EXECUTIVE SUMMARY OF THE MANUAL “SAFETY STANDARDS AND GOOD PRACTICES FOR FLAMMABLE REFRIGERANTS”

The Manual on Safety Standards and Good Practices for Flammable Refrigerants has been developed to support the safe and effective transition towards the use of **low-GWP** alternative refrigerants, in line with international commitments to climate and ozone protection.

The manual focuses on **the refrigeration, air-conditioning and heat pump (RACHP) sector**, which, while providing essential services, contributes significantly to greenhouse gas emissions through energy consumption and the use of high-GWP refrigerants.

International agreements such as **the Montreal Protocol and the Kigali Amendment** (also ratified by Albania, the first country in the region to do so) require an 80% reduction in HFC consumption by 2050. The solution lies in the transition towards **climate-friendly alternative refrigerants,** including natural refrigerants such as hydrocarbons (propane and isobutane), ammonia and CO_2, as well as new-generation HFO refrigerants.

The publication highlights that **the transition to low- or near-zero-GWP refrigerants** can significantly reduce both direct and indirect greenhouse gas emissions, particularly when accompanied by improvements in energy efficiency and the application of modern design, installation and servicing standards. Global studies indicate that the widespread adoption of these technologies has the potential to reduce annual global emissions by up to 26%.

However, these alternative refrigerants present specific challenges: some are **flammable,** some are **toxic**, and others operate under **very high pressures.** This is precisely the issue addressed by the manual: **how to use these refrigerants safely** and in compliance with international standards and European legislation. The manual presents the main safety requirements, national, European and international standards, as well as best practices for the design, installation, operation and maintenance of RACHP equipment using flammable and natural refrigerants.

The manual also examines the **safety challenges** associated with the use of flammable and natural refrigerants, such as hydrocarbons, ammonia and CO_2, emphasizing the need for specific technical approaches during the design, installation, operation and maintenance of equipment. For this reason, safety regulations and standards are considered an essential prerequisite for the safe use of these refrigerants.

In addition, the manual provides an up-to-date overview of **national, international and European safety standards,** together with practical recommendations for their harmonization with the Albanian legal framework, in line with European best practices and Albania’s EU approximation process.

The manual is structured into **seven main chapters,** complemented by a number of annexes:

1. **Alternative Refrigerants** – their classification, properties and characteristics, including GWP, flammability and energy efficiency.
2. **Safety and Risk Management** – safety classifications, explosion hazards, asphyxiation risks, high-pressure systems, and safe handling practices for CO_2, ammonia and hydrocarbons.
3. **System Design** – design principles and requirements for installations using alternative refrigerants such as CO_2, NH_3, R32 and HFOs.
4. **Leak Detection** – methods for identifying and monitoring refrigerant leaks, including bubble solutions, electronic detectors and ultrasonic technologies.
5. **Maintenance and Repair** – safe servicing procedures and best practices for RACHP systems.
6. **Retrofitting Existing Systems** – guidance on converting existing equipment to alternative refrigerants.
7. **Standards and Legislation** – relevant ISO, EN and IEC standards, European legislation (including ATEX and Regulation (EU) 2024/573), and Albanian legislation, including Law No. 2/2023 on Fluorinated Greenhouse Gases.

The publication is intended for:

- Technical associations;
- RACHP companies and operators;
- Equipment manufacturers;
- Engineers and technicians;
- Educational institutions and other interested stakeholders.

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CHAPTER SUMMARIES

CHAPTER 1 – Alternative Refrigerants: Types and Comparison

The first chapter serves as the technical introduction to the manual. It explains why the RACHP industry is moving away from high-GWP HFC refrigerants and presents the main alternative refrigerant options currently available. Five major groups of refrigerants are covered:

R744 (CO_2, carbon dioxide) – GWP = 1. Non-flammable and non-toxic, but operates at very high pressures (up to 90 bar). Its low critical temperature (31°C) requires specialized transcritical system designs. Due to its high volumetric cooling capacity, CO_2 systems can use smaller compressors and piping. It is now widely used in supermarkets and industrial refrigeration systems across Europe.

R717 (ammonia, NH_3) – GWP = 0. Offers excellent thermodynamic efficiency but is toxic and slightly flammable. Its strong odor allows leaks to be detected even at very low concentrations. Ammonia is incompatible with copper, requiring the use of steel piping. It is primarily used in industrial refrigeration, large cold storage facilities and ice rinks.

R290, R600a and R1270 (hydrocarbons) – GWP = 3. Propane, isobutane and propylene provide high energy efficiency and low environmental impact but are highly flammable (A3 classification). Their flammability limits the allowable refrigerant charge in many applications. Typical uses include domestic refrigerators, supermarket display cases and small air-conditioning systems.

R32 (low-GWP HFC) – GWP = 675. Although not a natural refrigerant, R32 has a significantly lower GWP than R410A, which it commonly replaces. It is classified as mildly flammable (A2L) and operates at pressures similar to R410A. Today, it has become one of the most widely used refrigerants in residential and commercial air-conditioning systems worldwide.

R1234yf and R1234ze (HFOs) – GWP = 4–7. These next-generation synthetic refrigerants have a very low climate impact and are classified as mildly flammable (A2L). R1234yf is widely used in mobile air-conditioning systems, while R1234ze is commonly applied in chillers and heat pumps.

The chapter also includes detailed information on refrigerant classification, performance characteristics, safety properties and environmental impacts, providing a comparative overview of the main low-GWP refrigerant options available to the RACHP sector.

The chapter also includes detailed tables on the maximum allowable refrigerant charge in accordance with the European Standard EN 378, taking into account room type, unit location (floor, wall, ceiling or window-mounted), and occupancy category (A = public access, B = restricted staff access, C = authorized personnel only). Calculation formulas and practical examples are provided for R32, R290, R744 and R717 systems.

CHAPTER 2 – Safety and Risk Management

The second chapter focuses entirely on the risks associated with alternative refrigerants and the measures required to protect people and equipment.

The three main hazards addressed are flammability, toxicity and high operating pressure. Each of these risks is examined in detail.

Flammability is classified into four categories: Class 1 (non-flammable), Class 2L (lower flammability), Class 2 (flammable) and Class 3 (highly flammable). The chapter explains that ignition can only occur when three elements are present simultaneously: refrigerant, oxygen and an ignition source. Typical ignition sources found in RACHP installations—including contactors, thermostats, pressure switches and electrical outlets—are identified, together with recommendations for their elimination or replacement with explosion-protected (Ex-rated) equipment.

The chapter also provides a detailed overview of ATEX zones, the European classification system for potentially explosive atmospheres (Zones 0, 1 and 2), as well as the mandatory documentation required for hazardous environments, including Explosion Protection Documents (EPDs) and work permits for operations such as welding.

Specific hazards associated with CO_2 systems are discussed in detail. As CO_2 is heavier than air, it can accumulate near the floor and create an asphyxiation risk. Pressure in trapped liquid can increase by approximately 10 bar for every 1°C rise in temperature, while dry ice may form if pressure falls below 4.2 bar. The chapter recommends alarm thresholds of 5,000 ppm (pre-alarm) and 20,000 ppm (main alarm) for CO_2 detection systems.

For ammonia systems, the chapter highlights ventilation activation at 500 ppm and full system isolation at 30,000 ppm as key safety measures.

The chapter further covers the transport of cylinders and systems charged with flammable refrigerants under the European ADR Agreement concerning the international carriage of dangerous goods by road. It includes UN classification references for different refrigerants (e.g., R290 = UN 1978; R32 = UN 3252). Albania has been a contracting party to ADR since 26 February 2005.

CHAPTER 3 – System Design with Alternative Refrigerants

The third chapter is intended for system designers and engineers. It explains how system design requirements change when transitioning from conventional HFC refrigerants to alternative refrigerants.

CO_2 (R744) systems are divided into two main categories: subcritical systems, which operate below 31°C and are typically used in colder climates or cascade applications, and transcritical systems, which operate above 31°C and are commonly used in supermarkets and warmer climates such as Albania. Unlike conventional refrigeration systems, transcritical CO_2 systems use a gas cooler instead of a traditional condenser. The chapter presents in detail simple transcritical systems, large transcritical installations, subcritical cascade systems and secondary refrigeration systems.

R717 (ammonia) systems require all components to be made of steel, as ammonia is incompatible with copper. Open-drive compressors are generally required, and special attention must be given to oil management because ammonia does not mix with mineral oils.

Hydrocarbon systems (R290, R600a and R1270) require the elimination of all potential ignition sources. Fans, electrical cables and electrical equipment must be appropriately certified for use with flammable refrigerants. Fan blades should not be made of steel in order to avoid the risk of sparks caused by friction.

R32 and HFO systems are designed in a manner similar to conventional HFC systems, with several important modifications. Electrical equipment installed in areas where refrigerant leaks may occur must be explosion-protected or spark-free.

For all system types, the chapter emphasizes the principle of leak minimization. This includes reducing the number of joints, components and Schrader valves, and using brazed or welded connections wherever possible to improve system safety, reliability and environmental performance.

CHAPTER 4 – Leak Detection and Monitoring

The fourth chapter provides a detailed overview of leak detection and monitoring methods, a critical aspect of system safety, performance and regulatory compliance.

Seven leak detection methods are presented:

- **Bubble solution testing** – a simple and effective method for pinpointing suspected leaks, although it can be time-consuming and is unsuitable for insulated piping.
- **Electronic leak detectors** – three main technologies are described: heated diode detectors (widely used and cost-effective), infrared (IR) detectors (offering higher accuracy and longer sensor life), and metal oxide semiconductor detectors (particularly suitable for hydrocarbons and ammonia). The chapter emphasizes that many detectors designed for HFC refrigerants are not suitable for flammable refrigerants and may not detect ammonia, making dedicated detectors necessary for each refrigerant type.
- **Fluorescent additives** – added to the system oil and detected using ultraviolet (UV) light to identify leak locations, even when refrigerant losses are small.
- **Ultrasonic detectors** – identify leaks by detecting the characteristic sound generated by pressurized refrigerant escaping from the system.
- **Litmus paper testing** – used exclusively for ammonia systems, as the paper changes color upon contact with NH_3.
- **Visual inspections** – oil stains around joints and connections often indicate potential leak locations.
- **Odor detection** – ammonia can be detected by smell even at very low concentrations, while hydrocarbons have a characteristic mild odor.

The chapter also addresses fixed leak detection systems, consisting of permanently installed detectors with alarm functions. It explains when such systems are required under EN 378 (for example, for systems containing more than 25 kg of refrigerant charge), as well as the system records and documentation that must be maintained in accordance with F-gas legislation.

CHAPTER 5 – Maintenance and Repair

The fifth chapter is intended for field technicians and provides guidance on carrying out servicing operations safely.

Before any intervention, flammable refrigerants must be removed from the system and replaced with dry nitrogen. Adequate ventilation of the work area must be ensured, a flammable gas detector must be available, no ignition sources should be present within three meters of the system, and a suitable fire extinguisher (dry powder or CO_2) should be readily accessible.

For work involving **CO_2 (R744)** systems, protective gloves and safety goggles are required. Venting procedures should be carried out in liquid form rather than gas form to avoid the formation of dry ice. Access to confined spaces must be prohibited whenever a gas detection alarm has been activated.

For work involving **ammonia (R717)** systems, the use of respiratory protection equipment may be necessary. Work areas must be adequately ventilated and kept free of ignition sources.

Recovery units designed for HFC refrigerants cannot be used with flammable refrigerants; dedicated recovery equipment is required. Charging accuracy is particularly important for hydrocarbon refrigerants, where a precision of up to ±5 grams may be required.

CHAPTER 6 – Retrofitting Existing Systems

The sixth chapter addresses a practical challenge facing many companies: how to convert existing systems from conventional HFC refrigerants to low-GWP alternatives.

The chapter explains the regulatory context, noting that Regulation (EU) 2024/573 and Albania's Law No. 2/2023 on Fluorinated Greenhouse Gases require the gradual phase-down of high-GWP F-gases. As a result, companies are encouraged to begin planning the replacement or conversion of existing equipment.

Most alternative refrigerants cannot simply be charged into existing systems without modifications. In many cases, redesign or component replacement is required. However, some HFO refrigerants, such as R1234ze, may serve as direct "drop-in" replacements for certain HFC applications. The chapter provides guidance on which conversions are feasible and which require modifications to system components, including lubricants, seals and other critical parts.

CHAPTER 7 – Standards and Legislation

The final chapter serves as the manual's regulatory roadmap, providing a comprehensive overview of the standards and legal framework governing the safe use of alternative refrigerants.

The chapter introduces the principal standardization bodies, including **ISO** (International Organization for Standardization), **IEC** (International Electrotechnical Commission), **EN/CEN** (European Committee for Standardization) and **ASHRAE** (American Society of Heating, Refrigerating and Air-Conditioning Engineers). It explains how standards are developed and how the appropriate standard is selected for different applications.

Key standards and regulations covered include:

- **EN 378** – the core European standard for RACHP systems, covering safety requirements, design, installation, operation and maintenance. Its refrigerant charge limitation tables (C1 and C2) are referenced throughout the manual.
- **ISO 817:2024** – the international refrigerant safety classification standard, including classifications such as A1, A2L, A3 and B2L.
- **EN 60079 and the ATEX Directive** – requirements for equipment and systems operating in potentially explosive atmospheres, including guidance on Explosion Protection Documents (EPDs).
- **Regulation (EU) 2024/573** – the new European F-gas Regulation, replacing the 2014 regulation and establishing stricter phase-down requirements.
- **Albanian Law No. 2/2023 on Fluorinated Greenhouse Gases** – the national legislation aligning Albania with the European regulatory framework.

The chapter concludes with practical recommendations for the Albanian RACHP sector, including the adoption of the latest editions of relevant standards and the development of national regulations that enable the safe and widespread use of low-GWP refrigerants while supporting compliance with international obligations and Albania's EU integration objectives.

The manual concludes with four annexes listing the ISO, IEC, ASHRAE, SAE and EN standards applicable to the RACHP sector, together with internationally recognized hazard symbols and safety markings.