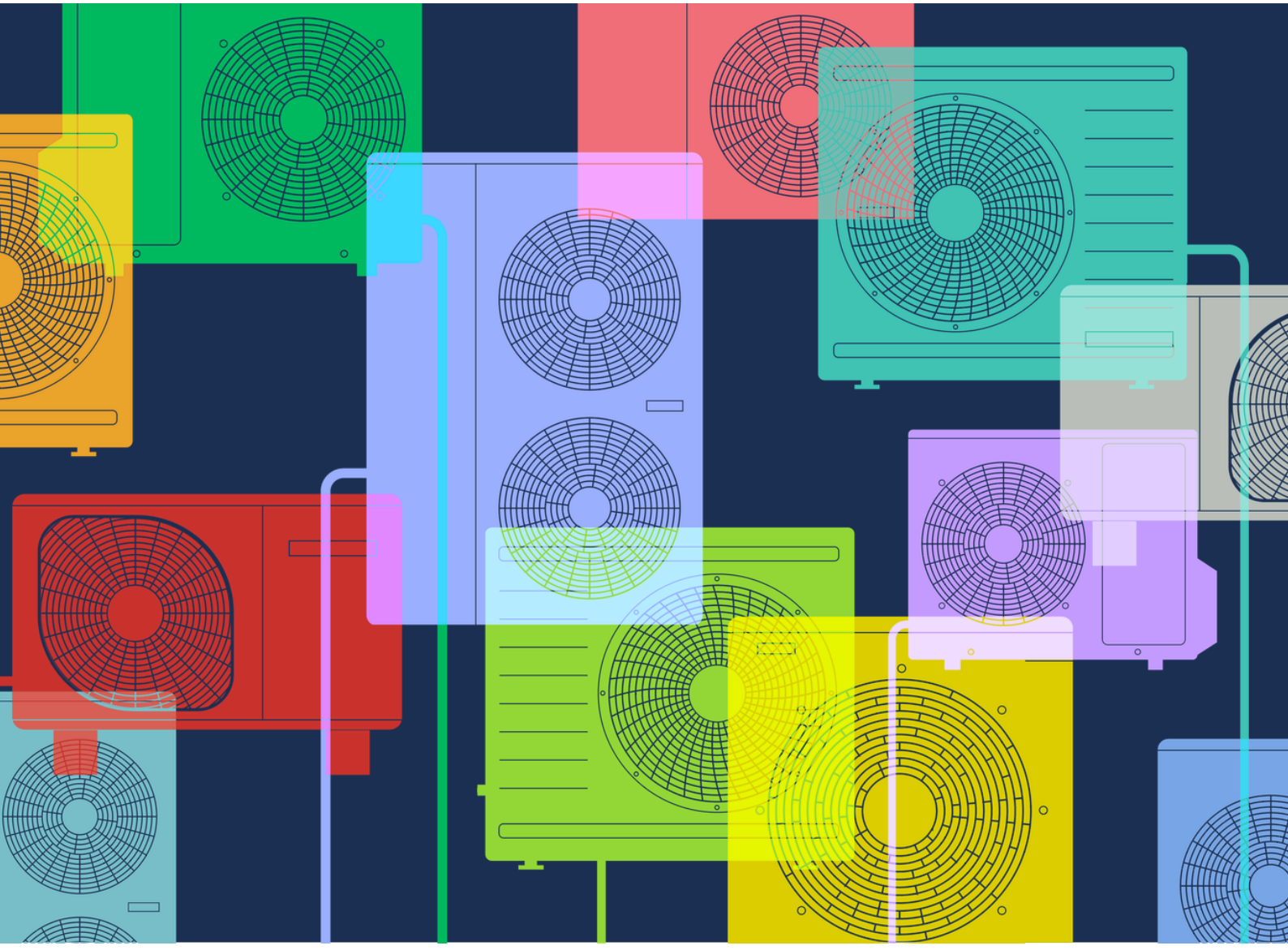
Flammable Refrigerants within Heat Pumps

Selection & Design Considerations



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Overview

With tightening F-gas regulations in Europe and the UK and increasing scrutiny around PFAS (per- and polyfluoroalkyl substances), consultants and specifiers face growing challenges in selecting refrigerants for HVAC and refrigeration applications. The choice of refrigerant impacts:

- **Environmental compliance (Global Warming Potential (GWP) values, phase-down schedules).**
- **Safety (flammability, toxicity, and system design).**
- **Long-term viability (futureproofing against regulatory changes).**

There are several low-GWP alternatives currently available for many applications, this guide will focus on R32 and R290 which are commonly found in several manufacturers heat pumps. Each carries distinct benefits and challenges which will be considered here.

Table to show GWP values for the Intergovernmental Panel on Climate Change (IPCC) Assessments AR4, AR5 and AR6.

The AR6 values are the most recent, but the AR4 and AR5 values are also provided because they are sometimes used.

Refrigerant	Class	Flammability Level	Type	GWP AR4 (2007)	GWP AR5 (2014)	GWP AR6 (2020)
R-290	A3	Highly Flammable	Propane	3	3	0.02
R-600a	A3	Highly Flammable	Isobutane	3	3	0.02
R-441A	A3	Highly Flammable	Hydrocarbon Blend	3	3	0.02
R-170	A3	Highly Flammable	Ethane	6	6	0.02
r-600	A3	Highly Flammable	Butane	4	4	0.02
R-1150	B3	Highly Flammable	Ethylene	4	4	0.02
R-1270	A3	Highly Flammable	Propylene	3	3	0.02
R-511A	A3	Highly Flammable	Blend (R-290/E170)	3	3	0.02
R-455A	A2L	Mildly Flammable	Blend (R-744/32/1234yf)	146	148	145
R-152a	A2	Flammable	HFC	124	138	164
R-454C	A2L	Mildly Flammable	Blend (R-1234yf/R32)	148	148	169
R-454B	A2L	Mildly Flammable	Blend (R-32/1234yf)	466	467	551
R-32	A2L	Mildly Flammable	HFC	675	677	771
R-1234yf	A2L	Mildly Flammable	HFO	4	<1	<1
R-1234ze(E)	A2L	Mildly Flammable	HFO	7	<1	<1

R32

To safely and effectively install an R32 heat pump, design and location consideration must balance operational efficiency, required clearances, and the safety precautions needed for its mildly flammable refrigerant. Key factors include air circulation, noise impact, planning regulations, and refrigerant charge limits.

2.1 Description & Key Properties

R32 is a low-toxicity, mildly flammable refrigerant classified as A2L, which is more difficult to ignite than other flammable refrigerants.

- **Chemical designation:** Difluoromethane (CH_2F_2).
- **Classification:** A2L (mildly flammable).
- **GWP:** ~675.
- **Typical water/flow temperatures:** Up to 65°C. (Ambient conditions should be considered)
- **Applications:** Widely used in heat pumps and air conditioning systems.

2.2 Regulations

- Subject to EU F-gas Regulation (573/2024) phase-down schedule. From January 1, 2027, R32 is prohibited in monoblock, plug-in, and self-contained AC/heat pumps (above 50kW), extending to smaller units by 2030.
- Not restricted under current PFAS regulations.
- Requires adherence to EN 378 -1, -3 and 4 and local Building and Fire regulations and ISO 5149 safety standards for installation.

2.3 Design & Location Considerations

- **Minimum water content:** Whether a Heat Pump is connected to a heating or hot water system, the water volume within the circuit acts as a thermal buffer. If the water content is too low, the system heats up and cools down too quickly, causing the heat pump to switch on and off frequently. This short cycling reduces efficiency, increases wear on components, and can shorten the lifespan of the unit. By maintaining a minimum water volume, the system achieves smoother temperature control, consistent heat delivery, and optimal performance.
- **Clearances and airflow:** To ensure optimal performance and prevent air recirculation, the unit must have ample, unobstructed space on all sides. Avoid placing units near corners where cold air can bounce back and reduce efficiency. Manufacturers literature will give specific guidance on this.
- **Base:** The unit must be placed on a firm, level surface, such as a concrete pad, to support its weight and minimize vibration noise.
- **Sunlight and wind:** While not essential, a location with maximum sun exposure, such as a south-facing wall, can slightly improve efficiency. The position should be somewhat sheltered from strong winds to prevent reduced performance.
- **Trees and other vegetation:** Heat pumps require clear, unobstructed airflow for efficiency, trees and vegetation can block this airflow, especially if leaves fall, potentially reducing performance and requiring additional maintenance
- **Noise impact:** Consider the location of neighbouring properties and avoid installing the unit directly outside windows, especially bedroom windows, to prevent nuisance.
- **Condensate:** Condensation is a natural by-product of heat pump operation, especially in colder months when moisture in the air collects on the unit's coils and drains away as water. If this runoff isn't properly managed, it can freeze in low temperatures and create hazardous slippery surfaces around paths, doorways, or outdoor areas. Good installation practice includes directing condensate to a suitable drain, the use of condensate trays if available, using insulated or heated drain lines, and ensuring the discharge point is positioned where water cannot pool or freeze. Regular maintenance such as checking for blockages and ensuring the drainage route remains clear also helps prevent ice build up and keeps surrounding areas safe and accessible. Unlike a gas appliance, the condensation generated by heat pumps is non-corrosive, so no special drainage requirements or neutralising is required.

- **Additional components:** Typical installs require buffer vessels and storage for DHW which must be considered for available space on site and minimising pipe runs when siting appliances. Only a certified technician should handle the refrigerant.
- **Frost protection:** Systems using R32 must be designed and installed to relevant standards (such as EN 378 and IEC 60335-2-40), ensuring adequate ventilation, leak detection where required, and proper electrical protection. Frost protection controls should minimize unnecessary refrigerant circulation and avoid conditions that could lead to refrigerant accumulation in enclosed spaces. It is recommended that both the heat pump and pipework are protected from frost.

Please refer to the manufacturer for specific guidance, both mechanical and electrical forms of protection are available. If glycol is to be used this can have adverse effects on performance & CoP.

3 R290 Refrigerant (Propane)

Key design and location considerations for an R290 heat pump are primarily driven by the refrigerant's high flammability. Careful installation is required to mitigate risk by maintaining safe distances from potential ignition sources and building openings, ensuring proper ventilation, and confirming the unit is hermetically sealed.

3.1 Description & Key Properties

R290, or propane, is a natural hydrocarbon refrigerant with a very low environmental impact and high energy efficiency. Unlike synthetic refrigerants, such as R32, R290 does not contain chlorine or fluorine, and it is gaining popularity as a greener alternative due to its low GWP and zero ozone depletion potential (ODP). The main drawback of R290 is its high flammability, which requires strict safety measures during handling and installation.

- **Chemical designation:** Propane (C_3H_8).
- **Classification:** A3 (highly flammable).
- **GWP:** 0.02 (very low, near-zero).
- **Typical water/flow temperatures:** up to 75°C. (Ambient conditions should be considered)
- **Applications:** Widely used in heat pumps for heating and cooling.

3.2 Regulations

- Exempt from F-gas phase-down.
- Subject to ATEX (**AT**mosphère **EX**plosible) and DSEAR (Dangerous Substances and Explosive Atmospheres Regulations) due to flammability. See Annex 1 for further detail.
- Installation must comply with EN 378-1, -3 and 4, ISO 5149, and local Building and Fire Regulations.

3.3 Design & Location Considerations

All design & location considerations included in 2.3 for R32 also apply for R290. The location of an R290 unit is the most important factor in a safe installation, as it directly addresses the risk of flammability.

- **Protective zones:** Manufacturers' installation manuals will define an exclusion zone or ATEX zone around the unit. It is mandatory for this area to be kept free of ignition sources and specific building features, considering the ATEX Directive 1999/92 (Directive 89/391). A further zone which extends beyond the exclusion zone will also usually be identified, sometimes referred to as a safety zone. Within the safety zone, in the event of a refrigerant leak, the concentration of the gas in the air is generally below the critical levels for the formation of flammable or hazardous atmospheres although compliance with certain conditions is usually still a requirement within this zone.
- **Distance from ignition sources:** No potential ignition sources—such as sparking electrical switches, outdoor sockets, or a gas meter—should be present within the protective zone.
  - It is forbidden to braze, weld or grind within 3m of the appliance without taking all the necessary measures related to an intervention on an R290 appliance (detection, ventilation, explosimeter).
- **Distance from building openings:** R290 is heavier than air, so it can pool in low areas if a leak occurs.
  - The unit must be a sufficient distance from openable doors, windows, and air bricks to prevent gas from entering the building.
  - A sufficient distance from any door, window, or air brick is a common manufacturer recommendation, though this can vary.
- **Distance from low points and drains:** Similarly, the heat pump must be located away from drains, wells, or other low points where gas could accumulate.
- **Natural ventilation and airflow:** Units must be installed in a location that allows for free air movement. Poor airflow will cause the unit to run less efficiently and can prevent the safe dispersal of refrigerant in case of a leak.
- **Transportation damage:** If a unit is damaged during transit, it must be moved to a safe outdoor area at specified distance away from ignition sources. Only a certified technician should handle the refrigerant.

4 Other Considerations

- Due to the unique safety requirements, only properly trained and certified professionals should install and service R290 heat pumps.
- A full site risk assessment should be carried out to determine any specific safety measures required.
- In addition to regular system checks, servicing an R290 unit involves creating a safe work area, checking for refrigerant leaks, and ensuring the area is properly ventilated.
- The installation must take additional precautions to prevent refrigerant leakages into the hydraulic circuit, via the heat exchanger, from reaching occupied spaces. A degasser or venting valve must be installed on the flow pipe as near as possible to each appliance and within the protective zone, to discharge the refrigerant safely into the atmosphere. In the unlikely event of a plate heat exchanger failure resulting in propane entering the heating system, this safety device would mitigate system damage and help ensure occupant safety.
- Mandatory use of ATEX rated components (fans, switches, electrical enclosures) is required in certain cases.
- Leak detection and automatic shut-off systems are recommended.
- The appliance should not be installed where it is accessible to the general-public or to untrained, unqualified or unskilled personnel.

4.1 Consultants and Specifiers Should:

- Evaluate local and EU regulatory frameworks before refrigerant selection.
- Match refrigerant choice to building type, occupancy, and system capacity, taking into account system temperatures and ambient design conditions.
- Consider long-term regulatory trends — PFAS bans may make natural refrigerants more attractive.
- Ensure all installations comply with EN 378, ISO 5149, ATEX/DSEAR, and national codes.

5 Regulations

BS EN 378-1:2016+A1:2020 Refrigerating systems and heat pumps. Safety and environmental requirements - Basic requirements, definitions, classification and selection criteria

BS EN 378-3:2016+A1:2020 Refrigerating systems and heat pumps. Safety and environmental requirements - Installation site and personal protection

BS EN 378-4:2016+A1:2019 Refrigerating systems and heat pumps. Safety and environmental requirements - Operation, maintenance, repair and recovery

EN 60079-10-1 Explosive atmospheres - Classification of areas. Explosive gas atmospheres

BS 7671:2018/A3:2024 Requirements for Electrical Installations. IET Wiring Regulations

BS EN 12828:2012+A1:2014 Heating systems in buildings. Design for water-based heating systems

Directive 2014/34/EU (also known as 'ATEX 114' or 'the ATEX Equipment Directive') Equipment and protective systems intended for use in potentially explosive atmospheres

Directive 1999/92/EC (also known as 'ATEX 137' or the 'ATEX Workplace Directive') Minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres

DSEAR Dangerous Substances and Explosive Atmosphere Regulations 2002

ISO 5149-1:2014 Refrigerating systems and heat pumps — Safety and environmental requirements Part 1: Definitions, classification and selection criteria

ISO 5149-2:2014 Refrigerating systems and heat pumps — Safety and environmental requirements Part 2: Design, construction, testing, marking and documentation

6 Glossary of Terms

A2L - A classification for gases used in air conditioning and refrigeration systems that have low toxicity (indicated by "A") and low flammability (indicated by "2L")

A3 - A classification for gases used in air conditioning and refrigeration systems that have low toxicity (indicated by "A") and high flammability (indicated by "3")

AR4 - 100 years - IPCC's Fourth Assessment Report (AR4) to express the climate impact of refrigerants relative to CO_2 over a 100-year period.

AR5 - 100 years - IPCC's Fifth Assessment Report (AR5) to express the climate impact of refrigerants relative to CO_2 over a 100-year period.

AR6 - 100 years - IPCC's Sixth Assessment Report (AR6) to express the climate impact of refrigerants relative to CO_2 over a 100-year period.

ATEX - From the French **AT**mosphère **EX**plosible and refers to two European Union directives that regulate equipment and protective systems for use in potentially explosive atmospheres, such as those containing flammable gases, mists, or combustible dusts.

Critical temperature - The highest temperature at which the substance can exist as a liquid. This sets an upper limit on its operating range for heat pumps.

DSEAR - Stands for the Dangerous Substances and Explosive Atmospheres Regulations 2002, a UK law that requires employers to assess and control the risks of fires and explosions from dangerous substances in the workplace, including gases, flammable liquids, and dusts.

GWP - Global Warming Potential. A metric that measures a greenhouse gas's impact on atmospheric warming over a specific period compared to carbon dioxide (CO_2).

Ozone depletion potential - Measures a chemical's relative ability to destroy stratospheric ozone compared to a reference substance, CFC-11, which has an ODP of 1.0.

PFAS - A large group of human-made chemicals, known as "forever chemicals," used in many products for their water-, grease-, and stain-resistant properties, like in non-stick cookware, food packaging, and firefighting foams.

7 Annex

ATEX is there to prevent explosions

ATEX is a set of EU directives (followed by the UK) that sets the rules for equipment used in explosive atmospheres

The directives relevant to the installation of heat pumps with flammable refrigerant include:

WORKPLACE DIRECTIVE – ATEX 137 or 1999/92/EC – on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres

PRODUCT DIRECTIVE – ATEX 95 or 1994/9/EC, now replaced with ATEX 114 or 2014/34/EU – relates to equipment and protective systems intended for use in potentially explosive atmospheres.

In the UK these directives were incorporated into The Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) – sections 7-11

ATEX covers :

Equipment Design:

Equipment used in ATEX Zones must be ‘intrinsically safe’. This means it will never be able to create an explosion.

Hazardous zones:

ATEX Zones define how often and for how long the atmosphere is potentially explosive in a given place.

Installation:

Installing equipment in an ATEX zone requires selecting certified ATEX equipment, ensuring the installation follows the manufacturer's instructions and hazardous area design, conducting risk assessments to classify the zone, and obtaining certification and a final inspection to confirm compliance and overall explosion safety.

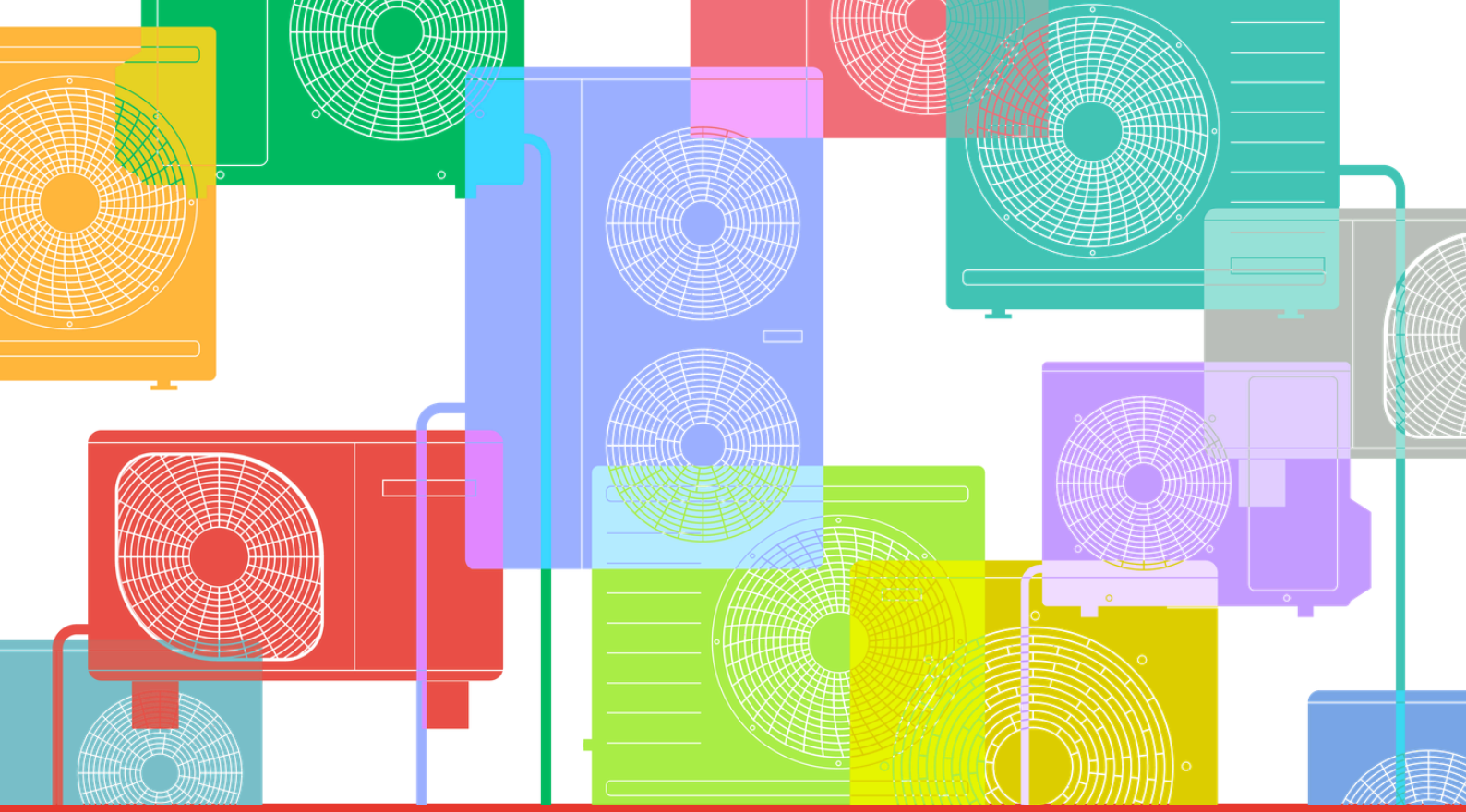
7 Annex

Safe Working:
Working safely in an ATEX zone requires strict adherence to the regulations and the implementation of robust safety protocols to prevent explosions. The core principle is to manage and eliminate ignition sources in an environment where flammable gases, vapors, mists, or combustible dusts are, or may be, present.

ATEX Zones :
Heat pumps that contain propane will require an ‘exclusion zone’ around them. This is mainly to act as anATEXZone2 (ATEXZone2 is an area where a flammable gas, vapor, or mist explosive atmosphere is not likely to occur in normal operation but, if it does, will only exist for a short time).

ATEX Zone 2 represents a lower risk environment than Zones 0 and 1, but it still requires ATEX-certified equipment, designed to prevent ignition, to be used (though the standards are less stringent than for Zones 0 and1.)

The size and extent of the ‘exclusion zone’ will generally have been determined by the manufacturer of the heat pump, based on the quantity of flammable refrigerant that could potentially escape and the methods for dispersal should a leak occur. Typically these zones will encompass an area within 2 to 4metres from the unit. As such there can’t be any source of ignition within that zone.



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