››Hot water supplemental heating coils in VRF-ERV unit ventilators were used in a recent school retrofit.

Retrofits

RSES Journal's first-ever Double Feature issue includes two double features. The following double feature centers on commercial and school retrofits. The school retrofit feature examines the use of unit ventilators with VRF and ERV technology. The commercial retrofit feature shows how VFDs and efficient pump combinations are used to reduce electrical demand.

NEW SCHOOL COOLING/ HEATING Retrofit

Retrofitting unit ventilators with VRF and ERV technology.

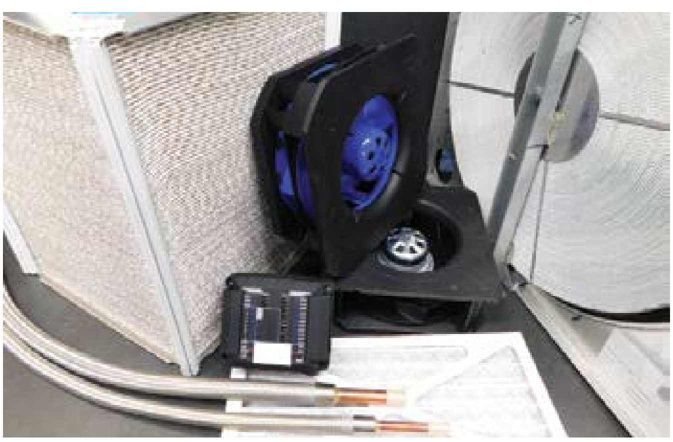
BY RANDY GUIGNARD

Images courtesy of Four Seasons Inc.

There are literally hundreds of thousands of outdated, inefficient hydronic, fan coil-style unit ventilators in school classrooms across North America. These basic units' inherently poor energy efficiency is bad news for the budgets of school districts facing rising HVAC maintenance and energy costs. However, for the HVAC design/build contractor or specifying engineer, these aged systems represent an unprecedented retrofit business opportunity thanks to new retrofit concepts utilizing variable refrigerant flow (VRF) technology.

Unit ventilators: a history

Conventional fan coil-style unit ventilator design has not changed much from the original systems that emerged in the 1950s. Basically, they consist of a belt-driven blower with approximately a 1,200-CFM capacity; a conventional motor assembly; and a supplemental coil that is supplied hot water via a two-pipe (supply and return) configuration from a central boiler. These systems were state-of-the-art during the second half of the 20th Century and perfect for classroom sizes averaging 600-800 sq ft. Most did not include air conditioning in the early stages, because outdoor air was used for cooling (similar to an economizer concept) during ideal ambient temperature/humidity conditions.



VRF/ERV unit ventilator energy saving components ideal for school retrofits.

Improvements such as air conditioning started appearing in the 1970s in new unit ventilators or as retrofits. In retrofits, air conditioning was provided by adding a central chiller plant that could supply the existing two-pipe systems. Both heating and cooling shared the same two-pipe system and required switchovers depending on the season. In new construction, four-pipe unit ventilator systems can accommodate both heating and cooling. The units also provide same day large outdoor ambient temperature swings without switching.

New construction school projects could also be specified with air conditioning unit ventilators featuring an on-board DX system of approximately 36,000 Btu, which typically functioned similar to a very large and significantly noisy window unit air conditioner. While most northern schools did not go to the expense of air conditioning, southern schools almost always converted to air conditioning because of inherently high temperature and humidity loads.

These fan coil units' poorly controlled environments, inefficiency by today's standards, and noisy operation have motivated school districts to search for alternatives. Additional incentives come from recent research study statistics revealing that student attendance/performance can improve significantly with better controlled temperature/humidity and year-round outdoor air induction. Outdoor air dilutes classroom airborne volatile organic compounds (VOC) and biological contaminants, such as contagious microbial bacteria and viruses, thus less absenteeism from sickness.

Increased attendance with IAQ

Besides energy efficiency and better environmental control, another advantage for indoor air quality (IAQ) improvement is that the federal government rewards schools monetarily for attendance. Federal incentive funds for reduced absenteeism can also help expedite HVAC retrofit cost paybacks.

A case in point is Clark County Public Schools' (CCPS) George Rogers Clark High School in Winchester, KY. The new school has decidedly better IAQ and air comfort versus the circa 1970s heating-only school building it replaced. CCPS Superintendent, Paul Christy, claimed the school registered a county-wide record for attendance the first year it opened. Healthier ventilation levels decreased absenteeism and the air conditioning comfort in the spring and fall increased student attention spans and academic performances. The increased attendance reaped $50,000 in federal incentive funds for the district.

> **One of the emerging favorites of school districts is VRF, where outdoor condensers supply a myriad of evaporator coils via line sets.**

Some states pay incentive funds to schools for every student in attendance (for a four-hour minimum school day). Therefore, there are various motivations for school districts to retrofit unit ventilators. However, there are also many choices. One of the emerging favorites of school districts is VRF, where outdoor condensers supply a myriad of evaporator coils via line sets. The equipment is significantly more expensive than packaged rooftop units (RTU). However, RTUs represent a major disruption of school life, because ductwork must be installed (if ductwork is feasible at all in regard to building envelope limitations).

A VRF/ERV drop-in replacement used in a school retrofit.

Furthermore, both VRF and RTUs still do not address the challenge of outdoor air compliance with American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 62.1 *Ventilation for Acceptable Indoor Air Quality*.Therefore, VRF systems are typically combined with dedicated outdoor air systems (DOAS) that dehumidify and condition outdoor air. DOAS add project costs and possibly the same ductwork challenge that RTU air distribution faces. RTUs also must either be specially designed for conditioning outdoor air with some type of onboard DOAS or supplemental DOAS equipment, especially with the huge humidity loads of southern schools, northern institutions during summer school schedules.

›› A VRF used at the Walter J. Baird Middle School in Lebanon, TN.

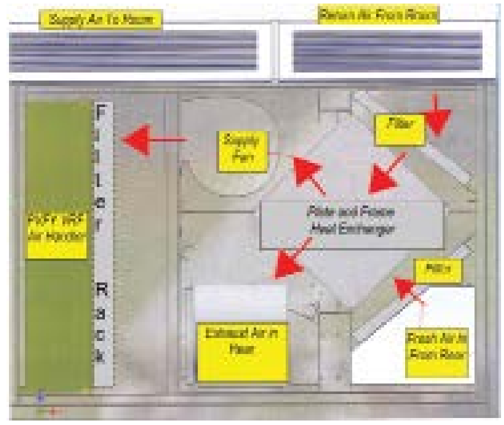
Drop-in unit ventilator replacements

School day disruption, structural and cosmetic remodeling costs associated with unit ventilator removal, installation ductwork and upfront equipment costs are all negatives of the aforementioned technologies. Furthermore, the building's roof may need added structural bolstering to accommodate a large RTU or DOAS. These disadvantages have been the driving force behind the interest and development of drop-in unit ventilator replacements using today's advanced technological HVAC concepts. Physically, the unit ventilator replacement has similar dimensions, such as the industry standard of 30–36-in. high, 104–114-in. wide, and 20–24 in. deep. Some even come in vertical configurations for classroom closets. However, instead of being supplied by conventional boilers or chillers, this new generation of unit ventilation is designed with contemporary HVAC concepts such as VRF, enthalpy wheels, energy recovery ventilators (ERV), water source heat pumps, heat pumps or other modern technologies.

> **"These disadvantages have been the driving force behind the interest and development of drop-in unit ventilator replacements using today's advanced technological HVAC concepts."**

Drop-in replacements with VRF/ERV

Perhaps the concept with the best potential value, especially in value engineering incidences, is a unit ventilator replacement with onboard VRF and ERV. It is an all-in-one package that uses VRF for heating and cooling/dehumidification, and ERV for energy recovery efficiency and outdoor air dehumidification and conditioning, without the expense of a DOAS and ductwork.



« Diagram of a plate and frame heat exchanger–enthalpy core.

CO_2, humidity, occupancy or temperature sensors, as well as set-back programming, can activate the unit. Other features include electronically commutated (EC) motors. These and other features help the system surpass requirements for ASHRAE Standard 62.1 and ASHRAE Standard 90.1 *Energy Standard for Buildings-Except Low-rise Residential Buildings.*

One benefit helping these systems surpass building standards in efficiency is sensible and latent load reduction with enthalpy, such as wheels with molecular sieve media or solid plate enthalpy cores. Besides the efficiency aspect, educators especially like the less than 30-NC rated quietness of VRF, because compressors are located outside the classroom.

While typical VRF-based installations consist of outdoor condensers feeding a mixing box with refrigerant that is distributed to individual classroom evaporator coils via line sets, the unit ventilator replacement concept with on-board VRF/ERV can offer more at a lesser price. The VRF unit ventilator has its own evaporator coil inside the unit ventilator-style stainless steel cabinet. An onboard enthalpy core recovers energy from exhaust air to temper and dehumidify outdoor air without cross contamination.

The main disadvantage to these 2.5-ton VRF/ERV drop-in replacements is upfront capital equipment costs. However, specifiers and procurement officers should look beyond just equipment costs and consider total project costs. The VRF/ERV drop-in replacement is a similar size to its predecessor, therefore there are little, if any, remodeling costs associated with the old unit's cosmetic disruptions, such as re-flooring, drywall repair and painting. Alternatives that are not drop-in unit ventilator replacements would require the same interior cosmetics, plus masonry structural repair of the original unit ventilator's wall hole.

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Retrofits GO COMMERCIAL

VFDs, efficient pump combinations reduce electrical demand for commercial building HVAC system upgrades.

BY KYLE DELPIANO

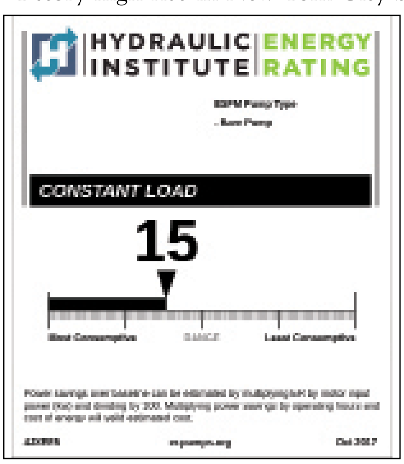
Images courtesy of Xylem/Bell & Gossett.

To retrofit or not to retrofit? It is an often-asked question in the commercial buildings market, as building owners and operators consider return on investment for replacing or upgrading heating and cooling and other building systems with new technology. Even though half of the 5.6 million U.S. commercial buildings were constructed prior to 1980*, the oldest buildings don't necessarily make the best candidates for retrofit.

The reasons are varied and complex—the costs might be too great to retrofit an old building with updated mechanical systems that was not initially designed with energy efficiency in mind; a building simply might be at the end of its useful life; or modern-day standards of living and working might not be achieved even with structural and mechanical upgrades.

Property owners and facility personnel can realize operational cost savings, increased building valuation and shorter payback periods when improvements are done at the right point in a building's life cycle. That could mean even relatively new buildings—those approaching 15 years old—might be good candidates for systems upgrades.

Such was the case in a retrofit project of a mixed-use 21-story high rise in New York City built in 2005. Prior to the retrofit, about 30% of utility costs were for electricity, with more than half of that total coming from the HVAC pumping system alone. The original pumps specified for the building were running at constant speed, along with being oversized for the true operational demands of the building. Centrifugal pumps installed in HVAC systems typically operate in variable load applications that see a fluctuation of flow requirements based on the heating or cooling load of a building at any given time.



An example of an energy rating from the Hydraulic Institute.

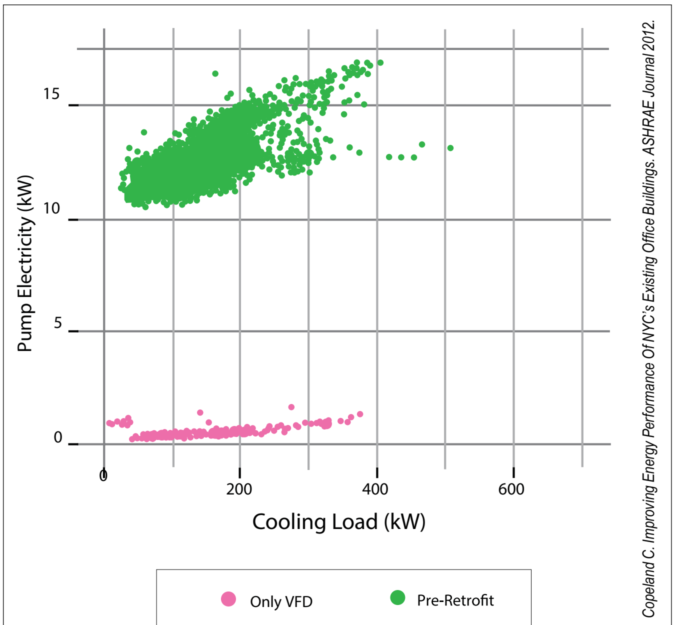


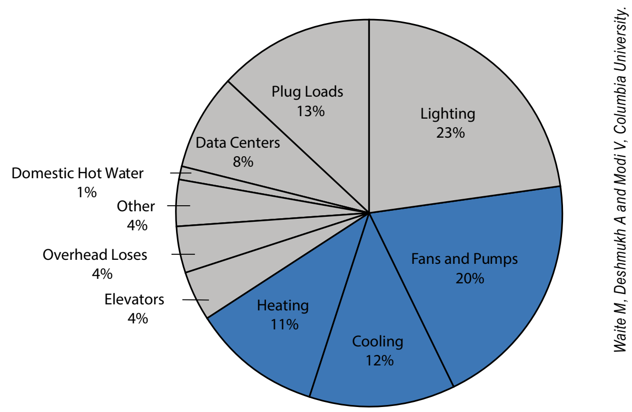
Figure shows the cooling load and pump electricity use before and after retrofit.

Oversizing pumps is sometimes done to add safety margins to account for installation overages completed by the installing contractor. However, this common practice comes at a cost, namely increases in the system's operation, maintenance and capital costs over the system's entire life cycle.

After smaller, yet more efficient, centrifugal pumps were installed and paired with variable frequency drives (VFD) and the installation of pressure independent control valves, the retrofit yielded a 95% reduction in hydronic energy. The VFD controllers change and vary the speed of the current to the pump motor, allowing the pump to adjust operating speed and respond smoothly and efficiently to fluctuations in demand. Even at peak cooling load, electricity reduction in the building was more than 50% after the retrofit compared to the system's old constant-speed pumps.

Commercial buildings account for 36% of all U.S. electricity consumption and cost more than $190 billion in energy every year, according to the U.S. Department of Energy (DOE). With HVAC as the biggest consumer of energy within a building—accounting for as much as 50% of energy use—even small updates can realize quick payback and immediate energy savings.

Yet as owners seek to improve efficiency of building systems, HVAC upgrades are often last on the list due to high perceived upfront costs. But when one considers that 30 cents of every dollar spent on energy use in commercial buildings is wasted through inefficiencies, according to energystar.gov, the energy-saving benefits of a retrofit can balance cash outlay. Participating in government rebate programs that offer financial incentives for system replacement and VFD installation can offset costs of replacing or upgrading HVAC systems.



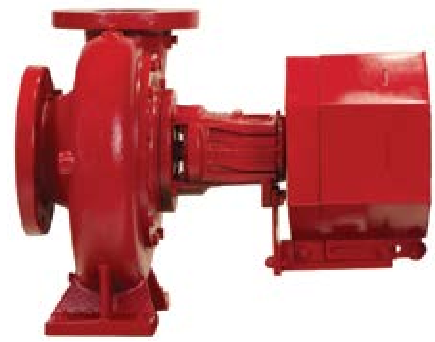
Heating, cooling, fans and pumps account for a significant portion of electricity use.

The New York project illustrates that even newer buildings can benefit from system upgrades when retrofits feature technologically advanced pumps and products in the context of total system design.

When a VFD is installed properly, pumps can work more efficiently, thereby extending product life, reducing energy consumption and decreasing electrical system stress. The flow control provided by VFDs ultimately enhances the efficiency of the motor and the application, resulting in higher efficiency and significant cost savings.

Pump efficiency ratings

The 2020 date is nearing for compliance with DOE efficiency standards for clean-water pumps, such as those used in hydronic heating and cooling systems. Pump manufacturers have products on the market that meet and exceed these new standards. A new metric called the Pump Energy Index (PEI)



Centrifugal pumps paired with VFDs can greatly reduce electricity consumption.

has been established to rate the efficiency of pumps. When the regulations take effect, pumps that meet the standard will have a PEI value of one or below, which will be included on the pump's nameplate.

Until that time, contractors, facility managers and others involved with upgrading commercial building HVAC systems can find pump efficiency information by searching a database established by the Hydraulic Institute (HI). The HI's Energy Rating (ER) is based on the PEI and is similar to the Energy Star rating for appliances. According to HI, the ER designation "is designed to clearly indicate the power savings obtained from pump system upgrades and changes."

The ER rating also means the products have undergone standardized performance testing that has been conducted in an independently audited and an HI-approved pump test lab. Products that meet efficiency benchmarks are listed at http://er.pumps.org/ratings/search. Users can search for pumps by basic model number, manufacturer or rating ID, which can be found on the hydraulic energy rating label distributed with the pump. This database is also intended to connect users to utility or government rebates associated with HVAC upgrades.

Legislative actions, such as the federal DOE pump efficiency standards, along with state and municipal environmental policies, continue to drive the trend toward energy-efficient and sustainable buildings. Growing public interest in living and working in green buildings is another factor that is encouraging retrofit projects. Plus, green building appears to be good for the bottom line—a 2016 SmartMarket Report, *Dodge Data & Analytics World Green Building Trends 2016*, reports that green buildings command a 7% increase in asset value over conventional buildings.

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›› New Fan Energy Ratings regulation will have a huge impact on the HVACR industry when they go into effect in 2019.

Regulations

RSES Journal's first-ever Double Feature issue includes two double features. The following double feature focuses on regulations related to the U.S. Department of Energy's Fan Energy Ratings (FER) and upcoming refrigerant rules. The FER regulation feature discusses the potential for regulatory compliance to actually drive technical innovations in the HVACR industry. The refrigerants feature provides a global perspective on a handful of worldwide refrigerant regulations and how they are impacting the industry.

IS *Regulation* THE MOTHER OF INVENTION?

How regulatory compliance–including DOE's Fan Energy Ratings (FER)–can drive technical innovations that benefit the HVACR industry.

BY DEEP DEY

New or revised federal regulations intended to reduce energy consumption, emissions and other environmental issues can blindside corporations. In many cases, the regulation can doom entire product lines to obsolescence in a matter of years. Across industries, a new regulation may require investing millions of dollars in research, development and retooling to meet the deadlines for the new guidelines—an often heavy and unwanted investment.

Yet paradoxically, regulatory demands can accelerate innovation and competition, as engineering enhancements initially intended simply to satisfy the new energy requirements turn into competitive advantages and novel technologies.

For example, from 1975–2007, a series of federal mandates required the automotive industry to increase the average fuel economy of cars from 15 mpg in 1975 to an unimaginable 35 mpg by 2020—regulations considered by many in the industry to be unreasonable, if not impossible. Yet, striving to meet the new standards yielded unexpected benefits for automakers and consumers. The new, more fuel-efficient cars sold briskly, dramatically increasing the domestic market share against foreign imports. The U.S. moved from being an oil importer to an oil exporter as demand for gasoline fell. Consumers are saving an average of $8,000 over the life of their cars. This led to hybrid and electric cars coming to the market. All of these are positive side effects of regulatory compliance[1].

DOE's Fan Energy Ratings (FER)

In June 2014, the Department of Energy (DOE) issued a new regulation imposing the first national efficiency standards for furnace fans. The new standards, which would take effect in 2019, specify maximum fan energy ratings based on the airflow provided by furnace fans, with the rating disclosed on every fan, much as ENERGY STAR rating stickers are attached to household appliances.

The goals of the FER mandate are to reduce energy consumption in furnaces by approximately 40% in 30 years, saving an equivalent of 500 billion kWh—energy savings equal to the annual electricity use of about 47 million U.S. households—and lower CO_2 emissions by 180 million megatons. With furnace fans consuming an average of 10% of a home's total energy cost, the regulations promised to save consumers $29 billion over decades[2]. The potential economic and environmental impacts are huge. Rhea Suh, President of the Natural Resources Council noted, "They will save about the same amount of energy as all the coal burned in the U.S. to generate electricity in a year."[3]

> **"The last furnace energy standards were set in 1987; the 2014 rules are the first regulations specifically aimed at furnace fans."**

For fan and motor manufacturers, the 33 pages outlining the FER standards[4]—and the short deadline—promise an equally huge impact on their businesses. The last furnace energy standards were set in 1987; the 2014 rules are the first regulations specifically aimed at furnace fans[5]. Bringing their product lines up to the new standards would likely require an investment in redesigning existing motors or developing new technologies.

The new requirements are having a significant impact on motor manufacturers, HVAC OEMs, fan and motor OEMs, distributors, contractors, technicians and households—and the impact and cost were largely unknowns initially.

Different motor manufacturers responded to the new FER regulations in different ways. Some argued that the four-year turnaround to meet the 2019 deadline would be impossible. Others report they have yet to test their motors to determine what energy efficiency improvements will be required. Other companies simply made the investment, developed innovative solutions, and performed the work necessary to make their motors and fans compliant by July 2019—looking for competitive advantages along the way.

A compliance resource channel

Motor manufacturers worked to ensure that their product lines met the FER guidelines. But the companies and OEMs that would be incorporating the motors into their furnaces, HVAC systems and fan arrays had their own compliance challenges: specifying the right FER-compliant motors for the output, performance requirements, physical configurations and controls of their products, without significantly higher costs.

The FER regulations define specific energy parameters for a wide range of motors and motor technologies; the motor manufacturers had to help OEMs select motors that would ensure fans and furnaces were compliant. With no central resource for information about the Furnace Fan Energy Rating program, furnace and fan manufacturers had to collect information and specifications about the program, as well as marketing information for their customers, from a wide array of sources.

The regulatory burden can become a regulatory advantage to those companies that see new guidelines as an opportunity to improve and innovate the performance of their products. Luke A. Stewart of the Information Technology & Innovation Foundation noted, "Regulations that are most effective at stimulating innovation will tend to require compliance innovation and, at the same time, will minimize the compliance burden and mitigate the risks. Regulation can promote more complete information about products and processes in the marketplace,"[6] a spur to marketing the resulting consumer benefits.

"The regulatory burden can become a regulatory advantage to those companies that see new guidelines as an opportunity to improve and innovate the performance of their products."

In the case of the DOE FER regulations, compliance is bringing more efficient and higher-performance motors with more advanced technologies to the market already—one year before the 2019 deadline.

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MAPPING THE REFRIGERANT *Regulation* LANDSCAPE

Putting recent EPA SNAP, DOE, CARB, E.U. and Kigali refrigerant regulation developments into a global perspective

BY DR. RAJAN RAJENDRAN

For those who are attempting to keep track of the regulations surrounding the use of certain refrigerants in commercial refrigeration, chances are they may find themselves more than a little confused—and with good reason. The story which began in 2015 with the introduction of groundbreaking regulations saw its fair share of plot twists in the latter half of 2017 and early 2018—developments that frankly caught most of the industry off guard.

At the heart of the issue is the Environmental Protection Agency's (EPA) Significant New Alternatives Policy (SNAP) Rule 20, which was introduced in 2015 to phase down and delist the use of hydrofluorocarbon (HFC) refrigerants, which contain a higher global warming potential (GWP) in certain commercial refrigeration applications.

Since 2015, the industry has made significant progress across the board through product development initiatives targeted at meeting compliance challenges posed not only by SNAP, but also the energy-efficiency mandates from the Department of Energy (DOE). Per the guidelines of Rule 20, the transition to more environmentally friendly refrigeration technologies was well underway.

U.S. Court vacates SNAP Rule 20

Then, in August 2017, the U.S. Court of Appeals for the DC Circuit ruled to vacate EPA SNAP Rule 20. Responding to a challenge submitted by two HFC refrigerant manufacturers (Mexichem Fluor and Arkema), the court decided that the EPA had exceeded its authority to require the replacement of HFCs under the Clean Air Act, Section 612. Their decision was based on the reasoning that Section 612 was originally adopted to curb substances containing higher ozone depletion potential and was not specifically targeted to address the matter of greenhouse gases and their associated GWPs.[1]

Immediately, the court's ruling elicited a wide range of responses from within the industry. Opponents of the decision—including leading alternative refrigerant manufacturers and third parties such as the Natural Resources Defense Council (NRDC)—soon filed petitions with the DC Circuit Court of Appeals for a rehearing en banc of the case. But in late January 2018, the court announced that it would deny the intervenor/respondents' petitions for a rehearing.[2] Prominent stakeholders such as Honeywell, Chemours and the NRDC have already vowed to file appeals with the United States Supreme Court.[3]

Most recently, a group of bipartisan senators introduced a bill called the American Innovation and Manufacturing Act; if it is passed, it would entitle the EPA to phase down HFCs used in refrigeration and air conditioning, in consultation with the industry.[4] This bill would operate in accordance with the guidelines set forth by the 2015 Kigali Amendment to the Montreal Protocol, a global treaty among 197 nations meant to phase out harmful greenhouse gases and ozone-depleting substances. It is important to note that while the U.S. has not yet ratified the Kigali Amendment, the U.S. State Department issued a statement on Nov. 23, 2017, at the 30th anniversary of the Montreal Protocol that it had "initiated the process to consider ratification."[5]

Suffice to say that the DC Circuit Court of Appeals ruling to vacate Rule 20 as initially enacted does not necessarily signify the end of the EPA SNAP, nor does it represent the global and state legislative efforts yet underway to reduce greenhouse gases. Let us take a look at some of this activity, starting with the state of California.

California Air Resources Board (CARB) HFC phase down

While California is subject to the rules handed down by the U.S. government's federal agencies, initiatives proposed by CARB continue to place the state into a class of its own. CARB has developed draft proposals that would not only preserve the federal framework set forth in EPA Rules 20 and 21, it would also call for more aggressive future phase-down measures in line with the E.U.'s fluorinated greenhouse gases (F-gases) efforts.

Initially, CARB looks to preserve the federal framework in new retail food refrigeration, food dispensing equipment, air-conditioning chillers and refrigerated vending machines. The second CARB proposal calls for future rules on refrigerant use according to their GWP and refrigerant charge in specific applications. Under these guidelines, refrigerants with a GWP of 150 or greater would be prohibited in new stationary refrigeration systems containing 50 or more pounds of refrigerant beginning in 2021. While these proposals are scheduled to take effect in mid-2019, CARB is giving the industry opportunities to provide input and has not yet set a deadline for comments.[6]

Canada ratifies Kigali amendment, HFC ruling

Canada was among the first countries to ratify the Kigali amendment to the Montreal Protocol, and its HFC phase-down guidelines are in step with its recommendations. Through an amendment to the Canadian Environmental Protection Act in Oct. 2017,[7] the country proposed a significant HFC phase-down schedule spanning the next few decades. The ruling impacts several refrigeration categories, including: stand-alone refrigeration, centralized refrigeration and chillers.

F-gas regulation lowers HFC quota

Enacted in 2015, the E.U.'s regulation designed to control emissions from F-gases—including HFCs—is mandating the next step of its phase-down schedule in 2018. This significant step-change lowers the consumption quota from the previous 93% of the original baseline to 63%. The step is intended to further drive scarcity of HFCs in Europe, which will inevitably result in rising HFC prices, at least in the European market.[8]

Factoring energy into regulatory equation

Refrigerants are only one factor in the regulatory equation affecting HVACR industry; it is also dealing with energy mandates by the DOE. While these were introduced in 2014, they have evolved to present significant implications across three classes of equipment.

Commercial Refrigeration Equipment (CRE). Since the enforcement date of March 2017, new CRE have been subject to 20-86% energy reductions, depending on the specific class of equipment. Compliance equations are factored according to the unit's daily energy consumption (kWh/24-hour) and its total display area.

Automatic Commercial Ice Makers (ACIM). As of this past January, new ACIMs must achieve 5-25% energy reductions, as measured in kWh/100 lb of ice. Again, each equipment class has a specific equation to measure compliance, so OEMs must be certain of their particular class requirements.

Walk-in Coolers and Freezers (WICF). WICF manufacturers are looking at a 2020 enforcement date to reduce energy consumption by 30-37%. These reductions are measured according to the AHRI-1250 annual walk-in efficiency factor (AWEF) standard. It is worth noting that while the original benchmark set for this standard has been reduced through persistent industry negotiations, it still represents a significant energy reduction target for WICF equipment.

Opportunity to align refrigerant, efficiency regulations

One of the challenges with the EPA's original ruling was that the timing of its HFC phase-down schedule was not necessarily in step with the DOE's energy efficiency mandates. This placed a tremendous burden on equipment manufacturers who were potentially looking at separate design cycles to address each requirement individually. It also presented difficult decisions for end users who were trying to choose the most economical and sustainable path forward.

Perhaps a silver lining of the most recent regulatory developments is a new opportunity for regulators to better align the EPA's refrigerant guidelines with the DOE's energy efficiency mandates. It is in the best interest of all parties to push for greater coordination and cooperation between the two efforts.

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