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2020 WHITE PAPER

STRATEGIC ELECTRIFICATION: SATISFY THE DEMAND WITH VRF TECHNOLOGY

INTRODUCTION

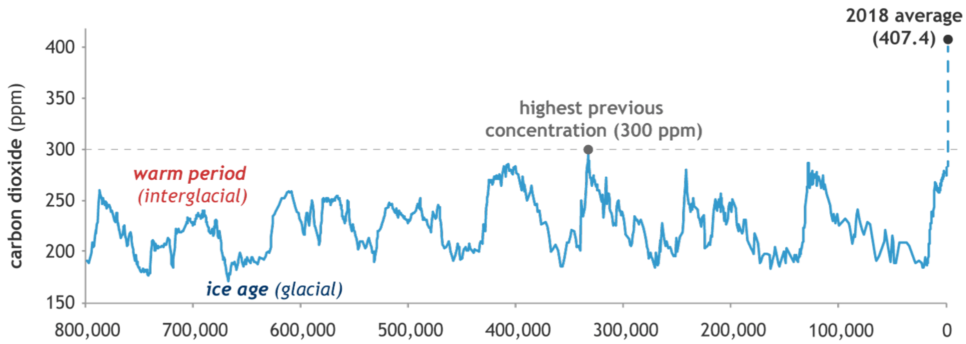
Strategic electrification aims to decarbonize Earth's atmosphere, decrease pollution and reduce the costs of modern comfort and technology. Also known as "beneficial electrification," this movement requires increased energy efficiency and end uses powered with electricity from cleaner grids and renewable sources. The movement will transform both the built environment and society's modes of transportation. Despite the enormity and complexity of its challenges, strategic electrification can't be dismissed as niche or a possibility of the far future. The movement's happening now, driven by a mix of public and private entities on the local, state and national level proceeding along voluntary and mandatory paths.

This White Paper gives an overview of strategic electrification and describes how Variable Refrigerant Flow (VRF) zoning systems help architects, engineers, building owners, cities and states solve its challenges. Worldwide, all-electric heat pumps are the most popular technology for decarbonizing heating and cooling.[1] VRF heat pumps and heat-recovery systems contribute to lower carbon footprints and benefit strategic electrification by **reducing overall costs for commercial building owners**, consumers and society.[2]

WHY DECARBONIZE?

Carbon dioxide (CO_2) absorbs and emits heat. As a naturally-occurring greenhouse gas (GHG), CO_2 helps Earth retain enough warmth to sustain life but too much can lead to excessive warming. For 800,000 years, before the Industrial Revolution and the widespread adoption of fossil-fuel burning technologies, the highest global average atmospheric amount of CO_2 was 300 parts per million (ppm).[3] As of 2018, the average amount was 407 ppm.[4]

CO_2 DURING ICE AGES AND WARM PERIODS FOR THE PAST 800,000 YEARS

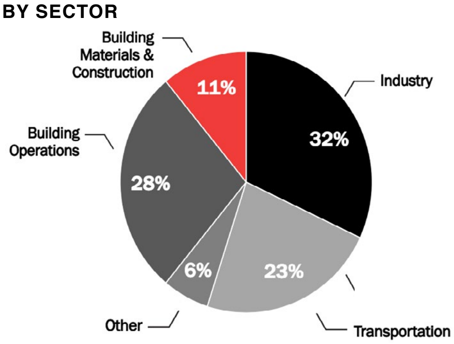


Source: NOAA Climate.gov Data: NCEI

Fossil fuels are hydrocarbons consisting primarily of carbon and hydrogen. During combustion, the fuel's carbon combines with oxygen. This makes CO_2 an inevitable byproduct when a system burns fossil fuels to release energy used for work or heat. Unfortunately, the amount emitted by fossil-fuel burning technologies is on pace to increase atmospheric CO_2 to volumes that will change our environment.

If our global energy demand grows and we continue using fossil fuels in the same way, the average amount of atmospheric CO_2 will likely exceed 900 ppm by 2100.[5] With increases in the amount of atmospheric CO_2 the global temperature also increases. If the global temperature continues to increase at its current rate of 0.2° Celsius per decade, the climate will likely reach 1.5° C above pre-industrial levels between 2030 and 2052. At this temperature, the majority of climate scientists expect environmental changes to include rising sea levels, increased flooding, droughts, extreme heat, wildfires and new risks to human lives, infrastructure and biodiversity.[6]

DECARBONIZATION AND THE BUILT ENVIRONMENT GLOBAL CO_2 EMISSIONS BY SECTOR



Source: Global Alliance for Buildings and Construction | 2018 Global Status Report

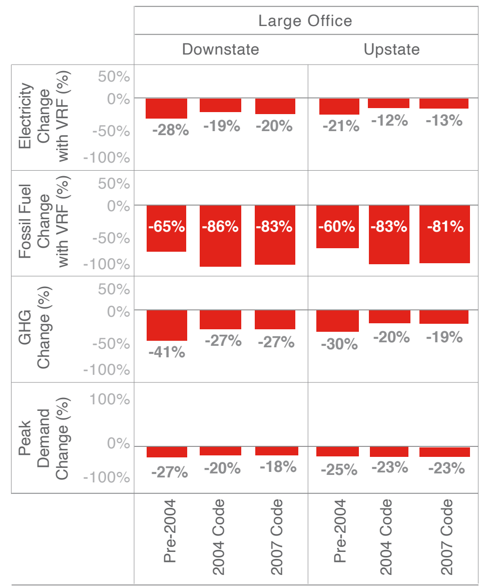
In climate models where global temperatures do not reach 1.5° C above pre-industrial levels, our society reduces its demand for energy and decarbonizes electricity for end uses. Per **the 2018 report** published by the U.N. Intergovernmental Panel on Climate Change (IPCC), the built environment in this scenario lowers its global net CO_2 emissions by 45 percent from 2010 levels by 2030 and achieves net-zero CO_2 emissions by 2050.[7] Building operations account for nearly 28 percent of annual global CO_2 emissions.[8]

ELECTRIFY EVERYTHING

Utilities, states, cities, agencies and non-profits have published a steady stream of studies and reports on how strategic electrification is the best way to achieve aggressive carbon emission reduction goals. An example is **New Jersey's 2019 Energy Master Plan: Pathway to 2050**. The report contains an analysis of decarbonization pathways performed by **Evolved Energy Research** and the **Rocky Mountain Institute** for the New Jersey Board of Public Utilities. The analysis found **that fully electrifying vehicles and building systems was the most sensible pathway for New Jersey.** Electric appliances and vehicles save money by using "roughly one-third the energy of gasoline vehicles or natural gas-fired water heaters and furnaces." Electrified buildings give the state more options for energy generation and can lead to new quality jobs in the electricity and building industries, including HVAC.[9]

New Jersey's report recommends wider adoption of heat pumps in residential and commercial buildings and suggests the state provide incentives for installing all-electric building systems.[10] This recommendation is consistent with other reports on decarbonization and electrification including **The Action Plan to Accelerate Strategic Electrification in the Northeast** and the **Variable Refrigerant Flow (VRF) Market Strategies Report** published by Northeast Energy Efficiency Partnerships (NEEP), one of six Regional Energy Efficiency Organizations (REEOs) funded in-part by the U.S. Department of Energy. In the latter report, NEEP referenced research conducted by the Vermont Energy Investment Corporation (VEIC) for the New York State Energy Research and Development Authority (NYSERDA) showing GHG emission reductions of up to 41 percent for older, large office buildings retrofit with VRF systems. The equipment included in the study demonstrated baseline VRF system performance and didn't include the most highly-efficient models currently on the market. Additional energy savings and reductions in GHG emissions are likely with newer equipment designed for cold-climate performance and higher integrated energy efficiency ratios (IEER) and coefficient of performance (COP) ratings.[11] IEER measures part-load efficiency during cooling. COP measures the average amount of heat a system can deliver compared to the amount of electrical energy it consumes.

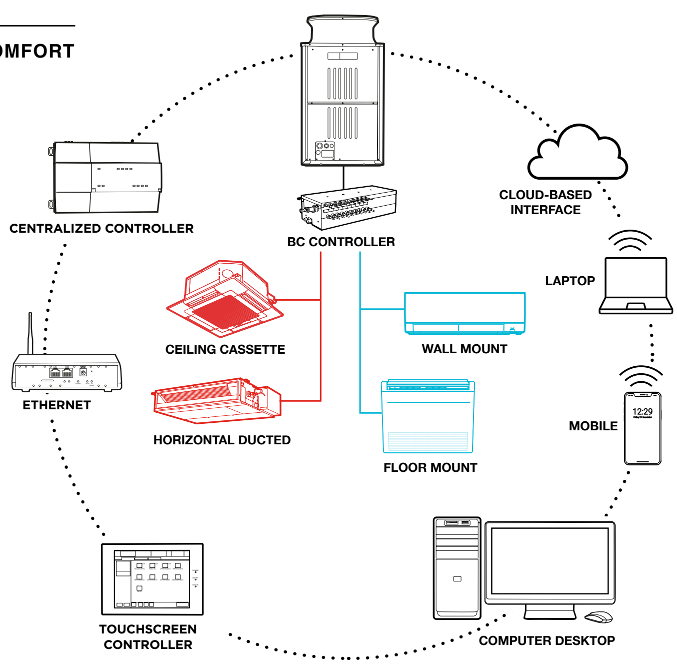
REDUCED GHG EMISSIONS WITH VRF SYSTEMS



Source: Northeast Energy Efficiency Partnerships Variable Refrigerant Flow (VRF) Market Strategies Report (September 2019)

ALL-ELECTRIC HEATING AND COOLING

CONNECTED FOR COMFORT



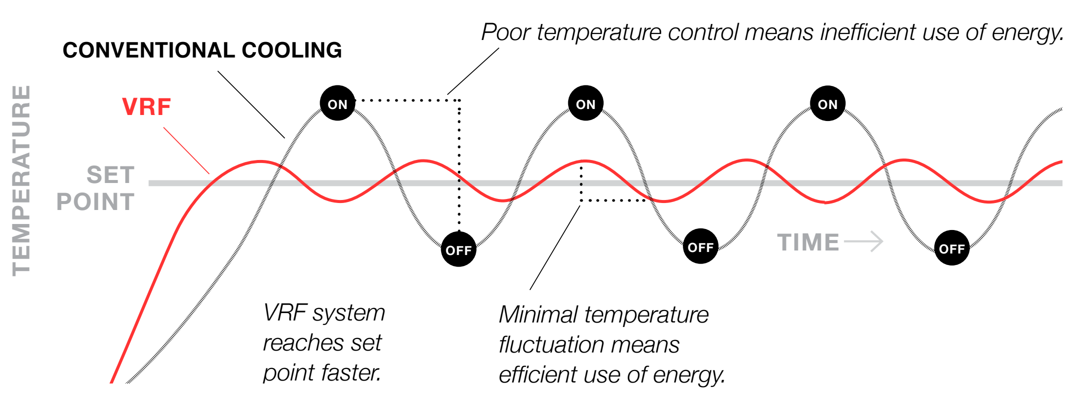
VRF technology consolidates heating and cooling into one all-electric, multi-zone system for offices, hotels, schools, multifamily buildings, indoor agriculture facilities and practically any commercial application. A VRF system consists of an outdoor unit and up to 50 indoor units connected via refrigerant lines and a communications network. Each zone is conditioned by its own indoor unit(s) and can have its own set point. Instead of burning fossil fuels, VRF heat pumps provide heating to zones by introducing ambient heat the outdoor unit extracts from the air or a nearby water source. During cooling, VRF heat pumps reverse this process as indoor units transfer heat from zones to the outdoor unit which then rejects the heat. Indoor units are available in ductless and ducted styles.

HEAT RECOVERY

VRF heat-recovery systems have the same capabilities as VRF heat pumps, but also use a branch circuit (BC) controller to leverage load diversity and provide simultaneous heating and cooling. They can move heat from zones calling for cooling to zones calling for heating. By repurposing thermal energy that would've been rejected by the outdoor unit, heat-recovery systems increase total applied capacity and energy efficiency.[12]

THE INVERTER ADVANTAGE

An INVERTER-driven compressor enables the outdoor unit to vary the system's capacity to match the load detected by each zone's indoor unit(s) or separate sensors. Indoor units continuously communicate with the outdoor unit and controllers. Continuous communication lets VRF systems modulate capacity based on loads, outdoor temperature and occupancy while providing self-diagnostics and tiers of remote management for facility managers. With precise management of capacity, VRF systems reliably maintain each zone's set point without the noisy and energy-intensive start/stop cycles of conventional systems.

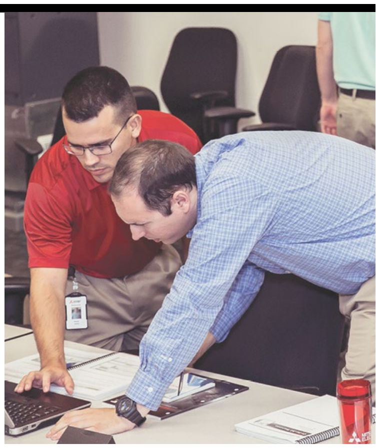


For more information on solving design challenges in cold climates, watch our webinar "**Applying VRF Systems in Cold Climate Applications**"

COMFORT IN ANY CLIMATE

While energy efficiency is a key benefit of VRF systems, it's not a common discussion point among building occupants. Facility managers constantly address complaints about comfort. If occupants aren't comfortable, decarbonization efforts can't succeed. Until recently, some specifiers in northern regions felt obligated to select a gas-powered furnace or electric resistance for their heating system due to air-source heat pump derating at sub-freezing temperatures. Today, air-source VRF systems use flash-injection technology in the compressor to offer unprecedented levels of capacity and efficiency at low outdoor ambient temperatures. This creates opportunities to replace fossil-fuel-burning equipment in more regions than before. For example, **CITY MULTI® VRF systems with Hyper-Heating INVERTER® (H2i®) technology** can provide up to 70% of **heating capacity down to -22° F** and continuous heating at temperatures **as low as -31° F.** Architects and engineers committed to low-carbon designs can also opt for **water-source VRF systems** for additional efficiency, application flexibility and performance in extreme climates.

SOLVING ELECTRIFICATION CHALLENGES WITH VRF TECHNOLOGY



While seemingly complex, strategic electrification consists of three primary components: **increase energy efficiency; power thermal end uses with renewable energy** and **decarbonize the electric grid.** VRF heat pumps and heat-recovery systems help building owners, architects and engineers solve challenges for each component as well as emerging building codes, standards and legislation related to decarbonization.

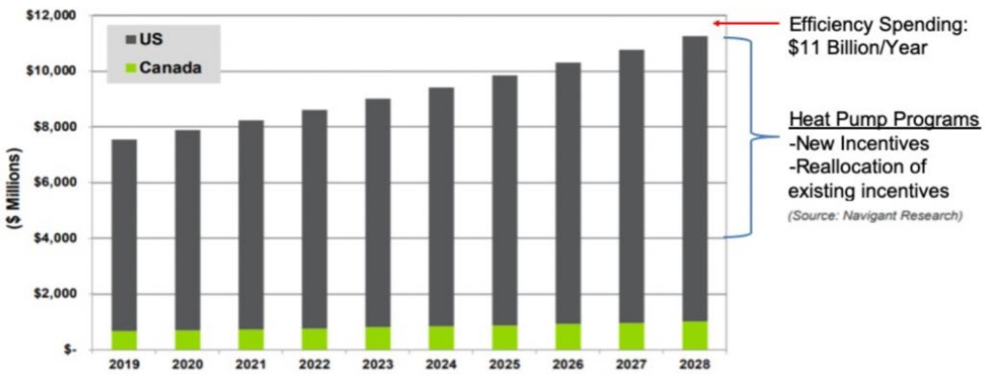
INCREASE ENERGY EFFICIENCY

Energy efficiency is a prerequisite for decarbonization. In regions with carbon-intensive power grids, using more efficient systems and appliances helps reduce energy consumption as a good first step toward lowering carbon footprints. VRF systems are up to 40 percent more energy-efficient than conventional, fixed-capacity HVAC equipment. Most of these savings occur during partial-load conditions as VRF systems continually adjust capacity and energy consumption to precisely match each zone's load. Also, while gas-fired HVAC systems can't exceed a COP of 1, VRF systems regularly achieve COPs of 3 and higher, meaning they can deliver much more heat than they consume in watts. Additionally, VRF systems require less ductwork than forced-air systems, further reducing energy consumed by fans.

LOWER LOADS

A high-performance building will have efficient mechanical systems, as well as low heating and cooling loads achieved through continuous insulation and an airtight thermal envelope. The INVERTER-driven ability of a VRF system to match capacity with loads enables it to heat and cool a low-load building with less risk of short cycling than fixed-capacity equipment.

ENERGY EFFICIENCY SPENDING BY COUNTRY, NORTH AMERICA: 2019-2028



REBATES AND INCENTIVES

Navigant suggests energy efficiency spending in North America will grow to nearly $11 billion per year over the next decade. This includes rebates and financial incentives to encourage more sustainable buildings and the adoption of high-performance heat pumps and VRF systems. Along with federal standards and programs like ENERGY STAR®, tax credits and utility rebates will continue accelerating adoption of energy efficient alternates to fossil-burning systems.

Approximately 80% of the top 10 and 65% of the top 20 architectural firms in the United States participate in the 2030 Challenge, which aims for new buildings, developments and major renovations to be carbon neutral by 2030. Firms report their progress toward meeting 2030 Challenge targets via the 2030 Commitment program managed by the **American Institute of Architects (AIA)**. To meet aggressive goals for sustainability and reduced GHG emissions, architects design high-performance buildings in accordance with requirements from LEED®, Green Globes®, Passive House US (PHIUS) and Zero-Net Energy (ZNE).

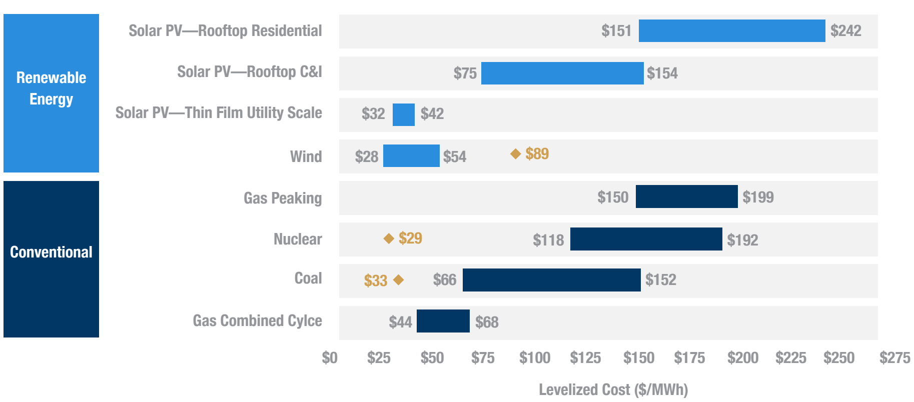
POWER THERMAL END USES WITH RENEWABLE ENERGY

Decarbonization and strategic electrification will ultimately require buildings to power space heating and water heating with renewable energy. Renewable energy sources like wind and sunlight are non-dispatchable, meaning they can't be turned on and off to meet power demands. Facilities still require heating and cooling at night, during cloudy days and when the wind isn't blowing. Given the current limitations of onsite and utility-scale storage technologies, renewable sources don't leave any room for electrical waste. By using the precise amount of electricity needed to maintain each zone's set point, VRF systems mitigate the challenge of variable energy generation with INVERTER-driven variable capacity. This creates opportunities for **well-insulated, high-performance buildings** to power VRF systems with on-site renewable energy.

DECARBONIZE THE ELECTRIC GRID

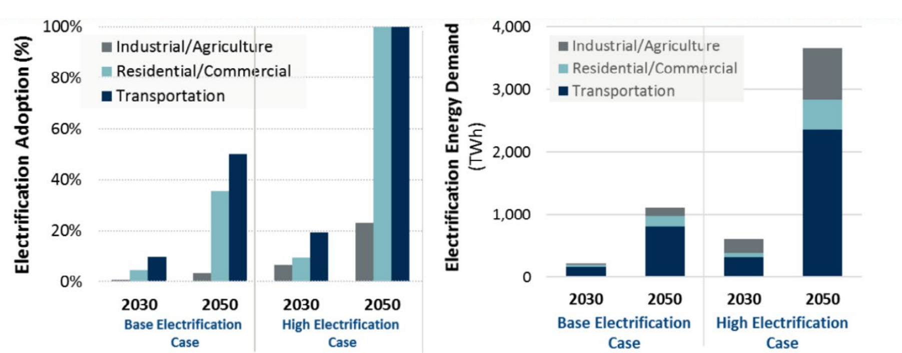
Across the United States, a decline in coal-fired electricity reduced CO_2 emissions by 2.1 percent in 2019.[13] The last large coal-fired power plant in New England closed in May of 2017 and the last of New York's coal plants are set to close by the end of 2020. But a decarbonized grid isn't contingent on altruism. Renewable energy is now cost competitive with fossil-fuel-based generation for utility companies. As of 2019, utility-scale solar electricity costs $32 to $42 per megawatt-hour (MWH) of electricity. Onshore wind costs between $28 and $54 per MWH. The cost of running existing coal plants is at an average of $33 per MWH while the cost of new coal plants ranges from $66 to $152 MWH.[14] The United States produced almost five times as much renewable solar and wind energy in 2019 as it did in 2009. Wind and solar currently provide nearly 10 percent of the nation's electricity.[15]

LEVELIZED COST OF ENERGY BY SOURCE



Source: Levelized Cost of Energy Analysis, Lazard

ELECTRIFICATION ADOPTION AND ENERGY DEMAND



Source: The Brattle Group and Wires: The Coming Electrification of the North American Economy

Falling costs aren't the only reason utilities are using renewable energy to strip electrons from their atoms. Mandates are responsible for about half of the growth in solar, wind and hydroelectric generation since 2000. 29 states and Washington, D.C. have set **Renewable Portfolio Standards (RPS)** that require a percentage of the electricity sold by utilities to come from renewable sources. State targets for this percentage currently range from 10 to 50 percent.[16] Also, the Department of Energy intends for 25 percent of electricity in the U.S. to be drawn from renewable sources by 2025.[17]

The energy efficiency and intelligence of VRF zoning systems may help utilities manage the challenges of peak loads, utility-scale storage and variable generation. This will be increasingly important as strategic electrification expands. Depending upon electrification adoption, the annual nationwide demand for electricity may increase by up to 3,700 terawatt hours (TWH) or 85 percent by 2050.[18] Their performance benefits give utilities and states incentives to support wider adoption of VRF systems, but also provide a means to offer value to building owners through lower electricity bills, improved comfort, streamlined control and lower carbon footprints.

CASE STUDY: MINNESOTA POWER

> ***"Our coworkers love it. We have some people that want their room to be 80° F even in the summer and then some want their room to be 65° F. The Mitsubishi Electric system allows them to do that."***
>
> ***— Craig Kedrowski***
> ***Business Service Advisor***
> ***Minnesota Power***

Cloquet, Minnesota | 5,000-square-foot office | -20° F design temp | VRF + Heat Recovery

READ CASE STUDY

Minnesota Power in Cloquet, Minnesota uses an all-electric VRF system to keep its office comfortable through Minnesota's cold winters and hot summers. The VRF technology also serves another purpose. Given the low-ambient design temperature of -20° F, the application demonstrates how VRF systems with heat-recovery make strategic electrification feasible in cold climates. "Because we recommend this equipment in our conservation program, we were interested in having a showcase where we present simultaneous heating and cooling," said Craig Kedrowski, business service advisor, Minnesota Power. "Our town's big university and city buildings are looking for options to increase sustainability and move away from fossil fuel use."

Inside Minnesota Power's conference room, two side-by-side thermostats, each connected to a different indoor unit, light up with blue to indicate cooling or red to indicate heating. The utility company uses the thermostats to explain simultaneous heating and cooling.

COMPLIANCE AND COST AVOIDANCE

Recognizing the need for decarbonization, public and private entities have adopted new standards for construction, energy production, energy consumption and CO_2 emissions. These standards may be voluntary or mandated by a state or city government. More than 438 cities have committed to an 80 percent reduction in GHG emissions by 2050, which they will achieve through taxes, building codes and portfolio standards.[19]

Decarbonization Pathway (Mandatory): The California Energy Efficiency Strategic Plan requires all new commercial construction to be zero net energy (ZNE) or net zero by 2030. The plan also requires 50 percent of commercial buildings to be retrofitted to ZNE by 2030.

DECARBONIZATION IS HAPPENING NOW: NEW YORK CITY

New York City (NYC) committed to the 80 percent reduction and has achieved a 15 percent reduction in GHG emissions since 2005. To meet the aggressive decarbonization goals described in the city's **Roadmap to 80 x 50**, 50 to 60 percent of buildings in NYC will need to adopt highly-efficient, electric-powered heat pumps and improve their building envelopes.[20]

MEETING THE CARBON CHALLENGE

As part of the **NYC Carbon Challenge** launched in 2017, many of the city's largest universities, hospitals, hotels, commercial building owners and residential property management firms committed to reducing their GHG emissions by 30 percent over 10 years. Participants in the NYC Carbon Challenge account for over 500 million square feet of real estate, which is more than 9 percent of NYC's building square footage, and 21 participants have achieved a 30 percent reduction in emissions. Collectively, participants have cut their annual emissions by 580,000 metric tons of carbon with collective savings of about $190 million annually in energy costs.[21]

LOCAL LAWS

NYC's Local Law 97 sets limits for the metric tons of CO_2 a building over 25,000-square-feet can produce per square foot according to 10 building categories. Building owners will be fined if CO_2 emissions for their facilities exceed the limits established for their category of building. Limits will become increasingly stringent in 2024 and 2030. Anyone can visit **Metered.nyc** to view a building's carbon emissions per the data pulled from mandatory benchmarking submissions. Currently, 32 percent of operational GHG emissions in NYC can be attributed to heating and cooling systems, which demonstrates the need for all-electric VRF systems.[22]

NYC's Local Law 96 established a **Property Assessed Clean Energy (PACE) loan program**. PACE loans feature low upfront costs, low interest rates and longer terms for energy efficiency projects and renewable energy projects and they can be repaid through a building's property tax bill.

REDUCE COSTS AND ACHIEVE VALUE

Architects, engineers, facility managers and building owners operating in areas where markets and policy require decarbonization will need to become familiar with how VRF systems work and solve challenges. But they should also consider how VRF technology and zoning benefits can help developers and building owners avoid costs and create competitive advantages. Besides the reduced energy and maintenance costs across the system's lifecycle, a VRF system can reduce costs for duct work, structural steel and alterations to building facades. VRF systems also contribute to the certification and marketability of high-performance buildings as "sustainable," which can result in higher net-effective rents and occupancy rates.[23] For more detail, read **Reducing Costs and Achieving Value with VRF Systems** and watch our **"Next Generation Office Building" video.**

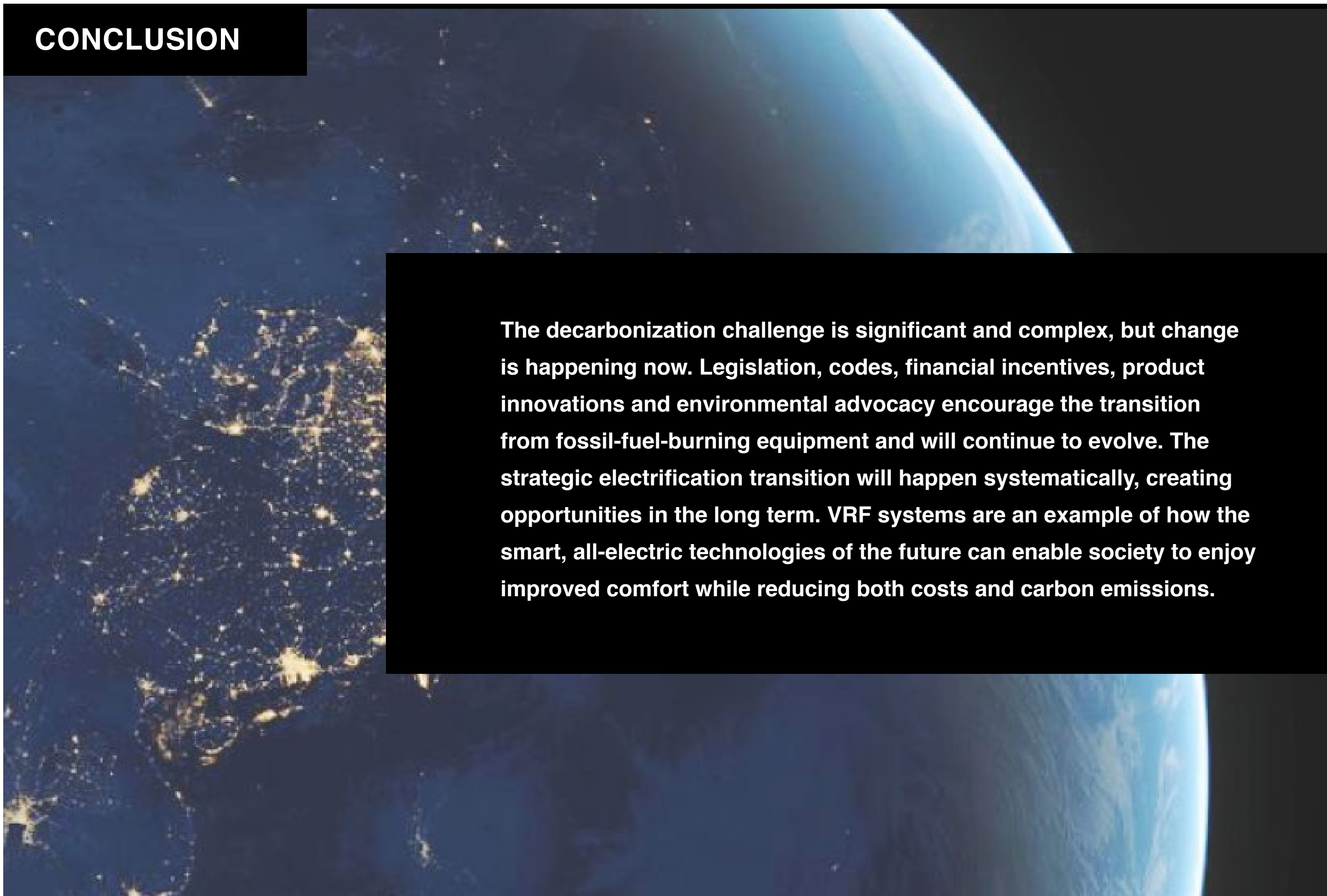
HOW VRF MANUFACTURERS SUPPORT STRATEGIC ELECTRIFICATION

The current generation of VRF systems can support the strategic electrification of buildings in all climates and include indoor unit styles such as wall mounts, floor mounts, recessed ceiling-cassettes, ceiling-suspended units, horizontal-ducted units and multi-position air handlers to suit any application. Besides engineering innovative equipment, VRF manufacturers provide product and building science expertise to help cities and utilities solve application challenges, gather data and identify effective incentives to encourage decarbonization. For example, Mitsubishi Electric Trane HVAC US (METUS) was one of **CNCA**'s first HVAC partners. METUS also works with implementers on program design and provides education and training for architects, engineers, HVAC contractors and other stakeholders in the building industry on heat pumps and VRF technologies.

Decarbonization Pathway (Mandatory):
The Carbon Neutral Cities Alliance (CNCA) is a coalition of cities working to reduce GHG emissions by 80 to 100% by 2050. CNCA cities in the U.S. include

- Boulder, CO
- Minneapolis, MN
- New York City, NY
- Portland, OR
- San Francisco, CA
- Seattle, WA
- Washington, D.C.

CONCLUSION



The decarbonization challenge is significant and complex, but change is happening now. Legislation, codes, financial incentives, product innovations and environmental advocacy encourage the transition from fossil-fuel-burning equipment and will continue to evolve. The strategic electrification transition will happen systematically, creating opportunities in the long term. VRF systems are an example of how the smart, all-electric technologies of the future can enable society to enjoy improved comfort while reducing both costs and carbon emissions.

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