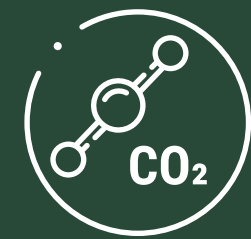


ENGINEERING TRANSCRITICAL CO₂ FOR 20 YEARS



With a rich history in working with transcritical CO₂ systems, LU-VE Group brings unparalleled expertise to the table. Our mastery of this technology has been honed through years of successful implementations and continuous refinement, making us pioneers in the field.

Notably, LU-VE Group has been at the forefront of developing optimized heat exchangers specifically tailored for transcritical CO₂ applications. This recognition is underscored by numerous customers choosing LU-VE Group for their inaugural transcritical installations. Our commitment to quality and expertise is evident in a significant number of first-country installations we proudly share.

At LU-VE Group, innovation is the cornerstone of our product development, propelling us to the forefront of technology in the field. Our unwavering commitment to advancing sustainability is evident in our proactive integration of adiabatic technologies. As pioneers, we are dedicated to enhancing the performance and efficiency of supermarket refrigeration and HVAC systems, especially in warmer climates.

Looking ahead, LU-VE Group remains resolute in its mission to establish transcritical CO₂ as a sustainable and environmentally friendly solution, setting the standard for the future of supermarket refrigeration. Our ultimate goal is to make this cutting-edge technology, along with our expertise and products, readily available in the North American market. By achieving this, we not only contribute to the greater good for the planet but also elevate the standards of the market itself.



The 1st in transcritical CO₂ installations

LU-VE US Inc.

Jacksonville, TX 75766 USA

Phone: +1-833-908-3355

E-mail: salesusa@luvegroup.com



www.luvegroup.com

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EMPOWERING SUPERMARKETS FOR FUTURE CHALLENGES

THE GROUP

LU-VE Group is an international company consisting of **20 manufacturing facilities** in 9 different countries (Italy, China, Finland, India, Poland, Czech Republic, Sweden, Russia and the USA) with a network of **more than 30 sales offices** in Europe, Asia, the Middle East and the USA.

- **4,000** qualified people
- **11,600,000 sqft** total surface area
- **40,000 sqft** Research & Development laboratories
- **80%** of products exported to 100 countries
- Revenues **USD 670 million** (2024)
- Listed on the Milan Stock Exchange (STAR)

LU-VE Group is one of the three major manufacturers in the world and second largest in Europe in the **air heat exchanger** segment.

In 2018, LU-VE Group entered the **North American market** by purchasing the local manufacturer Zyklus Heat Transfer Inc. (Jacksonville, TX), now LU-VE US.

In 2020, a new state-of-the-art facility was built in the same area and has been operational since 2021.

A major expansion of this facility will be completed in 2025.

CO₂ SUPERMARKET SOLUTIONS

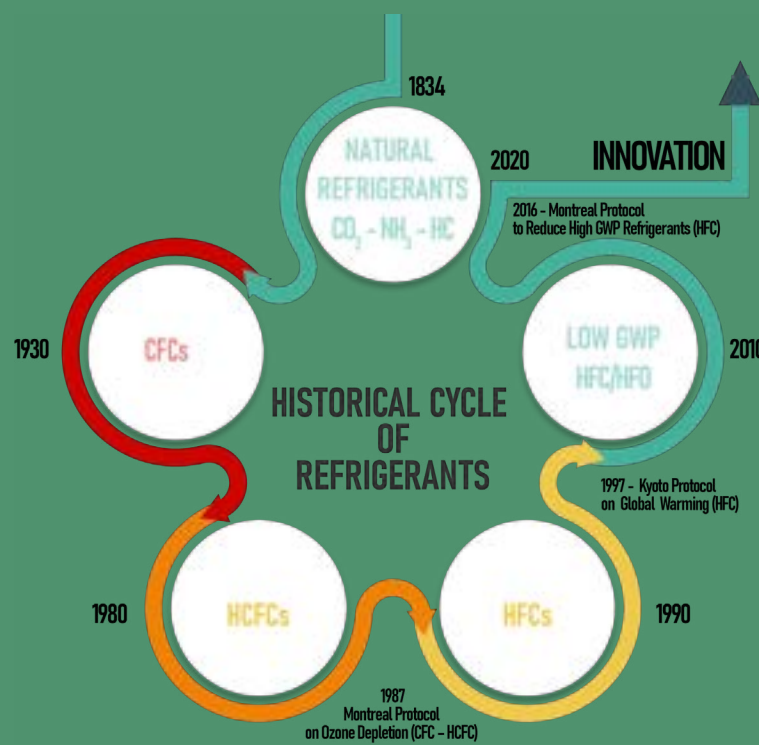
Your ally for a smooth transition to transcritical CO₂ refrigeration:

over 150,000 CO₂ units delivered

A HISTORICAL JOURNEY

With roots dating back to 1850, CO₂ was overshadowed by synthetic refrigerants in the 1930s. However, the imperative for sustainable alternatives has reignited interest in CO₂.

The GWP (Global Warming Potential) of CO₂ is in fact very low compared to HFCs; also, CO₂ does not present any problems of toxicity, flammability nor of impact on the ozone layer. The real challenge is to design plant with an efficiency level equal to or higher than current HFC plants.



INNOVATION IS IN OUR DNA

Recent technological innovations have reshaped the narrative of CO₂ in refrigeration, expanding its application and overcoming historical challenges.

- **Adiabatic panels:** achieving important annual energy savings thanks to the adiabatic air pre-cooling effect.
- **High-pressure sub-Cooler:** enhancing capacity and Coefficient of Performance (COP) through a small mechanical vapor-compression cycle for sub-cooling.
- **Parallel compression system:** significantly improving energy efficiency with peak savings 20% and significant annual savings
- **Gas ejector system:** harnessing the Venturi Effect for peak savings up to 25%, reducing compression ratio and flow rate handled by the compressor.

LU-VE decided to invest in CO₂ by exploiting such technologies and developing a line of products specifically for CO₂.

PUSHING BOUNDARIES

The LU-VE Group innovative solutions challenge conventional limitations, making high-efficiency CO₂ refrigeration systems viable even in regions with warmer ambient temperatures. The CO₂ equator delineates the geographical area where transcritical systems lose efficiency compared to standard HFC systems. Thanks to the LU-VE innovations, the CO₂ efficiency equator extends farther south, allowing for efficient CO₂ applications in warmer climates.

PERFORMANCE REDEFINED

CO₂ stands out as a frontrunner, offering a sustainable investment with lower operational costs. This winning combination of efficiency and environmental responsibility positions CO₂ as a key player in the present and in the future of refrigeration.

RELIABLE TOOLS

LU-VE Group commitment to excellence is further exemplified by our in-house developed selection software, that has played a pivotal role in deepening our understanding of the peculiar behavior of transcritical CO₂. This sophisticated software, backed and calibrated by rigorous laboratory testing, ensures the highest level of precision in our calculations. This dual approach, combining theoretical modeling with real-world verification, solidifies the reliability and accuracy of our solutions, making LU-VE Group a trusted name in transcritical CO₂ technology.

DRIVING CHANGE

Research and innovation are distinctive elements of LU-VE Group's philosophy. LU-VE has been able to make important developments thanks to its testing plant. The test equipment is made up of a climatic room, unique in Europe, operating at a constant temperature.



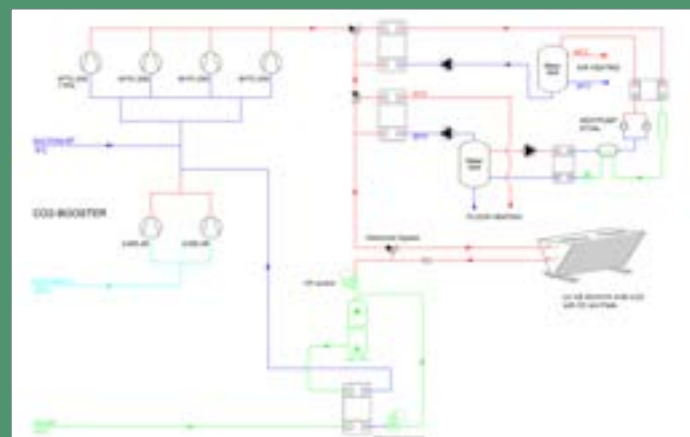
CASE STUDY: CO₂ booster with heat recovery system and adiabatic gas cooler

Since January 1st, 2016, all newly installed transcritical CO₂ systems in supermarkets within the Plus retail organization have embraced innovation with the integration of an **adiabatic humidification system** on the gas coolers.

A standard CO₂ booster system powers the cabinets and cold rooms, featuring 4 MT compressors, 2 LT compressors, and high-pressure and flash-gas bypass regulation, as shown in the installation layout.

In winter, the supermarket, warehouse, and social rooms are heated by the connected heat-recovery system, eliminating the need for additional heating. This advanced system includes a high and low-temperature water circuit for air curtains and floor heating. A LU-VE V-shape gas cooler with EC fans and adiabatic panels enhances efficiency.

The first generation of this system relies on a spray mechanism with nozzles spraying atomized water. In the Netherlands, this operation triggers when the ambient temperature reaches approximately 80.6 °F or 82.4 °F. For extended usage, a water treatment system becomes necessary, ensuring water quality, maintaining proper pH, conductivity, chloride levels, and hardness. In the second generation, we have evolved to factory-mounted panels irrigated by water through a distribution system integrated into the gas cooler. An essential feature is the system's ability to efficiently drain all used water after each working cycle, addressing concerns of legionella and freezing risks during winter. Notably, the significant advantage lies in the elimination of the need for water treatment, allowing the system to consistently draw water directly from the drinking water line.



Installation layout at Plus Supermarket, Gorinchem (NL)

THE HEAT-RECOVERY SYSTEM

In implementing an advanced heat recovery system in this supermarket, the winter heating primarily relies on a floor heating system and air curtains, each equipped with its high-temperature water circuit, as depicted in the installation layout. The water inlet temperature is regulated by a modulating 3-way valve, responding to the room temperature within the supermarket. This heating system is complemented by a heat pump during extended cold periods.

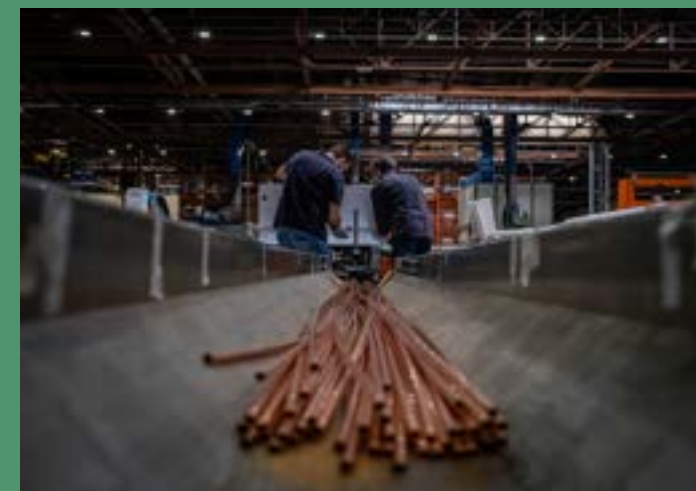
The CO₂ booster is regulated to achieve maximum COP. In this context, the CO₂ gas cooler outlet temperature is regulated 2K (3.6 °F) above the ambient temperature. Simultaneously, the water inlet temperature for the air curtains and the floor heating system is controlled by a modulating 3-way valve, adjusting according to the room temperature in the supermarket.



Extended Cold Ambient Conditions. Where prolonged cold ambient temperatures challenge the system's capacity to maintain the room temperature above 68 °F, the air heating system receives support from a heat pump. The heat pump extracts heat from the cold water return of the floor heating system. To enhance the floor heating system's efficiency, the pressure of the CO₂ booster installation is increased by slowing down or turning off the fan motors of the gas cooler.

Extreme Circumstances. Where the heat pump alone may not suffice to maintain the room temperature above 68 °F, a bypass of the gas cooler is employed to prevent static capacity loss. This is achieved by installing a modulating 3-way valve in the high-pressure line before the gas cooler, as illustrated in the installation layout. This strategic installation ensures preparedness for potential extreme temperatures in both summer and winter conditions. The decision to use an additional heat pump depends on the overall heat balance of the supermarket. In cases where floor heating is employed, linking a heat pump to the transcritical CO₂ system proves highly effective. Conversely, if only air heating is utilized, connecting the heat pump to the transcritical CO₂ system may be deemed an "expensive post heater." In such instances, a simple electrical heater, with sufficient power and in combination with pressurization of the CO₂ system, would suffice.

In this specific installation, the water valve of the adiabatic system opens at 82.4 °F. On the warmest day in of the year, where the ambient temperature reached 101 °F for several hours, our measurements indicated a gas cooler pressure of approximately 1160 psi. This pressure corresponds to a CO₂ gas cooler outlet temperature of 89.6 °F. Under these conditions (suction pressure To=-17.6 °F), the MT achieves a COP of 2. In comparison, an installation in the same region featuring a dry gas cooler without adiabatic systems measured a gas cooler pressure of 1378 psi on the same day. This pressure corresponds to a CO₂ gas cooler outlet temperature of 100.4 °F to 102.2 °F, resulting in a COP of 1.5. The use of adiabatic panels in our system has led to a **remarkable 30% increase in COP** under these conditions, highlighting the efficacy and performance enhancement achieved through this technological advancement.



PASSION FOR INNOVATION

LU-VE Group stands as an industry leader with over 20 years of dedicated experience in working with transcritical CO₂ systems. Through research projects on new refrigerants, LU-VE Group has had a track record of highly successful CO₂ installations in Europe, Latin America, the Middle East and Asia from 2004 to the present.

In the dynamic and mature landscape of European supermarkets, LU-VE Group has played a pivotal role since 2004, emerging as a key player with a significant market penetration.

In **2004**, the company built **Europe's first transcritical CO₂ plant (Coop Tägipark, Wettingen, Switzerland)**, with a strong focus on natural refrigerant fluids.

In 2018, a new challenge began to move the "CO₂ equator" and make this technology efficient in countries where it was not previously possible.

Two pilot systems are in operation in India (INDEE Project at the ITT - Indian Institute of Technology Madras, Chennai) and in Amman, Jordan, where one of the most advanced CO₂ refrigeration systems for supermarkets in the region is in operation, as part of a project developed by the United Nations Industrial Development Organization (UNIDO), with the support of the Jordanian Ministry of the Environment.

The first system was installed in Ukraine in **2020** for a supermarket (**Silpo, Kyiv, Ukraine**) with zero environmental impact, equipped with heat pumps, solar energy and a high-efficiency CO₂ cooling system.

TAILORED SOLUTIONS FOR NORTH AMERICA

LU-VE Group is dedicated to adapting and promoting its extensively tested and verified European success to meet the unique demands of the North American CO₂ transcritical landscape.

With a series of significant installations, LU-VE Group has already garnered confirmation of the exceptional quality and performance of our products in North America. These successful installations stand as a testament to LU-VE's prowess in meeting the rigorous standards and demands of the North American business landscape. Choosing LU-VE means choosing a proven and reliable solution, setting a significant milestone for our continued success in North America.

While LU-VE adiabatic CO₂ gas coolers may not be a novel technology, LU-VE's distinctive approach lies in providing North American businesses with a refined and advanced solution that has been rigorously tested and verified in European conditions.

Recognizing the **unique characteristics of the North American CO₂ transcritical market**, LU-VE Group has gone beyond a mere adjustment of measurements and references.

Our adaptation to the North American market includes the development of **specifically designed products** that cater to domestic market demands, facilitating a seamless transition towards CO₂ for North American businesses. This proactive approach ensures that our solutions not only **meet regulatory standards** but also **address the specific needs** of the North American market.

We understand that the benefits for the environment hinge on the availability of high-performing products with reliable performance and low operational costs. LU-VE Group is committed to providing North American businesses with tailored solutions that make the adoption of CO₂ technology both efficient and environmentally impactful.

