," Paratori said.

Charlotte McLaughlin

TRAINING

US INSPECTORS TO RECEIVE AMMONIA TRAINING

Two large US industrial refrigeration organisations, the Global Cold Chain Alliance (GCCA) and the International Institute of Ammonia Refrigeration (IIAR), are collaborating with the University of Wisconsin Madison's Industrial Refrigeration Consortium (IRC), to sponsor a five-week, web-based US Occupational Safety and Health Administration (OSHA) training course for OSHA safety inspectors.

The course seeks to familiarise safety inspectors with large ammonia refrigeration systems (usually over 10,000 lbs).

"It's about developing training for OSHA inspectors, so they are more appropriately focused on how an ammonia refrigeration system works," said Lowell Randel, vice-president (government and legal affairs) at the Global Cold Chain Alliance (GCCA).

Recognising the training gap and the need for more collaboration between the public and private sector, Randel commented, "we [the ammonia sector and OSHA] all share the goal of safety. So, we think it's good to ensure a good relationship and to share best practices between regulators and industry".

Charlotte McLaughlin

RESEARCH

HYDROCARBONS 'COULD REPLACE' MOST SYNTHETIC REFRIGERANTS

A new paper from European natural refrigerant advocates Eurammon argues that hydrocarbons have huge potential to replace HFCs due to their economic feasibility and environmental friendliness.

"They have application-specific advantages when selected correctly," Eurammon writes.

Hydrocarbons are feasible in many fields as an alternative to synthetic refrigerants because they feature similar pressure levels and similar specific refrigeration capacities.

Hydrocarbons also have excellent thermodynamic properties, which reduce the amount of energy input needed to generate a certain refrigeration capacity. This, in turn, also reduces the indirect global warming effect.

"Hydrocarbon-based systems are one step ahead in terms of operating costs," says Eurammon. Propane, for example, is considered to be one of the most efficient refrigerants.

Eurammon concludes, "due to their beneficial properties, hydrocarbons have the potential to develop new areas of application. For this reason, hydrocarbon-based refrigeration is the way to go. They are not only ecologically but also economically sustainable."

Charlotte McLaughlin

Australia all set for HFC phase-down, NZ strengthens stance

Australia and New Zealand have both made commitments under the Kigali Agreement to slash HFC emissions by 85% by 2036. *Accelerate Australia & NZ* looks at the two countries' strategies for delivering this goal.

— By Charlotte McLaughlin & Andrew Williams

To deliver on its ambitious timetable to curb HFC emissions by 85% by 2036, the Australian government must amend existing legislation by the end of 2017.

Although this appears to represent a big step forward for Australia's conservative government, to date, it has not explicitly stated how the phase-down will occur.

The new measures, amid proclamations that Australia will join the US, the EU and Japan as a "world leader" in reducing HFC emissions, are expected to reduce HFC emissions by up to 80 Mt CO_2 equivalent in the period to 2030.

Accelerate Australia & NZ has received indications that the amendment will be tabled in the Australian parliament in February-March 2017 and passed in May-June of the same year. This would allow for licences and quotas to be applied for and granted before the January 2018 start date.

Former Australian Environment Minister and current Health and Sports Minister Greg Hunt originally announced the review of the 'Ozone Protection and Synthetic Greenhouse Gas Management' (OPSGGM) programme in May 2014, with an options paper released after public consultation outlining a "strong preference" for a hardline stance on phasing down HFCs.

In June 2016, the Australian government made a long-awaited decision to apply a legislative phase-down of HFC imports from January 2018. This pace would be quicker than the phase-down pathway that Australia signed up to under October's Kigali Amendment to the Montreal Protocol, which

calls for reducing HFC consumption by 10% compared to 2011-2013 levels by 2019.

The amendments include provisions for future bans by the federal government on imports of new equipment containing high global-warming-potential (GWP) HFCs and domestic and automotive air conditioners containing high-GWP HFCs too.

"Further, compliance provisions of the legislation will be strengthened to support emission reduction including new offence provisions, increased penalty amounts, provision for suspension of licences and publishing of compliance actions," the OPSGGM review document reads.

In May 2016, Prime Minister Malcolm Turnbull and Minister for Environment and Energy Josh Frydenberg announced the introduction of a domestic cap on HFC imports from 2018 to meet 2030 emission reduction targets.

Ian Stangroome, president of VASA, which represents the Automotive Air Conditioning, Electrical and Cooling Technicians of Australasia, says, "there are new technologies being rolled out for automotive air-conditioning, including [...] CO_2 [as a refrigerant], that meet these requirements".

NEW ZEALAND MULLS EXTENDING GREENHOUSE GAS LEVY

In New Zealand, meanwhile, the government has begun consultations on a proposed extension of the Synthetic Greenhouse Gas (SGGs) Levy. SGGs include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6).

The government is considering extending the levy to HFCs imported as components in formulated polyol, used in the manufacture of polyurethane foam.

"The current consultation on extending the Synthetic Greenhouse Gas Levy to cover hydrofluorocarbons (HFCs) does not [however] cover the domestic implications of the Kigali Amendment to the Montreal Protocol on bulk HFCs," Elspeth McIntyre, Senior Communications Account Manager at the New Zealand Ministry for the Environment, told *Accelerate Australia & NZ*.

New Zealand has instead opted to increase tax rates on SGGs by 295.5% compared to last year. Raising the price from $0.30 per unit (as applied in 2016) to $9.85 from 1 January 2017 has increased the tax burden on importing HFCs into New Zealand.

The levy targets common goods like fridges, freezers, heat pumps and air conditioners, as well as refrigerated trailers and motor vehicles whose air-conditioning units contain HFCs.

The move should significantly help New Zealand to meet the first step of its HFC phase-down obligations under the Kigali Agreement. Kigali obliges New Zealand – like Australia – to reduce its HFC consumption by 10% compared to 2011-2013 levels by 2019.

New Zealand's environment minister, Dr. Nick Smith, said following October's Kigali deal: "The Ministry for the Environment will work closely with industry in New Zealand to implement the phase-down over the next 20 years."

Environment Ministry spokeswoman McIntyre confirmed that New Zealand is "still developing policy around how the HFC phase-down agreed at Kigali could be implemented in New Zealand. We are continuing to talk with industry about this and plan to consult publicly this year".

This is in addition to New Zealand's emissions trading scheme (ETS), which has now started to have a real impact on imports of HFCs. The price of New Zealand's carbon credits rose from around NZ $1 in 2014 to over NZ $17 in January 2017, forcing wholesalers to reassess the economic value of purchasing harmful refrigerants.

The New Zealand government in 2016 also removed a two-for-one clause that had essentially halved the price of the carbon credits. CM & AW

*For Henningsen, **less is more***


Pete Lepschat, Henningsen Cold Storage

The US cold storage operator has cut thousands of kilograms of ammonia from its refrigerated systems in two plants by questioning the need for so much of it.

— By Michael Garry

Some people have a knack for challenging the status quo. Pete Lepschat, engineering services manager for Henningsen Cold Storage, is one such person.

The conventional wisdom in the cold storage industry has long been to use copious amounts of ammonia and not worry about it. Nowadays, there is a shift in thinking that is leading to lower ammonia charges in rooftop packaged refrigeration units as well as in conventional engine room set-ups.

At Henningsen, based just outside of Portland, Oregon, Lepschat began questioning the need for large ammonia charges more than seven years ago.

"I would be asked, 'ammonia is cheap, so why use less?" says Lepschat. His answer: "Because it's the right thing to do – to protect your employees and your surroundings. Ammonia is a great refrigerant, it's natural, but it's toxic. As a fringe benefit in the US, when your systems contain less than 10,000 pounds (4,536 kg), you are a little less subject to scrutiny from the regulatory agencies."

That philosophy led Henningsen to install unorthodox ammonia refrigeration systems designed by Lepschat in two plants, with a third on the way. The systems, using an engine-room design, dramatically reduce the ammonia charge as well as energy consumption compared to conventional designs.

Henningsen, a fifth-generation family-owned business founded in 1923, operates 10 cold storage facilities, including six clustered in the Pacific Northwest, and four scattered across the US in Idaho, North Dakota, Pennsylvania and Oklahoma. They focus on the agricultural industry, storing everything from strawberries, cranberries and apples to sweet corn, green beans and potatoes.

For the past two decades, Henningsen has made a commitment to energy conservation, employing green building elements, LED lighting and computer-controlled refrigeration technology. The company's average energy consumption is 0.017 kW/m³ compared to an industry average of 1.6, said Lepschat, who has been with the company for 22 years. The company's two warehouses in Portland (Gresham) and Salem, Oregon both have solar power installations, one 200,000 W, the other 80,000 W.

KEEPING AMMONIA FLOWING

Having cut its energy consumption, Henningsen turned its attention to reducing the ammonia charge, but "without affecting energy conservation," Lepschat says. It made its first attempt at the second Gresham facility when it was built in 2009.

"The old way of designing a system was to say, if one pound of ammonia is good, five pounds is better," says Lepschat. "But those other four pounds (1.8 kg) don't really get you anything."

His basic approach was to "look at every component [in the traditional refrigeration system] and ask if we need that much ammonia," he says. "We took the system apart, eliminated a few pieces of equipment and got the charge down."

Traditionally, condensed liquid ammonia from the condenser goes to a high-pressure receiver (HPR) tank, where it remains until called upon. But Lepschat asked, why store the ammonia? Why not keep it busy? "So we eliminated the tank and put in a small vessel [0.61m diameter, 1.32m tall] that maintains a low level of ammonia."

The small vessel, essentially a way station, is fitted with a level probe and modulating Hansen valve; when the liquid level rises, the valve opens, feeding the ammonia directly to a low-pressure receiver (LPR) via a sub-cooler. Managed by a Logix control system, the overall design is called a "pump-down system".

"So instead of storing a charge in the high-pressure vessel where it does nothing, we send it down to the low side right

> *"We took the system apart, eliminated a few pieces of equipment and got the charge down."*

away. We put a little extra surge volume in our low-pressure vessel in a constant flow." By taking out the HPR, Henningsen reduced the ammonia charge by several thousand kilograms.

The constant-flow scenario also saves compressor energy, Lepschat explains. "With a constant flow, you can easily match the compressors exactly to the flow of refrigerant, rather than having surges and ebbs. That dovetails really well with a variable-speed compressor."

LOWERING THE FEED

Another way to reduce charge is to lower the overfeed ratio of ammonia in the evaporators, which in a typical Henningsen facility is 3-1 (for every three parts of liquid ammonia, one part changes to gas).

In the Gresham facility, Henningsen purchased evaporator coils from Frick that enabled a 2-1 overfeed ratio. The lower overfeed ratio reduced the size of components like the LPR, the liquid piping and the coil tubes, decreasing the ammonia charge by another several thousand kilograms.

The combination of the lower overfeed ratio and the pump-down system cut the charge to about 2,268 kg, from what would have been more than 4,536 kg "in most conventional design scenarios," says Lepschat. The refrigeration capacity for that charge was 430 TR.

In 2014, Henningsen added about 4,645m² of freezer space as well as additional refrigeration equipment to the Gresham facility, increasing the total ammonia charge to 3,400 kg and the capacity to about 630 TR.

In terms of equipment cost, though the Gresham refrigeration system did eliminate or downsize some parts in reducing the ammonia charge, its overall cost was about 12% to 15% more

ENERGY CONSUMPTION (KW/CU. FT.)

Industry Average (IARW): 1.6
Henningsen Average: 0.6
Second Gresham Facility: 0.3

COOLING FRIES WITH CO_2

CO_2 as a refrigerant in refrigerated transport is beginning to gain traction in Europe.

For example, the Delhaize Group uses the CryoTech liquid CO_2 system from Thermo King in 25 trailers in Belgium. The system allows liquid CO_2 to evaporate in coils in the cargo space, producing cooling, and then discharges the CO_2 gas into the atmosphere. (see 'NatRefs hit the Road', *Accelerate America*, October 2016).

Makers of CO_2 refrigerated transport systems have their eyes on the US, but the market has yet to develop. However, up until a decade ago, railcars using CO_2 cryogenic refrigeration carried frozen french fries to a Henningsen Cold Storage facility in Idaho, noted Pete Lepschat, Henningsen's engineering services manager.

"The railroad cars had trays filled with frozen fries and they shot liquid CO_2 into pans underneath to maintain the temperature," he said. "We had CO_2 tanks at our facility for refills." But the CO_2 system was replaced by mechanical HFC refrigeration about a decade ago.

"CO_2 was common for potato shipments for many years," he said.

Engine room of Henningsen's first Salem, Ore., facility.

than a conventional system. The increase in costs came from investing in energy-efficient equipment like larger evaporator coils. "We do a lot of things like that, which conserve energy but cost more money, because they pay dividends over the lifetime of the system," says Lepschat.

In fact, the changes made at Gresham made it more efficient than the average Henningsen warehouse. Over the past year, the facility's energy consumption has been 0.0085 kW/m³, or half of Henningsen's average, saving 1.7 million kWh per year and AU $156,600 in annual energy costs.

Moreover, the system's incremental equipment costs (compared to a standard system) were lessened by about 50% as a result of a roughly AU $408,500 energy-efficiency incentive provided by the Energy Trust of Oregon. With the incentive and annual energy savings, Henningsen realised a 2.6-year payback on the incremental cost of the refrigeration system.

While the technicians maintaining the Gresham facility's system required training on how the system works – its motorised valves and computer software, for example – it was "nothing earth-shattering," Lepschat noted. "The system at its essence is conventional, with pumped overfeed and economised screw compressors."

SYSTEM SPECS

The low-charge ammonia systems at Henningsen Cold Storage's plants in the Portland, Ore., suburb of Gresham and in Salem, Ore., have the following characteristics:

Gresham

Size of facility: 210,000 sq. ft.

Temperature range: 75% freezers (-5°F); 25% coolers (36°F-38°F); dock (38°F -40°F)

Frick evaporator coils, 2-1 overfeed ratio

Ammonia charge: 7,500 lbs.

System capacity: 630 TR

Pump-down system

Defrost: Hot gas

Water-cooled condenser

Salem

Size of facility: 220,000 sq. ft.

Temperature range: 100% freezers (-8°F); dock (36°F)

Evapco evaporator coils, 1.2-1 overfeed ratio

Ammonia charge: 4,500 lbs.

System capacity: 465 TR

Pump-down system

Thermosyphon glycol-based oil cooling

Defrost: Hot gas

Water-cooled condenser

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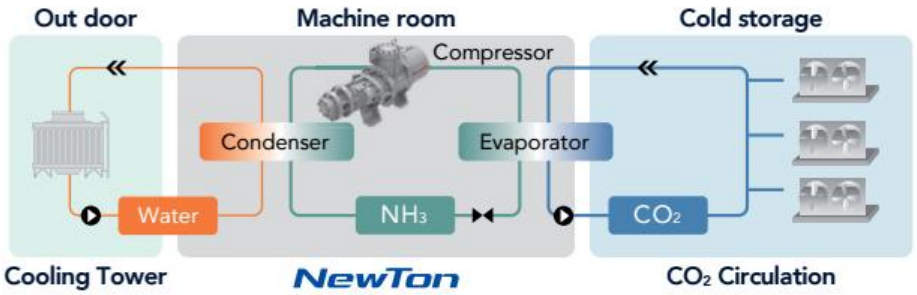

Model	R-3000	R-6000	R-8000
Cooling Capacity	94.7kW	189.4kW	270.0kW
NH_3 Charge	25kg	50kg	75kg

* -32°C CO_2 Temp. -32°C Cooling Tower Water Temp.

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Equipment in Salem, Ore., engine room, from left: Frick compressor; subcooler (smaller white vessel) and low-pressure receiver (larger white vessel).

NEXT OPPORTUNITY

Having successfully lowered the ammonia charge and energy consumption in its Gresham plant with a system that has "been stable and run well," Lepschat turned his attention to Henningsen's first Salem plant, built in 2013-2014. "That was my next chance with low-charge."

At the Salem plant, Henningsen installed the same pump-down system used at the Gresham warehouse, but changed to Evapco evaporator coils with a 1.2-1 overfeed ratio. "That's a really low rate; you have mostly gas coming back from the evaporators," says Lepschat. "It's the optimum 'happy spot' for an overfeed rate in terms of minimising your charge and still having really good ammonia surface wetting on the coils and good heat transfer." Moreover, the Evapco coils allowed Henningsen to use smaller liquid pipes and pumps.

Though the Salem plant is, at 20,440m², larger than the Portland facility (19,500m²), it has an effective ammonia charge of 2,040 kg vs. 3,400 kg at Portland, with a capacity of 465 TR vs. 630 TR. The Salem plant's energy efficiency is at least as good as Portland's, and the cost of the equipment is comparable.

The Salem warehouse also reduces the ammonia charge by employing glycol rather than ammonia in a thermosyphon oil cooling process. A conventional system uses 2,000 (900 kg) to 6,000 pounds (2,700 kg) of ammonia just to cool the oil in the screw compressors. "That seems silly," Lepschat says. Instead, in the Salem system glycol captures 360,000 BTU/hour of oil heat and channels it to the flooring underneath the freezers to keep them from freezing.

In its second Salem cold storage facility, expected to open later this year, Henningsen plans to leverage oil heat to reheat the air and thereby control the humidity in its docks. "We'll bring moisture out of the docks before it gets to the freezer, which will reduce defrosting," says Lepschat. MG

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F. Mayer *reaping rewards of innovation*

Industrial refrigeration firm Strathbrook is banking on natural refrigerant technologies to deliver efficiency and sustainability goals for customers across Australia. *Accelerate Australia & NZ* visits gourmet food firm F. Mayer Imports to find out more.

— By James Ranson & Jan Dusek

> *"In the end, it comes down to reliability, efficiency and capital costs."*
>
> – Robbie Mayer,
> Managing director, F. Mayer Imports

Step onto Australian shores and you'll find that innovation has become something of a buzzword. The Australian government hopes that the National Innovation and Science Agenda, launched by Prime Minister Malcolm Turnbull in December 2015, will produce an ideas boom leading to increased investment in innovative startups.

Yet the jury is still out as to whether it will succeed. History tells us that a lack of government support and environmental policy leadership has done little to aid end users, contractors and suppliers in introducing environmentally friendly natural refrigerant technologies in Australia's HVAC&R sector.

The onus, therefore, has typically been on innovative individuals and companies with an interest in the industry's future to shoulder a degree of commercial risk in pursuit of a long-term payoff. Ian Wilson, project engineer and co-owner of Strathbrook Industrial Services, is doing just that.

"It's heaps of fun. I'm paid to do my hobby – it's great!" says Wilson, who provides bespoke CO_2 and ammonia refrigeration plants for industrial end users.

"Unfortunately the current government removed the [carbon tax] incentive for industry, which was helping a lot. It made a huge difference because I could say: 'this price is going to keep going up. Your power is going to go up. All of the things that will rise as a result of global warming are going to affect your business'."

In 2003, Wilson developed one of the first commercially installed CO_2/HFC plants in Australia, for diet meal delivery service Lite n' Easy. "The first rack for Lite n' Easy I built myself; I did the oxy welding on the pipes," he says.

Back then Wilson was working for Bitzer Australia, with which he has maintained strong professional links while at Strathbrook. "We've never lost a CO_2 compressor since doing one of the first CO_2 jobs in Australia, using Bitzer compressors [12] years ago. We've probably installed 50. The compressor sumps are always warm, which greatly decreases refrigerant dilution in the oil."

Wilson tells the tale of Bitzer's then head of applications, Hermann Renz, who travelled the world telling everyone CO_2 was the future in Australia. "Bitzer were very keen to introduce CO_2. However, supermarkets – which were the biggest potential users of the technology – weren't prepared to take a risk that might invite a butt-kicking from their board of directors."

"So Bitzer basically gave a CO_2 plant to Lite n' Easy, who had also bought an R404A DX plant, provided they allowed them to monitor the energy of both plants and conduct an engineered scientific study," Wilson says.

The results were telling. Wilson compared the two plants over months with the same ambient temperature, graphing the days and comparing power consumption. In the end, the CO_2/R404A plant proved to be 20.6% more efficient than the R404A DX plant.

The Melbourne cold storage facility

What followed is one of Wilson and Strathbrook's pet projects, for food importer and wholesaler F. Mayer Imports Pty Ltd. Travelling far and wide to investigate optimal solutions, Strathbrook has since evolved its CO_2 technology: from a first-generation CO_2/HFC cascade plant to two CO_2 transcritical racks combined with an HFC cooler, and finally, to the third-generation *pièce de résistance* – a fully transcritical CO_2 plant with an ammonia chiller for F. Mayer's Melbourne distribution warehouse.

"Our aim became: how can we develop the most efficient plant in the Southern Hemisphere?" Wilson says.

"Ian [Wilson] explained clearly to us the advantages and disadvantages of the systems," says F. Mayer Managing Director Robbie Mayer. "We've really appreciated his no-fuss approach; if he doesn't know the answer to something, he'll go out and find out, and come back to us."

"We really rely on his guidance and do our due diligence through contacts in the industry here and overseas. In the end, it comes down to reliability, efficiency and capital costs."

QUALITY BUILDS TRUST

Wilson took *Accelerate Australia and NZ* on a tour of F. Mayer's second-generation plant in Banksmeadow, Sydney with Danfoss' Business Development Manager APA Inderpaul Saund in tow.

F. Mayer is "not afraid to spend a bit of money to get a good result," Wilson says. "Many end users want the cheapest system they can get. That's not what we're about. We seek out customers who pay their bills and want a quality result. The people that run the company – it's a family business – wanted a plant that would stand the test of time in 20 years."

"For us it's all about energy efficiency, savings and improving our carbon footprint," says Mayer. "We're really pleased that we've managed to drastically increase our business without increasing our power usage. We are a much greener business now."

Having wildly outstripped its own growth projections for the past decade, the firm has continued to work with Strathbrook to install more tailored natural refrigerant solutions in response to growing demand for its products.

F. Mayer imports premium gourmet food products, predominantly from Europe, for the HORECA and speciality food industries. It distributes dry and frozen goods to leading retailers and vendors across Australia including Belgian chocolate, cheeses from Europe, the UK and the Asia Pacific region, and brands like San Pellegrino.

The Banksmeadow site was built in two stages after F. Mayer doubled its business in 2006, prompting the company to move to a larger site and build the second-generation plant.

The first-generation cascade plant included an R134a cool room for chilling high-end cooking chocolate at high stage to a CO_2 freezer saw. Strathbrook constructed the freezer floor on top of the existing floor so that it could install cool glycol under-floor heating – far from a typical solution in Australia at the time. "It freed operating costs and recovered wasted heat," Wilson says. "They also installed solar 100 kW PVs on the roof."

The plant incorporated Bitzer compressors and was similar in design to those used in many Australian supermarkets. "It was about 20% more energy efficient than an R404A freezer would be, and going to the second generation transcritical system, we were about another 40% more efficient on top of that. The reason for that is quite simple: the freezers are pretty much the same but rejecting heat (second generation) affects the high stage and makes the overall system more energy efficient. Transcritical CO_2 is intrinsically more energy-efficient if it's done right," Wilson says.

"Australia is a unique place, it's an affluent country and there's money to spend. Clients want to buy premium products. There's a market there for refrigeration. It's also technically advanced and has no fear of going down a new path...but you've gotta take the risk. If you're going to build it yourself, there's some risk involved. That's a $100,000 package to build," he says.

RISK AND REWARD

For Strathbrook, the level of risk was tempered by the quality results. Yet F. Mayer had a problem on its hands. By the time the first-generation CO_2/R134a system was installed, the company had reached capacity after doubling its business again in just two years.

Luckily the site next door was available. F. Mayer purchased the property, hopped the fence and commissioned a second-generation, improved plant from Strathbrook. "The customer was developing trust with us and wanted to have a more energy-efficient system and a greener energy profile, so they elected for an all-CO_2 system with high and low stage in cascade," Wilson says.

Ian Wilson, Strathbrook (l.) & Inderpal Saund, Danfoss (r.)

"F. Mayer is not afraid to spend a bit of money to get a good result. A lot of end users want to get the cheapest system they can get. That's not what we're about. We seek out customers who pay their bills and want a quality result. It's a family business [and they] wanted a plant that would stand the test of time in 20 years."

– Ian Wilson,
co-owner, Strathbrook Industrial Services

The plant replicated the first version's combination of a 1,200m² cool room at 2-4°C and an identically sized freezer room (both 120 kW), effectively increasing the combined storage capacity of the two warehouses to 4,800m².

Yet the second-generation plant included a number of improvements, including heat reclaim from the low-stage CO_2 rack package to provide warm glycol for the defrosting system, and a patented freezer floor heating pump in between the heat exchangers – under the oversized gas cooler. The freezer floor is heated with pumped glycol in a nylon pipe grid laid out under the freezer floor. To heat the glycol, heat from the liquid CO_2 refrigerant leaving the gas coolers is passed through a plate heat exchanger, so that the cool glycol takes on heat from the warm liquid refrigerant and the warm liquid refrigerant is cooled by the cool glycol. This heats the floor for free and saves on compressor running costs.

"We tested [the pump] and it worked so well that we patented it and used the same design in Melbourne," Wilson explains. The pump typically takes heat out of the water at 18°C and circulates it up to the glycol-heated floor, which is 13°C. The advantage of this, he says, is that "the cold glycol in the freezer floor cools the water in the closed-loop system, which then uses the cold water to cool the CO_2...the colder you can make the CO_2, the more energy efficient it is!"

The two CO_2 racks cool mainly frozen cheese with CO_2 high stage as well as warm glycol defrosting and cool glycol underfoot heating. The two racks contain an oversized gas cooler and a small HFC screw chiller with R134a to precool the CO_2, a necessary measure given that the temperature can reach 45°C outside.

The high-stage freezer and cool room rack system each contain six 65 kW Bitzer CO_2 compressors, with the compressor package divided into two suction groups of three compressors. The glycol heat exchangers on the low-stage freezer rack system ensure that any heat pulled out of the system into the glycol is not passed onto the next stage, providing an immediate energy saving. The system's 20 kW heat reclaim capacity allows one compressor to be inactive.

An R134a screw chiller provides additional condenser capacity for the CO_2 gas cooler in warm weather and the system runs on demand. The CO_2 leaving the gas cooler always remains liquid and below 25°C which ensures the CO_2 never runs in the supercritical phase.

Low-stage CO_2 system for freezer room

The power consumption of the plant in cool weather is about four times better (in raw COP) than it would be on a hot day of 40°C ambient. A large insulated water tank provides additional thermal storage, so the R134a system only runs from time to time, in spring and autumn. The chiller remains totally off in winter and for the majority of the spring and autumn, but cycles a lot during summer.

"Without the chilled water heat exchangers, the plant would require another four compressors to maintain room conditions. It allows the system to be maintained at an optimal level. To do this in Sweden is easy but here, where it's 30°C or above for three months of the year and for a month either side of that, the system would run supercritical – and when it runs supercritical, the compressor capacity is half and the power consumption is double," Wilson says.

He says that the cost benefits obtained by reclaiming heat to warm the floor were previously unheard of in Australia. "With electric floor heaters in the 1,200m² room it would cost AU $30,000 per year. Using the floor heating more than offsets the cost of running the pump."

GOING FOR TRANSCRITICAL GOLD

That brings us to F. Mayer's latest foray with Strathbrook. While a number of industrial CO_2 transcritical plants have been installed in ice rinks and cold stores in Europe and the

SYSTEM SPECS

The second-generation CO_2 transcritical system at F. Mayer's Banksmeadow, Sydney plant has the following characteristics:

- **Size of facility: 2,400m²**
- **Temperature range: 120 kW freezers (-20°C); 120 kW cool room (2-4°C); Dock area (16°C)**
- **System capacity: 240 kW**
- **Freezer: 4 Bitzer CO_2 compressors (plus 3 high-stage Bitzer compressors)**
- **Cool room: 3 Bitzer CO_2 compressors (2 x 3 suction groups)**
- **Oversized Güntner gas cooler**
- **R134a screw chiller**
- **Floor heating: cool glycol**
- **Defrost: warm glycol (50°C)**
- **Heat reclaim capacity: 20 kW**
- **CO_2 charge: 300 kg**

High-stage CO_2 system

CAPITALISING ON THE CAPITAL CONUNDRUM

"Everyone wants a natural refrigerant plant," Wilson says. "They all want energy savings, but not everybody is prepared to pay for it."

When quoting customers, Wilson always fronts up with the price premium of a CO_2 transcritical plant and what each function will cost at 15c/kWh, as well as an estimate of the annual power bill. "I compare it to different plants running on R404A or R134a and tell them that this is the cheapest to buy and most expensive to run over 10 years."

"The customer has a certain amount to borrow over the basic plant and unfortunately not everybody can finance it."

F. Mayer had the advantage of owning its Melbourne facility – unlike its Sydney counterpart, which is leased. "To build a premium plant enables you to get a higher price when you sell, as well as negotiate a better lease deal. As a result we were given a much more favourable hand in the process."

Wilson is excited by the transition to CO_2 transcritical in industrial applications occurring in Australia and New Zealand and undoubtedly sees bespoke solutions as the key to optimal energy efficiency benchmarking and drastically reduced environmental impact.

"Oh, it's brilliant! The thing is, people have got to stop thinking so [commercially], you've got to think like an ammonia [person]. When you go into an ammonia plant, what do you expect to see? Every [plant] is different. You don't know what you're going to see until you open the door. That's the way CO_2 should be done. If you want to optimise the system you've got to build the plant that is going to work for each client," he says.

"OK, if you're doing work for Aldi or Coles, and there is a standard layout and equipment schedule, then you can develop a standard package that can be rolled out over multiple sites – which helps service technicians come to terms with the technology. But working in the cold storage area, we start from scratch with each project and build what is going to work for that customer on that site," Wilson concludes.

US, Strathbrook's third iteration with F. Mayer is one of only six transcritical plants in Australia. Two more Strathbook installations feature among the six: their second-generation plant in Sydney and a training plant at the TAFE Western Sydney Institute's Nirimba complex.

The 2,568m² facility once again marked an improvement on earlier plant designs. The focus became making the latest transcritical CO_2 solution even more efficient by adding two ammonia chillers. Danfoss supplied the CO_2 control systems and all the valves and electronics.

"We knew the colder climate in Melbourne would benefit the CO_2," Wilson says. "Once again [F. Mayer], having seen the success of the last two jobs, had built trust and they had the budget."

One of the first alterations was to add water sprays to the gas coolers to pre-cool the refrigerant going into a secondary heat exchanger system by 5-10°C. The system pressure was raised only moderately, but the greatest energy efficiency gains came in the form of two high-demand 240 kW ammonia chillers, each with an extremely low ammonia charge of 4.9 kg.

"We knew the low-hanging fruit was to replace the R134a chiller with an ammonia chiller," Wilson says. "We optimised the system to reduce the charge, that was the key thing. Less is better." With a COP of 10:1, the two ammonia chillers each provide 240 kW of cooling at +15°C saturated suction with "a tiny bit of gas going around very fast in a tiny bit of pipe path".

Wilson had factory-built one of the ammonia chillers before accepting the Melbourne job with F. Mayer. He later heard from Bitzer that no-one in the world had yet mastered the system. "Bitzer refused to warrant the chiller because no-one in the world had been able to build one, including Hillphoenix, whose R&D budget is larger than our total turnover! No-one has been able to get it right. So we were worried. However, it runs really well."

Ammonia's superior functionality owes to its exceptional performance at high suction temperatures. "It's unique in that if you can keep the ammonia condensing temperature constant, let's say at 35°C, you can raise the suction. Normally your power goes up, but with ammonia, once you get above about 7.5°C suction, your power consumption goes down and you're looking at a COP of 12."

"The CO_2 transcritical was a cost-effective no-brainer in the freezer because it's so much more efficient than anything else."

Due to F. Mayer's exponential growth, another plant extension or new facility purchase was on the horizon. To future-proof the plant, Strathbrook put freezer equipment and a freezer floor in the chiller so it could be converted into a freezer at a later date. "Now, we can turn the transcritical rack off, take the pipes off it in the plant room, connect it to low stage, and turn the existing chiller into a high-stage rack."

The long-term gains are yet to be calculated, but early estimates since January 2016 suggest the system has increased energy efficiency by 20% from the second generation. "We weren't expecting that. But it's largely because the ammonia chiller is so


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CO_2 gas cooler & two ammonia chillers, Melbourne

much more efficient than the R134a chiller, yet only runs for 3-4 months a year in Melbourne."

Compared to the existing plants F. Mayer is operating on R404A, the transcritical plant is 15 times bigger in terms of floor space and twice the ceiling height; in effect, 30 times the volume. Yet despite a refrigeration capacity 30 times greater, the plant has not even doubled the power bill (70% increase).

In terms of environmental impact, the CO_2 transcritical system represents a global warming potential of 350 kg CO_2 compared to an R134a/R404A plant at 1,140,000 kg CO_2.

The Stage 1 plant attracted attention at ARBS 2012, where it was the winner in the Refrigeration Project Excellence award. The Stage 2 plant was a finalist in 2014, and an ammonia chiller project for Sylvan Mushrooms was a finalist in 2016. All this helped to win another level of trust from the customer. "The system has to be reliable because there's millions of dollars worth of stock in these rooms coming from a long way away, so you can't build something that's technically fabulous but dubious in terms of reliability. This is why we cascaded these systems together rather than compounding them. So far we've had no problems in terms of reliability whatsoever."

What if F. Mayer comes back a fourth time? "If they did, we would probably compound the transcritical systems on the high and low stage and do away with the heat exchangers. That would give you about a 5% gain in COP. We could also raise the suction pressure of the CO_2," Wilson says.

Mayer says he has engaged with a number of end users on the proponents of CO_2 technology. "I always tell customers or competitors who ask about our refrigeration about our use of natural refrigerants like CO_2 and encourage them to look into it. I usually give them Ian's details to have a chat, and explain how we heat the floors with liquid glycol and heat exchangers to get those extra savings."

AUSTRALIA'S FIRST TASTE OF CO_2

Wilson and Danfoss' Saund have known each other a long while. Since the first CO_2 experimentations with Lite n' Easy in 2003, both have travelled far and wide to compare and contrast solutions abroad.

Eager to obtain the comparison with an R404A plant, suppliers like Bitzer and Danfoss basically donated all of the equipment – including the racks, compressors and controls, as well as their time – to install them on the first test systems.

SYSTEM SPECS

The third-generation CO_2 transcritical system at F. Mayer's Altona, Melbourne plant has the following characteristics:

- Size of facility: 2,568m²
- Temperature range: 120 kW freezers (-20°C); 240 kW cool room (-4°C); 134 kW dock area (16°C); 52 kW chocolate room
- Transcritical system capacity: 306 kW
- Freezer: 4 Bitzer CO_2 compressors (3 high-stage)
- Chocolate room and dock: 3 Bitzer CO_2 compressors
- Chiller room: 4 Bitzer CO_2 compressors
- Four Danfoss DX evaporators
- Danfoss electronic TX valves
- CO_2 charge: 350 kW across three packages
- Two ammonia chillers: 320 kW total capacity
- Ammonia charge: 4.9kg each
- Bitzer piston compressors
- Supplies 17°C water
- COP of 8 to 10
- Gas cooler: Güntner 440 kW
- Control system: Danfoss 850
- Floor heating: cool glycol
- Defrost: warm glycol (50°C)
- Heat reclaim capacity: 20 kW
- Maximum pressure: 130 bar (typical pressure 60 bar)
- K65 high pressure copper pipework

The plants were conveniently about the same size as a Coles supermarket freezer (72 kW). They shared the same condenser and machine room, but had three separate blowers each. After 12 months and Wilson's studious daily monitoring, the R404A/CO_2 rack came out a little over 20.6% more energy efficient.

On the strength of that, Wilson's Bitzer bosses asked him to build two R404A/CO_2 systems for Coles. "At that stage we were about one year behind the retailers in Denmark," who were global leaders at the time. "I thought: 'Does it work? Is it reliable? Do the compressors stand up? Do the cases ice up? Is the owner of the supermarket going to be happy with it?'"

"You're going to hang the CO_2 flag on this one job and if you cock this up, no-one will ever do another one!" joked Wilson's bosses at Bitzer.

And so in 2003 Wilson hopped on a plane to Aarhus, Denmark and visited a retailer who had installed such a system there. What he first noticed while in the plant room was that the rack was blue, but half the compressors were green. Half the compressors had been changed before it was even two years old – the plant didn't work. "We thought: 'this isn't going to work, the compressors are going to shit themselves!'"

Further inspection with retailers in Copenhagen revealed compressors about the size of a shoebox. "I thought: 'I can do this – copper pipe, tiny compressor – let's do this, because I'd never seen one before.'"

Confident he could go to Coles in the knowledge the system was safe, Wilson built the first two-compressor CO_2/HFC rack in Bitzer's R&D department for Frigrite in Melbourne, who had purchased the design based on the Carrier setup he had seen in Denmark. The rest is history. JR

Will ice rinks go CO_2 in future?

Ammonia has long been the refrigerant of choice for ice rink installers. But it is facing growing competition from another natural refrigerant – CO_2.

– By Charlotte McLaughlin, James Ranson, Yukari Sahashi & Alvaro De Oña

Jörgen Rogstam, managing director of Swedish refrigeration engineering consultants Energi & Kylanalys (EKA), is in confident mood. "Ice rinks will go CO_2 in the future," he declares.

Thanks to their impressive energy efficiency, ammonia systems dominate Sweden's ice rinks. 85% of them use the natural refrigerant, with the remainder using R404A, R134a or other hydrofluorocarbon (HFC) refrigerants.

With HFCs currently being phased down in Europe under the EU's F-Gas Regulation, manufacturers of CO_2 technology are targeting the ice rink sector too.

Yet for CO_2, "commercialisation has been a problem," according to Rogstam. While ammonia has a long history of use in ice rinks, CO_2 was first used in an ice rink in 1999 – in an ammonia cascade system in Austria. The first ammonia ice rink was installed in New York back in the 1870s.

In 2002, the International Hockey Federation called for the adoption of CO_2 as the primary refrigerant for ice rinks. Yet it was not until 2010 that the first transcritical CO_2 ice rink was installed – in Saint Gédéon, Canada to retrofit an R22 system.

WHY HAS UPTAKE BEEN SLOW?

In the early 2000s, components for transcritical CO_2 systems tended to be expensive and lacked cooling power. During this time, "the CO_2 ice rink refrigeration system would have required about 15 [compressors], whereas a typical ammonia system would only use two compressors, which made the CO_2 system seem expensive and impractical," Rogstam says.

"Today the number of CO_2 ice rinks is growing rapidly. There are now 25-30 CO_2 ice rinks in the world," he says. 20-25 of these CO_2 ice rinks are in North America, 20 of which are in Canada (mostly in Quebec) and three are in Alaska, according to EKA.

Carnot Refrigeration has been leading the way in North America. Marc-André Lesmerises, CEO and co-founder of Carnot, which has installed 65 CO_2 transcritical systems in supermarkets across Canada and the US, sees potential for CO_2 applications "everywhere". Carnot has already put CO_2 systems in "eleven rinks in eight different facilities," according to Lesmerises.

In Europe the ice rink market has been slower to pick up. Although there are over 8,500 transcritical CO_2 racks in supermarkets, there are fewer than ten CO_2 ice rinks in Europe. This may in part be due to Europe's long tradition of using ammonia in ice rinks. In the US, strict public safety regulation in some states has prevented ammonia installations.

THE TIMES THEY ARE A' CHANGING

The more the cost of system components has decreased, the more people have invested in CO_2 transcritical technology, Rogstam observes. EKA installed the continent's first CO_2 transcritical ice rink in the small town of Gimo, Sweden in 2014.

During the first six months of operation the system's total energy usage was 296 MWh, saving the operator 60% in energy costs. "Our electric energy consumption is way below what I thought was possible. It is less than half the cost compared to our second ice rink," says the ice centre's Technical Operations Manager Lasse Karlsson.

"We are very proud to have this facility. If I were to build a new ice rink facility today, I would only consider CO_2, because the benefits are so great," Karlsson adds.

"There are six CO_2 ice rinks in operation right now. We, EKA, have designed five out of these six. We will probably add another five to seven CO_2 rinks by the start of next season [...]. There is a huge interest in CO_2 technology in the ice rink business right now," says EKA's Rogstam.

CO_2 is also making inroads elsewhere in Europe. The new home of the Belgian national ice hockey team opened in Mechelen, Belgium in September 2016. The SCM Frigo facility is the country's first ice rink to use CO_2 as the sole refrigerant and the first capable of operating all year round.
"We noticed a much better ice quality in this installation. The feedback from the skaters and users is clear: they feel the difference [with CO_2]," says Mirko Bernabei, technical director at SCM Frigo.

CO_2 SERVES BOTH HEATING AND COOLING NEEDS

Ice rinks consume an enormous amount of energy, with the average usage of a Swedish rink weighing in at around 1,000 MWh per year. Typically the refrigeration system – whose cooling capacity is usually 300-350 kW – is the main contributor, consuming about 43% of total energy. Heat reclaim can help to mitigate these costs.

"CO_2 has favourable properties for heat reclaim," argues Rogstam, pointing out that CO_2 systems installed for ice rinks can be used to heat adjacent sports facilities as well.

EKA argue that CO_2 is the ideal choice for integrated systems. "CO_2 can provide more heat at higher temperatures compared with other refrigerants," Rogstam says. Compared with ammonia, which can only provide 15% of heat above 35°C, CO_2 can deliver 60% of heat above 35°C – according to EKA research.

The system in Gimo, Sweden was not just able to cool the ice rink but also heat a swimming pool in an adjacent facility via a secondary loop. EKA is now seeking to improve the heat reclaim technology further to make it more commercially viable and to build more CO_2 ice rinks in Europe.

CO_2 ice rink, Mechelen, Belgium

SCM Frigo also used heat reclaim. Excess heat from the Mechelen system's operation is recovered to provide sanitary hot water, and underground heating for the arena seating and the bar annexed to the ice rink – reducing energy consumption.

The ice rink is the latest fruit of cooperation between Italian firm SCM Frigo and Belgian partner Sabcobel that has been going on for 10 years now, helping to increase knowledge of natural refrigerants in the Benelux region.

Sabcobel has come a long way since its first installation with natural refrigerants in 2005. "90% of the installations we do currently, both for commercial and industrial systems, are with CO_2," says Herwig Coppens, Sabcobel's general manager. That said, the company has previously worked with ammonia in ice rinks and continues to do so.

US NATIONAL HOCKEY TEAM: SKATING ON AMMONIA

Ammonia seems to be going strong. Leading North American firm CIMCO has had a strong relationship with the National Hockey League for some time. "I'm the point guy with the NHL," says Jose Mergulhao, CIMCO's US operations manager, who has worked at CIMCO for 21 years and is a big hockey fan.

Working closely with the NHL to design and install most of their ice rinks is a dream come true for Mergulhao. "I played hockey up to university as well, so it's fun," he says.

CIMCO has been a force in the North American industrial refrigeration market since the early 1900s. Originally a Canadian company, it is now one of the largest refrigeration companies in Canada, the USA and Mexico.

Back in April 2016, CIMCO completed an ammonia ice rink at the T-Mobile NHL arena in south Las Vegas, Nevada. The 650,000 square-foot (198,000 square-metre) ice arena features a 17,000 square-foot (5,200 square-metre) ice rink.

The arena, which hosts 100-150 events per year, is designed to be a multipurpose entertainment venue capable of hosting NBA and NHL teams, concerts, boxing, mixed martial arts, award shows and other major events. Coldplay, the Los Angeles Lakers and Billy Joel have all recently played there.

In Las Vegas, Mergulhao worked to NHL specifications to project-manage and put in place a CIMCO ice rink with impressive energy efficiency and safety credentials. "The two packages [ammonia refrigerant and glycol solution] are designed for the most possible charge that we can put in there," he says.

The ammonia charge is kept as low as possible by "optimising the condenser design, optimising the chiller, and reducing the charge," says Mergulhao, helping to make it even safer for NHL players to skate on.

Mayekawa's NewTon System at Saitama ice arena, Japan

CIMCO's attention to detail and willingness to adapt technology has allowed it to develop a long-standing relationship with the NHL, he explains. They plan to build an ice rink for the Detroit Red Wings, and a rink in Las Vegas will be completed soon.

Diversification holds the key to success in any business, according to Mergulhao. With CO_2 now part of CIMCO's ice rink portfolio, he is enthusiastic about the growth possibilities in this market. "We hold patents for CO_2 ice rinks in Canada" and patent approval is pending in the USA, he says.

Natural refrigerants will play a crucial role in CIMCO's future success. "You can either roll the dice and take another blend of refrigerant or take a natural refrigerant," Mergulhao says.

JAPAN LOOKS TO COMBINE AMMONIA WITH CO_2

In Japan, meanwhile, the number of ice-skating rinks has fallen in recent years. From a peak of 550, the number of rinks had dwindled to 150-170 in 2016. The decline is largely due to higher energy costs. Nonetheless the tide is starting to turn, thanks to the work of companies like Patine Leisure, which are adopting efficient, natural refrigerant-based cooling technology.

Patine Leisure is a Japanese specialist in the ice-skating business, designing and installing rinks while operating and managing around 50. It covers 90% of the ice-rink market in Japan, and plans to expand its business to other Asian countries.

In 2014, Patine Leisure turned a corner by partnering with Mayekawa, a leading distributor of industrial natural refrigerant-based cooling technology, to open a next-generation ice-skating rink in Saitama that uses Mayekawa's NewTon NH_3/CO_2 packaged unit.

Today there are eight ice rinks – from Patine Leisure and others – that use natural refrigerants in Japan. Around 150 rinks still employ R22 as the primary refrigerant, but as Patine Leisure has a stake in the majority of them, it hopes to convert as many as it can to natural refrigerant technology by 2020.

The policy is a culmination of a four-year journey that began in Canada with Akinori Ogiwara, Patine Leisure's president and a former speed skater. Since then, "becoming environmentally friendly and energy efficient by using natural refrigerants" has become one of the company's core ambitions, Ogiwara says.

In Canada, Ogiwara learned about an ammonia/CO_2 cooling system from Mayekawa that had been used in Sweden. He expected to hear about energy savings in the realm of 10%. What he discovered came as a shock: the energy savings were in fact closer to 30%.

Excited by the prospect, Ogiwara and his team took the opportunity to see the system in action in Sweden alongside representatives of Mayekawa. After the expedition, Mayekawa worked with Patine Leisure for two years on a joint R&D project to develop an NH_3/CO_2 trial system for an ice rink in Japan.


Akinori Ogiwara, president, Patine Leisure

After returning to Japan, Ogiwara started trials at the company's factory in Karuizawa. The testing took two years, using ammonia freezers and CO_2 refrigerant, and comparing cooling pipes made of copper, aluminum, and other materials. The results revealed even higher energy savings of 50%.

Patine Leisure is also working on a new speed-skating ice rink project in Japan. If all goes according to plan, construction will start in 2017 and be completed in 2018.

CO_2 is unlikely to replace ammonia, but it looks like NH_3 will no longer dominate the market so dramatically. The duo are set to get the world skating on 100% natrefs! ■ CM, JR, YS & AdO

Target's propane programme rolls on

US discount supermarket chain Target has committed to using self-contained propane showcases in 580 of its stores across the country.

— By Michael Garry & James Ranson

At a White House-hosted meeting back in 2015, the Minneapolis-based retailer made its first pledge to convert all small self-contained cases to propane-based equipment.

Fast-forward to 2017 and Target's strategy has continued unabated, with plans to operate 580 of its 1,800-store fleet with nothing but propane cases for refrigeration. "We continue to proceed with that," says Target's director of engineering, Paul Anderson.

Speaking at the Food Marketing Institute's Energy & Store Development Conference in 2015, Anderson provided data on Target's evaluation of the energy efficiency of propane cases. Propane was found to use 53% less energy than R134a; annual savings for a chain of 100 stores with 10 cases per store would have come to AU $56,800 at the time.

Target was one of the first North American food retailers – along with Canadian grocer Sobeys – to make a public commitment to natural refrigerants in its stores. It installed an R404A-CO_2 cascade system in a store in 2010 and followed up by introducing propane in its beverage coolers.

Target also plans to complete its first few transcritical CO_2 stores in 2017, with the first scheduled to open in San Francisco in March.

Target Australia Pty Ltd. operates 308 stores in Australia but has no corporate affiliation with Target in the US. Operating under the same parent company Wesfarmers, major retailer Coles installed three hydrocarbon (R1270) water-loop showcases at the company's Coburg North store in 2016.

UK manufacturer Carter Retail Equipment provided the equipment to Coles and has so far installed over 20,000 of the water-loop systems throughout Europe and Asia. The factory-assembled water-loop systems chosen by major UK retailers like Waitrose require no work on site.

In Belgium, the Colruyt Group has wrapped up the production of all HFC-based systems, making a blanket commitment to hydrocarbons in late 2015. The retailer chose propane as the refrigerant for its compact chillers, which contain just under 2.5kg of refrigerant. Each provides 30-50 kW of refrigeration capacity.

"We were already adopting natural refrigerants before the European F-Gas Regulation came into force. The F-Gas Regulation was not the primary driver, but it does give us an extra stimulus," Colruyt Project Engineer Collin Bootsveld told *Accelerate Australia & NZ*'s sister publication *Accelerate Europe*. MG & JR

VOLUME 3

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Spotlight on Australia: *Innovations shaping change in 2017*

Accelerate Australia & NZ looks ahead to the next twelve months and beyond, hearing from local vendors about the technological innovation, policy developments and evolving standards that are creating new opportunities for natural refrigerants in industrial applications.

— By Devin Yoshimoto, James Ranson & Andrew Williams

Australia's uniquely remote landscape and strong agricultural sector have produced a long history of large-scale industrial plants using ammonia.

In modern times, the focus has been on optimising energy efficiency and reducing the ammonia charge, and as a by-product, carbon emissions, by harnessing cutting-edge technology.

It's no surprise that the convergence of these two goals has given rise to the proliferation of low-charge ammonia technology not just in Australia but all around the globe, as updated regulatory guidelines pave the way for increased uptake of this historic natural refrigerant.

In the US, for example, a growing number of industrial refrigeration end users are installing packaged low-charge ammonia units, in a major break from traditional refrigeration technology.

The NXTCOLD low-charge packaged ammonia refrigeration system has already been installed in several big cold storage facilities like LA Cold Storage, Lineage Logistics, Baker Cold Storage and Neptune Foods.

The beauty of the technology is that low-charge NH_3 systems can be applied in much smaller applications than conventional NH_3 'liquid overfeed' systems, typically used in semi-industrial applications of 30-50 kW and above.

LOW-CHARGE AMMONIA TAKING HOLD DOWN UNDER

Scantec, a leading Australian supplier of low-charge ammonia systems, recently commissioned two new projects, in Melbourne and Brisbane.

Scantec Managing Director Stefan Jensen argues that low-charge NH_3 systems can deliver 3-4 times as much cooling capacity per kilogram of charge than liquid overfeed systems.

"We recently commissioned our new low-charge NH_3 *ScanPAC* in Melbourne; this has an alcove evaporator with automatic ambient air defrost," says Jensen.

The Brisbane project, for a Japanese end user, was recently completed under significant time pressure, the Scantec boss reveals. The end user relocated from other premises to meet increasing demand for its product and was after a premium system.

"In Brisbane, the first stage compressors operate at -27°C saturated suction temperature, and the corresponding freezer store temperature is -22°C. This particular plant employs Japanese compressors and custom-engineered evaporators with special circuiting and distributors from a German manufacturer," Jensen says.

He is quick to point to the various benefits of low-charge systems compared to industry standard HFC-based systems, and for good reason. "The only feedback from the end user we've had is happiness."

"The initial capital investment differential between an industry-standard HFC-based, single-stage compression system (with air-cooled condensers and electric defrost) and a state-of-the-art, low-charge NH_3 system is usually returned in three years," Jensen says.

"The documented annual energy consumption difference between the two scenarios described above is 40 to 67%, depending on the circumstances, with the low-charge NH_3 system being the best performing," he reveals.

Jensen was discreet on confidential new projects but mentioned three more low-charge systems currently under construction in Sydney, Brisbane, and Dongguan in China.

In the US, meanwhile, the market continues to see impressive demand for low-charge technology.

Scantec's recently commissioned low-charge ammonia ScanPAC system, Melbourne

CO_2 transcritical system at F. Mayer's Banksmeadow, Sydney plant

"Owners and contractors are rapidly learning about the success of recent low-charge ammonia projects and their inherent benefits," says Kurt Liebendorfer, vice-president at Evapco.

CASCADE TECHNOLOGY STEPS UP TO THE PLATE

While stand-alone ammonia systems cater to various industrial applications, the market is currently marked by another trend – the adoption of NH_3/CO_2 cascade systems.

United States Cold Storage (USCS) – a refrigerated storage and logistics company – has now fitted 12 of its 36 cold storage facilities across the US with NH_3/CO_2 technology.

Mike Lynch, vice-president of engineering at USCS, is convinced. "The use of natural refrigerants such as ammonia and carbon dioxide, when used in a cascade refrigeration system, allows [companies] to operate very safe and highly-efficient refrigeration systems. We expect to bring another two to three new NH_3/CO_2 cascade refrigeration systems online in 2017."

Ian Wilson, project engineer and co-owner of Australia-based Strathbrook Industrial Services, has worked on his fair share of large-scale CO_2 systems, including some of the first CO_2 transcritical systems in the country (see cover story p. 24).

The company provides bespoke CO_2 and ammonia refrigeration plants for industrial end users and sees a combination of both refrigerants as a clear path forward.

"We currently hold two patents. The first is for our transcritical CO_2 system with the high demand, post-gas cooler chiller; and the second is an innovative freezer floor heating system," Wilson says.

"The transcritical system basically ensures the plant never runs in supercritical mode – therefore it maintains the best possible energy efficiency. The floor heating technology extracts heat from the liquid refrigerant and passes the heat into glycol that is pumped through the freezer floor."

Wilson explains that this warms the freezer floor and sub-cools the liquid at the same time, essentially ensuring free floor heating. "Who do you know that has a freezer floor that pays you to provide the under-floor heating, rather than gives you a power bill?!"

The global demand for industrial transcritical CO_2 is such that Denmark-based manufacturer Advansor has now dedicated a team to the industrial sector. "We've realised that demand for transcritical [in the industrial sector] has grown to the level where we can go in that direction," says Advansor's industrial sales manager, Mark Kristensen.

Most of Advansor's industrial transcritical systems operate in cold storage facilities. "But blast freezing is a growing area, because you can operate the systems down to -48°C," says Kristensen. "You don't need a more complex cascade system; it's purely CO_2."

US-based Hillphoenix, Advansor's parent company, has installed 250 CO_2 transcritical racks in the last three years, while Dorin S.p.A, Systemes LMP and Green & Cool (Carrier Group) are among the manufacturers expanding their global reach and overcoming performance challenges facing CO_2 transcritical systems in warm climates like Australia's.

Japanese manufacturer Mayekawa, known for its NewTon NH_3/CO_2 systems for small and large-scale industrial applications, offers its Unimo CO_2 heat pump on the Australian market.

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Three multi N6HK heat pump units, meat processing plant, South Australia

Mayekawa's Australian arm has already installed five UnimoAWW dual heat source CO_2 heat pumps Down Under. Mike Ono, senior consultant – industrial automation at Mayekawa Australia, confirmed the fifth installation for the King International Group's soy product processing centre in Brisbane at the end of 2016.

A BRIDGE TO AMMONIA

Strathbrook's Wilson – a man who clearly embraces a challenge – says ammonia will be central to the company's plans.

"Natural refrigerants require interesting systems, and I like a challenge. If everyone waits for someone else to do a thing, it doesn't get done. If you do the numbers and the theory stacks up, have some confidence in yourself and have a go!" he says.

"I think ammonia is a great gas. If it didn't smell so bad, it would be everywhere! That's not to say it's always the best choice, because it isn't, but it certainly performs very strongly in particular application ranges. It's a no-brainer if the system is in the megawatt range," Wilson says.

Strathbrook is looking at cold storage and distribution centres, namely clients looking for long-term gains with systems that are not carbon-intensive and thus insulated from climate change regulation.

"Our super-low charge ammonia chillers are being further developed to simplify the build process and to see if we can lower the cost. The fact that the COP is more than twice as good as a Chinese-assembled R134a chiller doesn't mean everyone wants one!" Wilson says.

Like Strathbrook, Scantec sees a significant role for ammonia if manufacturers can persuade end users of the greater long-term energy efficiency and cost gains available.

What sets Scantec's systems apart is that instead of pumping the refrigerant around, they utilise the normal pressure differences in the system – between condensing and evaporating pressure – to facilitate the process. "We've redesigned the way the evaporators are circuited, we have refined the way the temperature, pressure and quality sensors are positioned, and we have paid particular attention to the thermal conductivities of the evaporator materials," Jensen says.

Scantec has also developed a new control system that modulates injection into the evaporators. The control methodology relies on a combination of super-heat signal and quality signal at the evaporator exit. "We believe this control principle can be applied very broadly and very cheaply to a range of applications, including air conditioning. It's simply a matter of numbers to get the price down," Jensen says.

STANDARDS AND REGULATIONS

Safety regulations govern the use of ammonia in Australia.

"Once it becomes known what additional safety measures the new 4,500 kg ammonia inventory threshold in AS/NZS 5149 triggers, then the impact on systems with large charges could become as significant as PSM/RMP compliance is in the US. The latter is triggered by an ammonia inventory of 10,000 pounds (4,536kg) – 5,000 pounds in some jurisdictions," Jensen explains.

In response, Scantec is continuing to test new concepts that place the issue of future regulatory compliance firmly in the rear-view mirror.

"Suffice to say that 2017 will most likely be the year where a totally new hot gas defrost concept will be tested and verified," Jensen says. "This has the potential to further reduce ammonia inventories in low-charge NH_3 systems of the central type."


Evaporator coil, low-charge DX ammonia system

NewTon NH_3/CO_2 system

"There will also be an expansion of low-charge NH_3 technology into areas other than refrigerated warehouses," the Scantec boss says.

"Similar trends are visible in other jurisdictions – in particular in the US. It will not be possible, however, to sacrifice energy efficiency in return for ammonia inventory reduction. This would go against the intent of [climate objectives]," he says.

Herein lies the real engineering challenge. "This is where the new hot gas defrost system mentioned previously can contribute further to additional charge reductions," Jensen argues.

Strathbrook's Wilson, meanwhile, points out that the elephant in the room – R22 (with a GWP of 1,700) – still lingers on the market. "R22 is still out there in large volumes and most of the systems we have removed have been replaced with chemical refrigerants," he says.

STATE OF THE MARKET

For Scantec's Jensen, one of the most significant challenges facing the HVAC&R sector is shortsightedness. "Unfortunately, large sections of the ammonia industry are quite conservative and want to keep providing the same proven solutions year-in, year-out, with minimum risk and innovation," he says.

"Owners and operators of warehouses are, to a significant extent, unaware of what is emerging globally and what the consequences will be for them. Often their local service provider is unable to offer future-proof solutions based on natural refrigerants, and most owners rely completely on local service providers for refrigeration advice," Jensen says.
Charting a more environmentally friendly course can be problematic if service providers are reluctant to transition away from the HFC systems they are familiar with.

"New cycles of synthetic low-GWP refrigerants do very little for energy efficiency but will gain temporary market share based on convenience, lack of skills and short investment horizons. The result will be that end users pay twice, when they should only pay once to get a future-proof system," Jensen argues.

Strathbrook's Wilson believes that some end users and operators are simply unaware of the benefits of looking ahead that little bit further.

"The biggest obstacle is that there is a lack of understanding of how much cheaper it is to own a natural refrigerant system than an HFC system," Wilson says. "We are seeing power reductions of 60% compared to a conventional R404A system. The payback is usually about five years between the two, so it's not for everyone. Power is not going to get cheaper, ever! Less power is the only way to reduce your cost, and higher power cost shortens the payback."

POLICY DIMENSION

While government can play a key role in helping, managing, and encouraging change, Jensen sees lack of government aid as the biggest failure in Australia's case. "To ensure long-term survival [of the industry], this needs to change, but it needs to happen without individual business entities accepting excessive technical and commercial risks. For instance, the industry could be assisted by government with funding for demonstration projects."

One way government can help is by implementing a change management process. "This should be put in place, rather than merely leaving it to industry to deliver what is needed for compliance with the COP21 agreement this government ratified, as well as the amended Montreal Protocol," Jensen argues.

Scantec's recently commissioned low-charge ammonia ScanPAC system, Melbourne

"This is, to a very large extent, a function of how change is managed. This is a responsibility that rests with government. The Australian government has issued conflicting signals previously in relation to environmental issues. One example was the carbon tax. Another was the carbon equivalent levy on HFC refrigerants introduced in 2012 and abolished in 2014," he says.

Wilson, too, admits that the carbon tax helped a great deal. "Since its removal, most of our competitors offer R134a and R404A, and in the majority of cases the end user wants the cheaper option. The industry has a long way to go before it's ready for the HFC phase-out that's inevitably coming."

WHAT'S NEXT?

Jensen urges the Australian government to move quickly to implement the Kigali Amendment to the Montreal Protocol, which obliges developed nations to phase down HFCs by 85% by 2036.

"It is also worth observing that Australia does not appear to have a national energy plan similar to some of the EU-based energy agencies that were implemented following the energy crisis way back in 1974," he says.

"Now that the Australian government has joined with 196 other parties in amending the Montreal Protocol and also finally ratifying the COP21 agreement, it is time to send a clear signal to industry as to what the direction for HVAC&R will be," Jensen believes.

The market needs clear signals as to which way the wind is blowing. "A ban on the use of HFC refrigerants in all new refrigeration and air conditioning systems effective as of 2025 (with a charge exceeding 5kg and all new systems with a charge less than 150g) would send such a signal," he argues.

Jensen believes there are huge opportunities for the industrial refrigeration sector to improve performance through more active engagement and co-operation with the private sector and all levels of government.

"Replacing the bulk of the HVAC&R stock in Australia is a must. The very significant energy savings that will potentially flow from that (if the government plays its cards right) represent an opportunity for the nation to improve its competitiveness internationally," he argues.

As attention turns to the longer term, it is clear that Australian industry has an opportunity to capitalise on its technological know-how to bring natural refrigerant solutions to a wider audience. DY, JR & AW

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CD 400

CDS

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Ejectors:
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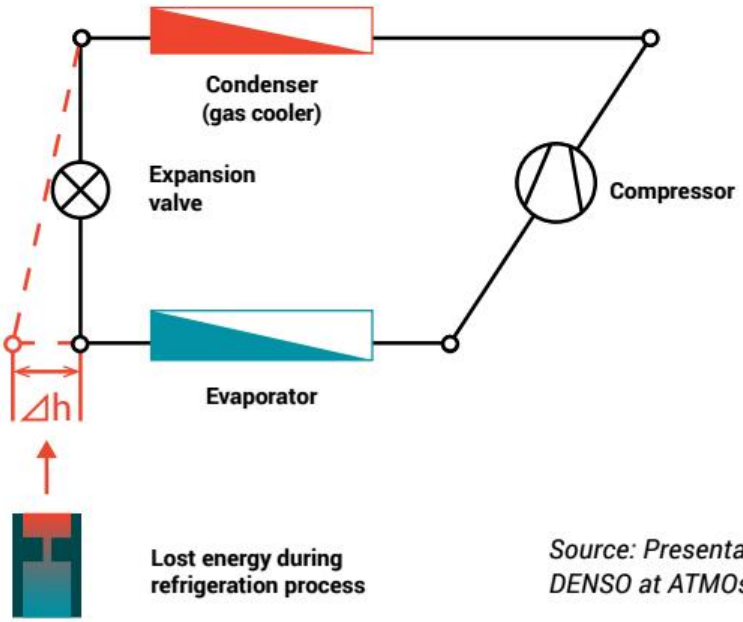
In today's dynamic refrigeration world in which CO_2 systems are becoming ever more innovative, ejectors are bringing the natural refrigerant to new locations and applications.

— By Charlotte McLaughlin

FIGURE 1:



Source: Presentation by Masahiro Takatsu, DENSO at ATMOsphere Asia 2016

Overcoming the so-called 'CO_2 equator' – the previously accepted geographical limit for cost-effective and efficient performance of CO_2 systems in all food retail store formats – would dramatically extend the scope to use CO_2 as a natural refrigerant across the spectrum, from smaller convenience stores to large hypermarkets.

The power of ejectors to help deliver this vision has never been clearer to the commercial refrigeration sector. With more companies entering the market and new ejector models being developed, *Accelerate Australia & NZ* asked industry experts how the technology works and why it is important.

Reducing energy demand can help industry to meet economic and sustainability targets alike. In the commercial refrigeration sector, ejectors are one way to get there. The devices can improve the efficiency of refrigeration systems by up to 20, 30 or in some cases 40%.

How do they work? Figure 1 depicts the energy lost during the refrigeration cycle as heat is transferred between the condenser, expansion valve and evaporator. Introducing an ejector into this space can improve compressor efficiency by recovering energy that is normally lost during the vapour compression cycle. The ejector achieves this by increasing the compressor's intake pressure.

Sounds complicated, right? The essential point is that ejectors yield significant long-term cost benefits to end users.

DELVING INTO THE SCIENCE

In Europe, ejector manufacturers have tended to focus on commercial refrigeration. Two common ejector types – the fixed and the modulating ejector – have both strengths and weaknesses.

"I think that the best one is the 'fixed nozzle' ejector in combination with parallel [compression]" configured in such a way to maximise system efficiency, says Sergio Girotto, president of Italian refrigeration firm Enex.

Carrier and CAREL have joined forces to develop and industrialise an electronic modulating ejector, potentially putting an end to the concept of the CO_2 equator. Launched at the ATMOsphere Europe conference in April 2016, "the electronic modulating ejector is capable of increasing system efficiency by up to 25% - with annual averages of 10% in the typical climates of southern Europe," says CAREL's Alessandro Greggio.

Danfoss has begun looking into stacking ejectors on top of each other to improve efficiency gains even further. "The multi-ejector is not commercially available but we have several prototypes that are just built for purpose and can be ordered [by customers]", Torben Funder-Kristensen, vice-president of public and industry affairs at Danfoss, told *Accelerate Australia & NZ*.

Ekaterini Kriezi, another Danfoss technology expert, explains how the concept works. "The multi-ejector is capable of recovering energy while controlling the high pressure of the transcritical application. [This] eliminates the need for redundant, cascade refrigeration systems, providing improvements in energy efficiency of 10% or more," she says.

Ejectors have long occupied the minds of academics. At last August's Gustav Lorentzen conference on natural refrigerants, many research papers looked into what ejectors are truly capable of. *Haida et al* demonstrated that the multi-ejector concept can increase a system's cooling power by 33% in their paper, 'Experimental analysis of the R744 [CO_2 as a refrigerant] vapour compression rack equipped with the multi- ejector expansion work recovery module'.

A comparison of various supermarkets carried out by *Fredslund et al*, in the paper 'CO_2 installations with a multi-ejector for

supermarkets, case studies from various locations', concluded that "operation efficiencies [can be] above 25%" provided that certain design conditions like pressure, oil and compressor size are met.

Smolka et al compared both fixed and modulating ejectors, determining that it is difficult to compare them as energy savings often depend on how the ejector is integrated into the system's design.

"I do not believe that some companies claiming to produce them have really understood the challenge," says Enex's Girotto. Despite the complexity of the science behind ejectors, the body of research clearly reveals that ejectors are capable of delivering huge energy savings.

TRAINING PLAYS KEY ROLE IN WIDER ROLLOUT

Ejector manufacturers often provide training themselves, so lack of training is not much of a barrier to increased ejector use. "Using ejectors is not complicated. It just means some things need to be different," says Girotto. "You just need to provide training, especially for installation," he argues.

Carrier also helps contractors and end users get to grips with ejectors. As reported in the spring edition of *Accelerate Europe*, Carrier's CO_2OL academy training facility in Mainz, Germany offers bespoke training programmes within a 400m^2 store environment.

The firm also provides wider training on CO_2 systems at the Mainz facility.

Industry experts quoted in the report 'F-Gas Regulation: Shaking up the HVAC&R industry' argued that the cost of ejectors is a non-issue – insisting that adding ejectors and parallel compression increases the price of a system by 10% at most.

Data from Danish CO_2 rack manufacturer Advansor reveals the strong relationship between increased efficiency of CO_2 systems and falling component prices (see Figure 2, p. 51).

TRAVERSING THE 'CO_2 EQUATOR'

Danfoss point out that the multi-ejector solution has been engineered specifically to overcome warm climate conditions. "We have reduced energy penalties associated with operating transcritical CO_2 systems in high ambient temperatures, making transcritical CO_2 systems more efficient than HFC systems in any climate zone," says Danfoss' Kriezi.

Over 100 manufacturers, retailers, contractors and consultants gathered in the Italian city of Padova on 29 September 2016 to address the issue of how developments in ejector technology can improve the performance of CO_2 refrigeration systems in warm climates.

Enex's Girotto, who helped to organise the Padova event, demonstrated how using ejectors improves upon system design. "This is critical in a southern European climate, because several component breakdowns were recorded using the conventional system in warm climates," he says.
"With ejectors, units in Italy are working during the warmest summer days at air temperatures of higher than 40°C for a significant number of hours. It means that even if they have not yet been installed in the extreme south of Europe, like Greece, they will work there," Girotto explains.

OPPORTUNITIES ELSEWHERE

Ejectors can improve system efficiency wherever they are deployed. "In the warm climates of southern Europe, Carrier's high-efficiency vapour ejector system has achieved total store energy savings of more than 13% versus our standard transcritical CO_2OLtec system. Similar energy savings may be achieved in northern climates, although this depends on a number of factors such as ambient temperature profile and heat recovery configuration," says James Nutting, director of marketing, key accounts and sales development at Carrier Commercial Refrigeration Europe.

"In addition, the ejector can be combined with other high efficiency components including the economiser cycle and liquid pump to further maximise energy savings across all climates," Nutting says.

Danfoss has installed over 50 ejectors in Europe. Once it has refined the technology in the European market, the company plans to roll it out elsewhere. "We now have to get a good foot in the market. We will then push in North America in the second instance and then we will go to other markets," says Funder-Kristensen.

Enex has sold about the same number of ejectors as Danfoss in Europe, including in Italy, Poland, Romania, Switzerland and Germany. Most European countries, with the exception of Scandinavian nations and northern Germany, would benefit from ejectors and parallel compression, according to Girotto.

"Those countries all have at least two to three days of warm temperatures from an operational point-of-view," he says.

Girotto says Enex is open to partnering with a US company to bring its systems to the United States.

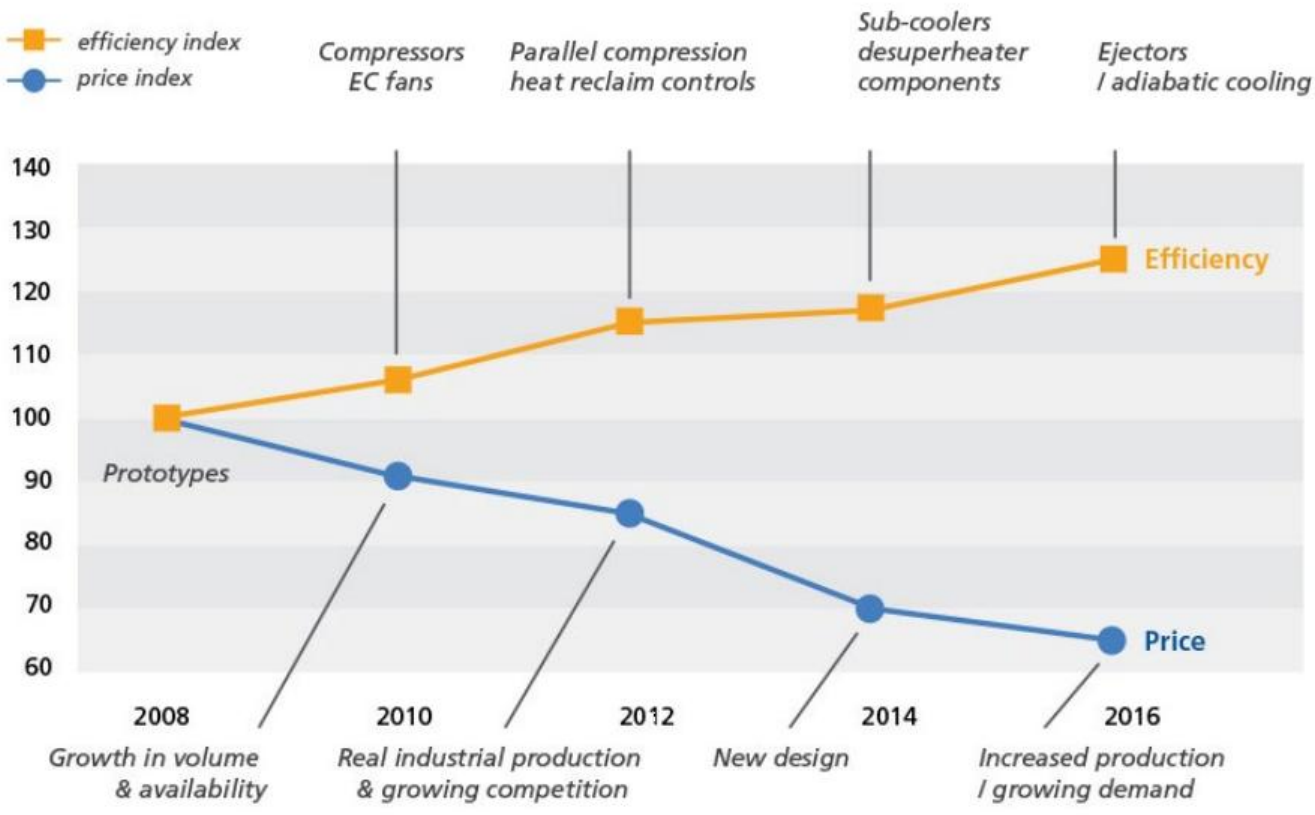
Other companies sense an opportunity to develop their own ejector. Compact Kältetechnik's Stephan Leideck told *Accelerate Australia & NZ* that the company's ejector for transcritical CO_2 systems would hit the market in 2017.

The German manufacturer assembles custom-built CO_2, ammonia and propane solutions according to market demand. "The examples at [Chillventa 2016] are made for our customers and they will go to them after the show. Due to the market situation we decided to manufacture our own ejector," says Leideck.

The company is currently testing a prototype at its test site. It plans to bring to market in 2017 a gas and liquid ejector system with a built-in controller – developed together with German controls manufacturer Eckelmann.

Accelerate Australia & NZ has heard whispers of other commercial refrigeration players in the CO_2 arena taking the plunge. Stay tuned for more on this story! CM

FIGURE 2:



Source: Advansor, ATMOsphere Europe 2016

Heat pumps, *system integration herald bright future for natrefs*

The refrigeration devices of the future will provide heating alongside cooling, harnessing natural refrigerants to help reduce electricity consumption and wean the world off fossil fuels, argues Eric Delforge of the European Heat Pump Association (EHPA), which represents the heat pump industry in Europe.

– By Andrew Williams

Eric Delforge, EHPA

Driven by innovation and a passion for sustainable solutions, EHPA board member Eric Delforge is keen to discuss ways of integrating heat pumps into smart energy systems on a massive scale. Comparing synthetic fluids to tobacco, he sees natural refrigerants as the only sustainable solution for the industry.

"In every refrigeration device, to a certain extent the refrigeration is a by-product of a cycle which in fact offers more heating than cooling," says Delforge, who chairs an EHPA working group on industrial and commercial heat pumps.

The trend towards more integrated systems is sweeping through the HVAC&R world just like in other sectors. "Especially in industry – sectors that use or need refrigeration also need heat, upstream or downstream. It's should be self-evident to combine the use of heating and cooling," the expert argues.

HEATING AND COOLING... WITH NATURAL REFRIGERANTS

Let us take the example of conventional fridges. Like other refrigeration technology, they use the traditional Carnot thermodynamic cycle of expansion and compression to reject energy. The rejected heat is pushed into the room via a heat exchanger at the back of the fridge or into the atmosphere via rooftop ventilation. "If on top of that you're burning fossil fuels for your heating, then in fact you're investing in a heating device twice," Delforge argues.

Rather than evacuating waste heat solely into the building, the EHPA expert believes refrigeration equipment should be connected to space heating systems. "In a house, you always need hot water – even in summer. The heat exchanger in your fridge should feed into your water boiler," he argues.

The logical next step would be for manufacturers of cooling devices and their boiler-making counterparts to offer heating and cooling in a single product – saving energy by requiring just one electrical input. "Why not? Heating and cooling with the Carnot cycle is simple, energy-efficient and doesn't need fossil fuels," says Delforge. "Ideally it should use natural refrigerants," he adds.

He argues that the effort required to deliver this vision pales in comparison to the trials of finding and extracting Earth's remaining fossil fuels.

The dairy industry epitomises his vision. "At the end of the chain, dairy products need to be cool. But before you can process the milk, it needs to be pasteurised. So the cooling plant offers waste thermal energy to provide water at 90 degrees Celsius for the pasteurisation process. You only need one electrical motor to do that, and the hot air from the cooling machine is reused," the EHPA expert explains.

MAYEKAWA PUTTING FAITH IN NATURAL REFRIGERANTS

Delforge is also corporate business and policy officer at Mayekawa Europe, where he sees his vision is shared. "The transition of this century is to stop burning fossil fuels," he declares.

With HFC phase-down deadlines under the EU's F-Gas Regulation on the horizon, he believes that "for natural refrigerants, we're well beyond the point of no return".

In Europe, he observes that many companies that have been actively using HFCs in their technologies are slowly but surely making the transition to natural alternatives.

Delforge sees opportunities for natural refrigerants here. "It will be a huge challenge for the chemical industry to justify the penetration of HFOs into the industrial market. I'm confident that end users will leapfrog them and decide to go for natural refrigerants," he says.

"If as a company you opt for a chemical as the refrigerant, you're bound by the technical boundaries of that refrigerant. Your customers will also be at the mercy of availability and pricing" – thus you find yourself restricted in terms of the type of technology you can build, Delforge argues.

At Mayekawa, "we have a lot of experience in different applications and in different industries. This carries us forward

to proclaim that ammonia, CO_2, propane and other natural refrigerants are the solution – especially for industrial thermal applications," Delforge says.

HEAT PUMPS ON THE RISE

At the domestic and light commercial scale, he expects heat pumps to eclipse refrigerators in terms of their importance to the HVAC&R sector. What place for natural refrigerants here? According to Delforge, heating will play a crucial role in their growth.

"Most domestic energy goes into heating. Take Sweden: 90% of households use heat pumps, not condensing boilers. Imagine how much refrigerants they account for! The revolution is going to take place in households – switching from fossil fuels [in condensing boilers], which will one day be extinguished, over to heat pumps or hybrid systems. This accounts for dramatically more refrigerants than refrigeration only," he says, arguing that natural refrigerants will increasingly be applied in domestic heating applications.

Delforge is dismissive of those who believe that 2050 – the deadline by which the EU is seeking to cut carbon emissions to 80% below 1990 levels – is a long way off.

"Investments in thermal energy-generating devices are meant to last 20-30 years. A decision today to use synthetic refrigerants means being held hostage to consume them for 30 years," he warns.

Delforge compares today's battles over energy sources and the refrigerant mix to the past tussles of health advocates over tobacco. "It took fifty years for it to be accepted that tobacco is bad for your health. Production and use of synthetic refrigerants and fossil fuels are simply bad for our children and for the planet," he says.

"There is no other pathway than to step away from carbon-emitting activities and massively apply heat pump technology for heating, from domestic and commercial to industrial applications," argues Delforge, stressing the importance of ensuring that heat pump manufacturers opt for natural refrigerants. "Tomorrow is too late," he warns.

HEAT PUMPS IN THE HOME

Refrigeration on an industrial scale deals in megawatts, but a household heat pump accounts for just 5-11 kW. Putting his EHPA hat back on, Delforge nonetheless insists that the battle will be decided by the future choices of consumers.

"Domestic is going to be a game-changer. We're talking about a lot of devices. To influence the domestic market, you need to reach many more individuals – it's another public entirely," he says.

Delforge highlights the potential for governments to help change the game, drawing parallels with European legislation introduced to phase out incandescent light bulbs.

"I don't think there's any sensible citizen who'd like to turn back the clock on light bulbs. For refrigerants in certain applications, we need bold decisions from legislators," he says, citing the example of Denmark, where a political decision to ban most uses of HFCs is already delivering innovation benefits as demand for alternatives soars.

"Just imagine if French politicians – whose country is Europe's most electrified – were to decide, 'from 2020 onwards, every new building must have a heat pump'. It's doable and would be a game changer." AW

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California:
America's shining light

The Golden State's national leadership on environmental issues – never more important given January's change of administrations in Washington, D.C. – includes its latest plan to reduce emissions of HFCs and spark adoption of natural refrigerants.

– By Michael Garry

California Governor Jerry Brown, a longtime environmental advocate who acquired the moniker 'Governor Moonbeam' in the 1970s, came out swinging at a meeting of the American Geophysical Union in San Francisco in December 2016.

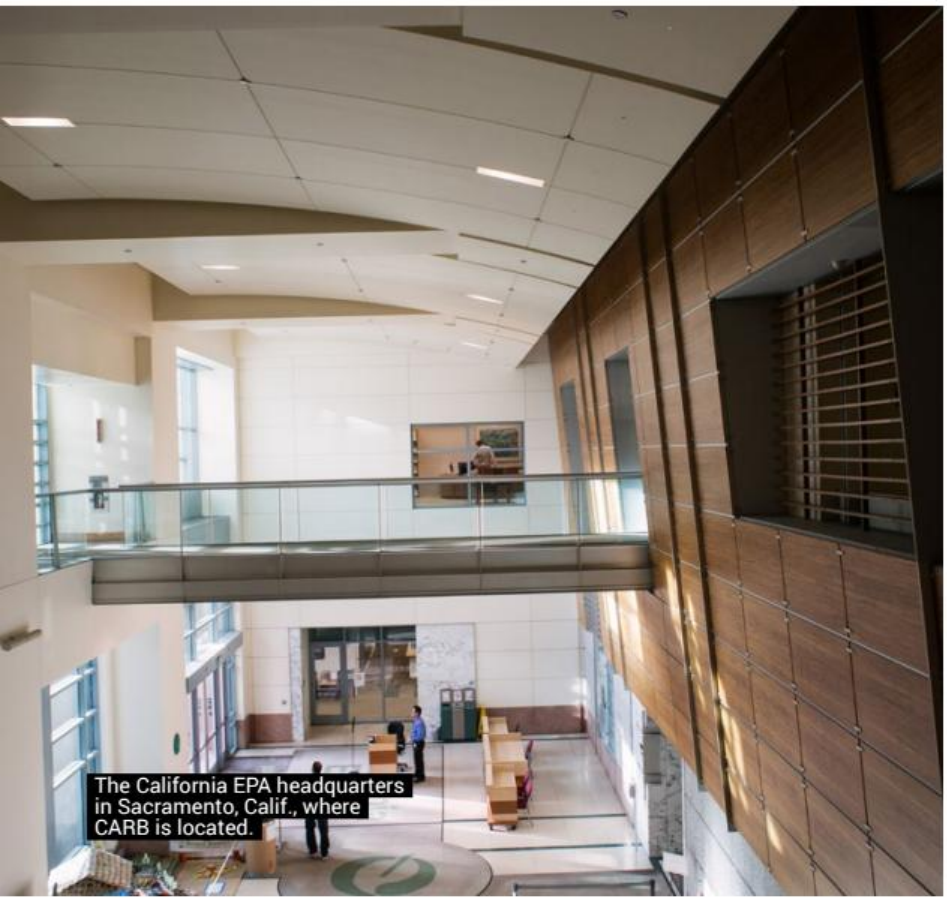
The 2,000 or so Earth and climate scientists in attendance were anxious about the incoming Trump Administration's penchant for downplaying or denying the science behind climate change. But Brown sought to reassure them that his state – the most populous in the United States and one of the 10 largest economies in the world, as well as the 12th largest carbon emitter – would not backtrack on its ambitious climate goals regardless of national policy.

"We have the scientists, we have the lawyers and we are ready to fight!" declared Brown to thunderous applause. And he reminded them of California's traditional and expected future role in leading the way for environmental progress in the US. "Our emission standards, our energy rules, drove US policy. We will set the stage, we'll set the example, and whatever Washington thinks it is doing, California is the future."

With regard to fighting climate change, California led the nation in 2006 with the passage of the Global Warming Solutions Act, or Assembly Bill (AB) 32, which established a comprehensive programme to reduce greenhouse gas emissions from all sources. Since then, the state government has adopted a cap-and-trade programme for emissions and updated its emissions reduction goal to 40% below 1990 levels by 2030.

On a global level, California has spearheaded the Under2MOU, an unprecedented alliance of 165 subnational jurisdictions (states and regions) representing more than one billion people and more than one-third of the global economy, which is focused on limiting global warming to below 2°C. The state has also signed a number of agreements to work with other countries on actions to fight climate change, including China and Mexico.

The state agency responsible for formulating and executing AB32's emission-reduction rules is the Sacramento-based California Air Resources Board (CARB). "California is determined to continue to play a leadership role in fighting climate change and ensuring that all Californians breathe clean air,"


The California EPA headquarters in Sacramento, Calif., where CARB is located.


Glenn Gallagher, CARB

said Glenn Gallagher, air pollution specialist at CARB. "We know there are other like-minded states that will continue to join with us in these efforts."

In addition to CO_2 emissions, CARB is also targeting greenhouse gases known as short-lived climate pollutants (SLCPs) – notably methane, black carbon (soot) and HFCs (hydrofluorocarbons). These 'super pollutants' remain in the atmosphere for a relatively brief time but pack a powerful warming punch compared to CO_2, the most common greenhouse gas.

"Science tells us that controlling [SLCPs] will buy time for countries to make the transition to clean energy while continuing to grow their economies," said Mary D. Nichols, chair of CARB.

With regard to HFCs (the fastest-growing source of greenhouse gas emissions), California's Senate Bill (SB) 1383, enacted 31 August 2016, sets a target for a statewide reduction of 40% below 2013 levels by 2030. By phasing down HFC emissions from refrigeration, air conditioning and other sources, the state is surpassing the US Environmental Protection Agency (EPA) and helping to shape the course of the HVAC&R industry in California and beyond, opening the door for environmentally friendly alternatives like natural refrigerant technology.

MIXED SIGNALS FROM AUSTRALIA

Australia, which infamously became the world's first developed nation to repeal carbon laws that put a price on greenhouse gas emissions, has committed to reducing HFCs by 85% by 2036 as well as greenhouse gas emissions by 26-28% below 2005 levels by 2030. But it is yet to disclose how exactly this will be achieved.

Further mixed signals were sent to industry in the shape of the carbon equivalent levy on HFC refrigerants introduced in 2012, which was abolished in 2014. In addition, Australia is yet to put in place a robust national energy plan similar to those of EU-based energy agencies.

Meanwhile, California began regulating HFCs and HCFCs in 2011 with its Refrigerant Management Program, which requires end users of more than 50 lbs. of high-GWP refrigerants to conduct leak inspections, repair leaks and keep records; the U.S. Environmental Protection Agency (EPA) only updated its leak inspection programme to include HFCs last year.

But the state will go much further in reducing emissions of HFCs and other SLCPs, as outlined in its Proposed Short-Lived Climate Pollutant Reduction Strategy. CARB will hold a public meeting of its governing board on 23-24 March 2017, when it will consider approving a final draft of the SLCP Strategy.

The Strategy calls for SLCP emission reduction to take place through a combination of voluntary and regulatory measures, including some that can promote adoption of low-GWP alternatives such as natural refrigerants. Among the proposed measures are: a ban on refrigerants with GWPs of 150 or more in new stationary non-residential refrigeration equipment and new residential refrigerator-freezers; a ban on refrigerants with a GWP of 750 or greater in air conditioning (non-residential and residential); and a prohibition on sales of high-GWP refrigerants (2,500 or more).

"CARB will focus on measures that can move low-GWP alternatives and technologies forward both nationally and internationally," said the November edition of the Revised Proposed SLCP Climate Pollutant Reduction Strategy. With its wide range of climates, California "could be instrumental as a proving ground for low-GWP refrigeration and air-conditioning technologies that can be used in extreme environments across the world".

The revised edition of the SLCP takes into account recent developments, notably the mid-October announcement in Kigali, Rwanda of an amendment to the Montreal Protocol, which calls for a global phase-down of HFCs. CARB will sponsor a third-party assessment of the impact of the Kigali amendment on HFC emissions and reductions in California.

CARB does not anticipate conducting its own HFC phase-down, "as long as the Kigali Agreement schedule proceeds as originally planned for the developed countries such as the US," said Gallagher. Pending further review and analysis, he anticipates that the Kigali Agreement will result in HFC emissions reductions that could cover approximately 55% to 75% of California's requirements (40% below 2013 levels by 2030).

One indication of California's leadership not just in natural refrigerant installations, but also leak prevention and charge reduction, is the number of stores that have received certification from the EPA's GreenChill Partnership; three of the nine current platinum-certified stores and 16 of the 31 gold stores are located in in the Golden State.

The US retailer with the most diverse array of natural refrigerant installations in California is Whole Foods Market. In addition to three HFC/CO_2 cascade stores in Northern California, the organic/natural foods giant operates four stores with transcritical CO_2, one with ammonia/CO_2 cascade and one with propane/CO_2 cascade (see 'Whole Foods Pushes the Propane Envelope,' *Accelerate America*, October 2016).

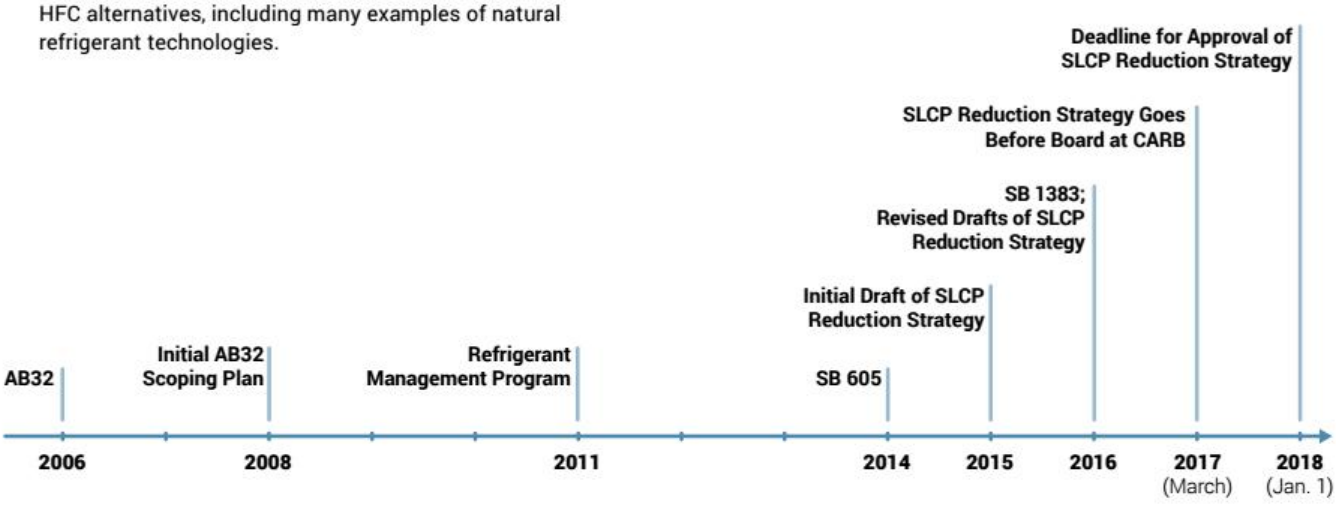
Also, the majority of the approximately 68 Whole Foods stores nationwide that use self-contained propane cases are located in California. Whole Foods was "an early adopter of the True and AHT [propane] spec" for self-contained systems, said Tristam Coffin, director of sustainability & facilities in Whole Foods Market's Northern California division.

Coffin estimates that 80%-90% of Whole Foods' natural refrigerant stores are in California. "California is a champion for progressive environmental legislation, which is a further incentive for us to move toward naturals quicker," he said.

Howell Feig, sales director for strategic accounts with AHT Cooling Systems US, estimated that of the more than 1,000 US stores equipped with the company's propane display cases, about 100 are located in California.

A MULTITUDE OF NATREF INSTALLATIONS

With specific HFC regulations looming in the next few years, California's food retailers, foodservice providers and industrial operators have been motivated to start implementing HFC alternatives, including many examples of natural refrigerant technologies.



Timeline for California Laws/Programs Impacting Natural Refrigerant Adoption

NXTCOLD low-charge-ammonia unit and cooling tower, on the roof of the Baker Cold Storage Facility, Long Beach, Calif.

US ENERGY UTILITY INCENTIVES

Another factor supporting the adoption of natural refrigerant systems in California is the availability of energy incentives from utilities to defray the initial cost of the technology. One of the more active utilities in this regard is SCE, led by Senior Engineer Paul Delaney.

"For Southern California Edison and other California utilities, it is about market potential and energy/demand savings opportunities," Delaney said. Most of the incentives are of the 'custom' variety tailored to a particular system, though SCE is also working on developing 'deemed' incentives given for classes of equipment.

Delaney is seeing more interest in natural refrigerant systems among food retailers and industrial operators than he did several years ago. "The usual players are still investigating and trying to understand ammonia/CO_2, CO_2, propane and other systems," he said. But the most activity with incentives has been with low-charge ammonia systems.

For example, SCE provided support from its 'Emerging Technologies' fund for evaluating a NXTCOLD low-charge ammonia system's performance in comparison to a traditional flooded ammonia system at a Lineage Logistics plant. "This funding essentially paid for about half of a retrofit system, engineering analysis and report," said Delaney.

The installation of 46 NXTCOLD units at a new Baker Cold Storage facility (overseen by Lineage Logistics) in California will be receiving incentives through SCE's 'Savings by Design' programme, which uses a "whole building" approach.

SCE is comparing the performance of low-charge ammonia systems "with more and more refrigerant baselines," including R22, R404A, R134a, and R507A.

SCE is also in the process of developing deemed incentives for propane self-contained cases. The process involves validating performance, followed by custom-incented projects "where we collect enough data to make the CPUC [California Public Utilities Commission] happy," Delaney said.

SCE has been less receptive to CO_2 transcritical, though it is now trying to work with interested customers in this space. "I am adding CO_2 transcritical systems to the laboratory efforts with EPRI," said Delaney. "With national interest from other utilities I see expanding, what started as a low-charge ammonia system evaluation, to as many configurations and refrigerants that make sense."

Delaney does not expect the change in administrations in Washington to deter what SCE and other utilities are trying to accomplish with energy-efficient natural refrigerant systems. "I would be very surprised considering the very large amount of money in EPIC [Electric Program Investment Charge] research funding and the CARB funding projects that reduce greenhouse gases," he said.

"There is every indication that we are not slowing down our efforts to evaluate and influence market transformation."

Low-temperature propane chillers on the roof of Whole Foods Market in Santa Clara, Calif.

Feig confirmed the openness of California retailers to the technology. "No California retailer we have spoken with has objected to AHT's propane systems," he said. "In fact, they have been pleased to learn that we are providing a solution that uses a natural refrigerant which provides greater efficiency." He attributed this to "the general population's view of the environment, progressive/forward-looking legislation, and energy concerns".

In the industrial refrigeration sector, California has been a hub for the installation of low-charge ammonia packaged systems, particularly those developed by NXTCOLD. While these systems are designed to replace refrigeration systems with much larger ammonia charges, they can also be used in lieu of industrial HFC systems.

The NXTCOLD system, developed by Chief Technology Officer John Scherer, is installed at 50 cold storage facilities operating across the US. In 2017, NXTCOLD units will be installed at a further 27 facilities, with the capacity of the units ranging from 15 TR to 75 TR.

Another industrial system, Mayekawa's NewTon NH_3/CO_2 unit, was installed at the company's Imuraya USA plant in California, which manufactures desserts for Japanese restaurants. Southern California Edison (SCE) and Mayekawa have been tracking the energy efficiency of the system and expect it to provide a 20-50% energy saving compared to an existing refrigeration system at the plant.

Though it is technology and chemical-neutral as far as low-GWP refrigerants are concerned, CARB recognises that natural refrigerants "are quickly proving themselves viable alternatives to high-GWP HFCs," said Gallagher. He cited several natural refrigerant technologies as being among those that "compete in a growing market for low-GWP refrigeration," including transcritical CO_2, low-charge ammonia, self-contained propane cases, ammonia-CO_2 cascade systems, and propane-CO_2 cascade systems.

"The rapid development of low-GWP refrigeration and air conditioning equipment in the past few years has been remarkable, and a very welcome advance in technology," Gallagher said. "We expect low-GWP options to become even better and less expensive in the next few years."

Among low-GWP options, CARB includes HFO chillers and air-conditioning, and low-GWP HFO-HFC blends for refrigeration and air-conditioning, deferring to the EPA SNAP programme's designation of HFOs/HFO blends as acceptable in certain applications. But CARB is aware of HFOs' conversion to trifluoroacetic acid (TFA) in the atmosphere, with resulting TFA accumulations in surface waters.

"At this time, it is not clear if HFOs will lead to significant environmental harm or not, with some studies indicating that HFOs will not increase TFA levels to toxic levels, and other studies indicating great potential harm from HFOs," said Gallagher. "However, CARB will continue to look into the potential long-term impact of HFOs contributing to increasing TFA concentrations to toxic levels in surface waters, and we have identified as a top f-gas research priority the potential HFO contribution to increasing TFA levels and any subsequent environmental impacts."

California's national leadership regarding natural refrigerants is reflected in its AU $660,000 contribution last year to industry research on safety standards for A3 refrigerants (such as hydrocarbons) and A2Ls. Other entities in the project include the Air-Conditioning, Heating, and Refrigeration Institute (AHRI), the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE), Johnson Controls, and the US Department of Energy. MG

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