

APPLIANCE & HVAC

REPORT

Reaching Design Engineers at the OEM Level

October 2023

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COLD-CLIMATE HEAT PUMPS

(See page 22)



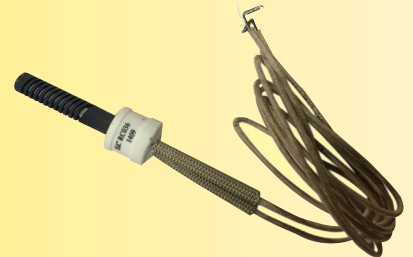
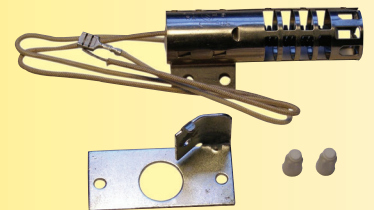
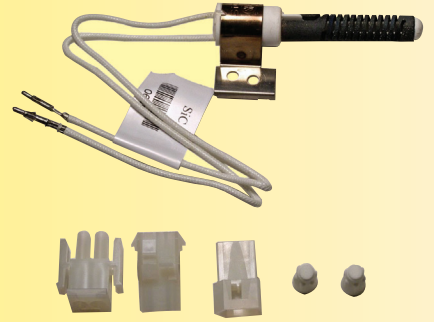
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Hello 4th Quarter



Welcome to our fourth and final issue of 2023. And this completes our fourth full year of publication.

To begin, I want to thank our readership, OEM design engineers; the companies that contribute editorially and our advertisers for their continued support. Without all three constituencies *The Appliance & HVAC Report* could not exist.

This is our structure:

- 25,000 subscribers
- Nine or so whitepapers/tech articles per issue
- Four issues per year, monthly enewsletters, physical distribution at various tradeshow (AHR being the major one).

This manner of doing business has allowed us to be profitable from our beginning (autumn, 2019), and also allowed us to separate our editorial mission from the sale of media. And we believe that has earned us respect from the marketplace.

The biggest issue facing the industry? Without a doubt it's the movement towards electrification of everything we cover...not just appliances and HVAC products but power tools, lawn/garden equipment, etc. And it creates a lot of challenges and some turmoil for OEMs and their vendors alike. This is a subject matter that we continue to cover editorially.

Here are the companies/organizations that contributed editorially to this issue: Certifigroup, Danfoss, ebm-papst, International Copper/Microgroove, Fieldpiece, Littelfuse, Robert Bosch and Telsonic

Now for our newest endeavor...“book publishing”. The word book is in quotes because you won’t find any hard cover or paperback titles in stores from us. That’s not what we mean. What we are doing for individual companies is taking their various whitepapers, tech articles, case studies and other materials and combining them into one single publication. They can be used in any manner by the company however they see fit, such as giving to their sales and engineering teams, putting them on their websites, etc.

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Thanks for your continued interest and attention. Next year starts Year 5 for us, a real milestone for new titles in the world of publishing. We are glad to have made it this far and look forward to continuing in the future.

Be happy, healthy, safe and prosperous.

Brad

Brad Glazer, Founder & Publisher

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APPLIANCE & HVAC
REPORT Reaching Design Engineers at the OEM Level

Reaching
Design Engineers
at the
OEM Level

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CONTENTS

October

FEATURES



6

Heat Pumps Are on The Rise

by Ian McIver

Are you noticing an increased demand for electrified heating and cooling options? Change is on the horizon.



8

Common Sense About Sensors

by Paulius Juskevicius

Essential facts about your sensor choices and four crucial questions whose answers should carry significant weight in the decision process.

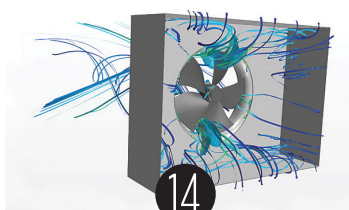


12

Preparing Your HVAC Business for Sale

by Deniz Mezheritskiy

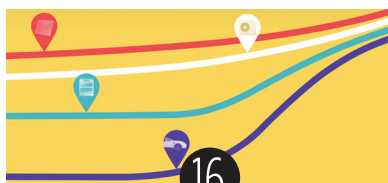
Despite current concerns over banking, and some turbulence in the economy, this is still a good time to sell a business.



14

Passive Noise Reduction Options for Axial and Centrifugal Fans

Learn more about controlling operating noise.

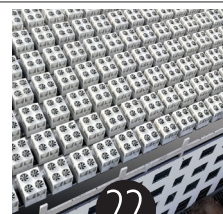


16

Pace of Progress

by Rewiring America

Electrifying the machines in our lives at the rate required to transform the market and meet our climate goals.



22

HVACR Engineers Focus on Cold-Climate Heat Pumps

by Frank Gao, Harry Schmitz, Yoram Shabtay, Kerry Song, Cooper Zhao

The development and deployment of cold climate heat pumps is important to the energy future of our planet.



35

Understanding A2L Refrigerants

by Tony Gonzalez

The EPA introduced a rule mandating an 85% nationwide phasedown in high-global warming potential hydrofluorocarbon refrigerants by 2036.



38

The Net Value of the Ultrasonic Metal Welding Process

by Saeed Mogadam

No matter how many variables are being considered in the selection of the joining method, ultrasonic welding seems to offer a better long-term return on investment.



42

Roadmap For Decarbonizing Cities

by Mika Kulju

Skyscrapers, traffic jams, shopping malls, and air conditioners. It is not hard to see why cities account for two-thirds of global energy consumption and more than 70% of annual global carbon emissions.



46

The 6 Hazards of Product Safety #3 Risk of Fire

by Bill Bisenius

All electrical circuits, other than those at Class II voltage/power levels, are considered to involve a "Risk of Fire".



48

Condensate Pumps for Computer Room Air Conditioning

This case study deals with OEMs of data center cooling systems to deliver stock and semi-custom condensate pump solutions for manufacturers of Computer Room Air Conditioning Systems.

DEPARTMENTS

30 News Beat

50 Advertisers Index

Heat Pumps Are on The Rise: What's Driving Change and How Pros Can Stay Ahead

BY IAN MCIVER

Are you noticing an increased demand for electrified heating and cooling options? Change is on the horizon.

Green HVAC alternatives are on the rise, as evidenced by the over 4 million heat pumps purchased by Americans in 2022 – outperforming more traditional gas-powered units, which saw approximately 3.9 million sales.

This shift in consumer sentiment, however, isn't only driven by a desire to be more eco-friendly. There are a number of external factors incentivizing this shift, so let's break them down.

Driving The Shift

While heat pumps have been widely adopted in Europe, it is taking a more concerted effort to educate consumers and contractors in the U.S. as to what exactly this HVAC solution is and the benefits it provides. Historically, the name heat pump alone has created mass confusion. Often seen as an alternative to gas furnaces only, heat pumps are actually electrifying the HVAC industry with more sustainable heating and cooling capabilities in a variety of geographic regions. As of late, however, a collaborative effort between HVAC manufacturers, energy providers and



technicians have put myth-busting and education at the forefront, which is helping to shift the tide in the favor of heat pumps.

Further fueling this pivot is increasing consumer demand for more efficient household appliances and HVAC systems. There is a dual interest in reducing carbon footprints, while also exploring cost-cutting measures—a point that has only solidified in the post-pandemic era of economic uncertainty. It has been shown that consumers with heat pumps experience a positive return on their investment when totaling up the month-to-month and utility cost savings heat pumps provide.

Regulatory & Rebate Push Adoption

There are also activations happening across local and federal government that are driving this shift toward electrification. New York made headlines earlier this year for provisions in their \$229 billion state

budget which will ban the use of natural gas and other fossil fuels in some new construction as soon as 2025, while similar efforts are actively being executed in California toward the same end goal.

While bans on natural gas are dominating the green HVAC push at the federal level, local agents are finding alternative ways of driving change. In July, ComEd – the largest energy provider for the greater Chicago area – ceased all existing rebates offered for installation of central AC units in an effort to redirect consumers toward more energy efficient options for heating and cooling.

All in all, there's a lot contributing to the rapidly increasing demand for electrified HVAC technology – so what does this all mean for HVAC professionals?

Residential Installers Will Get to Know a New Normal

Heat pumps work a lot differently than the traditional heating and cooling systems many professionals are used to working with – and while hailed as being relatively simple to install, they necessitate electrical capabilities the units of yesterday did not. This has left many contractors rushing to catch up with an industry that's demands have outpaced the level of training possessed by their staff.

Professionals should work ahead of the curve by learning whatever possible about heat pumps before demand outpaces capacity. At a high level, heat pumps work by drawing warmth from the air, ground or water outside and transferring it inside to warm homes – and vice versa to cool. These units are adept at maintaining consistent temperatures indoors, and since they use electricity, which can be generated from renewable energy

sources, like solar and wind, to transfer heat rather than generate it using fossil fuels, they are both more efficient and less taxing on the environment than traditional HVAC units.

On the professional side, HVAC contractors will reap the rewards of their efforts to get familiar with electric systems through enjoying the simpler installation and maintenance procedures that accompany heat pumps, thanks to their dual functionality in offering both heating and cooling in one unit.

Incentives Will Steer You and Your Customers Toward Electric

Electrified HVAC systems may cost more upfront, but they tend to save customers money in the long run by enabling them to decrease their energy usage and thereby pay less on utilities each month. Rebates and other incentives are also being offered on the local and national levels to lessen that initial financial burden as well – so it's important you keep some of these incentives in your back pocket should your customers express interest in going electric.

Some of the chief federal incentives driving heat pump adoption are the new or updated rebate and tax credit programs defined in the Inflation Reduction Act (IRA), which seeks to reduce greenhouse gas emissions through the following programs:

- **25C: Energy Efficient Home Improvement Credit:** This program offers homeowners tax credits of 30% of the project cost up to \$1,200-\$3,200 depending on the energy-efficient home improvements. This includes a \$2,000 cap on qualifying heat pump installations.

- **25D: Residential Clean Energy Credit:** This incentive offers tax savings on green HVAC purchases, such as a tax credit equal to 30% of the product

and installation cost for Energy Star-qualified geothermal heat pumps.

- **High-Efficiency Electric Home Rebate (HEEHR) Program:** Through this program, states can provide up to \$14,000 in rebates for households that take on electrification projects, such as qualifying heat pump installations.

- **Home Energy Performance-Based, Whole-house Rebate (HOMES) Program:** This program offers rebates of up to \$4,000 to homes that demonstrate a certain percentage of energy saved through energy saving projects.

Chicago's ComEd is setting an example of how local entities can step up to the plate and act as changemakers driving a more concentrated shift toward electrified HVAC in their own communities. The energy provider is offering residential customers the following incentives:

- Up to \$2,000 for air source heat pump installations (the most common variant)
- Up to \$9,000 per household for installing ground-source geothermal heat pumps
- Up to \$1,350 for mini-split heat pumps (two-part units with indoor and outdoor fixtures that don't rely on ductwork to heat and cool homes)

ComEd's industry-shaking move to pivot away from central AC incentives and staunchly promote energy-efficient alternatives sets an interesting precedent for future local regulation – professionals should keep an eye out for similar organizations following suit in metropolitan areas near them.

The Bottom Line

The HVAC industry as professionals have come to know it is in for plenty of big changes, from the equipment customers are most often having installed to the types of incentives available to them. To emerge as a preferred

source of expertise on electrified HVAC solutions, consider following these few best practices:

- **Understand what incentives are out there** for customers who switch to electric heating and cooling, and be able to identify where a particular client qualifies.
- **Get your team up to speed** by investing in training programs and electrified HVAC certifications.
- **Establish valuable partnerships with suppliers** who can provide high-quality heat pump technology.
- **Keep abreast of new developments in electrification** to gain insights into what new products and incentives might be on the horizon.
- **Document each electrification project you take part in** so your customers and your team can qualify for all of the relevant incentives and guarantee compliance with evolving regulations.
- **Educate customers** who are still on the fence to do your part in driving the shift toward the electrified future. ●



Ian McIver is a Product Manager at Bosch Home Comfort, North America. Focused on bringing geothermal water source heat pumps to market, McIver is an experienced engineer with a demonstrated history of working in the consumer goods industry.





Common Sense About Sensors: 4 Important Questions to Ask Before Selecting Sensors For Your Next Design

BY PAULIUS JUSKEVICIUS

As you work through the product development process to complete your latest small appliance, large appliance, or home and building automation product design, you carefully define the requirements for suitable sensors. You realize you may also need some customization for a specific sensor assembly. While price and delivery are critical decision factors, other considerations determine a successful sensor selection. Here are some essential facts about your sensor choices and four crucial questions whose answers should carry significant weight in the decision process.

Six Types of Sensors

Magnetic Detection Sensors For Proximity Detection, Positioning, and Control

1. Reed switches have two ferromagnetic blades (called reeds) hermetically sealed in a tubular glass envelope. The contacts on each reed blade have a thin layer of precious metal deposited on them to provide a low-resistance electrical connection. The glass envelope is filled with nitrogen gas to eliminate oxygen and prevent contact oxidation. Reed switches can be activated by either a permanent magnet or an electromagnet. The relative stiffness

of the reed blades, the small gap, and the overlap between the two contacts determine the switch's sensitivity, defined by the intensity of the magnetic field required to change the state of the contacts. Unlike an integrated circuit sensor, a reed switch does not require power to operate. Thus, a reed switch is an excellent control element in battery-powered products.

2. A Hall effect sensor generates a voltage when exposed to a magnetic field intensity and when supplied by a source current. The sensor is a semiconductor-based material. Hall voltages are microvolt and millivolt levels; thus, a Hall effect sensor requires signal conditioning. In addition, the semiconductor element requires temperature compensation and EMC/ESD protection. Hall effect sensors monitor proximity and provide continuous rotary or linear positioning.

3. A reed relay combines a reed switch with a control coil. As with other relays, this provides galvanic isolation between the coil control circuit and the controlled load. The reed relay's small size and high magnetic efficiency enable lower coil drive power than other relay types. Other advantages include high insulation resistance, low contact resistance, and long contact life.

4. The TMR switch integrates Tunneling Magneto Resistance (TMR) and CMOS technology to provide a magnetically triggered digital switch with high sensitivity and ultra-low power consumption. It contains TMR magnetic sensor and CMOS signal processing circuitry within the same package. It includes an on-chip TMR voltage generator for precise magnetic sensing, a TMR voltage amplifier, a comparator, and a Schmitt trigger to provide switching hysteresis for noise rejection. An

internal bandgap regulator provides a temperature-compensated supply voltage for internal circuits, permitting a wide range of supply voltages.

Temperature Sensors

5. Thermistors are thermally sensitive resistors whose resistance is a function of their temperature. Negative temperature coefficient (NTC) thermistors decrease their resistance when the temperature rises. Positive Temperature Coefficient (PTC) thermistors increase resistance when the temperature rises. Thermistors provide high accuracy but operate over a narrow range of approximately -50 °C to 100 °C. Thermistors, with their highly predictable characteristics and excellent long-term stability, are ideal sensors for temperature measurement and control applications.

6. Platinum Resistance Temperature Detectors (Pt-RTDs) have a near-linear change in resistance with any temperature changes. Platinum RTDs maintain a significant and uniform rate-of-resistance change over an extended operating temperature range, a much wider range than a thermistor. Platinum RTDs are excellent for measurement and control applications with temperatures ranging from -70 °C to 500 °C.

4 Questions to Ask Before Selecting Sensors

1. Does the supplier offer a wide-ranging product line of sensors and other components?

Consider a manufacturer that produces multiple sensor types. Such a manufacturer will have expertise in a broad range of technologies and be more likely to have capabilities to meet custom requirements.

In addition, a manufacturer with an extensive product line can address many of your other component requirements. That allows you to reduce the number of vendors and reduce the number of vendors and simplify your supply chain.

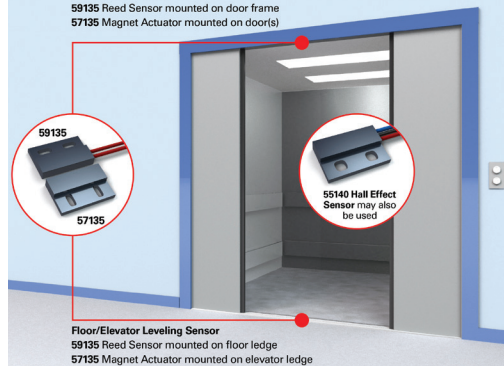
The manufacturer's knowledge and experience with an extensive portfolio can translate into innovations in new products. Their innovations can give your products a decisive competitive advantage in the market.

2. Does the supplier offer application assistance?

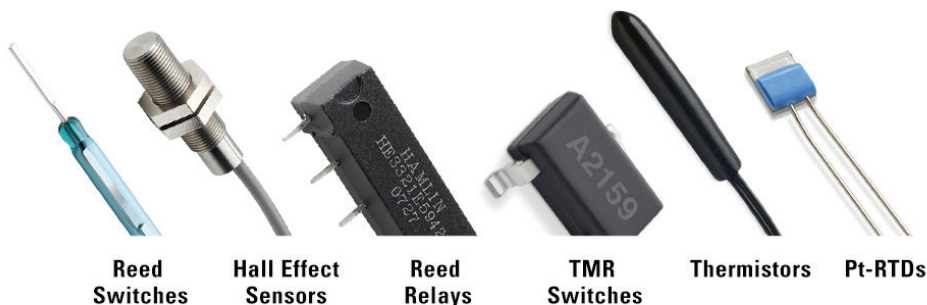
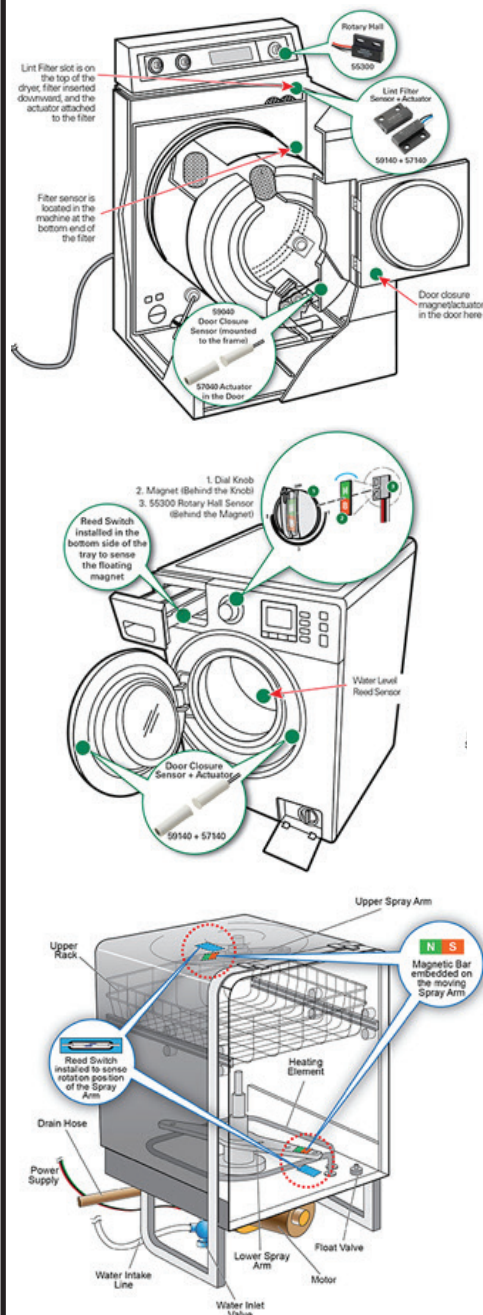
Applications assistance from technical personnel can save precious development time and help select the appropriate sensor model. They can ensure that you consider all parameters related to the use of the sensor, such as temperature effects, vibration, and susceptibility to electrical noise.

Sensor applications in building and industrial automation

Door Closure Sensor
59135 Reed Sensor mounted on door frame
57135 Magnet Actuator mounted on door(s)



Sensor Applications in Appliances





3. Does the supplier provide custom engineering?

Do you have critical size or shape requirements for your sensor? You may need more sensitivity or a specific type of electrical connector. You will want your supplier's custom engineering capability to address unique needs. Many suppliers sell only their standard products, and that lack of service should preclude any expectation of having a long-term relationship with the supplier.

4. Does the supplier have the capacity to manage your order requirements?

You do not want to lose revenue due to unduly long lead times for sensors and other components. Ensure that your supplier can meet your forecasted order requirements and adequately respond to unexpected large orders.

Benefits of Selecting a Capable Sensors Supplier

While a supplier can meet the essential requirements discussed here, the price for their sensor may not be the lowest available. However, you benefit from savings in development time, reduced in-warranty expenses, higher reliability, and greater customer satisfaction in the long term. Supplier selection should be as important as the selection of your sensors. ●

Sensor Design Resources

Download these helpful sensing design resources courtesy of Littelfuse, Inc.

Eight Sensor Considerations for Your Next Appliance Design

Design engineers and purchasing professionals must look beyond price and delivery when specifying sensors

for a new appliance design. Knowing the answers to several questions is essential before placing an order. This white paper addresses eight key questions and includes a section on making sense of the five types of sensortechnologies.



Sensing Products Selection Guide

This guide and application matrix helps solve sensor design challenges for appliance projects. Easily find the most suitable sensors for a variety of applications, including open/closed sensing for doors, positioning of compartments and drawers, fluid level sensing, temperature sensing for air/liquids/refrigerants, battery pack temperature monitoring, motor or power semiconductor temperature monitoring, and general safety and functional interlocks.



Paulius Juskevicius is a Strategic Marketing Manager for the Electronics Business Unit at Littelfuse. Paulius joined Littelfuse in 2016 as field application engineer for the EMEA

region. His current responsibilities include the management of marketing activities for new product launches and performing marketing studies and feasibility analysis for new product ideas. Paulius earned his master's in electrical engineering from Kaunas University of technology.

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Preparing Your HVAC Business for Sale: What Every Owner Should Know

BY DENIZ MEZHERITSKIY

You've owned a successful HVAC business for the last 30 years. And, as you eye retirement, the idea of selling your business is an option you're considering.

Despite current concerns over banking, and some turbulence in the economy, this is still a good time to sell a business. Our industry research and experience tells us that there are a large number of qualified buyers looking for opportunities.

For the best chance of success in selling an HVAC business, the seller should try to identify the ideal buyer ahead of putting the business on the market. Recognizing the ideal buyer's likely characteristics ahead of time can help the owner prepare a more

targeted sale strategy and negotiate more effectively during the sale, leading to a more successful outcome.

There are several categories of buyers that may be interested in purchasing an HVAC business. One category is strategic buyers, such as other HVAC companies that are looking to expand their operations or acquire new customers. Private equity firms are another category of buyers, which are focused on investing in companies with strong growth potential. Family offices and high-net-worth individuals are also potential buyers, as they may be seeking to diversify their investment portfolios. Finally, there are individual buyers, such as entrepreneurs or HVAC professionals, who are looking to start

or expand their own businesses in the industry.

Knowing who might be interested in an HVAC business is an important first step. Another step is understanding what additionally might motivate these buyers – what they are looking for in the acquisition of a business.

A Business News Daily article cites freedom, satisfaction and flexibility as among the key reasons people seek to purchase businesses.

And then there is the question about pricing or valuing the business.

In general terms, the sale price of most businesses is based upon what is called a multiple of cash flow. For example, if an HVAC business shows a positive annual cash flow of \$350,000, the selling price would be based on a multiple of that number. The multiple varies from industry to industry.

Within the HVAC industry, companies that concentrate on services, such as maintenance, repair, and replacement of existing heating and cooling systems, often sell for higher multiples than those focused on new construction – for several reasons:

- Service-focused companies typically have a more stable revenue stream and recurring customer base, which can provide more predictable cash flow compared to

new construction companies that may experience more volatile revenue patterns. This stability can be attractive to buyers, particularly those seeking a steady return on investment.



PREPARING TO SELL

A FEW MORE FACTORS TO KEEP IN MIND

1. EVALUATE YOUR FACILITY'S CONCENTRATION OF CUSTOMERS

and vendors. Is your HVAC business overly dependent on one customer or one vendor? For example, if 40% of your revenues are derived from one client, a potential buyer might be hesitant about going forward. The reason why is that an outside buyer would recognize that the loss of either a major customer or major vendor could alter the profitability of the business. You can address these potential red flags by seeing that no one customer represents a significant portion of your overall revenues, and that you have multiple sources (vendors) for materials.

2. DO YOU HAVE A MANAGEMENT OR LEADERSHIP TEAM that will remain with the business after the sale? A prospective buyer will be more attracted to a business that has a team in place to carry the business forward. A buyer can be reassured even further if there are employment contracts in place with key personnel.

3. WORKING WITH YOUR CPA FIRM, are your financial reports in good shape? Are the numbers accurate and easy to understand? That is one of the first places a prospective buyer will go – to the company's financials. How profitable is the business?

4. IS THERE REAL ESTATE WITH THE BUSINESS? If not, and the facility is leased, is there a long-term lease available? How does the real estate piece fit into the overall picture?

Your best strategy as you contemplate the sale is to be sure you have the right team of professionals in place – an attorney, a CPA, and a broker who can guide you through the process.

- Service-focused companies may have a stronger brand reputation and customer loyalty, as they have established long-term relationships with their customers through ongoing maintenance and repair services. This can make them more attractive to buyers looking for a company with an established customer base and a strong reputation in the market.

- Service-focused companies may require less capital expenditure and lower overhead costs compared with new construction companies, which can result in higher profit margins and valuation.

Overall, while new construction-focused HVAC companies may have higher revenue potential, service-focused companies are more attractive to buyers due to their stable revenue stream, strong customer relationships, and higher profit margins.

As people take a breath after the last two years of Covid restrictions, prospective buyers will find a strong market with many opportunities to purchase businesses across a wide range of industries. We see people on both sides – sellers and buyers – coming out of their shells and giving the market another look. And HVAC is one of the hotter business opportunities on the market. ●



Denis Mezheritskiy

is president of ROI Corporation, a business brokerage firm with offices in Massachusetts, Connecticut, and Georgia serving clients throughout

the U.S. and among the leading brokers in New England specializing in HVAC sales. A graduate of Suffolk University in Massachusetts, he owned several businesses before taking the reins at ROI, where he had been a broker for seven years prior to becoming the owner and president. Denis can be reached at dmezheritskiy@roibusinessbrokers.com.

Passive Noise Reduction Options For Axial and Centrifugal Fans

In applications relating to refrigeration, air conditioning and ventilation technology, users frequently notice that the selected fan installed in the device does not run as quietly as expected. Such fans often generate a level of operating noise considerably higher than that stated in the product documentation, simply because the values stated in the documentation reflect measurements made under optimal test conditions. In the applications themselves, however, the fans are subject to inflow disruptions of varying intensity that result from real life installation conditions. These disruptions generate a non-uniform inflow field causing additional noise which, as perceived by the human ear, often has an annoying or even uncomfortable low frequency tonal quality. Specially designed air inlet grills can reduce these disturbances by essentially straightening the inflow and significantly lowering the level of noise generation.

Fans in air handlers, heat pumps, air conditioners, refrigeration

units, electronics cabinets and filtration equipment are installed in many different ways, with varying dimensions and designs. Differences occur in the positioning of the openings required for ventilation, in the heat exchanger surface and in the packing density. When adjacent fans or the walls of a device near the fan inlet create obstacles or asymmetrical constrictions to the air flow, powerful vortices can form that generate high levels of turbulence (Figure 1). This turbulence then hits the rotating blades of the fan, causing major fluctuations in the pressure and speed at the front edge of the blade. This can result in a noticeable increase in broadband air flow noise, but even more significant are large increases in the low-frequency narrowband, tonal frequency noise components.

The tonal components consist of the blade-passing frequency and its harmonics. The blade-passing frequency is a function of the fan speed and the number of blades. An axial fan with five blades spinning at 1,200 rpm, for example, would result in a

blade-passing frequency of 100 Hz. These types of low frequency tones are perceived as an audible hum that is particularly difficult to attenuate. It is not possible to compensate for disruptions to the inflow by optimizing the fan. Providing mechanical isolation or insulation can involve prolonged analysis or experimentation that still may not yield satisfactory results.

One solution to reduce the noise-generating disruptions to the inflow is to deploy an air straightening grill on the fan intake. Such grills, properly designed, can be equally effective with both axial and centrifugal fans. Their use does not impact fan efficiency. Examples of air inlet grills for both fan types are shown in Figure 2. These are easily mounted to common fan housing styles and also lend themselves to field retrofits in many situations. Actual results of sound pressure level measurements performed on an example condenser are shown by the sound spectrum in Figure 3. The use of the inlet grill reduced the sound pressure level and considerably weakened the tonal noise. Typical results on many application types including central air handling units, air purifiers, air-water heat pumps and condensers show that a reduction in the overall sound power level of 3 dB(A) and a sound pressure level reduction of 9dB or more in the blade-passing frequency are possible.

Applications in the field of

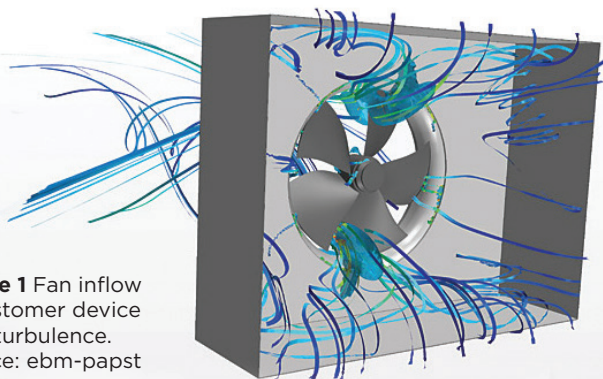


Figure 1 Fan inflow in customer device with turbulence.
Source: ebm-papst



Figure 2 Air inlet grills mounted to common axial and centrifugal fan housings.
Source: ebm-papst



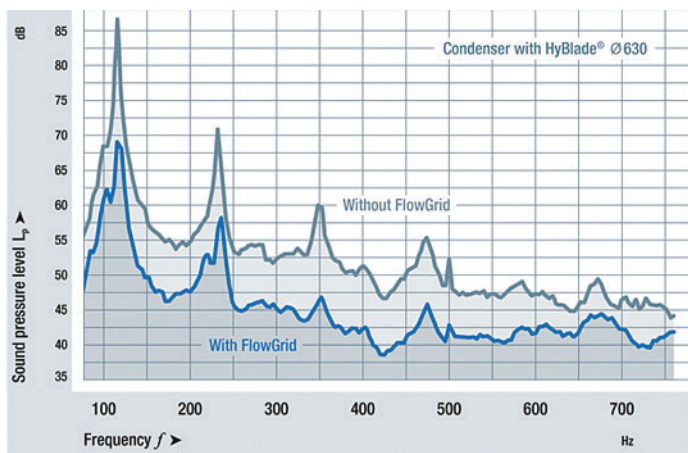


Figure 3 Adding an air inlet grill to a condenser fan can achieve a significant reduction in the sound pressure level and considerable weakening of tonal noise. Source: ebm-papst

ventilation, refrigeration and air conditioning technology have an additional option regarding noise reduction with the help of another passive component. This time the component works on the exhaust side of the fan and is restricted to use on axial fans. Adding a diffuser to the exhaust side of axial fans is a common technique used in agriculture and is often seen on animal barns where they are typically referred to as discharge cones. (Figure 4). These are often of thin sheet metal construction which is sometimes even delivered as flat stock to be mounted into a cone shape in the field. But until recently, nothing similar has been available that was easily adaptable to more commercial type applications.

These applications often use unducted axial fans and such an unducted or free exhaust can be an underestimated source of energy loss. This is because the total work generated by a fan is the sum of the static pressure and velocity pressure. Axial fans impart a relatively high velocity to the air flow, meaning low static pressure and high velocity pressure at the fan discharge. Freely exhausting the airflow at the discharge, as in unducted fan applications, loses the energy of the velocity pressure as turbulence and eventually as heat to the environment. Since these applications typically have ample clearance above and between fans, a well-designed diffuser can be

added to the fan exhaust to recover a significant portion of this velocity pressure as static pressure and use it to overcome the resistance to air flow in the application.

The diffuser shape provides a gently expanding diameter to gradually reduce the velocity of the air flow, resulting in a reasonably efficient conversion of velocity pressure to static pressure. Static regain is the term often used for this. Since the diffuser recovers some of the velocity pressure as static pressure before the air flow escapes to the atmosphere, the work required of the fan to overcome the system resistance is reduced. Consequently, the fan speed can be lowered—reducing both noise and input power—while still maintaining the same air flow.

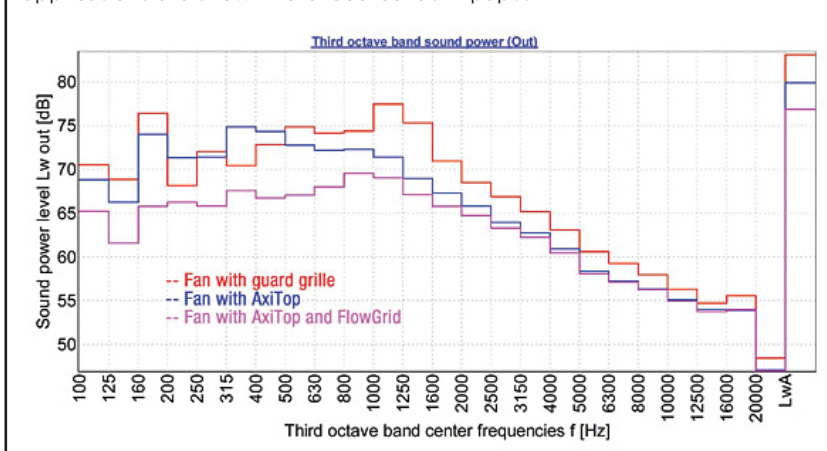
Examples of axial fan diffusers mounted in common applications

Figure 4 Adding a diffuser to the exhaust side of axial fans is a common technique used in agriculture and is often seen on animal barns where they are typically referred to as discharge cones. Source: ebm-papst



are shown in Figure 5. As with the air straightening grill on the fan inlet, the diffuser hardware is made from light, reinforced composite material and is easily mounted to the exhaust side of a typical axial fan housing by the fan OEM or as a field retrofit with a bit more work. The ability to lower the fan speed as a result of the efficiency gained from the diffuser while maintaining the same air flow can result in an overall noise level reduction of 5dBA or more, mainly from the mid-frequency sound spectrum. In axial fan applications where the air inlet grill and the diffuser can be used together, the synthesis of their effect on the fan intake and exhaust air streams can create an even more substantial impact on a combination of low frequency tonal noise and mid-frequency broadband noise. ●

Figure 5 Examples of axial fan diffusers mounted in common applications are shown here. Source: ebm-papst





Pace of Progress

June 2023 Baseline Report

BY REWIRING AMERICA

Electrifying the machines in our lives at the rate required to transform the market and meet our climate goals.

Charting Course

The story of new technology emerging in the marketplace, proving itself to be the better option, and becoming the standard is an inevitable one. Refrigerators. The car. Electricity itself. When a transformative new technology gains popularity over an incumbent, such as a mobile phone over a landline, adoption of that technology usually follows an S-shaped curve. Early adopters acquire the technology first, followed by a rapid uptick in adoption as the technology

reaches the majority, culminating in market saturation, and the eventual replacement of the incumbent technology.

There will be an S-shaped curve for the electrification of the 1 billion fossil fuel machines across our 121 million households as well: the cars we drive, how we heat the air and water in our homes, cook our food, dry our clothes, and where the power comes for those activities. It's the shape of this S-curve that's important. The learning curves for clean energy are evolving at a rapid clip, with costs forever being revised down. The Inflation Reduction Act (IRA) is expected to bring climate technology costs down by 40 percent. The more costs come down, the further we will steepen the ascent of

adoption.

The adoption curves of these technologies on their own, however, do not tell us the full story. Because these machines account for 42 percent of our energy-related emissions, we need to understand the adoption curve required for each of these machines to achieve our climate goals.

That is why Rewiring America has put together our first Pace of Progress report, mapping the current state of the market against what needs to be true in order to meet our emissions targets by 2050. In this report, we establish the national benchmark for the machines we need to electrify in our homes. The upshot? We have a gap of 14 million machines over the next three years above baseline market adoption projections. These first years are critically important as they will define the ramp of adoption over the next twenty years. The faster we move now, the more readily we will achieve our goals. In this report, we establish the national benchmark for the machines we need to electrify in our homes. The upshot? We have

a gap of 14 million machines over the next three years above baseline market adoption projections. These first years are critically important as they will define the ramp of adoption over the next twenty years. The faster we move now, the more readily we will achieve our goals.

We are optimistic about our ability to achieve these goals because of the opportunity presented by the largest climate investment in history, the \$369 billion in clean energy provisions of the IRA, which creates an electric bank account for every household in America.

Our optimism is further reinforced by the fact that all-electric technologies bring profound technological improvements with manifold co-benefits: Much like smartphones enabled billions of people around the world to have affordable access to the internet, and thus revolutionized entire segments of the world economy, there is every indication that virtuous cycles and network effects will exponentially improve the adoption of products like heat pumps and induction stoves, largely because these technologies are just so much better. And while even the highest social cost of carbon estimates do not price in these externalities, early signs tell us the market understands the broader

Closing the gap: the next three years	Three year business as usual (2023-2025, in thousands)	Three year climate target (2023-2025, in thousands)
 Heat pump HVAC	5,307	7,684
 Heat pump water heater	614	819
 Induction stove	1,472	3,232
 Rooftop solar	2,689	5,469
 Electric vehicles	2,739	9,439
TOTAL	12,820	26,642

implications of these co-benefits and is moving accordingly.

Together, these points represent key shifts in our thinking and models and illustrate why the electrification Pace of Progress is all at once extraordinarily ambitious and absolutely possible.

This report marks the beginning of Rewiring America's efforts to count the machines and measure our progress together. We believe this is foundational because every household, community, city, state, and business has a part to play in owning their piece of this number, and working to meet the pace. In the months ahead, we will use the pace of progress to benchmark every community in the country, and to delve into Justice40 and other equity-centered considerations, to ensure that, as we work to hit our topline numbers, we do so in a way that brings everyone along.

We look forward to hearing your thoughts on this approach. Please email us directly at research@rewiringamerica.org.

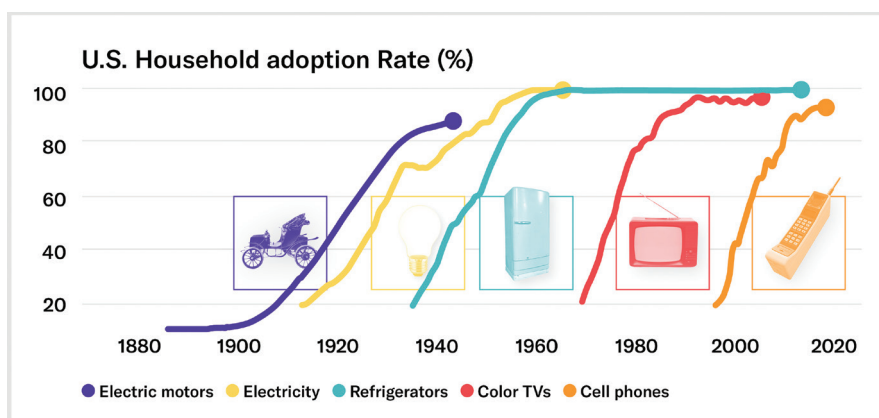
Let's Trace The Pace

At Rewiring America, we are working to accelerate the transition so that every household in the U.S. is using efficient electric machines powered by clean renewable energy by 2050.

The IPCC and other groups have set the target of zeroing out our national greenhouse gas emissions by 2050 to avert the worst of the climate crisis. To reach zero emissions, we know we need to stop burning fossil fuels in our homes and on our roads by electrifying everything.

To track progress toward this goal, we have calculated how many efficient electric machines (heat pumps for heating and cooling, heat pump water heaters, electric or induction stoves, electric vehicles, and rooftop solar installations) must be sold each year between now and 2050 to achieve these goals.

We know the average lifetimes of incumbent fossil-fueled machines, so we can calculate how many of each machine type must be replaced in a given year, then assume that those are replaced according to that year's sales proportions. This is called a stock turnover model: sales proportions plus equipment lifetimes lead to equipment stock in a given year.



Sales Curve, Stock Curve and Target curve

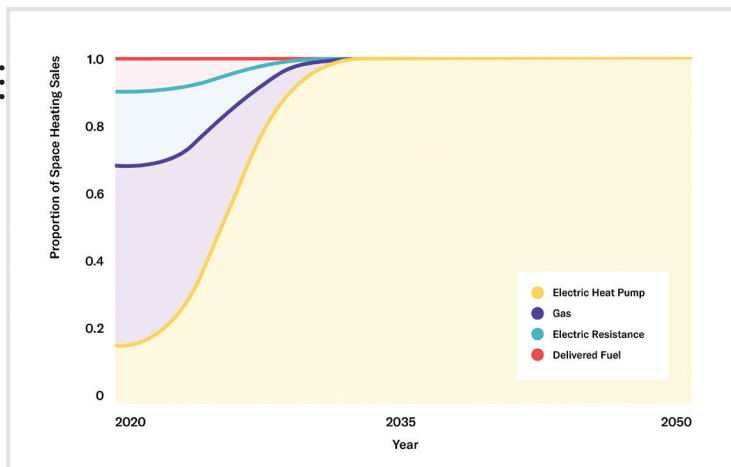
Sales curve: the sales percentage in each year of each type of machine required to reach our climate goals.

Stock curve: the number of machines of each type present in each household each year implied by the sales curve.

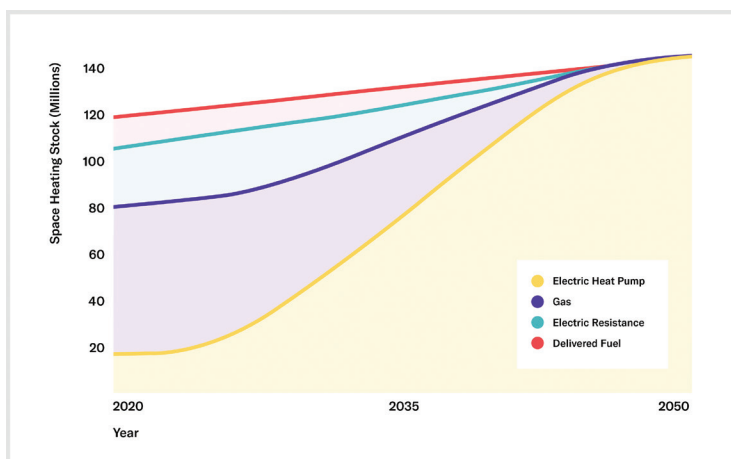
Target curve: how the required sales of efficient, electric machines compare to business-as-usual sales projections.

The S-curve adoption model starts off fairly slowly, representing modest increases in adoption in early “runway” years, then begins to accelerate quickly into widespread mass-market adoption. For products like heating systems and stoves with longer (~15- year) lifetimes, this means that we still have a three to five year runway period in which to accelerate market adoption at a manageable pace, on the order of hundreds of thousands of new sales above baseline rates. For products like water heaters, which have a shorter (~10-year) lifetime, the runway to mass-market adoption is even a bit longer. The scale of near-term runway market adoption coincides well with the rebates and tax credits in the Inflation Reduction Act. At the same time, we must act decisively and set the stage for mass-market adoption, for within a few years we will be out of runway. In time the market must move forward sustainably on its own.

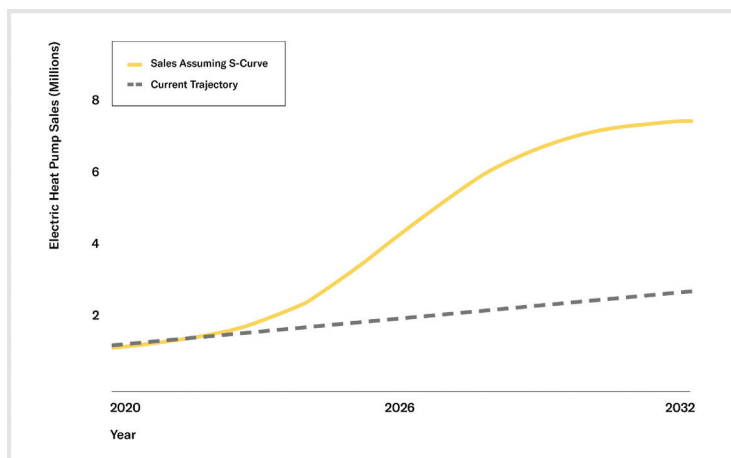
Finally, we emphasize that the projections in this report are not based in any way on the current policy environment for building electrification, including the impact of the Inflation Reduction Act and the Infrastructure Investment and Jobs Act. Rather, they are meant to demonstrate a projection of the pace of progress necessary to meet the scale of the climate crisis.



Most space heating machines have a lifetime around 15 years, so we set a target of electric heat pumps comprising 100 percent of sales by 2035. This yields the sales curve above.



100 percent electric heat pump sales by 2035 would therefore result in 100 percent turnover of the stock of homes heating with fossil fuels by 2050. This is demonstrated in the stock curve above.



We next compare the necessary sales growth rate (yellow solid line, derived from the sales proportions plot above) to existing sales growth projections (grey dashed line) to identify the sales over baseline required to put the U.S. on the desired S-curve trajectory to achieve 100 percent efficient electric heating and cooling by 2050. This is shown in the target curve above.

Results

Space heating: Currently, 16 percent of homes in the U.S. use electric heat pumps for space heating. We target 100 percent of homes using heat pumps for space heating

by 2050, which is about 140 million homes after accounting for growth in the building stock. To determine the market acceleration necessary to meet these goals, we compare our modeling to existing sales trends.

This tells us that we need to inspire 240,000 sales of electric heat pumps over baseline in 2023, and 2.38 million sales of electric heat pumps over baseline cumulatively in the next three years.

Now that we understand the full scope of the challenge, we can zoom in on the first few years of the target curve to identify short-term market transformation targets that, if met, will give us confidence that we are on an S-curve trajectory. For space heating we find that nationally, By 2032, electric heat pump sales need to increase three times over the business-as-usual scenario.

Water heating: Currently, just one percent of homes in the U.S. use electric heat pump water heaters for water heating. We target 100 percent of homes using heat pump water heaters for water heating by 2050, which is about 140 million homes after accounting for growth in the building stock. While electric resistance water heaters are technically already electrified, heat pump water heaters are three times more energy efficient and can yield significant annual energy bill savings, so for purposes of this report we assume that the nation's stock of electric resistance water heaters are also replaced with heat pump water heaters. To determine the market acceleration necessary to meet these goals, we compare our modeling to existing sales trends.

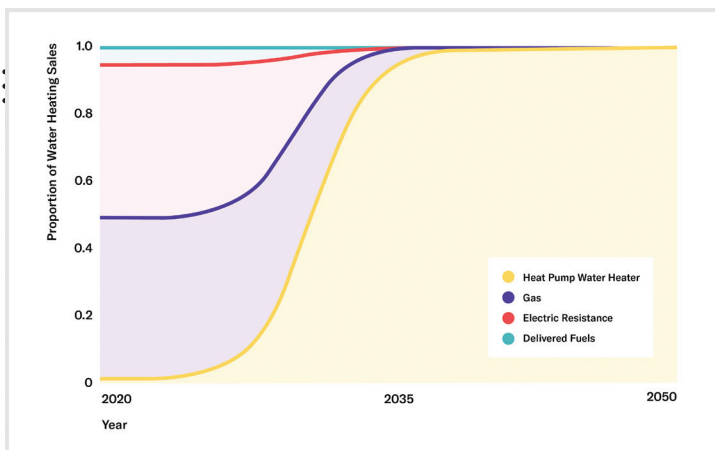
This tells us that we need to inspire 8,000 sales of heat pump water heaters over baseline in 2023, and 200,000 sales of heat pump water heaters over baseline cumulatively in the next three years.

Now that we understand the full scope of the challenge, we can zoom in on the first few years of the target curve to identify short-term market transformation targets that, if met, will give us confidence that we are on an

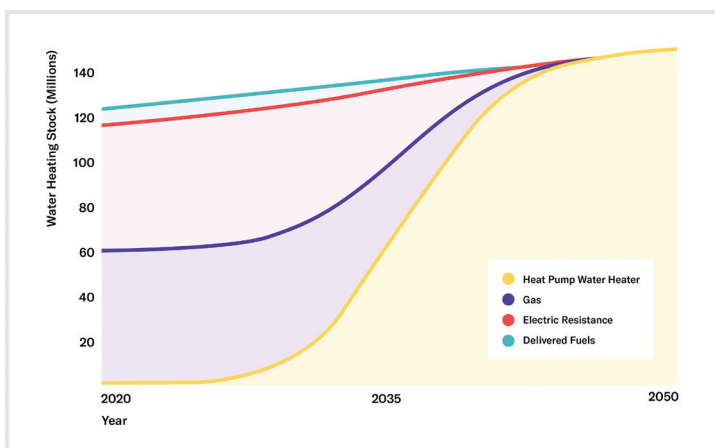
S-curve trajectory. By 2032, heat pump water heater sales need to increase more than ten times over the business-as-usual scenario.

Cooking: Currently, four percent of homes in the U.S. use induction stoves

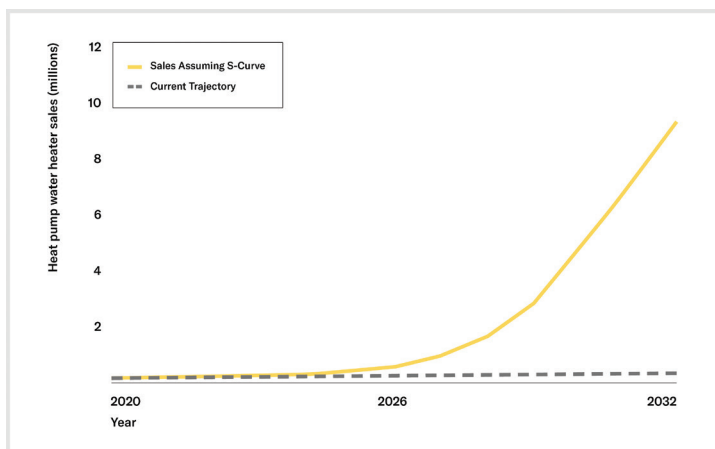
for cooking, and 57 percent of homes in the U.S. use electric resistance stoves. Unlike the comparison between heat pumps/heat pump water heaters and electric resistance space/ water heating, induction stoves do not



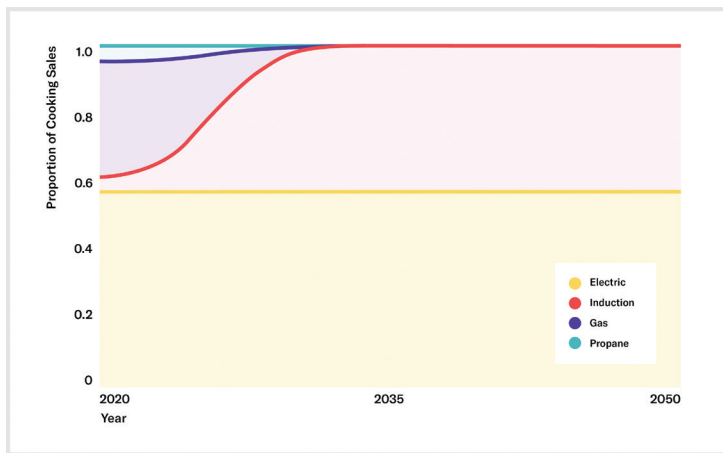
Water heaters have a lifetime around 10 years, so we set a target of electric heat pump water heaters comprising 100 percent of sales by 2040. This yields the sales curve above.



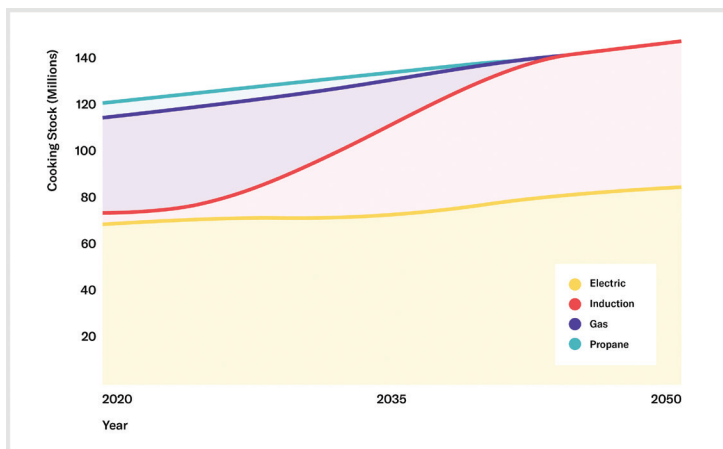
100 percent heat pump water heater sales by 2040 would therefore result in 100 percent turnover of the stock of homes using fossil fuels for water heating by 2050. This is demonstrated in the stock curve above.



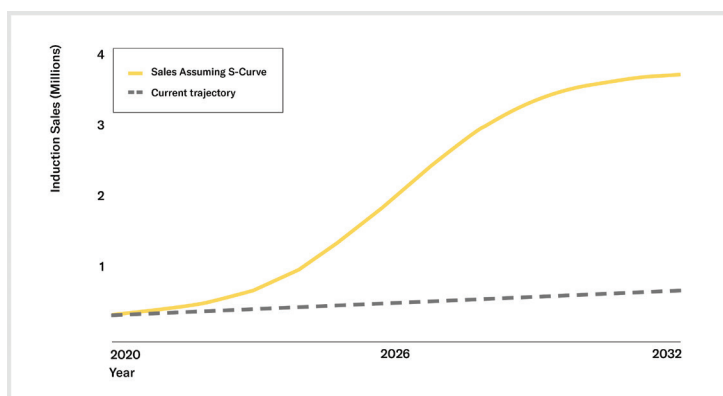
We next compare the necessary sales growth rate (yellow solid line, derived from the sales proportions plot above) to existing sales growth projections (grey dashed line) to identify the sales over baseline required to put the U.S. on the desired S-curve trajectory to achieve 100 percent efficient electric water heating by 2050. This is shown in the target curve above.



Most stoves have a lifetime around 15 years, so we set a target of electric and induction stoves combined comprising 100 percent of sales by 2035. This yields the sales curve above.



100 percent electric or induction sales by 2035 would therefore result in 100 percent turnover of the stock of homes cooking with fossil fuels by 2050. This is demonstrated in the stock curve above.



We next compare the necessary sales growth rate (yellow solid line, derived from the sales proportions plot above) to existing sales growth projections (grey dashed line) to identify the sales over baseline required to put the U.S. on the desired S-curve trajectory to achieve 100 percent electric cooking by 2050. This is shown in the target curve at left.

have a significant efficiency benefit relative to electric resistance stoves. Both are about 80 percent efficient and therefore have similar energy

bill impacts. For purposes of this analysis, we assume induction stoves replace only gas and propane stoves, and assume that the sales proportion

of electric resistance stoves remains constant. To determine the market acceleration necessary to meet these goals, we compare our modeling to existing sales trends.

This tells us that we need to inspire 260,000 sales of induction stoves over baseline in 2023, and 1.76 million sales of induction stoves over baseline cumulatively in the next three years.

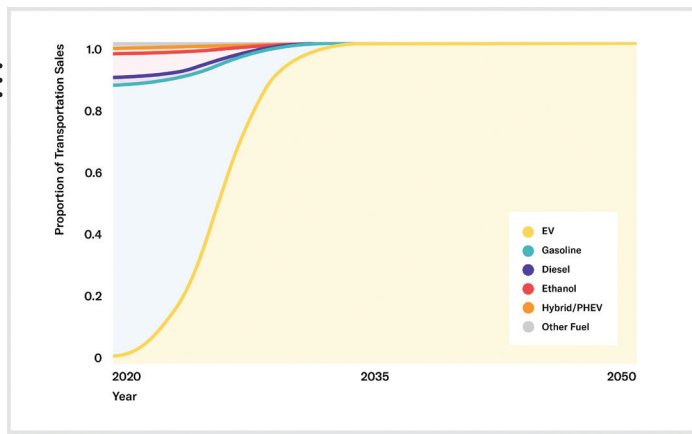
Now that we understand the full scope of the challenge, we can zoom in on the first few years of the target curve to identify short-term market transformation targets that, if met, will give us confidence that we are on an S-curve trajectory. By 2032, induction stove sales need to increase five times over the business-as-usual scenario.

Transportation: Currently, two percent of passenger cars in the U.S. are electric vehicles. We target 100 percent of passenger vehicles being all-electric by 2050, which is about 350 million cars after accounting for growth in the vehicle stock. To determine the market acceleration necessary to meet these goals, we compare our modeling to existing sales trends.

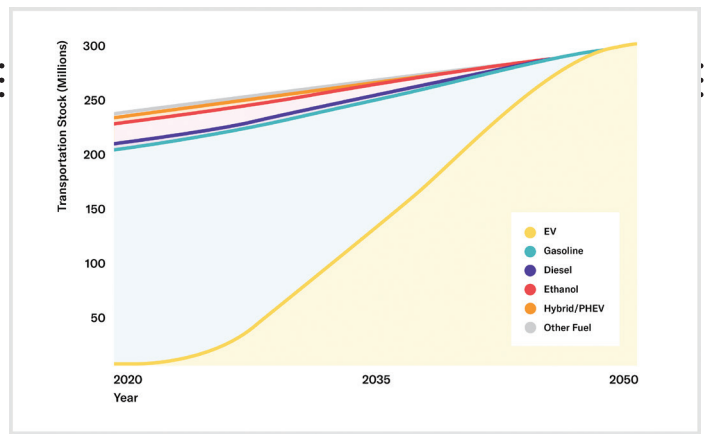
This tells us that we need to inspire 920,000 sales of electric vehicles over baseline in 2023, and 6.70 million sales of electric vehicles over baseline cumulatively in the next three years.

Now that we understand the full scope of the challenge, we can zoom in on the first few years of the target curve to identify short-term market transformation targets that, if met, will give us confidence that we are on an S-curve trajectory. By 2032, electric vehicle sales need to increase approximately seven times over the business-as-usual scenario.

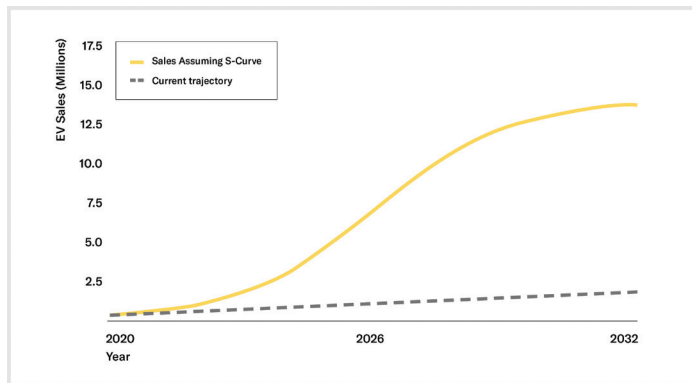
Rooftop Solar: Currently, five percent of homes in the U.S. have rooftop solar. We target 100 percent of single-family homes having



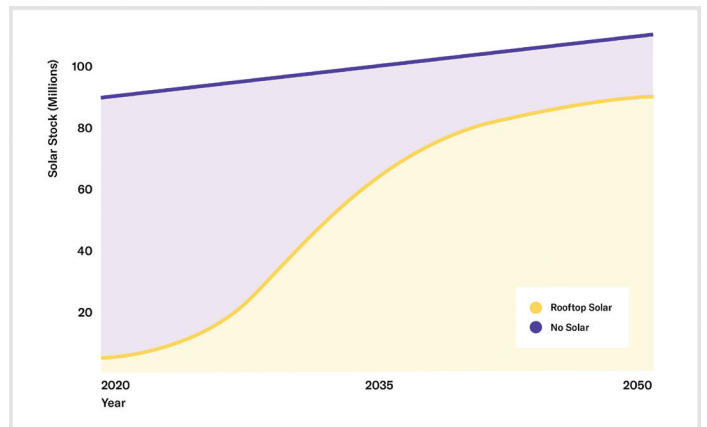
Most vehicles have a lifetime around 20 years, so we set a target of electric vehicles comprising 100 percent of sales by 2035. This yields the sales curve above.



100 percent electric vehicle sales by 2035 would therefore result in 100 percent turnover of internal combustion engines and other non-electric vehicles by 2050. This is demonstrated in the stock curve above.



We next compare the necessary sales growth rate (yellow solid line, derived from the sales proportions plot above) to existing sales growth projections (grey dashed line) to identify the sales over baseline required to put the U.S. on the desired S-curve trajectory to achieve 100 percent electric vehicles by 2050. This is shown in the target curve above.

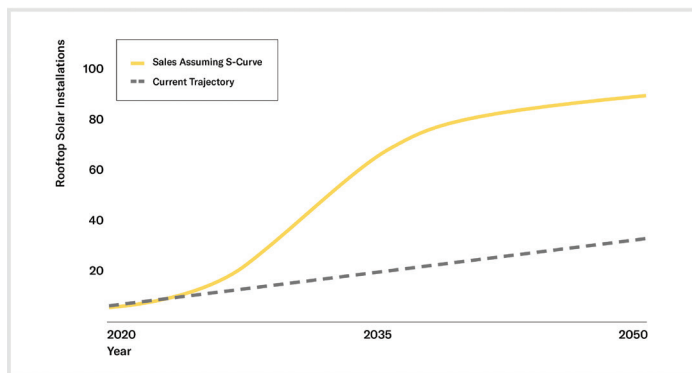


100 percent of feasible residential buildings with rooftop solar would result in over 80 million cumulative installations by 2050. This is demonstrated in the stock curve above.

rooftop solar by 2050, where it is technically feasible to do so according to the National Renewable Energy Laboratory's report on Rooftop Solar Technical Potential. Since rooftop solar is not replacing existing machines, there's no need to set a sales curve, and we can simply calculate the stock of rooftop solar over time. To determine the market acceleration necessary to meet these goals, we compare our modeling to existing sales trends.

This tells us that we need to inspire 442,000 rooftop solar installations over baseline in 2023, and 2.78 million rooftop solar installations over baseline cumulatively in the next three years.

Now that we understand the full



We compare the necessary installation growth rate (yellow solid line, derived from the stock plot above) to existing installation growth projections (grey dashed line) to identify the installations over baseline required to put the U.S. on the desired S-curve trajectory.

scope of the challenge, we can zoom in on the first few years of the target curve to identify short-term market transformation targets that, if met, will give us confidence that we are on an S-curve trajectory. By 2032,

installations need to be accelerated approximately seven times over the business-as-usual scenario. ●

Questions? Contact:
research@rewiringamerica.org

U.S. energy consumption by source and sector

quadrillion British thermal units (Btu)

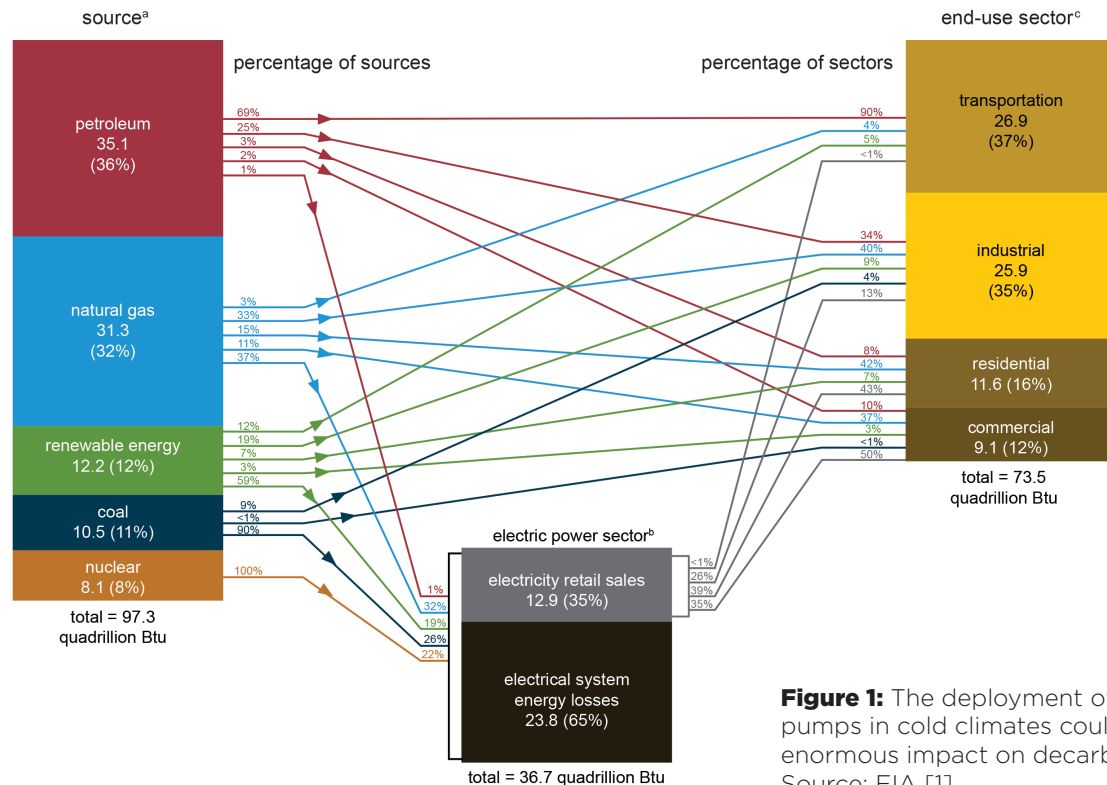


Figure 1: The deployment of heat pumps in cold climates could have an enormous impact on decarbonization. Source: EIA [1].

HVACR Engineers Focus on Cold-Climate Heat Pumps

Smaller-Diameter Copper Tubes Improve the Performance of Outdoor Evaporators

BY FRANK GAO, HARRY SCHMITZ, YORAM SHABTAY, KERRY SONG

The development and deployment of cold climate heat pumps (CCHPs) is important to the energy future of our planet. The data on energy consumption (Fig. 1) clearly shows why [1]. In 2021, the United States consumed 97.3 quadrillion Btus of energy. That's equivalent to 3250 GW of power running for one year, that is, 3250 GW-yr of energy [2].

In units of GW-yr, primary sources included petroleum (1172), natural gas (1045), renewables (407), coal (351), and nuclear (270). Similarly, end-uses included transportation (898), industrial (865), residential (387) and commercial (304). Between these two sides of the ledger is the

electric power sector, which is neither a primary source nor an end user as indicated in Figure 1. This sector consumed 1225 GW-yr, selling only 431 GW-yr to end users. Electrical systems energy losses account for the discrepancy of 795 GW-yr.

Figure 1 further reveals that industrial, residential, and commercial end uses accounted for 33, 15, and 11 percent of all the end uses of natural gas. That's a whopping 59 percent of the natural gas sources. Giant steps toward decarbonization will come from replacing natural gas with electricity from renewable sources.

Figure 1 suggests that the

deployment of heat pumps in cold climates could have an enormous impact on decarbonization. Heat pumps uniquely act as energy multipliers, not only enabling electrification but also using much less energy compared to electrical resistance heating or gas heating, even in cold climates.

This paper reviews the latest trends in the development of cold climate heat pumps as well as their deployment.

Breakthroughs Wanted

In view of the above analysis as well as recent geopolitical and climate events, it's not surprising that research,

development, demonstration, and deployment (RDD&D) on heat pumps are accelerating.

Fortunately, recent parallel breakthroughs in heat exchangers have consequences for CCHPs. This was especially evident at expos and conferences in the past year, including the 2022 Chillventa, 2022 Interclima, 2023 AHR Expo, 2023 ISH Expo as well as the May 2023 IEA Heat Pump Conference in Chicago. These have been reviewed in recent issues of the *MicroGroove Update* newsletter [3].

Technology breakthroughs made in recent years allow for a new generation of air source heat pumps (ASHPs) to extract heat even at temperatures well below the freezing point of water. At recent expos, OEMs displayed products that boasted efficiencies well above the breakeven point with electrical resistance heating even at frigid temperatures. OEMs typically are guaranteeing stable operation even with outdoor temperatures as low as -15°F (-26°C), effectively satisfying the heating demand in extremely cold areas.

How can they do that?

The first requirement is a large outdoor evaporator. As the liquid refrigerant passes through an expansion valve, its pressure drops, and its temperature plummets. The temperature of the refrigerant, when it enters the outdoor evaporator, is below the outdoor ambient of a cold winter night.

The key to the function of the CCHP is an evaporator coil large enough to capture heat from the outdoors despite the relatively small temperature differences between the refrigerant and outdoor ambient temperature. Much heat also is captured from the latent heat of evaporation as seen in a typical Pressure-Enthalpy (P-h) or Mollier Diagram (Fig. 2). Using propane as

a refrigerant, the liquid refrigerant can be cooled to 3°C and then as it expands the temperature drops to -30°C . This segment of the vapor compression cycle for R290 refrigerant is indicated by the line between points C and D.

Smaller diameter copper tubes offer high heat transfer coefficients (HTCs) and extra circuits allow for enough cold refrigerant to flow through the evaporator and pick up heat from the cold air. A cold climate heat pump adds heat from the ambient to the work of the compressor.

Even if no heat is picked up from the ambient, the compressor performs 15 kW of work on the refrigerant, and this work is converted to heat. A CCHP is not going to be less efficient than electrical resistance heating albeit the

CCHP is more complex. Depending on the outdoor ambient temperature, the 15 kW of work can be amplified or multiplied by removing heat from the outdoor ambient air. A properly sized evaporator pulls enough heat from the cold climate ambient to provide COP > 2 on most or all "heating days" even in the coldest climate zones. COP > 4 would be commonplace for many heating days.

Evaporator Simulations

A key to efficient CCHPs is the evaporator design. To assist in the design of such heat exchangers, the International Copper Association developed a user-friendly simulation software program named HXSim. It is available to qualified designers at no charge. The use of HXSim software

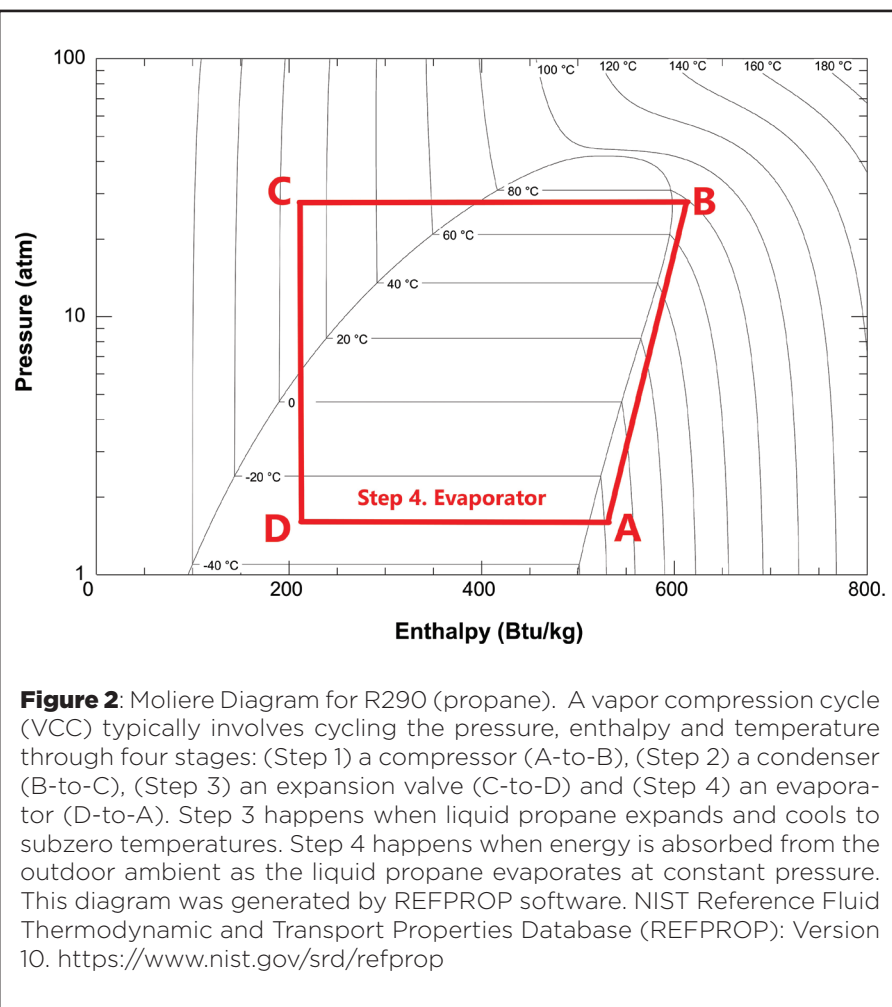


Figure 2: Mollier Diagram for R290 (propane). A vapor compression cycle (VCC) typically involves cycling the pressure, enthalpy and temperature through four stages: (Step 1) a compressor (A-to-B), (Step 2) a condenser (B-to-C), (Step 3) an expansion valve (C-to-D) and (Step 4) an evaporator (D-to-A). Step 3 happens when liquid propane expands and cools to subzero temperatures. Step 4 happens when energy is absorbed from the outdoor ambient as the liquid propane evaporates at constant pressure. This diagram was generated by REFPROP software. NIST Reference Fluid Thermodynamic and Transport Properties Database (REFPROP): Version 10. <https://www.nist.gov/srd/refprop>

TABLE 1

EFFECTS OF REDUCING TUBE DIAMETER ON HEAT EXCHANGER DESIGN

	5 mm	7 mm	7.94 mm	9.52 mm
Fins per Inch (FPI)	14	13	16	17
Number of Tubes	228	228	164	164
Coil Depth (mm)	50.8	66	65	88
Airside Pressure Drop (Pa)	50	62	68	73
Air Velocity (m/s)	2.45	2.45	2.42	2.42
Fin Weight (kg)	13.44	16.23	19.36	19.49
Internal Volume (liter)	3.99	8.58	8.50	12.40
Refrigerant Side Pressure Drop (kPa)	4.1	4.7	4.4	3.6
Refrigerant Flow (kg/min)	3.31	3.31	3.31	3.36
Refrigerant Velocity (kg/min)	5.92	5.51	5.74	4.96
Refrigerant Charge (kg)	0.52	1.13	1.10	1.64
Output (kW)	14.4	14.35	14.35	14.4

Table 1 shows the differences in heat exchanger properties that occur as tube diameter is varied from 9.52 mm to 5 mm, while maintaining the same output. Inputs were adjusted to produce an output of about 14.4 kW for a constant flow rate of about 3.3 kg/min. In this initial study, the number of smaller diameter tubes (5 mm and 7 mm) was increased from 164 to 228 and coil depth was decreased to accommodate the refrigerant flow rate, which was held approximately constant for all four coils.

has been described in past issues of the *Appliance Design & HVACR Report*. [4-5]

A presentation at the most recent International Congress of Refrigeration (ICR2023.org) describes various capabilities of the HXSim software in considerable detail [6]. The authors of that paper describe simulations run on a simple L-shape coil with two rows of 5 mm tubes. They varied the internal tube surface enhancements (microfins), fin types and fin densities. Simulations were also run for an L-type, 15 kW evaporator with six rows of copper tubes, varying the diameter, tube spacing, fin density and tube circuitry. Results are compared with respect to weight, refrigerant charge and pressure drop (Table 1). The paper is available for downloading from MicroGroove.net on the HXSim landing page.

The upshot is that small diameter round copper tubes in heat exchanger coils can reduce refrigerant charge, increase efficiency, and decrease the size of CCHPs.

Rapid Innovation

A designer of cold-climate heat pumps needs to first set design criteria. What will be the end uses? How will the energy be transferred from the outside evaporator to the various spaces in the residential or commercial space? What will be the required capacity?

Marek Miara from the Fraunhofer Institute for Solar Energy Systems ISE, Freiburg, Germany, developed a system of classification of heat pump solutions for multifamily buildings [7]. Heat pump products and building solutions are classified according to a simplified schematic for the visualization of multifamily buildings. This project was developed within the context of Annex 50 of the IEA Heat Pumping Technologies Technical Collaboration Programme (IEA HPT TCP) and will continue as part of Annex 62 on "Heat pumps for multifamily buildings in cities" [8].

Global OEMs are developing CCHPs for the USA, Europe, China, Japan and South Korea. They are

re-positioning their heating products to take advantage of game changing CCHP technology.

Dozens of companies, large and small, around the world, are intent on capitalizing on the rapid energy transition. These companies will fail or succeed according to the basic rules of market competition: Whoever produces superior products at low cost will dominate the marketplace.

These companies will succeed by developing the sustainable technologies and services internally, through acquiring technology-rich companies, or by partnering with successful companies. A case in point is global A.C. and comfort-control giant Carrier Global Corp., who recently acquired a successful technology-rich unit of the Viessmann Group, a German industrial firm. The Viessmann unit acquired by Carrier makes heating boilers and heat pumps [9].

It's no secret that European heat-pump technology in general is "way ahead" of the heat pump technology currently available in the USA. That partly has to do with its accelerated HFC phasedown as well as the high cost of energy in the European Union.

Rapid Implementation

To have a meaningful effect on energy consumption, heat pumping technologies must be implemented on a broad scale in real world applications globally. A case study from China serves as a preview of things to come. The project is described as the largest air source heat pump (ASHP) central heating project in China and one of the largest in the world [10].

Participants in the project included Guangdong New Energy Technology Development Co., the China Heat Pump Alliance (CHPA), Emerson Climate Technologies (Suzhou) Co.,



Figure 3: More than 1200 units of ASHPs were deployed as heating sources for approximately four million square meters of living spaces in large residential buildings. The challenge was how to best distribute these units and move the heat from the ASHPs to the living spaces.



Figure 4: The “cold island” effect occurs if the air circulation around the ASHP units is not optimized. In this case, all the stations were designed as frame structures at least eight meters above the ground.

and the Harbin Institute of Technology. Emerson Climate Technologies (now Copeland) provided a “vapor injection technology,” which allows the system to be used down to ambient temperatures as low as -30°C , delivering hot water at temperatures high enough to heat living spaces through radiators.

Zhao County is in the southwest of Hebei province, about 280 km (170 mi) south of Beijing. In 2019, the local government decided to replace coal-burning power plants with ASHPs, to reduce running costs and air pollution. This part of north China has cold winters and requires considerable space heating in winter. The space heating necessary during the heating season was estimated as 138 MW. A simple calculation suggested that 1200 ASHPs (each producing 120 kW of heating) could produce 144 MW of heating.

The challenge was how to best distribute these units and move the heat from the ASHPs to the living spaces. More than 1200 units of ASHPs were deployed as heating sources for approximately four million square meters of living spaces in large residential buildings (Fig. 3). (Note that

4,000,000 sqm is about 43,000,000 sq ft.) That’s enough heating for a community of about 30,000 apartments in a cold region of China.

The heating medium was water heated to 55°C (131°F) and returned at 45°C (113°F) at the end of the radiator. For floor heating, the water was supplied at 45°C (113°F) and returned at 35°C (95°F) at the end of floor heating.

For this large and complex project, detailed knowledge of the climate was essential to determine the initial investment and operating costs. From the beginning, the historical climate and environmental characteristics of Zhao County were investigated.

A factor in the systems design was to avoid the “cold island” effect, which occurs if the air circulation around the ASHP units is not optimized. In this case, all the stations were designed as frame structures at least eight meters above the ground (Fig. 4). That allows cold air from the units to flow downward into nearby open spaces. The ASHP units at each station were arranged in-line with no more than three units in the row direction.

Some other features of the ASHP were the use of vapor injection technology for the compressors of the ASHP unit. The winter climate record data indicated that ambient temperature could go as low as -15°C . Vapor injection technology brings the benefits for ASHP heating in cold ambient conditions. According to Copeland laboratory test results, this technology can improve heating capacity by 21 to 40 percent and efficiency by 7 to 22 percent, depending on the ambient temperature. Vapor injection technology allows the system to be used down to ambient temperatures as low as -30°C , delivering hot water at temperatures high enough even for heating through radiators.

The 1200 units of ASHP were managed with higher system performance in mind, using Internet of Things (IoT) technology. Depending on the temperatures of outlet water and return water, the operation of the individual ASHPs could be adjusted for better system efficiency.

This project serves as a real-world example from which much

can be learned about large scale implementation of heat pumps in cold regions.

It is fully described in a paper by Zhao *et al.* titled “Largest Air Source Heat Pumps Central Heating Project in China” and presented at the 2023 IEA HPC in Chicago [10].

Tubes to Coils to Systems

Components for CCHPs include heat exchangers with smaller diameter copper tubes. Efficient copper tubes lead to efficient coils and ultimately to efficient heat pumping technologies and systems.

The first step in designing a CCHP would be to select the tubes for the evaporator. The next step would be to select a suitable refrigerant, consistent with the regional regulations regarding GWP and flammability. Smaller diameter tubes are advantageous in both cases because they allow for less refrigerant charge for any desired capacity.

Heat pumps can range in size from a few kilowatts to hundreds of kilowatts. They can run on conventional refrigerants such as R410A (GWP of 2088), natural refrigerants such as R290 or R744, or R32 (GWP of 675).

R290 (propane) offers excellent performance, providing 70 °C hot water even at low outdoor temperatures. However, because of its flammability, its indoor use has been limited to only the smallest capacity indoor split units. Its adoption rate in various regions of the world will be heavily dependent on regulations on charge usage driven by concerns about flammability. Propane has been used successfully in refrigerated cabinets where charge limitations can be managed using smaller diameter copper tubes in the evaporators and condensers of refrigerated cabinets, for example. However, heat pumps

typically require larger refrigerant charges.

One popular model of CCHP that uses propane as a refrigerant is an air-to-water “monoblock” heat pump, which is self-contained and located outside. Space heating is accomplished by circulating hot water or other liquid to the indoor radiators and floor heating systems. In this manner, no flammable refrigerant is used indoors.

Right-Sizing Heat Pumps

Air source heat pumps (ASHPs) can be further classified as Air-To-Air (ATA) heat pumps and Air-To-Water (ATW) heat pumps. The common denominator is that the evaporator captures heat from the ambient air.

ASHPs offer several advantages compared to GSHPs. The main advantage is lower cost. In the USA, where ducted furnaces and central AC are everywhere, ASHPs look a lot like central air conditioners, but the roles of the outdoor unit (ODU) and indoor unit (IDU) are reversed. Indeed, many brands of ASHPs are reversible. They can be used for cooling in the summer

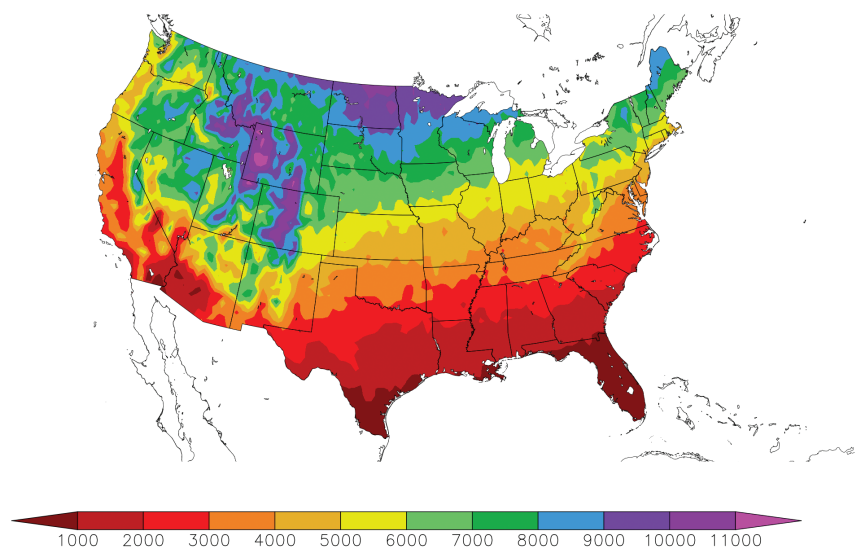
and heating in the winter, especially in lower latitudes where winters are mild. ATA ASHPs in the heating mode use the ODU as an evaporator and the IDU as a condenser. Ducted systems are especially common in legacy homes that previously used a gas furnace for heating.

When the ODU serves as an evaporator, the copper tubing in round tube plate fin (RTPF) heat exchangers tends to be larger in diameter than the copper tubing in outdoor condensers. Copper tube diameters as large as 3/8 inches (9.52 mm) or 1/4 inches (6.35 mm) are not uncommon for this application. In RTPF style heat exchanger, condensate drains easily away from the flat vertical fins. Microchannel heat exchangers are rarely used in outdoor evaporator because of issues with drainage that leads to the condensate freezing over the heat exchanger.

The IDU could be configured to allow heated air from the condenser to be directed through a system of ducts; alternatively, the IDU could be remote from the ODU. Refrigerant from the compressor could be routed

Figure 5

HEAT DEGREE DAYS (BASE 65) 8/1/2022 - 7/31/2023



through insulated copper pipes to wall units (condenser) hung in various living spaces. Either of these configurations would be considered an ATA ASHP.

A new generation of low-cost, mass-produced window units was recently introduced into the marketplace. These units use smaller-diameter copper tubes in a reversible configuration. In other words, the compressor can pump refrigerant to the indoor facing heat exchanger in the heating season, or to the outdoor facing heat exchanger in the cooling season. Since these window units typically do not operate efficiently at temperatures below 45 °F they are not considered heating systems *per se* but are useful as efficient supplemental space heaters for most heating days, especially in milder climates.

The number of heating degree days is a figure of merit for heat pump selection. These are essentially weather statistics for local areas. An outdoor temperature of 1°F below 65 °F for a 24 h period represents one heating degree day; an outdoor temperature of 45 °F for a 24 h period represents 20 heating degree days; and so on. Thanks to the abundance of weather stations across the USA and most other countries, extensive historical databases of local temperatures are available. Heating degree days can be readily calculated for no charge using various online apps [11].

High Plains Climate Center has tools for creating climate maps for the USA [12]. Figure 5 shows how Heating Degree Days vary across the USA, ranging from 1000 in Texas and Florida to more than 10,000 on the border with Canada.

The trend now is toward ASHPs. Except for extremely cold climate zones, ASHPs can provide adequate heating for most heating days throughout the year although COPs will drop on very cold winter nights. Using the latest technology, the ASHPs are saving energy for homeowners even in New England.

Condensers and evaporators in such heat pumps can be readily modeled for performance under various operating conditions using HXSim simulation software. (As mentioned, HXSim is available at no charge from the International Copper Association via its microgroove.net website.) The software can model I-type, L-type and C-type heat exchanger blocks with copper tubes as small as 4 mm in diameter for many different refrigerants.

Outdoor evaporators for heat pumps come in many shapes and sizes. In the United States, they are typically C-Type heat exchangers like the outdoor condenser for a residential central air conditioning system. Simple I-Type (flat slab) and L-Type heat exchangers also can serve as evaporators. Figure 6 shows 3D representations of an L-shaped

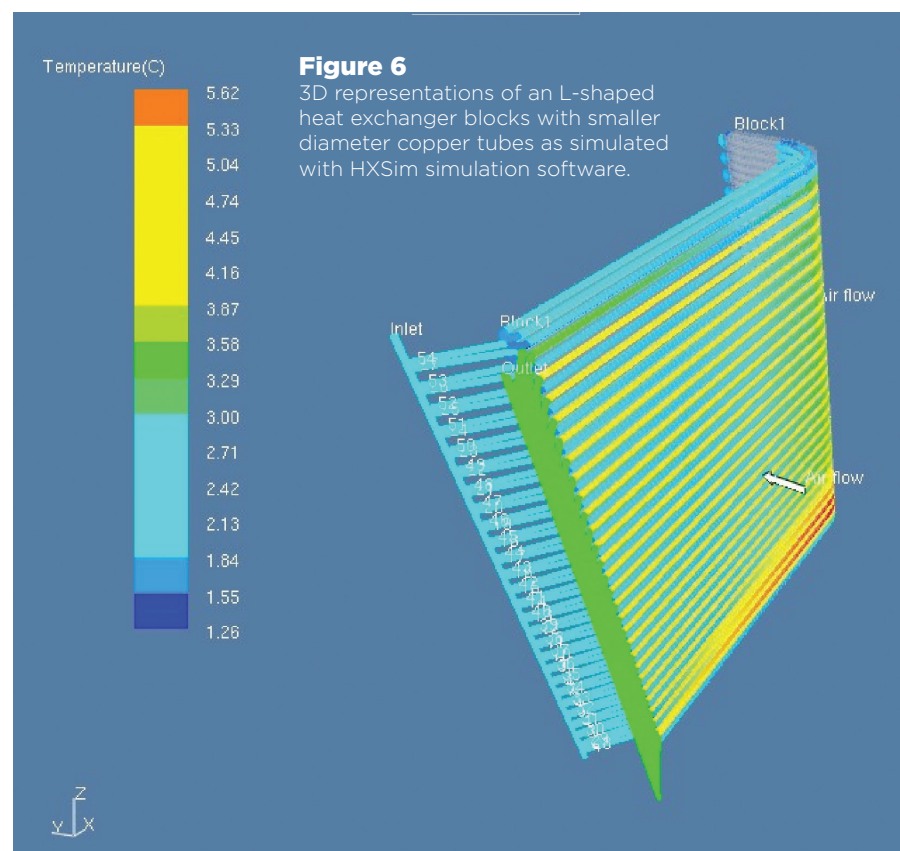
heat exchanger block with smaller diameter copper tubes as simulated with HXSim simulation software.

Toward the Future

The magic of thermodynamics revolutionized our modern world. It ushered in the age of air conditioning, leading to major demographic changes and creating whole industries dedicated to comfort. Simultaneously, refrigeration led to the creation of a global cold chain, crossing national boundaries “from farm to fork” in ways never possible before.

Yet the whole story has not yet fully unfolded. The use of heat pumps for heating has barely begun, mainly because there has been no need. If necessity is the mother of invention, then innovations in heat pump designs can be assured in the next few years.

The stakes couldn't be higher. ●



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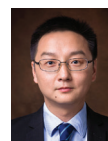
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Yoram Shabtay is President of Heat Transfer Technologies. He has extensive background in heat exchangers development and production and has been working with the ICA for over two decades.



Kerry Song is a Project Manager with the ICA. He is also the Secretary-General of Refrigeration and Air-conditioning Heat Exchanger Technology Alliance in China.

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What's Happening



Leif-Erik Lindner will join **IFA Management GmbH** as the new Managing Director. With this personnel appointment, the company is continuing its course of creating new impulses in the trade show business while planning for the long term.

"We are delighted that Leif-Erik Lindner will be joining our management team", says Lisa Hannant, Chief Executive Officer at Clarion Ltd. "His industry knowledge, sales experience and approach to large-scale projects will make a valuable contribution to further strengthening our position as the leading global trade show in our industry."

Leif-Erik Lindner will succeed current managing director Oliver Merlin, who has been leading IFA Management GmbH on an interim basis since last November alongside co-Managing Director, Jörg Arntz, who is responsible for human resources, operations and finance.

Oliver Merlin has been in charge of building a team at IFA Management GmbH, while being responsible not only for the existing business but also the change management of the entire IFA project. He has been very successful with these tasks: In addition to established elements that are to be expanded, such as the start-up area IFA Next, he and his team developed and added new features such as The Sustainability Village, #BerlinTechWeek, an eSports Arena and the completely redesigned conference format IFA Leaders Summit.

Together with Jörg Arntz, Oliver Merlin will oversee the planning and execution of the 2023 edition. Leif-Erik Lindner will join IFA Management GmbH on July 1, 2023 and, following his induction, will then take over responsibility for the planning and implementation of IFA Berlin 2024. Oliver Merlin will move into a Strategy role leading on future strategy and transformation of the IFA brand.



Mactac®, a **LINTEC Company**, is acquiring Label Supply, headquartered in Ontario, Canada. Label Supply has been servicing the Canadian roll label market for more than three decades.

The acquisition consists of an established, turnkey facility with 11 finishing assets, a comprehensive transportation/shipping fleet, robust laboratory and technical resource group, and an in-house ink partner. With the added support of Mactac, Label Supply benefits from a larger customer base, capital access, information technology, and broad, consistent product supply.

The acquisition expands the geographic reach of both companies in the Canadian market, creating a unique service and product offering that provides specialty products, service, and large quantities to more customers throughout Eastern Canada.

"Label Supply runs a highly successful business that is fast, agile and customer service centric. They excel at meeting small to medium converters' needs within Ontario, Canada, particularly the greater Toronto region," said Ed LaForge, Mactac President and CEO. "This acquisition, like others we've made within the past two years, will build upon the proven success of Label Supply. We will enhance what they do by broadening service throughout Eastern Canada and providing additional equipment and technology solutions that will also meet the needs of the region's larger customers."

Expanding the operational and commercial capabilities of Label Supply, Mactac will invest in the facility's resources, technology, and equipment, including adding high-volume slitting assets designed for larger material rolls.

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By having a network of over 150 representative offices, knowledgeable in Ruskin's products located nationwide, Ruskin can assist clients with every aspect of their HVAC project needs. This includes product selection, ordering and application. Ruskin is committed to providing the highest level of customer service.

Ruskin leads the industry by developing new and innovative solutions for air control processes in commercial and industrial applications. With a new larger advanced Air Movement and Control Association - AMCA accredited research and development test laboratory, Ruskin can carry out rigorous testing, ensuring that products meet and exceed customer requirements and industry standards.





Bourns, Inc., a leading manufacturer and supplier of electronic components for power, protection, and sensing solutions, today announced its first **650 V – 1200 V Silicon Carbide (SiC) Schottky Barrier Diodes (SBDs)**. The Bourns® SiC SBD line consists of six models engineered to provide excellent current carrying and thermal capabilities and high power density for increased performance and reliability. These capabilities make Bourns® SiC SBDs optimal high efficiency power conversion solutions for the growing variety of high frequency applications that need to meet reduced size and lower system cost requirements. Telecom/Server Switched-Mode Power Supplies (SMPS), photovoltaic inverters, PC power and motor drives are a few of the applications that can benefit from the features provided in the Bourns® BSD Series SiC SBDs.

To address ongoing design demands for ever higher power efficiency, Bourns® SiC SBDs feature low forward voltage (VF) and high thermal conductivity, which increases efficiency while lowering power dissipation, satisfying application requirements of 650 V and 1200 V solutions. The series also has no reverse recovery current to reduce EMI, enabling these SiC SBDs to significantly lower energy losses. In addition to offering 650 V to 1200 V operation with currents in the 6-10 A range, the six new BSD models of wide band gap diodes from Bourns offer designers various forward voltage, current and package options including TO220-2, TO247-3, TO252, and DFN8x8.

The six Bourns® Model BSD SiC SBDs are available now. These models are RoHS compliant*, halogen free**, Pb free and their epoxy potting compound is flame retardant to the UL 94V-0 standard. For more detailed product information, please see: www.bourns.com/products/diodes/silicon-carbide-sic-schottky-barrier-diodes



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Spectronics Corporation announces the release of the **GLO Seal™ Single-Use Syringe Injector & Dual Adapter kit**

under their Spectrolin brand. The GLO Seal syringe and adapter kit, SPE-SDSK-CS, contains a 0.3 oz (10 ml) syringe prefilled with GLO Seal, and one dual adapter for injecting into the system. GLO Seal is an OEM-Grade fluorescent UV dye combined with a powerful non-polymer sealant that can treat up to 2.5 tons (8.79kW) of cooling in this delivery method. The inexpensive price point allows for flexible entry into various different markets and applications.

The single-use disposable syringe injector is new for Spectrolin and offers a convenient way to inject into the system with no additional tools needed. However, what makes this kit unique is the new Spectrolin pivoting dual adapter. This was designed to treat systems with ease as a versatile 2-in-1 tool that easily switches from 5/8" and 5/16th flare fittings.

The kit provides a fast and easy way to find and fix AC leaks and is a key component to have on hand to extend equipment lifespan, eliminate call-backs and prevent costly breakdowns through its 24/7 continuous leak detection and ongoing sealing.

As ductless mini-split systems are increasing in popularity due to their convenience of zoned comfort, energy efficiency, ease of installation, flexible sizing/configuration options, built-in air quality filters, and ability to provide both heating and cooling, Spectrolin's new product is the perfect complementary tool. The new GLO Seal with Single-Use Syringe Injector & Dual Adapter finds and seals every leak in mini-splits and small appliances alike.

ASHRAE, announced its unwavering commitment to reducing **greenhouse gas** (GHG) emissions with the launch of its redesigned building decarbonization webpage and the release of a new **Building Performance Standards Technical Resource Guide**.

The **ASHRAE Task Force For Building Decarbonization** (TFBD) webpage includes technical resources, information, videos and publications to expedite the adoption of climate change mitigation policies and reaffirms the Society's goals stated in the ASHRAE Vision 2020 report, approved by ASHRAE's board of directors, as well as the **ASHRAE Position Document on Building Decarbonization**, to achieve net zero GHG emissions in operation for all new buildings by 2030.

"Over the years, ASHRAE has demonstrated its leadership in reducing GHG emissions by addressing energy efficiency and sustainability, as articulated in some of our most notable technical guidance such as Standards 90.1 and 189.1," said ASHRAE TFBD chair Kent Peterson. "The TFBD is working

to provide vital technical guidance in new guidebooks and the redesigned webpage. ASHRAE is helping accelerate the transition from commitment to action in reducing global built environment GHG emissions."

Additional features of the redesigned Building Decarbonization webpage include:

- Descriptions of seven new guidebooks focused on building decarbonization.
- A list of related outside decarbonization resources.
- A list of key decarbonization terminology.

The newly released Building Performance Standards (BPS): A Technical Resource Guide was created to provide a technical basis for policymakers, building owners, practitioners and other stakeholders interested in developing and implementing a BPS policy. The first in a series of seven guidebooks by ASHRAE on building decarbonization, this guide focuses on reducing building operating energy use and resulting emissions in existing commercial and multifamily buildings, as established by leading U.S. cities and states.



Vitrek, a major manufacturer of precision electrical safety testing equipment, high-speed data acquisition and signal recording, and advanced metrology and simulation instruments and systems, announces the launch of its fully redesigned and expanded website.

The new website at **vitrek.com** provides easy navigation of the company's extensive product portfolio. Its intuitive menu selection presents solutions by type, specific application and by signature brand (Vitrek, MTI Instruments and GaGe).

"Vitrek offers a unique selection of test & measurement instruments and systems used in an exceptionally wide range of industries," said Don Millstein, Vitrek's President and CEO. "Our new website has been designed to allow efficient access to our products, either by type or by application. And visitors who want to find Vitrek, MTI or GaGe products by their particular brand will find fast and relevant results."

The organization of the Vitrek homepage allows visitors to quickly drill down to find the information needed. Top-level tabs include:

- Vitrek Test & Measurement: Hipot testers, power analyzers, electronic loads and hi-voltage instruments
- Gage Digitizers & RF Recording: Hi-speed digitizers, digital signal processors, signal recording systems



- MTI Instrumentation and Turbine Engine Machine Vibration & Balancing Systems: Measurement and analysis, signal simulators, charge amplifiers, metrology systems
- Industry Applications: Products by aerospace, semiconductor, medical, automotive and many other industries

- Knowledge Center: A compendium of news releases, educational articles and video tutorials
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GE Appliances (GEA), a Haier company, and its wholly owned subsidiary **Roper Corporation** today joined with state and local officials to **celebrate 50 years of cooking leadership** in Georgia and a multi-million-dollar investment that's adding new products, good jobs and the latest in advanced manufacturing technology.

During a first look at the factory's transformation, GE Appliances and Roper unveiled new assembly lines, presses, and robotics—the result of the company's \$118 million investment that will enable the plant to build new models of freestanding ranges, which will be available in early 2024. Roper, with 2,500 employees, is GEA's largest manufacturing operation outside of its Louisville, Ky. headquarters.

"At GE Appliances, we are relentlessly focused on making great products for our customers and consumers," said Kevin Nolan, president and CEO for GE Appliances. "Over the past six years our investments in new product development, digital technologies and advanced manufacturing have helped us deliver some of the world's most innovative appliances. For 50 years, the team here in LaFayette has built ranges, cooktops and ovens with technology that has shaped the way Americans cook at home. I want to thank the employees here at Roper for their dedication to creating new possibilities for life at home. I also want to thank Governor Kemp and the Georgia economic development team, the legislative delegation, and our partners in the City of LaFayette, Walker County and Northwest Georgia for the support they continue to provide."

Over the last six years, GE Appliances has invested over \$2 billion in its operations and moved from benchmarking companies in the aerospace and auto industries to being recognized as one of the leaders in implementing digital engineering and manufacturing technology.



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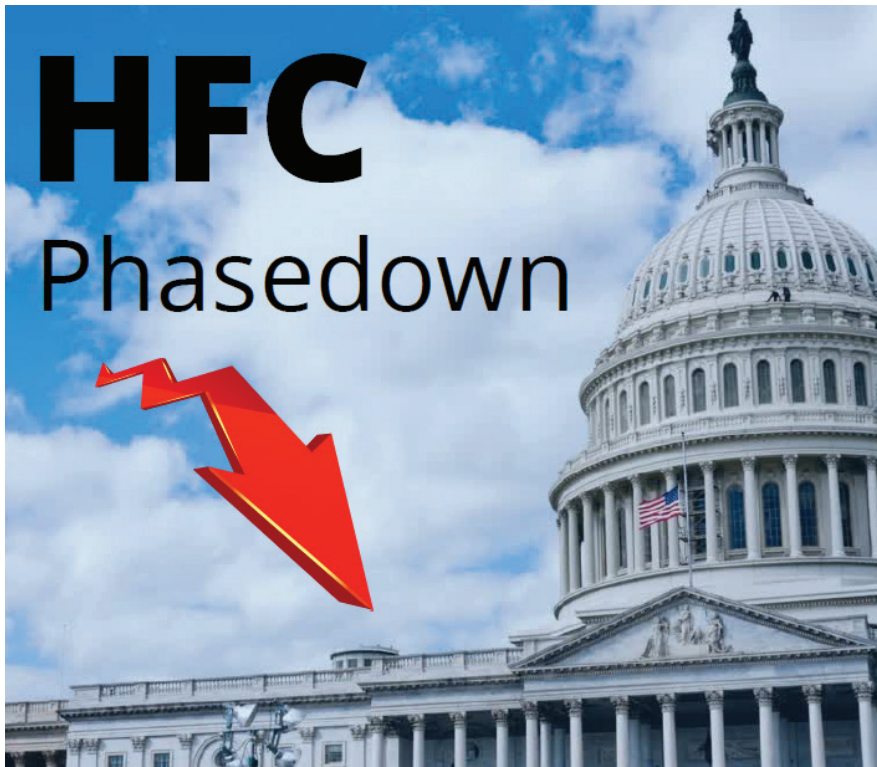


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Understanding A2L Refrigerants

BY TONY GONZALEZ

In December 2020, congress passed the American Innovation and Manufacturing (AIM) Act and in 2021 the EPA introduced a rule mandating an 85% nationwide phasedown in high-global warming potential (GWP) hydrofluorocarbon (HFC) refrigerants by 2036. This phasedown will be accomplished in three ways:

- (1) Phasing down production and consumption
- (2) Maximizing reclamation and minimizing releases from equipment
- (3) Facilitating the transition to next-generation technologies and low-GWP refrigerants through sector-based restrictions. Many of these lower-GWP refrigerants are considered mildly flammable with an ASHRAE Standard 34 designation of A2L.

The transition to next-generation refrigerant technologies is being aided by the EPA's Significant New Alternatives Policy (SNAP) program

which approves the use of low-GWP refrigerant for specific uses. Many A2L refrigerants have already been approved by the EPA with many more approvals in the works.

The goal of this paper is to provide information on refrigerant classifications, the differences

between refrigerants and the influences driving the shift away from traditional refrigerants to A2L refrigerants.

Refrigerant Classification

The ASHRAE Standard 34 classification table is designed to categorize refrigerants according to two primary factors: flammability and toxicity. Regarding flammability, refrigerants are tested and categorized by several factors including how much refrigerant per unit volume of air will support combustion, the amount of energy needed to initiate combustion, the amount of energy released from combustion, and the rate of combustion propagation. Toxicity designated as A or B is defined by the occupational exposure limit (OEL). Lower toxicity refrigerants (A) have an OEL of ≥ 400 ppm while higher toxicity refrigerants (B) have an OEL of <400 ppm.⁷

Flammability

Since A2L refrigerants are mildly flammable it is important to understand the characteristics of flammability and how they are affected by the HVAC environment. There

Higher Flammability ↑	Higher Flammability	A3	B3	Class 3 Requirements 1. Exhibit flame propagation @ 60°C & 101.3 kPa 2. LFL ≤ 0.10 kg/m ³ or HOC $\geq 19,000$ kJ/kg
	Flammable	A2	B2	
	Lower Flammability	A2L	B2L	
	No Flame Propagation	A1	B1	
		Higher Toxicity →		Class 2 Requirements 1. Exhibit flame propagation @ 60°C & 101.3 kPa 2. LFL > 0.10 kg/m ³ 3. HOC $< 19,000$ kJ/kg
				Class 2L Requirements 1. Exhibit flame propagation @ 60°C & 101.3 kPa 2. LFL > 0.10 kg/m ³ 3. HOC $< 19,000$ kJ/kg 4. $S_u \leq 10$ cm/s
				Class 1 Requirements 1. No flame propagation @ 60°C & 101.3 kPa

kPa = pressure in kilopascals
 kJ/kg = energy in kilojoules per kilogram
 S_u = burning velocity in centimeters per second

VARIOUS REFRIGERANTS

CLASSIFICATIONS

CLASS A

A3 refrigerants such as R-290 Propane have a higher flammability and a lower toxicity.

A2 refrigerants such as R141B and R-406A are flammable and have a lower toxicity.

A2L classified refrigerants such as R32, R-454B, and R-1234yf have a lower flammability than A2 and lower toxicity.

A1 classified refrigerants such as HFC R-407C and HFC R-410A have no flame propagation and low toxicity¹.

CLASS B

At present there are no known B3 refrigerants.

B2 classified refrigerants such as R-30 and R-40 are flammable and have a higher toxicity⁸.

B2L classified refrigerants such as R-717 Ammonia⁹ have lower flammability and higher toxicity.

B1 classified refrigerants such as R-10, R-21 and the rather obscure R-764 sulfur dioxide² have no flame propagation but higher toxicity.

are three important factors when understanding flammability.

- Lower Flammability Limit (LFL):

The concentration in air necessary to generate a flammable mixture.

- Minimum ignition energy (MIE):

The lowest energy required to ignite the flammable material in air or oxygen found at a certain optimum (stoichiometric) mixture.

- Heat of combustion (HOC): The amount of energy that is obtained from the burning of a volume of gas is measured in Btu.

LFL - Lower Flammability Limit

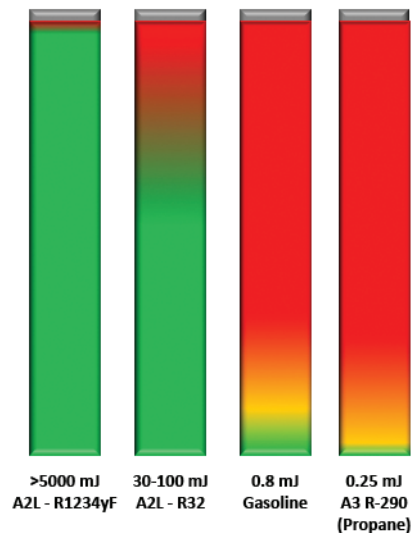
Mildly flammable A2Ls consist of HFCs, hydrofluoroolefins (HFOs), and also blends of these two synthetic refrigerants which have a high LFL, often 8 times higher than A3 refrigerants such as R-290 Propane. This means that a much larger concentration of A2L must be present to form flammable

concentrations. This is important when considering refrigerant leakage especially in enclosed spaces. While a very low amount of A3 refrigerant or a low amount of A2 refrigerant in an enclosed space can be very dangerous, A2L refrigerants require a much larger amount of gas leakage to reach sufficient concentrations necessary for ignition.

MIE - Minimum Ignition Energy

A2L refrigerants have a significantly higher minimum ignition energy (MIE) which means it is harder to ignite than A3 refrigerants. Hydrocarbon vapors such as propane (R-290) can be easily ignited by many energy sources, even sometimes by the lower levels produced by static electricity.⁵ This can be orders of magnitude lower than the levels required to ignite the A2L refrigerants. Even gasoline has a much lower MIE than A2L refrigerants by almost a factor of 10!⁶

MIE Comparison

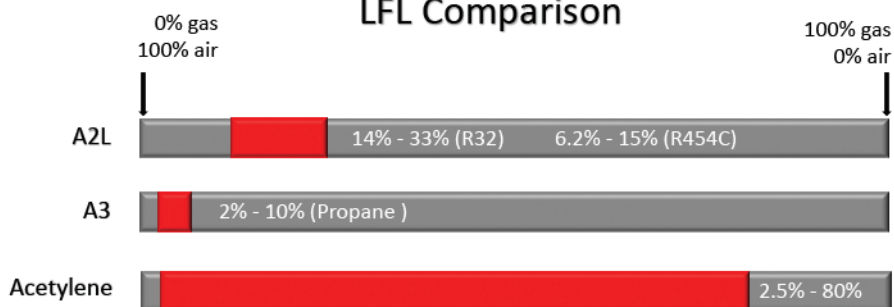


HOC - Heat of combustion

Heat of combustion is the amount of energy released during combustion. The units of measure for HOC are expressed either in kilojoules per gram (kJ/g) or Btu/lb. Simply stated, you can think of HOC as the violence of the reaction when a gas ignites. A3 refrigerants like Propane have a very high HOC, on the order of 19,905 Btu/lb. whereas A2 and A2L have much lower values on the order of 2700-4400 Btu/lb. This means that while A2 and A2L refrigerants can, under the right circumstances, burn with veracity, they are generally not in the category of explosion hazard like you would find in A3 refrigerants.

What you may find interesting is that the HOC for an A1 refrigerant like R-410A is 2,800 Btu/lb. and a nominal A2L refrigerant such as R-32 has a HOC is 3,869 Btu/lb. Given a typical residential ducted split unit charge being ~ 15 lbs., there is essentially only about 24,000 Btu difference between the A2L and R-410A. This difference is equivalent in relative comparison to burning 3.4 lbs. of dry wood (about 2.5 feet of dry 2 x 4) versus burning 1.7 lbs. Duraflame™ wax fire log (about 38% of a single log.)^{3,9}

LFL Comparison



Credits: IOR

Flammability Summary

You can summarize refrigerant flammability into the ease of ignition, expansion or propagation of the flame, and the amount of energy release.⁹

- Class 1 refrigerants have no propagation at 60°C but may still be flammable at higher temperatures.
- Class 2L refrigerants are “mildly flammable”, difficult to ignite with a relatively low energy release and low flame propagation speed.
- Class 2 refrigerants ignite easily with a relatively high energy release.
- Class 3 refrigerants ignite very easily and are potentially explosive.

Compared to A1 refrigerants, A2Ls have slightly higher flammability properties, and if burned, produce similar types and amounts of by-products (e.g. HF), and somewhat higher heat of combustion/fuel value. Flammability risks from A2L refrigerants will be mitigated by a variety of equipment design changes, applicable codes and standards, and technician training. The lower flammability limit of A2L refrigerants is very high, which means that a high concentration of refrigerant is needed to create a flammable mixture (ASHRAE 34).^{9, 10}

So How Does This Affect Me?

The move to A2L refrigerants is happening now and is likely to accelerate. Even though the EPA has issued their rules to move away from high GWP refrigerants to low GWP refrigerants as found in A2Ls, state and local legislation will still need to allow the use of these more flammable refrigerants. There are currently 25 states that allow the use of A2Ls either for air conditioning only or air conditioning and refrigeration. Many more states have legislation under review.

Since each state handles the code-making process differently, it is important to understand your local building codes for A2L allowance. Except for a few like Illinois and Texas, most states have a statewide code process. For states without codes, legislation needs to pass guaranteeing the acceptance of A2L refrigerants approved by U.S. EPA SNAP throughout the state. Please refer to your state and local building codes for specific information on your situation.

The shift to more flammable refrigerants will require the appropriate equipment for installation and servicing. It is critical to make sure your test equipment is

FIELDPIECE TEST TOOL COMPATIBLE WITH A2L REFRIGERANTS	
PRODUCT #	DESCRIPTION
MR45	Recovery Machine
SM380V, SM480V	Refrigerant Manifolds
JL3KH6, JL3KR4, JL3PC, JL3PR, JL3RH	Charge and Air Kit Probes
VPX7, VP87, VP67	Vacuum Pumps
DR58, DR82	Leak Detectors
MG44	Vacuum Gauge
SR47	Refrigerant Scale

compatible with A2L refrigerants. At Fieldpiece, we have the products you will need to safely navigate this transition. The following Fieldpiece test tools have been deemed compatible for use with A2L refrigerants: ●



Tony Gonzalez is the Technical Training Manager for Fieldpiece Instruments.



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The Net Value of the Ultrasonic Metal Welding Process

BY SAEED MOGADAM

There are many factors to consider when deciding on a metal joining method including its tangible and intangible features. Depending on the application, the investment will vary based on joining design, materials to be welded, geometrical shapes, dimensions and sizes, environmental effects, and the mechanical and electrical integrity that the given product demands. It's not possible to address all joining applications within a single article, so we'll highlight the automotive wiring harness industry and products to clarify the differences in crimping, soldering, ultrasonic, laser, and resistance welding.

In some cases, ultrasonic welding is the only solution or may not be feasible at all. However, no matter how many variables are being considered in the selection of the joining method, ultrasonic welding seems to offer a better long-term return on investment than all other viable processes.

The initial investment in ultrasonic metal welding equipment is higher relative to other welding processes such as resistance welding and crimping, and mechanical joining, and yet lower than laser welding equipment. So, why has this technology dominated wire harness manufacturing and become a necessity for EV, HEV batteries, and electrical distribution? Ultrasonic welding of non-ferrous metals has been a proven technology for decades. However, since the early 1980s, ultrasonic metal welding has dominated the

automotive industry, with automotive wire harness manufacturers as the single largest user of this technology (Figure 1). Due to its efficiency and unbeatable quality, ultrasonic welding replaced mechanical crimping and resistance welding for all car brands almost immediately upon inception. The utilization of ultrasonic welding for automotive wire harnesses has seen even more rapid growth in the last decade due to the increase in electrically powered vehicles (EVs). Telsonic's innovative and industry-changing torsional welding technique has in large part contributed to this rapid growth due to its unrivaled ability to address challenges such as weld size, welding in smaller areas, geometrical shapes, reaching the weld area, the orientation of welding, and vibration effects on peripheral components.

An average automotive wire harness contains 180 splices, and that number grows with each vehicle model year. OEMs are adding more electronic features to cars which require more splices. The splices and wire terminations together make up a long and complex heavy harness that controls the entire electrical system throughout the vehicle. Wire splicing has always been a major focus in the manufacturing of wire harnesses due to the inherent labor intensity in wire processing. The industry still applies crimping or resistance welding for applications such as small wire crimping or tin wire splicing. In general, ultrasonic welding is not feasible for tin-plated parts or hard materials such as steel. This is where resistance or laser welding options

Figure 1: Conventional ultrasonic welding application



become viable. Ultrasonic welding is the ultimate option when welding aluminum to another non-ferrous metal. Because of its cold fusion welding nature, aluminum is welded strongly without melting or being significantly affected by heat. The advantages of ultrasonic welding apply to thermally conductive materials, such as aluminum, copper, and magnesium, which can be troublesome to weld by resistance welders and lasers. Ultrasonics is also very useful for joining a thin material with a thick material. If minimal disturbance of material properties due to heat is a requirement, ultrasonics is often the best welding process.

Wire splicing is an excellent example to evaluate some of the joining processes in today's manufacturing of wiring harnesses. Manufacturers utilized the crimping process for many years before welding became a viable option. Some OEMs just used the clip to crimp the wires in a splice. Some added dipping in a solder bath to secure the electrical integrity. That had the disadvantages of added material (many different sizes of clips), space needed for dedicated presses, the requirement of soldering skills, and impact on wire strands due to the mechanical stress and the heat from the clip and solder. Therefore, welding of wires became very desirable, starting with resistance welding and then the inception of ultrasonic welding. The cold fusion nature of ultrasonic metal welding, its ability to eliminate oxidation before welding, joining of dissimilar metal, very low energy consumption, and ability to weld a variety of splice sizes with one machine and the same universal tooling, were convincing factors in making ultrasonic wire splicing an acceptable process

globally. It took several years for wiring harness manufacturers to become familiar with the process and to adopt the technology. Some moved from crimping to ultrasonic welding, and some used resistance welding before moving to ultrasonic welding. Ultrasonic welding equipment offered advantages over other joining methods that are still true today.

Throughout the progression of welding technology over the past 30 years, quality and reliability were always the ultimate deciding factors. The return on investment was easily justified - ultrasonically welded joints presented longer life in vehicles. Today, most of the features in the comparison table below (Table 1) are applicable to other metal welding applications such as wires to terminals, terminals to terminals, and busbars.

The operation/maintenance cost per joint must be validated concurrently

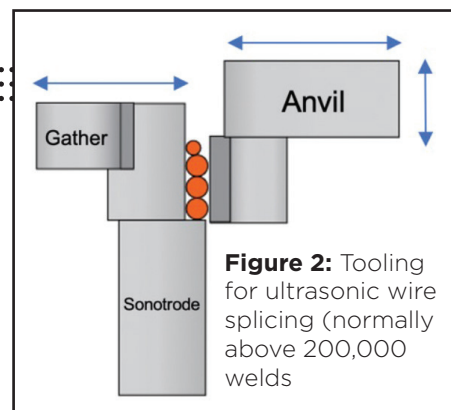


Figure 2: Tooling for ultrasonic wire splicing (normally above 200,000 welds)

but with quality as the highest priority. Here are some of the factors that are considered in selecting a joining method:

- Initial investment and volume
- Output rate
- Consumables
- Electrical consumption - ultrasonic welding requires 5% of that of resistance welding
 - Additional infrastructure such as water cooling, ventilation, and additional power installation
 - Floor space required for equipment
 - Changeover time
 - Setup time for each application
 - Tooling life and its effect on quality (Figure 2)

Table 1 shows each process's advantages and direct and indirect costs of operation. There are many cases where one joining method may be clearly the better choice or even the only option. Consider the features in the table below when deciding among multiple joining options.

Features	Ultrasound	Resistance	Crimping	Soldering	Laser
Cold welding process	yes	no	no	no	no
Consumables needed	no	no	yes	yes	no
Joining dissimilar materials	yes	limited	yes	limited	limited
Durability of the connection	excellent	good	moderate	low	good
Mechanical strength	high	high	moderate	low	moderate
Electrical conductivity	excellent	good	moderate	low	good
Change of material property	unchanged	changed	unchanged	changed	changed
Power consumption	low	high	low	moderate	moderate
Process time	short	short	short	long	short
Heat generation	low	high	low	high	high
Influence of surface conditions	moderate	moderate	yes	yes	yes
Quality control, consistency	high	low	moderate	very low	moderate
Occupational safety (vapors, electric shock)	good	low	good	low	good
Tool life	high	low	high	moderate	high
Qualified operator required	no	no	no	yes	yes
Simple automation	limited	limited	good	no	limited
Maintenance requirements	low	high	low	low	high

Advantages of Ultrasonic Metal Welding

- Low-temperature process does not affect material properties
- Pure metallurgical bond for many non-ferrous materials
- Ability to weld dissimilar materials
- No consumable materials such as splice clips or solder
- Environmentally friendly process
- Consistent weld quality, mechanical, and electrical properties
- Fast cycle time
- HMI friendly
- Operator safety with no fumes or chemicals such as lead

The Process

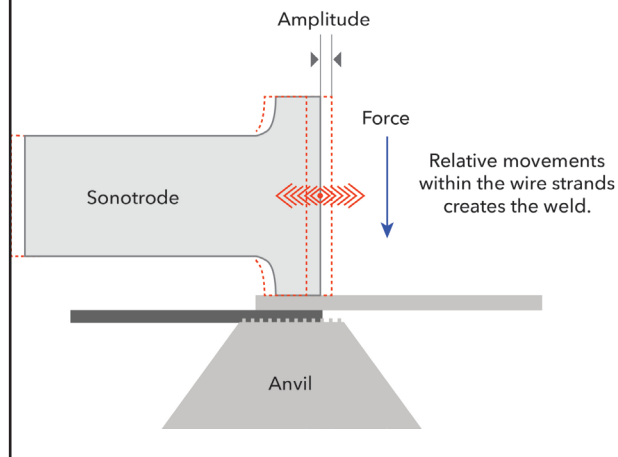
There are two types of ultrasonic welding methods for metal and plastic. Linear welding is the more common technique used by equipment manufacturers and a standard for the splicing of wires (Figure 3). Torsional welding, developed by Telsonic, came into the picture over a decade ago. The torsional welding technique can be used for most common applications of linear welding. However, because of its unique capabilities, it has certain advantages in terms of the application's geometrical shape and its gentle process that leads to a wider spectrum of applications in the market. In fact, this technology is sometimes found to be the only

solution for electric car battery manufacturers and in the termination of high-voltage cables (Figure 4). Other examples where torsional ultrasonic welding proves to be the superior method are bus bars, 3D terminals, and integrated gate bipolar transistors (IGBT).

How it Works

The wires are stacked between the vibrating/oscillating tool (sonotrode) and the anvil block. They are confined in a pre-determined space before the static force is applied through the anvil. As oscillation ensues, the metal surfaces heat up and plasticize, and the strands are bonded together by inter-mingling at the molecular level (Figure 6). The result is a continuous weld with a finely-grained structure like the structure of cold-worked metals. The entire process is very rapid, with welds typically completed in a fraction of a second. Most common splicing machines used today are operated at 20KHz frequency mechanical vibration. The vibration under the force dissipates any contaminants and starts the cold friction welding until the splice is completed. The temperature rise

Figure 6: The vibration and motion involving ultrasonic linear welding of metal



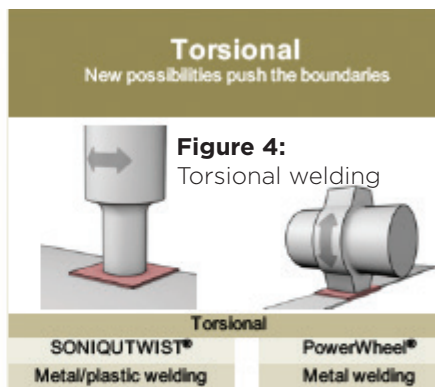
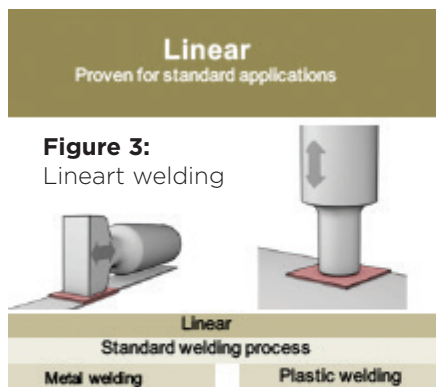
of the welded material is less than 30% due to the friction force at the welding interface. Therefore, there is no hardening of the wire material which makes the wire strands brittle in the weld transition area. This is one of the many advantages over resistance welding, which involves melting of the material to make the splice nugget.

Basic Welding Parameters and Variables

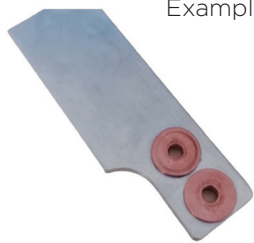
Wire welding with ultrasonics has also proved to be high-quality and safe in practice. Because the welding parameters can be adjusted and monitored for each application, it is now possible in Industry 4.0 environments.

Welding Parameters: In addition to the condition of the welding tools and dimensions that are always predetermined, four welding parameters need to be set up. These parameters are normally established by a default given by the machine controller to begin the qualification of the weld quality.

- Width of the weld: Set up by the machine
- Weld energy: The fixed number of watt-seconds to be delivered to complete the weld
- Amplitude: The oscillation that can be adjusted up to 100% capability of the sonotrode



Examples of ultrasonic welding applications



Cu insert welded to Al busbar



Leoni connection bolt welded to Al



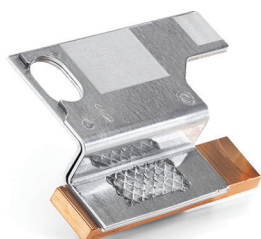
Flat braided cable welding



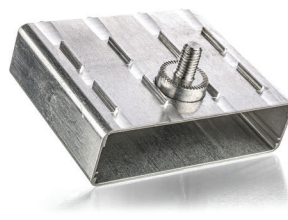
48V to Ni plated Cu connector



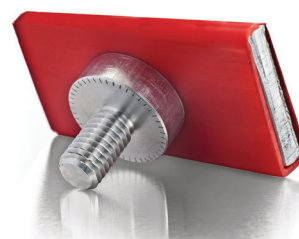
Welding of 3D Terminal to Bus Bar



Power Tapping Bolt



Mounting Solution for Electronic Components



Insulated Al Bus Bar & Cable Terminations



Mini HPLB extension blade



Two steps welding of insert and cables



120 mm² Al cable welding



Electrical connection to IGBT

• Force-pressure setting: To set the welding force

Quality Variables: To control the process for the best quality when welding with fixed energy, the following variables are measured and compared to the upper and lower allowed limits determined by the machine or the user.

- Weld time (duration of welding)
- Compaction height before ultrasonic is started
- Final weld height
- Power consumed

Stable Production and Data Integrity

Ultrasonic metal welding is a crucial process for all aspects of wire harness assemblies due to its ability to provide a reliable bond to meet all low and

high current-carrying characteristics. Therefore, certain standards and specifications have been prepared by individual companies. USCAR 45 & 38 for Ultrasonic Wire Splicing and termination are some examples, as well as other specs that can be applied to most industrial products in the market. The following table is a summary of ultrasonic welding quality guidelines.

In today's fast-paced development of electric vehicle batteries and high-voltage connection systems, prompt response with a solid joining solution is necessary. Product engineers must select the joining technique while they are in the design and development stage. This will require communication between welding solutions providers and product designers to speed

up the process and have all tooling prepared for prototyping and initial product testing.

As the knowledge of ultrasonic welding grows, more applications are being designed to work with its current capabilities. However, if you are new to the technology, then hopefully this article helps you to better understand some of the fundamental principles of welding technologies and clarifies the potential financial opportunities available in automotive and other industries. There are many factors to consider when choosing the most appropriate joining method before your design is finalized. The information in this article should provide a good start. ●



a green urban transition, it shows how cities can act as ambitious, inspirational front-runners that showcase green technology and create attractive places to live and work. In the coming chapters we take a deep dive into the carbon footprints of all major aspects of our lives in cities: the heating and cooling of the buildings we live in, the construction sites that build our homes, roads, and workplaces, the transport that gets us to work, the infrastructure that supplies our goods and handles waste, and the data centers that constitute the digital backbone of the city. In the next few years, the battle against climate change will be won – or lost – in cities. The solutions are there, but political leaders need to take action in scaling them. Let's get started.

Roadmap For Decarbonizing Cities

BY MIKA KULJU

Skyscrapers, traffic jams, shopping malls, and air conditioners. It is not hard to see why cities account for two-thirds of global energy consumption and more than 70% of annual global carbon emissions. With more than half of the world's population living in cities today – a number expected to increase to almost 70% in 2050 – we will not reach the goals of the Paris Agreement without a deep decarbonization of cities.

Many cities all over the world have committed to ambitious climate targets and are taking steps to reduce their emissions. However, as the most recent IPCC report exposed, the 1.5°C target is moving out of reach, and it's likely that the world will exceed 1.5°C of warming in the near term if we “keep walking instead of sprinting.” Climate change

has already resulted in negative impacts on human well-being and key infrastructure in cities. For instance, heatwaves and air pollution have intensified in cities. To prevent the worst of the climate crisis, rapid, deep, and sustained change is necessary. Or as UN Secretary-General António Guterres puts it: “Our world needs climate action on all fronts — everything, everywhere, all at once.” The ambition of this whitepaper is to demonstrate how “everything, everywhere, all at once” can be done in cities.

Cities offer some of the best possibilities to optimize urban planning and accelerate a green transition, and there are already accessible, cost-efficient technologies out there capable of cutting emissions sufficiently to meet global climate goals. By offering a roadmap for

Brief Note

With evidence from credible sources, Danfoss Impact is written to show how existing efficiency technologies can lower the cost of decarbonization and accelerate the electrification of our economies.

This special, longer issue of Danfoss Impact aims to provide a concrete roadmap for mayors, local decisionmakers, and urban planners on how to eliminate all major drivers of the carbon footprint of cities. The paper explores how available technologies can improve the livelihoods of citizens while at the same time making our economies more resilient and creating jobs. It offers a holistic and concrete view of the major opportunities for decarbonizing cities.

However, the solutions presented are not exhaustive and the paper will not explore the provision and build out of renewable sources of energy. Crucial as this is, it is a theme well-researched and analyzed. In addition, although they fall outside the scope of this paper, urban planning measures such as creating walkable cities, parks and open spaces,

wetlands, and urban agriculture to reduce flood risk and heat-island effects should also be implemented.

In cities, the transport sector and the building sector are the largest contributors to carbon-emissions, and therefore the paper focuses on all major levers for decarbonizing those two sectors – reducing energy waste through efficiency measures, electrifying, and integrating sectors to reuse otherwise wasted energy. These measures need to be at the heart of any realistic deep decarbonization of cities. Our roadmap for decarbonizing cities uncover the major drivers of carbon emissions and the solutions needed to reduce them.

Key Takeaways

► **Energy efficiency.** If all urban areas and cities in Europe, the US, and China invested in energy-efficient heating and cooling of buildings, this would contribute 20% to the 1.5°C target of the Paris Agreement. Reducing energy waste is possible across sectors and the technologies to do this are already accessible.

► **Electrification of urban transport** needs a drastic acceleration. Similarly, an urgent political focus on the potential of electrifying the whole transport sector – including both maritime transport and heavy vehicles – is pivotal. If all urban areas in Europe, the US, and China electrified their private and public transport, this would contribute 28% to the 1.5°C target of the Paris Agreement. As we will see, technology for the electrification of cars, buses, and trucks, as well as marine equipment and transport such as city boats, ferries, cranes, etc. already exist.

► **Sector integration** is an enabler of energy efficiency and electrification and can together with the

build-out of renewables decarbonize the power supply to cities. In urban areas, the high density of buildings, infrastructure, and services makes it possible to connect urban energy-consumers with energy-producers and convert and store energy. Supermarkets, data centers, and wastewater facilities can all be turned from heavy energy consumers into energy suppliers.

► **Implementation of existing technology** for buildings, transport, and sector integration can bridge half the gap in the urban GHG emissions reductions needed for a 1.5°C pathway.

The Carbon Footprint of Cities

In the first half of this white paper publication, we will visit two of our three stops in the city: heating and cooling, and urban transport, including policy recommendations for how to decarbonize these sectors effectively. In the second part, to be published in the next issue of Appliance & HVAC Report, we will explore how to decarbonize urban energy supply, as well as present three key steps to decarbonize cities as a whole.



Decarbonizing Heating and Cooling in The City

Our roadmap for decarbonizing cities starts in the buildings where we live, work, and spend most of our time. Our homes, offices, hospitals, schools, and factories all require energy for power, heating, and cooling. Globally, buildings are the second largest source of energy-related carbon emissions. In total, 28% of global energy-related CO₂ emissions come from day-to-day energy consumption in buildings. And in urban areas, buildings can often account for over 50% of emissions.

As climate change progresses and temperatures inevitably rise, demand for energy in buildings to maintain ambient conditions is predicted to increase further. High temperatures and heat waves have already begun to drive demand for air conditioning and will continue to do so. As the world's population continues to grow, so will the expanse of buildings needed to house and service growing communities. Reducing emissions from buildings is therefore critical if we are to meet the goals of the Paris Agreement.

An effective strategy for decarbonizing buildings must address both the energy supply and demand requirements. We must simultaneously ensure that energy sources for heating and cooling buildings are decarbonized, while also making efforts to reduce the overall demand for energy from buildings.

According to the IEA, if we are to achieve net-zero emissions by 2050, nearly 85% of buildings must be zero-carbon-ready, meaning highly energy efficient and using decarbonized energy. To achieve this goal, most existing buildings

would require retrofits by 2050 and all new buildings must be built as zero-carbon-ready by 2030. But we are currently off track: as of September 2022, retrofitting rates for existing buildings were around 1% and need to double, and only 5% of new buildings were zero-carbon ready. However, solutions to reach the necessary efficiency in buildings already exist.

To reduce the energy intensity of buildings we need to look at both passive and active measures that span space heating and cooling, lighting, ventilation, and water.

Passive measures, such as architectural design or improvements to the building envelope, can play an important role in reducing the demand for heating, cooling, ventilation, lighting, etc. In this paper, however, we will focus on active measures.

Active measures achieve energy savings by measuring, monitoring, and controlling a building's energy usage. While installing energy-efficient lighting or heating is essential to reducing overall energy use, active measures must also be implemented to ensure that the lighting or heating is only switched on according to demand. Taking a hard look at whether to retrofit existing buildings or create new, active measures can have an enormous, fast, and cost-attractive energy-saving potential that is far from realized today. In the following pages, several existing technologies with large energy-saving potential are presented. And while geographic location often dictates which active measures make most sense (e.g., heating vs. cooling), the

following examples are particularly relevant in the context of heating buildings.

Thermostats: One of the simplest ways to save energy is to maintain a room's temperature level automatically by using a thermostat. Simple as they may be, thermostatic radiator valves save up to 7% of final energy in a multi-family building with a payback time of one year. However, many buildings still do not utilize this simple measure. Across the EU, thermostatic radiator valves have the potential to save 130 TWh of heating energy per year without affecting the thermal comfort of households. The energy savings can be increased even further with an electronic thermostat, which is regulated digitally and can be set according to occupant behavior, for example by lowering the room temperature when a building is empty.

Hydronic balancing: Many heating or cooling units utilize a hydronic system that transfers water through pipes and radiators to heat or cool buildings. The flow resistance inside the system is – unless controlled – fluctuating. This causes radiators closer to the pump to become warmer than their intended temperature, meanwhile radiators further from the pump are cooler. This inefficiency means that water is often overheated, larger pumps are installed to accommodate people living far from the pump. Besides installing thermostats, the installation of automatic balancing valves with differential pressure control leads to ideal indoor temperatures, reduced operating costs, and creating higher efficiency.

In a multi-family building, a

hydronic balancing system can save up to 10% on final energy with a payback time of 1 year.

Model predictive controls are driven by artificial intelligence using building, weather, and user data to predict heating and ventilation demand. By utilizing these controls, buildings can pre-heat ahead of peak hours, or lower the heat supply when the sun is about to shine on the building facades, thus saving energy. Observations on 100,000 flats equipped with this technology based mainly in Finland show the energy consumption of heating and ventilation was reduced on average by over 7% and 10%, respectively.

Meanwhile, by shifting the consumption to the most economical period, the system ensures up to 20% savings in a building's energy costs. In 2021, a London Local Authority installed model predictive controls in eight residential buildings. In the first 11 months of operation, the technology paid back its initial cost and saved 600 MWh of heat – the equivalent of heating 50 homes in the UK for a year.

Heat pumps upgrade the low temperature heat stored in the air, bedrock, ground, or groundwater to a usable temperature level. Buildings are consuming this by heating our living spaces, offices, and water. Because they upgrade heat instead of generating it, on average heat pumps can keep a building warm with only a third of the electricity used by traditional electric equipment. Heat pumps can also provide cooling, eliminating the need for a separate air conditioner for the 2.6 billion people who will live in regions requiring



both heating and cooling by 2050. The IEA estimates that heat pumps have the potential to reduce global CO₂ emissions by at least 500 million tons in 2030 – equal to the annual CO₂ emissions of all cars in Europe today. However, although heat pump adoption has increased in recent years, it still represented less than 10% of global heating equipment sales in 2021, while fossil fuel equipment accounted for 45%. And this is despite lower energy costs for the average household or business using a heat pump than for those using a gas boiler.

Policy Recommendations

A deep decarbonization of cities requires a comprehensive and holistic approach that involves multiple stakeholders, including local governments, businesses, and residents. In the following, some of the crucial initiatives for heating, cooling, and transport are presented, although the list is not exhaustive.

Systematic Energy-Saving Strategies Can Save Energy Across Sectors

► Reducing energy waste across sectors starts with mapping energy use to identify areas for improvement. Mandate energy planning, set ambitious and actionable short-, mid-, and long-term targets and plans, and a suitable regulatory framework to incentivize investments.

► Seize the quick wins first, as this can leverage finance for deeper renovation or sustainable new-build projects. Quick wins include optimizing the heating, cooling, and ventilation systems in the public building stock (see p. 10-11). These measures can be implemented immediately with very short payback times, and without

compromising long-term energy-saving efforts.

► Design and implement mandatory building energy codes for new and existing buildings to accelerate the transition towards zero-carbon-ready buildings and to increase the renovation rate of the building stock.

► Set minimum energy performance standards to support the uptake of energy efficient equipment. Energy labels can further stimulate the market and are most suitable for off-the-shelf products with end consumers as main target groups.

► Set up long-term renovation strategies, including suitable regulation and incentives to stimulate renovation, to use renewable energy, and to boost renovation rates of existing buildings. Currently, renovation rates are often less than 1% and must rise to at least 2-3% per year in most regions to meet 1.5°C by 2050.

► Incentivize the replacement of technical building systems running on fossil fuels for space heating, domestic hot water, and cooling with those using renewable energy, such as heat pumps or district energy networks.

► Ensure or facilitate access to funding for implementation. One way this can be done is by using or asking for innovative financial business models like ESCOs.

Electrify Transport Through Investments, Regulation, and Incentives

► Invest in the electrification of the city's fleet now (vehicles, buses, city boats, ferries). Remember that also partial electrification of heavy transport entails significant cost and energy savings and can be done immediately.

► Investing in electric charging infrastructure and incentivizing the installation of charging points at (semi-) public locations like office buildings, parking facilities, supermarkets, and tourist attractions. Introduce parking incentives and other fiscal incentives for moving toward electrifying transport.

► If the national policy allows it, use local regulation and permitting options to create low or zero-emissions construction sites and electrify last-mile inner-city freight and goods delivery traffic.

► Using franchise agreements with public transport operators to enforce zero emission goals for buses, taxis, and more.

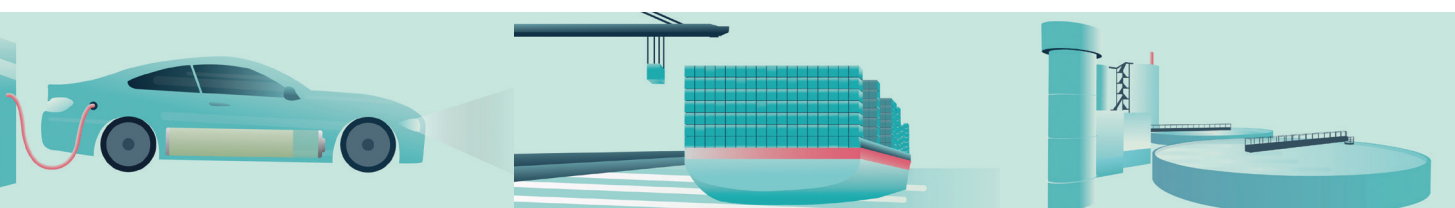
► Incentivize the installation of shore supply in harbors and present a plan for how to address that all vessels use electric shore supply when at berth.

Stay tuned for the second half of the white paper in the next issue of Appliance & HVAC Report. To download the full white paper and additional insights from Danfoss on energy efficiency, visit [whyee.com](https://www.whyeec.com).



Mika Kulju has more than 25 years of business experience in the drives and power electronics industry. In October 2022, he joined Danfoss as President of

Danfoss Drives. Before that, Mika Kulju was President of the Drive Products division at ABB, where he started his career in 1992. His professional and executive experience at ABB includes various local and international roles involving general management, supply chain management, sales, product management, operations and product development.



3 IN A SERIES

THE 6 HAZARDS OF PRODUCT SAFETY – RISK OF FIRE

BV BILL BISENIU , DIRECTOR OF TECHNICAL SERVICES, EUROFINs MET LABS

Designing for Compliance is critical to getting your product certified on the first try. Designing for Compliance requires owning, knowing, and applying the standard(s) while designing your product. However, in order to successfully read and understand the standard, you have to know the intent of the requirements. Our “Designing for Compliance” series of whitepapers will educate you on “The 6 Hazards of Product Safety”. The intent of the requirements in all UL/CSA/EN/IEC safety standards is to protect the user from the “6 Hazards of Product Safety”. This whitepaper covers Hazard #3 – Risk of Fire..

Risk of Fire Definition

All electrical circuits, other than those at Class II voltage/power levels, are considered to involve a “Risk of Fire”. Due to the potential for catastrophe as a result of a fire, the standards take the safest approach and assume that all products can catch fire at some point over their useful life. The requirements in

the product safety standards are therefore focused on requiring design principles that limit the chances for a fire to start, spread, and escape from the product.

Risk of Fire – Only A Hazard If It Leaves the Enclosure

The potential for an electrically induced fire always exists within an electrical product. The sole concern with fire in the product safety standards is whether it can spread from the product to the building contents and structure, at which point it would be a threat to the building occupants. The product safety standards generally do not care if a product burns and turns to ash inside the enclosure, as long as fire does not get out of the product's enclosure. (There is generally no concern with smoke in the product safety standards other than smoke that is hot enough to spread fire.)

Risk of Fire: A 3-Step Approach

To help insure that any product fire is contained within the product's

enclosure, the safety standards require a 3-step approach:

- 1) Limit the likelihood that combustible materials will catch fire in the first place by maintaining operating temperatures that are below the material's temperature rating. And,
- 2) Limit the likelihood that any fire will spread internally and grow by limiting the flammability of combustible materials – by requiring UL flame ratings for printed circuit boards, wiring, insulating materials, and internal plastics. And,
- 3) Limit the likelihood that fire can get out of the enclosure by controlling vent size and location near combustible materials so that any fire does not spread through the openings – the primary concern is a fault condition causing a fire that drips flaming particles onto the supporting surface. In addition, higher flame ratings are required for all plastic enclosures to insure fire containment.

We then perform fault testing to verify that there is no “Risk of Fire”. One of the pass/fail criteria when performing fault testing is whether

there was a "Risk of Fire" as a result of the fault condition = did fire escape the enclosure during testing? To make this determination, the standard specifies conducting fault tests with the product sitting on tissue paper and covered with cheese cloth. The tissue paper and cheese cloth are used as the "fire indicators" – should either of these materials discolor or char, the results are considered a "Risk of Fire" which is a test failure.

Fire Hazard Protection

Let's now dig deeper into the Fire Hazard Protection design principles that accomplish the 3 elements of Risk of Fire protection. Based on the definition of a Risk of Fire, the ultimate goal is to design the product for fire containment – during fault testing, the product can burn internally as long as the fire does not escape the enclosure.

We can take the 3 elements of Risk of Fire protection, and translate each into the design principles that achieve the intended level of protection.

1) We can limit the likelihood that the product will catch fire by:

a) Keeping temperatures on combustible materials below their temperature rating. Components used within their ratings are unlikely to catch fire during normal operation.

b) Providing adequate electrical circuit spacings to limit the chance of a fault and subsequent fire. Fires on circuit boards can occur when arcing between traces causes carbon to build up over time. This carbon conducts current causing heating that can lead to a fire.

2) We limit fuel to a fire so that any fire is unlikely to grow by:

a) Limiting the flammability of combustible materials thru the selection of plastics, wiring, and insulating materials with suitable UL

flame ratings.

b) Using certified wiring with a VW-1 rating (Vertical Wire Flame Test). This helps to insure that the wire insulation doesn't drip flaming particles or spread fire throughout the product.

c) Using printed circuit boards with a minimum V-0 flame rating. The most flammable part of electrical products are their integrated circuits. If you light a circuit board on fire, it looks like flaming popping corn. It's important these components are on a flame rated board so the board doesn't ignite during a component fire. The intent is for the fire to self-extinguish on the board with fire contained at all times.

d) Using plastics with the appropriate flame rating for the application. The 5V rating being the highest rating and least flammable, typically required for enclosures of stationary and fixed equipment (where it can be critical that the fire remains contained or it will spread to the building structure). Lesser ratings are often permitted for portable appliances, this includes in descending order V-0, V-1, and V-2 ratings (V-0 being just below 5V). At the lower end of the plastics ratings is HB, which is typically permitted for decorative plastics (external) and enclosures of products that do not involve a risk of fire (i.e. computer mouse). For other internal plastics, a V-2 rating is usually acceptable.

3) Design the enclosure so that any internal fire will not escape the enclosure:

a) The primary concern is a fault condition causing a fire that drips flaming particles onto the supporting surface. The standards generally assume that fire can drip vertically and at up to a 5° angle from vertical. This puts the focus on side and bottom openings. Therefore, you should avoid positioning flammable materials above

vent openings or within a 5° drip angle.

b) By controlling vent size and vent location near combustible materials, you will limit the likelihood that fire escapes through the openings. This is especially important with bottom openings. When you cannot avoid putting flammable materials above or within the 5° drip angle, the vents need to be very small in size and/or louvered to prevent flaming particles from escaping the enclosure.

c) For plastic enclosures, using the highest flame rated material to insure that any internal fire does not spread along the enclosure surface or burn through the enclosure material. Make sure the enclosure plastic also has any additional ratings necessary for the application (Glow Wire, Needle Flame, Hot Wire Ignition, High Current Arc Ignition, High Voltage Tracking Resistance, Flame Spread, & UV Resistance).

d) Finally, confirm the suitability of the design by conducting single fault tests to verify that fire does not escape the enclosure.

Risk of Fire – Summary

In summary, Risk of Fire can certainly be viewed as one of the most important of the 6 Hazards of Product Safety. The potential for a single product to risk many lives by causing a structural fire must be considered in the Risk Analysis of electronic products. Compounded by the fact that product fires are dramatic and, in today's social media era, the results of a single event can be shared with millions of potential customers. Yet there are no 100% fault free components meaning there are no 100% fault free products. As such, it is important that you fully understand and apply all the principles of fire containment as a means to help mitigate the inevitable potential for a fire in your product. ●



Condensate Pumps for Computer Room Air Conditioning

This case study explores Beckett Corporation's extensive experience working with OEMs of data center cooling systems to deliver stock and semi-custom condensate pump solutions for manufacturers of Computer Room Air Conditioning Systems (aka CRAC).

When it comes to component reliability, performance, and cost effectiveness, CRAC OEMs are continually exploring new options for major components, including condensate removal pumps.

Due to confidentiality agreements

with OEMs, we are not able to share specific de-tails on any manufacturers, models or specific application details in this article. Why do computer rooms and data centers need air conditioning?

Poorly managed computer room temperature, humidity, and air quality can negatively affect the performance and lifespan of computer equipment and put priceless data at risk. To protect servers and data, specialized HVAC equipment is essential to monitor and control temperature, humidity, and air quality in computer rooms, data centers, and server farms.

What is Computer Room Air Conditioning (CRAC)?

A CRAC unit is similar to traditional air conditioning equipment. It is designed to maintain the temperature, air distribution, and humidity in a data center's computer rooms. CRAC units use a direct expansion refrigeration cycle. Air is cooled by blowing over a cooling coil. The cooling coil is filled with refrigerant, which itself is kept cool by compression. The extra heat is ejected using a glycol mix, water, or ambient air.

Why do CRAC systems need condensate pumps?

Condensate is created during a change in the state of water from a gas or vapor form into a liquid form. It generally occurs when vapor in warm air encounters a cool surface, which normally occurs in air conditioning systems, refrigeration equipment, and other types of cooling and heating equipment.

To prevent the unwanted collection of condensate water, it should be drained away by gravity through a drain pipe or hose. If gravity drainage is not possible or practical, a condensate pump is used to automatically pump the condensate water to a drainage point.

What are the main components of a CRAC Unit?

The major components of most CRAC systems can include mechanical items, monitoring/controls, refrigerants, air filters, compressors, evaporator coils, and condensate removal pumps. The actual components vary based on the make, model, and size of the CRAC system.

Are CRAC and CRAH (Computer Room Air Handlers) the same?

No. CRAH cooling units have a similar function to chilled water air handling units in buildings. Like CRAC systems, these units use fans to blow air over cooling coils to remove excess heat. However, these cooling coils are filled with chilled water rather than refrigerant. The chilled water typically comes from a separate chiller or chilled water plant. The unit draws in warm air from the computer room, and the air flows over the chilled water coils. Heat transfers from the air

to the water, which then returns to the chiller. CRAH units can regulate fan speed, ensuring humidity and temperature levels stay stable while also allowing variability.

CRAH cooling is typically used in mid-to-large-sized data centers and server farms. Because CRAH units don't use compressors, they typically use less energy, are more efficient and require less maintenance, all of which can also mean lower operating costs. However, CRAH systems include a significant capital investment because they're designed for medium to large data centers.

CRAC OEM Problems

Beckett works with CRAC OEMs during projects related to new product development and existing product improvements. OEMs explore alternative pump solutions for a variety of reasons.

- Pump reliability and durability issues
- Pump performance problems
- Unacceptable pump operating noise
- High temperature requirements from steam humidifiers
- Tight dimension requirements from low profile or aisle/row/rack cooling
- Plenum rated pumps for placement in plenums or ducts due to space limitations
- Uncompetitive pump price points
- Unresponsive or inflexible engineering and technical support
- Issues related to supply chain and product availability
- Slow time to market capabilities

Solutions and Benefits for CRAC OEMs

With over 75 years of experience, Beckett offers a range of stock and semi-custom condensate pumps to meet a wide range of applications

at a cost-effective price point. With in-house engineering and production, Beckett offers a range of high-quality condensate pump solutions.

Beckett's extensive OEM experience backed by a range of important capabilities makes Beckett condensate pumps the ideal solution for many CRAC manufacturers.

- Proven Pump Technologies - With a range of stock pump technologies, Beckett can meet different needs with proven high-quality condensate pumps at a competitive price point. In addition, Beckett can assist with control switches and integration with other control systems. The Beckett IPC13, CL20, BK22, CB25 and CB50 condensate pumps have been used in a wide variety CRAC applications including but not limited to high-temperature, plenum, and low profile applications.
- In-House Engineering - Our technical resources are available for assistance with product sizing, selection and semi-custom applications.
- In-house Production - Ensures a more reliable supply chain, lower tooling costs, faster cycle times, and overall greater flexibility to meet your needs.
- Time to Market - Beckett understands the need for speed and flexibility. Our in-house capabilities shorten cycle times and lead times to give our OEM customers another advantage.
- Production Tooling - In rare cases where custom tooling is needed, Beckett offers more affordable tooling and shorter lead times to help keep costs down.
- Experience - Since 1948, Beckett has built a proven track record for producing high-quality pumps known for reliability, long-term durability, quiet operation, and great overall value. ●

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10



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29



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www.asge-national.org
31



Solar & Palau

www.solerpalau-usa.com
33, 34



Tower Manufacturing

www.towermfg.com
37



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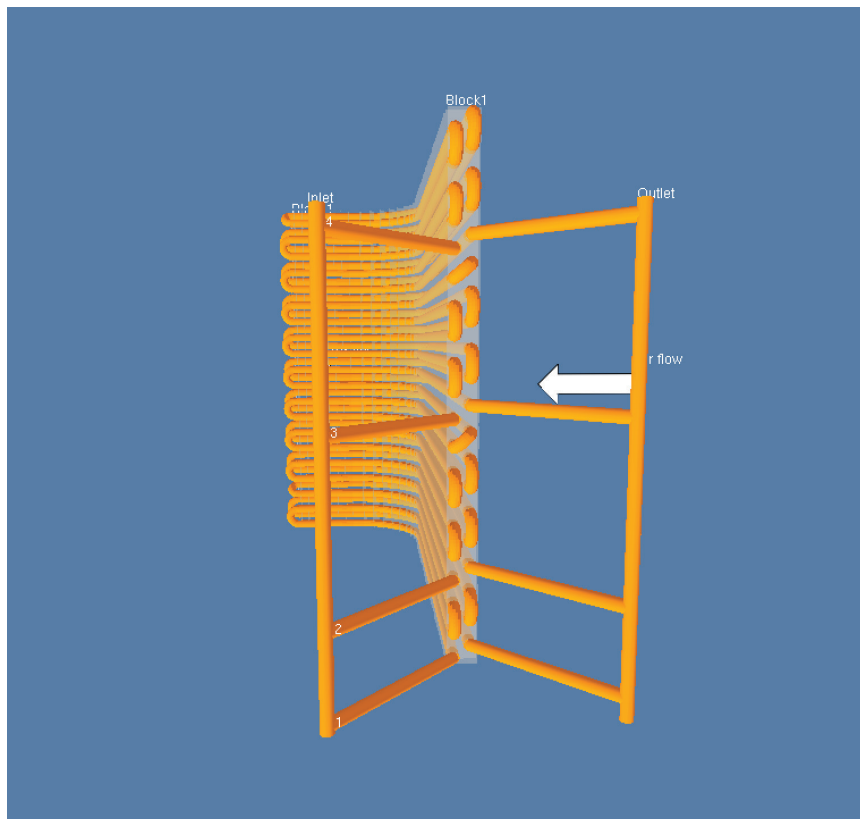
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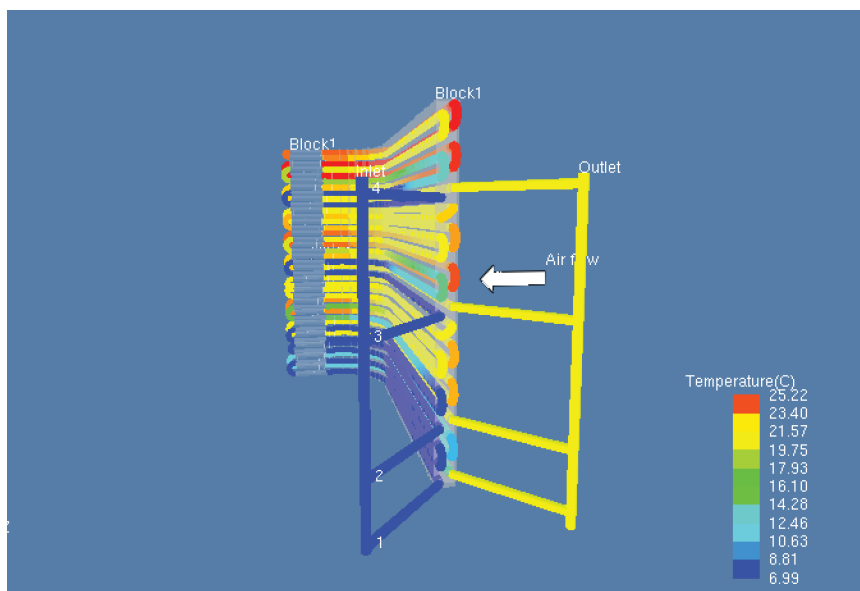


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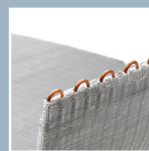
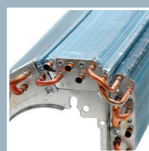
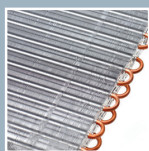
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