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Hydrocarbons

The Quest For A Green Solution To The Changing Future Of Refrigeration And Air-Conditioning

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***The Hydrocarbon White Paper** by Morey Publishing*

Executive Summary:

Around the world hydrofluorocarbons (HFCs), which are powerful greenhouse gases, have started to come under increasing regulatory pressure and ultimately will be phased out altogether. As a result, the refrigerant industry should confront its use of HFCs now and plan to do without them in the near future.

HFCs have been found to have a potential for global warming that can be much more destructive than carbon dioxide. At first, these compounds were hailed when they were introduced to replace hydrochlorofluorocarbons (HCFCs), which were used as a substitute for chlorofluorocarbons (CFCs). In the 1970s, CFCs had been found to be causing a huge hole in the ozone layer above Antarctica. As a result of that disturbing scientific finding, the Montreal Protocol was established by the United Nations to phase out CFCs—and its success in this regard has been noteworthy. But researchers have since learned that HCFCs are not the solution, and they should be totally phased out by 2030 under the Copenhagen amendment to the Montreal Protocol. Recently some environmentalists and government officials have proposed expanding the Montreal Protocol's mandate to phase out HFCs as well.

And so the search continues. The refrigeration business is on the front line of this shift from using gases with a high global warming potential to adopting substitutes that are better for the Earth's atmosphere.

Finding a replacement remains a daunting challenge because the new material must meet ever tightening national and international environmental standards and prove both economical and safe to operate.

Among the promising alternatives in cooling technologies, hydrocarbons are showing increasing prominence due to their green energy properties and their ability to out-perform other refrigerants.

How The Montreal Protocol Played A Role In Developing New Refrigerants:

As the refrigerant industry knows well, there is no future for Freon. The reason is that this once widely popular product was shown to be one of the major causes of the rapid depletion of the ozone layer. This concentration of naturally occurring ozone gas molecules in the stratosphere filters the sun's ultraviolet radiation. When the ozone layer is diminished, more radiation reaches the Earth's surface, causing skin cancer, cataracts and weakened immune systems in humans, and crop reductions and marine food chain disruptions in nature. If all the ozone molecules in the upper atmosphere were compressed to the air pressure corresponding to sea level, the layer would be only 3 millimeters thick or less than one-eighth of an inch. But ozone's role in preserving life on the planet is huge.

Over the years molecules of chlorofluorocarbons (CFCs), hydrofluorocarbons (HCFCs) and other ozone-depleting substances (ODS) used widely as refrigerants, insulating foams and solvents would float up to the stratosphere where the sun's ultraviolet radiation started a chemical reaction. When these substances broke apart, they released chlorine atoms that put the ozone layer in jeopardy because one chlorine atom can tear apart more than 100,000 ozone molecules.

Unlike the naturally occurring chlorine released from volcanoes and oceans, the chlorine from CFCs and HCFCs does not dissolve in water and is not broken down in the lower atmosphere. That's why these human-manufactured molecules pose such a threat to the stratosphere—and why they are being phased out today.

According to atmospheric scientist Dr. Matthew Rigby, a research affiliate with MIT's Joint Program on the Science and Policy of Global Change and an advanced research fellow at the University of Bristol, once chlorine atoms reach the stratosphere and they've been zapped by ultraviolet light, they can trigger catalytic reactions.

"What that means is that this chlorine just persists up there," explained Dr. Rigby, "and it's free to destroy quite a few ozone molecules before it's eventually used up."

Until the ozone hole was discovered, the refrigerant industry, among other industrial sectors, was reluctant to believe that there was any harm associated with CFCs because these inflammable gases were thought to be so benign. Now the world knows differently.

"Actually it turns out that CFCs—and a lot of refrigerant gases—are really quite potent greenhouse gases as well," said Dr. Rigby.

Besides reacting catalytically to ozone, the CFCs also have a carbon-fluorine bond, which absorbs infrared light. When the sun warms the surface of the planet, the Earth radiates heat back into space in the infrared spectrum, the climate scientist explained, and that infrared light makes the carbon-fluorine bonds vibrate.

"What that vibration means is that the CFC can absorb the infrared light and radiate it back toward the ground," said Dr. Rigby. "Some molecules are much better than others at warming the Earth's surface and it so happens that CFCs—and a lot of gases that have these carbon-fluorine bonds—happen to be really good at absorbing infrared and then radiating it back."

Not only are they effective at global warming, CFCs also have a long shelf life, so to speak, staying in the atmosphere from 15 to 100 years or more, depending upon its molecular structure.

"Basically we're stuck with it for the next few centuries," Dr. Rigby said.

The use of hydrochlorofluorocarbons (HCFCs) has enabled CFCs to be phased out under the Montreal Protocol. In these alternative compounds, as Dr. Rigby explains, "some of the chlorine has been replaced by hydrogen. What that means essentially is that it's not going to be around long enough in the atmosphere to destroy the ozone."

But because there's still chlorine in these HCFCs, they still pose a risk to the ozone layer, and their carbon-fluorine bonds are still really potent greenhouse gases.

The next generation of refrigerant gases removes chlorine from the equation. Called hydrofluorocarbons (HFCs), they've got no chlorine in them anymore so they don't destroy the ozone layer. From the point of view of the stratosphere, they're benign. But because they have the carbon-fluorine bond in them and they can last more than 10 years before they disintegrate, HFCs still have a serious global warming potential.

Those reasons are why the refrigerant industry is turning toward alternatives like hydrocarbons, carbon dioxide and hydrofluoroolefin (HFOs), which don't linger around long enough in the atmosphere to contribute to more global warming. The need to deploy these alternatives is growing more urgent by the day.

"The risks we face are very serious," said Dr. Peter Frumhoff, the director of science and policy, and chief scientist at the Union of Concerned Scientists. "We're seeing evidence of climate change already across every continent, and across the oceans. The longer we wait—and the higher our emissions—the greater the risks and the more severe the impacts."

But Frumhoff and others like him remain encouraged by the success of the Montreal Protocol.

"We're already starting to see evidence that the ozone hole over the southern atmosphere is diminishing because of the decision to ban chlorofluorocarbons. We are seeing fundamentally positive change in the restoration of the ozone hole—change that would not have happened had we not moved aggressively internationally towards that ban."

It took a long time before scientists realized what was going on to the ozone layer. The first step to reverse the destruction was the ban imposed in 1978 on the use of chlorofluorocarbon gases as propellants in spray cans. Then in the 1985 scientists discovered that an "ozone hole" larger than the size of North America was opening in the atmosphere above the Antarctic every spring. If the world didn't act fast, the entire ozone layer around the Earth might be gone within a generation. If that happened, then spending just a few minutes outdoors in the summer could lead to severe sun burn.

For their landmark work on detecting the ozone depletion, Dutch scientist Paul Crutzen, MIT Professor Mario Molina and University of California at Irvine Professor Sherwood Rowland won a Nobel prize in 1995. Crutzen says we're now living in a human-dominated geological epoch he calls the Anthropocene, a term that is gaining ground fast in scientific and laymen's circles.

"The global climate is likely to depart significantly from natural behavior for many millennia to come," he wrote in his essay, "The Geology of Mankind."

And so in 1987, the Montreal Protocol was signed by 46 countries, including the United States, with the signatory nations pledging to reduce their use of ozone-depleting substances. At this point, more than 190 countries have ratified the treaty, which has been amended many times to speed up the phase-out of other problematic substances. Under the scientific guidelines, carbon dioxide is assigned a baseline measurement of its global warming potential (GWP) as 1, a thousand times less than what the potent greenhouse gases like hydrofluorocarbons have.

Over the last two centuries, the concentration of carbon dioxide in the air has risen by 40 percent while the concentration of methane, an even more potent greenhouse gas, has more than doubled. It's scientific findings like these that are driving the regulatory bodies to act.

According to a recent report from the UN's Intergovernmental Panel on Climate Change, the carbon dioxide, methane and nitrous oxide that the Industrial Age has poured into the atmosphere is now "at its highest levels in at least 800,000 years." The IPCC report said that if current global warming trends go unchecked, then by the turn of the century the average global temperature increase could be 4.6° Celsius (8.3° Fahrenheit). The damage from such an increase would be, in the language of the IPCC report, "severe, widespread, and irreversible."

"We have little time before the window of opportunity to stay within 2°C of warming closes," said R.K. Pachauri, chair of the IPCC, shortly before the recent climate talks got underway in Lima, Peru. "To keep a good chance of staying below 2°C, and at manageable costs, our emissions should drop by 40 to 70 percent globally between 2010 and 2050, falling to zero or below by 2100. We have that opportunity, and the choice is in our hands."

Here in the United States the Environmental Protection Agency banned the production of the most harmful HCFCs in 2010. The EPA could take this important step to meet the U.S.'s obligation to comply with the Montreal Protocol because of the increasing development of substitute chemicals and technologies. In the summer of 2014, the EPA proposed banning the use of certain hydrofluorocarbons (HFCs) in motor vehicles and aerosols among other restrictions. HFCs were introduced in the 1990s as non-ozone depleting replacements for both CFCs and HCFCs, which have been found to not only lead to ozone depletion but contribute significantly to global climate change.

Meanwhile ozone protection policies have been instituted internationally to meet the deadline. Canada's Ministry of Environment has established its baseline timetable of hydrofluorocarbon reduction. The United Kingdom has its Voluntary Green Guide (BRE). The European Union has called for a general phase-down of hydrofluorocarbon consumption between 2015 and 2030. Some countries like Denmark, Norway, Slovenia, and Spain have already started to impose taxes to accomplish this directive while France, Poland and Sweden are considering these measures. The Japanese Ministry of Economy, Trade and Industry has started regulating HFCs this year. China's President Xi Jinping pledged that China would take steps to reduce its greenhouse gas emissions starting with a new cap-and-trade system that would force domestic polluters to pay for their emissions next year.

As one of the first countries to ratify the Montreal Protocol, Australia has been a leader in the phase-out of ozone-depleting substances. According to the Australian government's Department of the Environment, Australia has met or exceeded all of its phase-out obligations under the Protocol. The country will largely phase out consumption of HCFC by 2016—four years ahead of schedule. By hitting that benchmark, Australia will be consuming 61 percent less HCFC in the period up to 2020 than what is allowed under the Montreal Protocol.

Under Australia's Ozone Protection and Synthetic Greenhouse Gas Management Regulations, new application fees for refrigeration handling licenses and trading authorizations increased Jan. 1, 2015, with the indexation based on the country's wage price figures. For example, a two-year refrigerant handling license that cost $134 in 2014 rose to $137 in 2015. The new fees help the Australian Refrigeration Council (ARC) administer the stricter regulations regarding the handling of ozone depleting substances and synthetic greenhouse gases in the refrigeration and air-conditioning industry. Another goal of ARC is to oversee the transition from fluorocarbon refrigerants to more natural alternatives including ammonia, carbon dioxide and hydrocarbons. As the government's Department of the Environment explains, "These substances have been used as refrigerants for many years; however, they are now finding their way into applications where previously fluorocarbons were the preferred option."

Around the world, government and industry leaders have taken aggressive steps to curtail the usage of ozone-depleting refrigerant and their global-warming substitutes. They're doing their part. Individuals can do theirs by educating themselves about the crucial issue of ozone depletion and global warming. In their daily life, American consumers can make sure that technicians working on air conditioning and refrigeration equipment are certified by the EPA and that harmful refrigerants are recaptured and not released. And whenever possible, the public can help influence decisions about what replacement refrigerants offer the best hope for the environment and make sure that they are given the top priority.

If the production of ozone-depleting substances ceases, then the ozone layer should start to return to normal levels by the year 2050 because the natural processes that create ozone would not be impeded. But any delay in complying with the Montreal Protocol makes it much harder to achieve—and that holdup threatens to put the world at risk.

Scientists and researchers around the globe have universally praised the Montreal Protocol as the most successful environmental treaty in human history, considering its speedy implementation, its near total ratification and its indisputable accomplishment in protecting the ozone layer from catastrophic destruction. Hopes that the Kyoto Protocol could match its success have been dashed as countries have been unable to agree on what measures, if any, should be taken to combat global warming, which was that treaty's intention. It targeted four main greenhouse gases—CO^2, methane, nitrous oxide and sulphur hexafluoride—and two other groups of gases, hydrofluorocarbons and perfluorocarbons (PFCs). Originally signed by President Bill Clinton's administration in 1998, the U.S. Senate refused to ratify the Kyoto treaty, in large part because of concerns that limits on emissions would unfairly harm the American economy. President George W. Bush withdrew from it altogether. Tellingly, the United States still releases more greenhouse gases than any other nation except for China, Russia, India, and the European Union.

Doing nothing in the face of the growing evidence of global warming is not an option. In December, the world's climate negotiators spent two weeks in Lima, Peru. They settled on preliminary language for an international agreement that will be hammered out in Paris later this year in order to prevent the planet from warming more than 3.6 degrees Fahrenheit—or 2 degrees Celsius, as it's more commonly described—by the middle of the 21st century from what the global average temperature was at the dawn of the Industrial Revolution.

The 3.6 degrees Fahrenheit target may not mean the world can breathe any easier, some scientists claim, since the increase in the average temperature could indeed trigger an irreversible meltdown of the Greenland ice sheet, which might raise the sea by as much as 23 feet, devastating coastal regions where most of humanity resides. How vulnerable the ice sheets are is a hotly disputed topic today. In the U.S. Congress, conservative politicians are still heatedly contesting the concept that global warming is something humans should even worry about, let alone mitigate.

But at the recently concluded Lima conference, some environmentalists seized on the opportunity to present their case that the world must do more to reduce CO^2 emissions as well as decrease the use of what these experts call short-lived climate pollutants (SLCP), which include hydrofluorocarbons among other substances. Taking those steps, they claim, would greatly improve the chances of keeping the Earth's temperature increase to less than 3.6 degrees Fahrenheit compared to its pre-industrial levels.

One of the leading proponents of this approach who was on hand at the Lima negotiations was Durwood Zaelke, president of the Institute for Governance & Sustainable Development, a nonprofit organization based in Washington, D.C. Zaelke, who co-wrote a paper with Nobel Laureate Mario Molina and Prof. V. Ramanathan at Scripps Institution of Oceanography, University of California, San Diego, called "As Climate Impacts Accelerate, Speed of Mitigation Becomes Key," highlighted the importance of taking fast action to cut these pollutants in order to slow down near-term climate change. His thinking is indicative of many scientists and environmentalists in the international community who want to use the Montreal Protocol as a tool to accomplish this goal. The refrigerant industries cannot afford to ignore them.

"The Lima agreement sets the table for Paris, but the deal will be meager indeed unless it is expanded to include fast mitigation from other available laws and institutions outside of the UN process," said Zaelke.

"Getting all countries on board is historic. But the commitments so far will be modest from many countries and collectively insufficient to prevent the growing climate crisis," he said. "This shifts a major mitigation burden to other available laws and institutions to shoulder, including the Montreal Protocol, which is ready to eliminate one of the six main greenhouse gases. It also means that the broad UN platform will have to get stronger quickly as countries learn how to reduce their emissions."

Zaelke praised President Obama for "pioneering an approach that embraces complementary mitigation opportunities, including the Montreal Protocol and the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants." The coalition, which was started by the U.S. and a small group of allies in 2012, now has 100 partners, including 50 countries, divided "fairly evenly between developing and developed," Zaelke said.

When President Obama signed the Copenhagen Accord in 2009, he joined other countries in trying to achieve this goal: "The world is committed to holding warming to no more than 2 degrees Celsius (3.6 degrees Fahrenheit)." Developed countries, the president promised, would mobilize to spend $100 billion a year by 2020 to assist the developing world address the challenge posed by climate change. Obama also pledged to reduce America's greenhouse gas emissions by 17 percent, at least, from 2005 levels by 2020.

At the recent Lima conference in December, Zaelke said that the world community should accept the limits of any future UN climate agreement that might come out of this year's Paris talks, considering the failure of the Kyoto Protocol to take hold, and instead act quickly now.

"Accepting the limits of the future UN climate agreement puts the spotlight on initiatives that can bring home additional mitigation, especially in the gap up to 2020," said Zaelke. "We could lose the game by 2020 without immediate mitigation to complement the future climate agreement. The need for speed is imperative, and the UN climate agreement is clearly not going to provide it on its own."

To observers like Zaelke, "the biggest and fastest near-term mitigation opportunity is to cut 'short-lived climate pollutants'—black carbon, methane and tropospheric ozone, and hydrofluorocarbons, or HFCs," he said. "Cutting these pollutants using existing technologies and existing laws and institutions can cut the rate of warming in half, and in the Arctic by two thirds in the near-term." He added that reducing these short-lived climate pollutants by the end of the century "can avoid up to 1.5°C of warming, comparable to aggressive CO^2 mitigation."

Last October, the governments of Canada, Mexico and the U.S. submitted a proposed amendment to the Montreal Protocol that took into account what they called the "many reliable peer-reviewed scientific reports and papers that provide information about the effect of HFCs and greenhouse gases on the climate system."

The amendment's language is quite revealing: "These studies have shown that, although HFCs currently constitute a small portion of total greenhouse gas emissions, HFCs are rapidly increasing in the atmosphere mostly due to increased demand for refrigeration and air conditioning, particularly in developing countries, and because they are substituting for ozone-depleting substances. If HFC use and emissions are left unchecked, they will have a significant impact on radiative forcing and the climate system. HFCs, unlike carbon dioxide which resides in the atmosphere for millennia, are short-lived climate pollutants (SLCPs) with average atmospheric lifetimes of 15 years. Decreasing HFC use and emissions can thus reduce the radiative forcing effect within a short time frame."

As can be seen from the above, a consensus seems to be growing in the science and policy literature that reducing these short-lived climate pollutants has become an important priority. This shift in thinking may directly affect the refrigerant industry, which has come to regard HFCs as a possible alternative. But that assumption may soon turn out to be woefully short-sighted.

"HFCs can be phased down next year under the Montreal Protocol, which has already phased out nearly 100 similar fluorinated gases by nearly 100 percent," Zaelke said. "This would provide the equivalent of between 100 and 200 billion tonnes of CO^2 in mitigation, with further mitigation from improvements in energy efficiency of air conditioners and other appliances as they shift to climate friendly refrigerants to replace HFCs."

President Obama's climate détente with President Xi of China started with a series of historic agreements on HFCs negotiated with President Xi, beginning last June at their first meeting at the Annenberg Retreat at Sunnylands in Rancho Mirage, California. More recently President Obama reached agreement with Prime Minister Modi of India to use the Montreal Protocol to phase down HFCs in the subcontinent. At the 26th annual Meeting of the Parties to the Montreal Protocol, held last November in Paris, donor countries agreed to put $507.5 million into the Montreal Protocol's dedicated funding mechanism in order to help developing countries achieve the treaty's goal, and to hold an extra meeting next April to address HFCs, along with their regularly scheduled meetings in July and November 2015.

"Success in phasing down HFCs under the Montreal Protocol next year in November will provide further momentum for success with the climate negotiations in Paris in December," Zaelke said. "The fastest road to Paris goes through Montreal."

Meeting The Criteria For A Better Refrigerant:

Many refrigerant makers hope their products will become the next industry standard after the phase-out.

The key will be to find a replacement that functions as well as Freon and doesn't entail additional costs that will make it prohibitive. The product should perform well in a variety of uses, be relatively safe to employ, and not require more energy to achieve the same effects as the original refrigerant.

The criteria for any new refrigerant should include:

- Matching present designs for equipment and compressors as closely as possible
- Allowing quick and easy replacement that's cost-effective
- Including being suitable for retrofitting when required
- Performing well and efficiently over a broad range of temperatures
- Operating under relatively the same pressures as current hydrofluorocarbon refrigerants or lower
- Having a marked reduction in global warming potential and ozone depletion potential (ODP)

An ideal replacement should be technology-neutral and not require new technology that could prove prohibitively expensive and cumbersome. The substitute should permit flexible implementation without imposing any undue financial burden. It should be ready for quick adoption so both industry and consumer won't have to face any unnecessary costs that come with unforeseen delays.

The faster the phase-out is completed, the better off the world will be. Letting emerging economies skip over outmoded hydrofluorocarbon technology and rapidly embrace increasingly available new alternatives that have low global-warming potential is one of the best ways to achieve this goal. When a country can accomplish its transition away from greenhouse gases quickly, the costs are manageable and the benefits are universal.

As recent developments have shown, the market is responding dynamically. Engineers from original equipment manufacturers and system/components suppliers are developing alternatives including hydrocarbon systems and other compounds. Retailers and other end-users are looking for sustainable refrigeration systems. Around the world public authorities plus NGOs and other groups are focusing on climate change and the latest environmental technology that shows promise to address it.

Reporting from the most recent Food Marketing Institute Energy & Store Development Conference, held September 2014 in St. Louis, Air Conditioning Heating Refrigeration News (ACHR) declared that no portion of the natural refrigerant market has been more cutting edge than supermarkets as this important business sector shifts from refrigerants with high global warming potential. The conference timing was significant because the U.S. Environmental Protection Agency had just announced a proposal to essentially ban R-404A, R-507—two of the most commonly used refrigerants—and a number of other refrigerants with a high global warming potential from use in a broad range of commercial refrigeration equipment installed in 2016 or later. At the conference, Drusilla Hufford, director of the EPA's Stratospheric Protection Division, reportedly told the audience that the proposal stemmed from the agency's effort to promote the search for lower-GWP refrigerants that reduce the risk to human health and the global environment.

"The EPA continues to seek comments on technical challenges, availability of alternatives, need for changes to manufacturing processes, safety upgrades, and its ability to meet proposed compliance dates," Hufford said at the conference.

The EPA's ban was seen as indicative of a trend with world-wide implications, as Robert Wilkins, a public affairs executive with Danfoss, reportedly pointed out that "an HFC phase-down is increasingly likely." He also said, "The issue is when and how—not if. Change in the supermarket is likely to accelerate."

Finding refrigerants with no global warming potential was on the minds of those attending the two-and-a-half day conference as Hussman Corp.'s principal engineer, Tim Anderson, emphasized in his presentation comparing HFC, CO^2, glycol, and propane refrigeration systems, and assessing their relative "strengths and weaknesses, and how supermarket operators can determine which system is right for their companies and cultures." According to ACHR, Anderson examined six system configurations and concluded, "There is no perfect solution, and the refrigerant choice cannot be separated from the system choice."

Further research into low-GWP alternatives is currently being conducted by the Air-Conditioning, Heating, and Refrigeration Institute's Air-Conditioning, Heating, and Refrigeration Institute Low-GWP Alternative Refrigerant Evaluation Program (Low-GWP AREP), according to Danfoss's application engineer manager for the Americas, Jeff Staub. He reportedly encouraged the industry "to consider pilots with new technologies, natural refrigerant options, and alternative system architectures."

His Danfoss colleague, Wilkins, referred to the supermarket industries' increasing use of CO^2 systems in a "cascade configuration using HFCs and HFOs." He added, "Legacy HFC systems are under increased pressure to reduce leaks and switch to lower-GWP alternatives."

Some supermarket owners have already begun pairing new equipment with low- or no-GWP refrigerants, according to Anderson, Hussman Corp.'s principal engineer.

As ACHR reported, Anderson mentioned three main refrigerant choices: synthetic HFCs such as R-134a and R-407A; synthetic blends such as HFO-1234yf (co-developed by DuPont) and HFO-1234ze (made by Honeywell); and natural refrigerants like R-744 (CO^2), R-290 (propane), R-600a (isobutene), and R-717 (ammonia).

"There is no perfect solution," Anderson reiterated. "Improving one thing always causes something else to get worse. For example, lowering the environmental impact often causes the blend to be flammable."

Addressing The Flammability Factor:

Flammability is an important consideration. As listed by the Air-Conditioning, Heating, and Refrigeration Institute, there are currently these flammability classifications: Class 1, with no flame propagation consisting of many existing HFCs and blends and CO^2; Class 2L, with low flammability such as HFO-1234yf and R-32; Class 2, which is considered flammable, includes refrigerants such as R-152a; and Class 3, deemed highly flammable, includes hydrocarbons (HCs) R-290 and R-600a.

Concerns that a hydrocarbon formula's flammability factor might preclude it from getting EPA approval have been shown to be misguided.

The EPA's Significant New Alternatives Policy program has started approving some hydrocarbon refrigerants as well as other environmentally friendly technologies as it continues to evaluate and regulate substitutes for the ozone-depleting chemicals that are being phased out to meet government guidelines. A replacement refrigerant formula that involves hydrocarbons has been approved by the EPA for specific uses in domestic refrigerators, some window air-conditioner units, as well as select industrial and commercial refrigeration.

The use of hydrocarbon refrigerants is clearly permitted in certain applications and in adherence to well-established best practices for safety and care. Because of the energy savings and the environmental benefits, hydrocarbon refrigerants have been accepted by the industry for increasing applications. As the industry adapts to its introduction, the EPA said it would expect the public to become increasingly comfortable with its use. The public and industry, in general, have a long history of using flammable products in gas appliances, fireplaces, barbecues and automobiles, but that does not mean there should be any lessening of appropriate levels of caution and common sense. Because those standards have been met routinely, there have been no official calls for bans on gasoline and fuel oil, for example. Although accidents do occur, fortunately they are seldom because the vast majority of people is willing to subject these materials to rigorous safeguards in order to achieve the benefits they provide to their daily life.

This issue warrants more attention as the refrigerant industry contemplates meeting the phase-out deadlines with hydrocarbons.

The United Nations Environmental Programme report on hydrocarbons' use in industrial refrigeration says that "they offer excellent efficiency and compatibility with most materials and lubricants." But the report advises that "precautions required to prevent ignition are significantly more expensive than those required for R-717 systems. HC-290 is generally similar to HCFC-22 and R-717 in terms of operating temperatures and pressures, and requires similarly sized compressors."

But automatically assuming that R-22 and other conventional refrigerants have low flammability potential would be a mistake. When it comes out of the cylinder, R-22 does have a low flammability rating, but once it mixes with the compressor lubricating oil inside the refrigerant system, it can become very flammable if it's discharged in a high enough concentration. It shouldn't be forgotten that when a conventional refrigerant such as R-22 is burned, it produces phosgene gas, which is highly toxic. Yet the EPA has allowed its widespread use.

One reason there have not been a spate of reports of explosions and fires caused by either R-22 or hydrocarbons like HC-290 is that major discharges of refrigerants are extremely rare. The industry as a whole has taken great strides in this regard. Large refrigerant systems have pressure-relief valves that are designed to release any refrigerant leakage in such a way that prevents a pipe rupturing under a high-pressure condition.

There is no reason to expect that industry conduct and product safety codes will be relaxed to permit the replacement of an environmentally friendly substitute refrigerant. These standards will remain in place, and if anything, they will get stricter in the years ahead. In large systems, combustible-gas leak detectors and shut-off valves that minimize the loss of refrigerants are recommended. For that matter, refrigerant-leak detectors are a code requirement for conventional refrigerants because all refrigerants displace oxygen and that can be worrisome if they are suddenly discharged in a small confined area.

As the EPA put it: "The concerns usually associated with refrigerants are toxicity, flammability, and physical hazards. Are refrigerants completely safe? No, all pose one or more of these concerns. But can refrigerants, and especially the new refrigerants, be used safely? Yes, and generally more so than in the past."

Considering the history of refrigeration, we've come a long way from using water and sulfuric acid, the formula developed by Edmond Carr in 1850; or chemogene, the mix of petrol ether and naphtha first patented in 1866; or solutions that depended on volatile mixes of carbon dioxide, ammonia, or sulfur dioxide and methyl ether. Methylene chloride was celebrated as a breakthrough in 1926 but castigated later in the 1920s when it leaked out of refrigerators and caused a series of fatal accidents. The quest for a nonflammable refrigerant with good stability was far from over. Thanks to American chemist Thomas Midgley and his collaborators in Dayton, Ohio, progress was made, and the era of fluorocarbon refrigerants was formally announced in April 1930. The first synthesized substance, now known as R-12, was dichlorodifluoromethane. By 1936, the hydrochlorofluorocarbon (HCFC) refrigerant, R-22, was produced and the age of Freon commenced. Essentially, it set the standard for almost half a century.

Now it's time to advance to the next round of refrigerants.

Searching For Superior Energy Performance:

When comparing replacement refrigerants like CO^2 and hydrocarbons, it's instructive to look at the switch occurring in automobile coolants. As part of the European Union's Sustainable Development Strategy, the Mobile Air Conditioning (MAC) Directive was adopted in 2006 to reduce the impact of air conditioning in cars sold in the EU. The MAC Directive, which went into force on Jan. 1, 2013, called for an automotive refrigerant with a GWP factor of less than 150 for use in new vehicles. DuPont believed that its product, HFO-1234yf, has "very distinct benefits with regard to fuel efficiency and overall sustainability" when compared with CO^2 as an automotive refrigerant. It said that CO^2 would require a much larger, heavier air-conditioning system than what was used in most cars, contrary to the trend toward smaller, more fuel-efficient sustainable vehicles. DuPont's climate performance evaluations concluded that the CO^2 is not as efficient as HFO-1234yf in warmer climates, and would contribute considerably more overall to total greenhouse gas emissions, especially as sales of new vehicles in India and China, for example, continue to increase as projected.

The new refrigerant, known as HFO-1234yf , is a hydrofluoroolefin (HFO) originally developed by Honeywell Specialty Materials, DuPont and Arkema in response to the EU's 2011 ban on HFC-134, the hydrofluorocarbon blamed for its role in contributing to global warming. The chemical makers admit that HFO-1234yf is flammable, but they insist that it is no more hazardous than nonflammable HFC-134a, which has been used in car air conditioners today and has a history of safe use. But the catch is that HFC-134a has a global warming potential that is 1,400 times than that of CO^2. The new HFO-1234yf accommodates the EU's mandate for carmakers to use refrigerants that have a GWP of less than 150; its GWP is 4.

In related news announced last year, Honeywell and DuPont were able to develop their vehicular refrigerant—after an apparent falling out with the French company Arkema—in time to meet EU's 2017 deadline for new climate rules. The product is now used in almost 2 million cars around the world, according to Honeywell.

Another benefit for HFOs, these chemical makers have asserted, is that coolant systems using them are much more energy efficient than systems that use CO^2, and the new HFOs can be added to existing air-conditioning systems with relatively little tweaking. By contrast, CO^2 requires a new compressor system that works at higher pressures than fluorochemical systems in order to prevent unwanted leaks.

As explained in a recent article in *The Journal of Physical Chemistry* by Lin Yank and Sandro R. P. da Rocha, researchers at Wayne State University, HFOs, which have zero ozone-depleting effects and very low global warming potential, "are considered to be the next generation" of high-pressure working fluids because "they have industrial relevance in areas including refrigeration and medical aerosols." One major challenge, they noted, is "the solubility and salvation of additives in such hydrophobic and oleophobic low dielectic semifluorinated solvents." But, citing Honeywell's new compound, they concluded that "the solvation behavior of HFO-1234ze was found to be similar to that of HFA-134a, thus suggesting similar considerations may apply for both propellants, when solvation properties are of a concern to the application."

Meanwhile, as explained by presentations at the recent Food Marketing Institute Energy & Store Development Conference, CO^2 is among the supermarket refrigerants getting a lot of attention along with the lower-GWP 407 series of HFCs and propane.

A supermarket in Turner, Maine, has served as a pilot project for the Delhaize Group SA in its installation of a CO^2 system, which is reportedly being installed at a more rapid pace in Europe and other parts of the world than in the U.S. A supermarket in Saratoga, N.Y., run by the Price Chopper Supermarkets, has reportedly used a pilot cascade or 'transcritical" refrigeration system that combines CO^2 with an HFC refrigerant. United Natural Foods, Inc., a leading distributor of natural and organic foods in the U.S. and Canada, installed an ammonia-based refrigerant system at its 590,000-square-foot facility in Lancaster, Texas, which it said helped to reduce energy consumption by 30 percent, and a CO^2-based refrigerant system at its newest facility in Montgomery, N.Y., to serve its customers in the New York City metropolitan area.

In early January 2015, Honeywell announced that it had begun full-scale commercial production of HFO-1234ze at its Baton Rouge production facility. The product, used as an aerosol propellant, insulating agent and refrigerant, is marketed under its Solstice line of low-global-warming materials. "We are seeing increasing demand for our entire Solstice line of low-GWP materials," said Ken Gayer, vice president and general manager of Honeywell's Fluorine Products business, "and this new product has already been adopted by a range of customers globally."

This growing trend is also taking shape in Idaho, just across the border from Spokane, Washington, where Priority Cool Refrigerants says it will start production in February of its blend of three naturally occurring hydrocarbon-based refrigerants at its new facility there.

A number of companies that are already making the transition away from HFCs report significant gains in energy efficiency. For example, the Coca-Cola Company and PepsiCo have reported energy efficiency gains of up to 47 percent in their new CO^2 and hydrocarbon-based refrigeration equipment over baseline HFC-based models. Global supermarket chains Tesco and Unilever both report a 10 percent gain from new hydrocarbon-based commercial refrigeration equipment and freezer cabinets over HFC-models.

The energy efficiency gains catalyzed by the HFC phase-down and complementary energy efficiency programs will ease pressure on overloaded electricity grids, a significant benefit in Asian countries, according to the Institute for Governance & Sustainable Development, a not-for-profit organization based in Washington, D.C. In many cities in India, for example, air conditioning accounts for 40 percent to 60 percent of peak electricity demand during hot weather. A recent study by the U.S. DOE's Lawrence Berkeley National Laboratory calculates that ownership of room air conditioners in India will increase from 3 percent to 47 percent between 2010 and 2030. Over the next 15 years, the potential energy savings in India from improving the energy efficiency of room air conditioning is the equivalent of building 120 new medium-sized coal power plants. The economic benefits of finding a suitable refrigerant are obvious.

Commercially available non-fluorinated or "natural refrigerants" primarily include ammonia with a GWP of near zero, hydrocarbons (e.g., propane and isobutene) with GWPs of less than four, and CO^2 with a GWP of one. In the room air-conditioning sector, thousands of hydrocarbon units have been sold and new production lines are coming on line each year. The Indian manufacturer, Godrej, and the Chinese manufacturer, Gree Electric, have developed models of propane (HC-290) room air conditioners. The Godrej models are up to 11 percent more efficient than the minimum requirements for the 5-Star energy efficiency rating set by the Indian Bureau of Energy Efficiency. China, Japan, India, Indonesia, and other countries now have projects underway using moderate-GWP HFC-32 with high levels of operating efficiency. CO^2 air conditioning prototypes are also available.

The Montreal Protocol's Technology and Economic Assessment Panel (TEAP) uses the term "low-GWP' to refer to refrigerants with GWPs of 300 or lower while "moderate-GWP" refers to refrigerants with GWPs of 1,000 or lower. For comparison, the GWP of HFC-134a, one of the most commonly used high-GWP HFC refrigerants today, is 1,300.

Low-GWP alternatives to high-GWP HFCs are becoming more available as their benefits gain wider recognition. They tend to fall into two basic categories: non-fluorinated substances with low-GWP, and fluorinated substances with low- to mid-range GWPs. The TEAP found that low-GWP alternatives are available that achieve equal or superior energy efficiency in a number of sectors stating, "hydrocarbon and ammonia systems are typically 10-30 percent more energy efficient than conventional high-GWP HFC systems." Tests of room air conditioning utilizing hydrocarbon refrigerants showed energy improvements of up to 20 percent over HFC models. In Japan, an HFC-32 room air conditioner was awarded the 2012 Grand Prize for Excellence in Energy Efficiency and Conservation and the prestigious "Top Runner" designation as the most energy efficient room air conditioning then available.

The Next Generation Is Here:

Around the world there are signs that global phase-down of hydrofluorocarbons is underway and accelerating as the 2030 deadline approaches for its phase-out. Companies that produce climate-safe alternatives to HFCs are ramping up their investment and speeding their commercialization, as an increasing number of firms that are phasing out HCFCs are picking climate-friendly alternatives rather than shifting into high-GWP HFCs.

Last year, the European Parliament accelerated its crackdown on fluorinated greenhouse gases by repealing its 2006 regulation and called for a significant reduction in emissions of these climate-warming gases. As the European Union's Climate Action and Energy Commissioner Miguel Arias Canete said, "The science is clear. The time to act is now."

The new EU F-Gas Regulation, as it's known, was agreed among the EU institutions and its 28 member states and became binding on Jan. 1, 2015. As a refrigerant industry newsletter published by Shecco put it, the strict regulation and the HCFC phase-out "will see the appeal of natural refrigerants increase exponentially in Europe and beyond."

Shecco's deputy public affairs manager, Alexandra Maratou, reported that the new F-Gas rules foresee HFC bans in commercial regulation as of 2022, the result of a gradually declining cap on bulk HFCs placed on the EU market that will affect new plug-in and centralized commercial refrigeration.

The political winds are blowing, so to speak. EU Climate Commissioner Connie Hedegaard reportedly said that the EU F-Gas regulation "will deliver substantial emissions reductions and ensure innovation... [and] will give renewed political momentum to come to a global agreement on phasing down F-gases under the Montreal Protocol."

According to Bas Eickhout, a member of the European Parliament, who played a part in the new regulation's passage, "With this agreement, large supermarkets soon will be required to switch to climate friendly cooling systems, which will give a boost to green jobs."

Here are some more details of this EU F-Gas regulation, according to news reports:

- Hermetically sealed commercial refrigeration that contains F-Gases with global warming potential of 150 or more is banned as of 2022.
- Centralized systems for commercial use with an overall capacity of 40kW or more that contain F-Gases with GWP of 150 or more are banned as of 2022, except in the primary refrigerant circuit of cascade systems where fluorinated greenhouse gases with a GWP of less than 1500 may be used.

As of this year in the EU, it is no longer legal to use recycled or reclaimed R-22 to service R-22 equipment. That technology has become obsolete.

What these developments in Europe portend for the U.S. remains to be seen. But clearly the interest in natural refrigerants is steadily increasing world-wide, which promises to open the market for alternatives to HFCs. As they are subject to a phase-down, their usage may become a luxury, and perhaps an unsustainable expense for many firms. Not only will these commercial users want something new, they'll demand it.

And the sentiment will no doubt be shared by a growing number of consumers. As atmosphere research scientist Dr. Matthew Rigby observed, "People are waking up to the issue of the climate impact of these refrigerants, so I think it's probably a good bet there's going to be some part of the market where we can buy refrigerators or air conditioners that use compounds that have a very low global warming potential."

The Changing World Of Environmental Regulations:

As the refrigerant industry has learned the hard way, keeping up with the world's governing bodies that oversee environmental regulations has required constant attention because the scientific understanding of the long-term impacts of these materials is ever expanding as the knowledge deepens.

But that doesn't mean that manufacturers should stop innovating. Far from it. New opportunities are always arising as market conditions change.

Take this example from the 2010 United Nations Environmental Programme's assessment report on the Montreal Protocol by its Refrigeration, Air Conditioning, and Heat Pumps Technical Options Committee:

"Unsaturated hydrofluorocarbons such as HFC-1234yf and HFC-1243zf have not to date been used in industrial systems. The low global warming potential suggests that they may be a suitable alternative to R-717 and R-744, but it is very likely that they will be even more expensive than R-410A, with the further disadvantage of being flammable. It is therefore likely that none of this family of chemicals will achieve any significant market penetration in the industrial sector, even if blended with other compounds to reduce price or flammability."

In another section the report, the panel asserted: "Hydrocarbons are not widely used in industrial refrigeration except where the additional safety measures required to ensure that leaking refrigerant cannot be ignited are required anyway, for example in a petrochemical plant. They offer excellent efficiency, and compatibility with most materials and lubricants. However the precautions required to prevent ignition are significantly more expensive than those required for R-717 systems. HC-290 is generally similar to HCFC-22 and R-717 in terms of operating temperatures and pressures, and requires similarly sized compressors."

But beginning in 2015 comes news that DuPont is vigorously promoting its ISCEON refrigerants, which it claims provides "superior energy performance compared to R-407F after R-22 supermarket conversions."

Some experts in the HVAC familiar with claims for ISCEON MO99 (R-438A) say that the new compound may not save as much energy as the company claims. It does allow the compressor in a unit to run at a lower amperage per kW, but because of its reportedly poorer thermodynamic performance, the compressor may have to run longer in duration, thereby minimizing its efficiency. Another possible drawback to this replacement is that it is not a simple "drop-in" because some seals and other components may need to be replaced in order to accommodate it properly.

By contrast, DuPont claims that its ISCEON MO99 does have superior energy performance compared to R-407F after supermarkets have converted from R-22, in terms of capacity and efficiency, and has a significantly lower discharge temperature that may prolong the life of the compressor. Compared to R-404A, its ISCEON has a 42 percent lower GWP. The company does say that when retrofitting its product in most R-22 systems, "all you need to do is recover the R-22, replace critical seals, charge [the] refrigerant, restart and monitor for leaks..." These steps are not taken lightly, and they could prove costly.

It is helpful to look at what's happening in the manufacturing industry as makers of air conditioners and refrigerators adjust to the changing standards. Changing government regulation can make the process complicated because the product manufacturers must meet the new requirements, which may be substantially more onerous than the previous ones.

"We must manufacture to standards set by the EPA," explained a spokeswoman for Nordyne, which makes heating and cooling products for Westinghouse. "Right now, that standard is for R-410A refrigerant, so all of our cooling products use that refrigerant."

A key trend in the refrigerant industry is the ever-increasing minimum efficiency standard, known by the acronym SEER, which stands for Seasonal Energy Efficiency Ratio. In 2005, the minimum efficiency was 10 SEER. In 2006, it was bumped up to 13 SEER. In 2015, it is changing to 14 SEER for many products. That means a homeowner who is replacing a 12-year-old air conditioner could see a 40 percent increase in energy efficiency with the purchase of a new one. Today's air conditioners are quieter and more energy efficient than ever before. And the consumers expect that trend to continue.

But that expectation only adds to their concerns.

"Many homeowners may be misinformed about how much longer R-22 will be available to service their central A/C systems and heat pumps," advises the EPA in a fact sheet regarding the ban on the production and importation of ozone-depleting refrigerants. R-22, also known as the hydrochlorofluorocarbon HCFC-22, has been the refrigerant of choice for decades. But it is a greenhouse gas, and its manufacture results in a by-product, HFC-23, that also significantly contributes to global warming. Its production has been curtailed and supplies are running out as the transition takes hold. Just as importantly, it is a violation of the Clean Air Act to allow any of this refrigerant to be vented into the atmosphere during the installation, service or retirement of the old equipment. But as the EPA said, "The transition away from R-22 to the use of ozone-friendly refrigerants should be smooth. For the next 10 years or more, R-22 should continue to be available for all systems that require R-22 for servicing."

It sounds straightforward enough but questions about this transition will be echoing around the world in the years to come as consumers cope with the transition.

Westinghouse, for example, has been dealing with this issue firsthand. On the giant retailer's website, an Indianapolis woman complained that a heating and cooling contractor told her that it would cost $200 to replace her air conditioner's refrigerant, which was running low. She thought the increased cost was worrisome. The company assured her that the cost increase was correct.

"If your air conditioner was manufactured before 2010, it could use an A/C coolant known as R-22," Westinghouse explained. "The Environmental Protection Agency ordered the phasing out of R-22 because of the refrigerant's ozone-depleting properties and in its place is a new, more environmentally friendly refrigerant called R-410A. The new coolant, though, won't work with the older R-22 units."

As implemented by the EPA, the phase-out of R-22 is a gradual process that began in 2004 and will end by the year 2020. Here are the milestones for that gradual phase-out:

- 2004: U.S. must reduce consumption of HCFCs by 35 percent
- 2010: U.S. must reduce consumption of HCFCs by 75 percent (R-22 may only be imported or produced by allowance holders in order to service existing R-22 compatible equipment at factories)
- 2015: U.S. must reduce consumption of HCFCs by 90 percent
- 2020: U.S. must reduce consumption of HCFCs by 99.5 percent (R-22 refrigerant that has been recovered and recycled/reclaimed can be used past 2020 to service existing R-22 systems, but new R-22 refrigerant can no longer be produced to service existing equipment)

Westinghouse is encouraging consumers to make the switch to products using R-410A, a blend of hydrofluorocarbons that does not contribute to the depletion of the ozone layer but, like R-22, does add to global warming. But the manufacturer mentions that quite a few replacements are being touted as acceptable alternatives—and that they have lower global warming potential. This retail giant advises consumers that combustible refrigerants can be a gamble, because if ignited they can burn up the refrigerant supply or result in an explosion. So far, there are no flammable refrigerants that have been approved by the EPA for use in heating and air conditioning equipment. But that regulatory situation is subject to change, as has already been shown above.

Under the Clean Air Act, EPA reviews alternatives to ozone-depleting substances to evaluate their effects on human health and the environment. The Significant New Alternatives Policy (SNAP) Program is EPA's program to evaluate and regulate substitutes for the ozone-depleting chemicals that are being phased out under the stratospheric ozone protection provisions of the Clean Air Act (CAA). Substitutes are reviewed on the basis of ozone depletion potential, global warming potential, toxicity, flammability, and exposure potential. Lists of acceptable and unacceptable substitutes are updated several times each year.

What would be an ideal refrigerant? The EPA has the answer: "In addition to having the desired thermodynamic properties, an ideal refrigerant would be nontoxic, nonflammable, completely stable inside a system, environmentally benign even with respect to decomposition products, and abundantly available or easy to manufacture. It also would be self-lubricating (or at least compatible with lubricants), compatible with other materials used to fabricate and service refrigeration systems, easy to handle and detect, and low in cost. It would not require extreme pressures, either high or low." Now here's the bad news: None of the current refrigerants are ideal and, says the EPA, "No ideal refrigerants are likely to be discovered in the future."

But the good news is that the SNAP program administrator has determined that a large number of alternatives exist that do reduce overall risk to human health and the environment. The purpose of the program is to allow a safe, smooth transition away from ozone-depleting compounds by identifying substitutes that offer lower overall risks to human health and the environment. One of these substitutes that's passed muster with the EPA is R-410A, a blend of hydrofluorocarbons that does not contribute to depletion of the ozone layer, but, like R-22, contributes to global warming. R-410A is manufactured and sold under various trade names, including GENETRON AZ-20®, SUVA 410A®, Forane® 410A, and Puron®. An additional refrigerant on the list of acceptable substitutes for R-22 in residential air conditioners and other products is R-407C. Residential air conditioners and heat pumps using R-407C are not available in the U.S., but are commonly found in Europe. The EPA vows that it will continue to review new non-ozone-depleting refrigerants as they are developed.

Although the EPA has not listed any flammable hydrocarbons as acceptable substitutes for use in room air conditioning equipment so far, it has listed several flammable hydrocarbon refrigerants as acceptable substitutes for specific refrigeration uses, including:

- butane, propane, propylene, Hydrocarbon Blends A and B (trade names OZ-12® for blend A; and HC-12a® and DURACOOL 12a® for blend B) in industrial process refrigeration;
- isobutane (R–600a) as acceptable, subject to use conditions, in new household refrigerators, freezers, and combination refrigerators and freezers;
- propane (R–290) as acceptable, subject to use conditions, in new retail food refrigerators and freezers (stand- alone units only); and
- R-441A, a hydrocarbon refrigerant blend consisting of ethane, propane, isobutane, and n-butane (trade name HCR-188C), found acceptable subject to use conditions in new household refrigerators, freezers, and combination refrigerator/freezers.

As the EPA notes, its listings for household and commercial refrigerators and freezers apply only to equipment specifically designed to be used with that particular refrigerant. The EPA has not found hydrocarbon refrigerants acceptable for use in refrigerators that were originally made for a different, non-flammable refrigerant.

Making the switch has merit. The price of R-22 will skyrocket as the supply dwindles. Heating and air conditioning manufacturers in the U.S. and elsewhere will stop making equipment that is R-22 compatible. Labor costs to service R-22 compatible equipment will also climb because HVAC technicians will be required to perform the proper recovery, recycling and reclamation of the obsolete refrigerant in order to comply with EPA certification. Technicians often call this designation the “Section 608 certification,” because it refers to the part of the Clean Air Act that requires minimizing releases of ozone-depleting chemicals from HVAC equipment.

Alternative refrigerants will be increasingly touted for their energy savings on consumers’ and businesses’ utility bills. But the cost of obtaining new equipment may be a significant factor to the bottom line because equipment using different refrigerants do not mix. If an outdoor condensing unit is replaced with an R-410A compatible unit, the indoor coil and line-set will also have to be replaced as well. One drawback with R-410A is that it is more sensitive to proper charging than R-22, although manufacturers claim that the new equipment is no less reliable than R-22 compatible units. Another factor is that the EPA does not allow R-410A to be used in former R-22 units due to its higher working pressures, but it does permit R-407C in these conversions, or “retrofits.” In general, using new substitute refrigerants in old equipment will require making some changes to the system components in order for the replacement to perform well.

Conclusion:

Considering that the average life expectancy of an air conditioner is approximately 16 years, purchases of air conditioners made today will most likely mean that the unit will last long past the R-22 phase-out date. So, just when the air conditioner is reaching an age when it may require more maintenance attention, the price of obtaining R-22, due to the phase-out, may be budget busting and because the contractor doing the work will have to be EPA certified, the service charge could also be costly.

Replacing the refrigerant in an air conditioner with something else that is less efficient makes no sense. The new refrigerant should not make the air conditioner consume more power to operate effectively. As recent developments have shown here and abroad, some of these new replacement compounds such as hydrocarbons definitely fit the bill. It’s going to become increasingly clear to consumers and commercial business owners around the world that seeking an affordable, environmentally approved refrigerant product is the best solution for the times ahead. And the next generation is at hand.

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