# APPLICATIONS OF TRANSCRITICAL $CO_2$

## Part 2
## Chapter 2

# An overview

Transcritical $CO_2$ technology has been deployed in a variety of applications across the world for many years. From traditional supermarket applications to convenience stores and industrial cold storage applications; even on cruise ships and for ice rinks – there are hundreds of examples of successful installations globally.

The following pages showcase examples of a multitude of different transcritical $CO_2$ installations, varying in size and location, categorized by type of application. Whether in a small, convenience store type of installation, or the more conventional commercial retail one; even industrial projects – transcritical $CO_2$ is worth considering when designing an HVAC&R installation. Here is how others have done it...

# COMMERCIAL APPLICATIONS

## SUPERMARKETS/ RETAIL

[4]**U.S.:** A 75,000ft² [6,968m²] Seed to Table Market, a refurbished Albertsons store that opened in December 2019 in North Naples, Florida, the most southeastern state in the U.S., has installed a transcritical $CO_2$ system. The system includes three rooftop adiabatic gas coolers, which helps the system function efficiently in the balmy climes of southwest Florida.

Having recently been installed, the energy usage of the transcritical system has yet to be assessed. But, despite the high ambient of North Naples, the energy consumption of the system as compared to that of a traditional DX system is "parity, probably using a little more."

[5]**U.S.:** Weis Markets, a Mid-Atlantic chain of 204 grocery stores, reported dramatic energy savings with transcritical $CO_2$ in 2019. The chain's first transcritical system consumed less energy than three other store systems during an 8.5-month test.

Weis's first transcritical $CO_2$ refrigeration system was installed at a 54,000 ft² [5,017 m²] store in Randolph, N.J., in July 2018. Its energy usage during that period was 250,790kWh [71,654RTh], substantially below the energy consumed by the other systems, all based on HFC or HFO refrigerants: 32% less than a 1.5-year-old secondary glycol/DX system, 39% less than a seven-year-old distributed rack system, and 86% below a 23-year-old centralized DX system.

The test period included August and September 2018, when high ambient temperatures, particularly during a two-week period, challenged the efficiency of a transcritical system. Yet Weis's unit consumed less energy during that period than the other systems.

[6]**Europe:** An Italian supermarket chain is using groundwater as a cooling fluid to condense the $CO_2$ in a transcritical system in a remodeled store in Milan. The 400m² [4,306ft²] remodeled store was officially opened in December 2019, after a two-month refurbishment period.

Using groundwater as a cooling fluid allows the system to run subcritically in the warm summer months and reduces the electricity consumption of the compressors. The groundwater used as a cooling fluid in the system is 15 to 20°C [59 to 68°F] warm year-round. This allowed to set a 25°C [77°F] condensing temperature in the system, using a plate heat exchanger. The use of groundwater, instead of air, to condense the $CO_2$, allows the system to run in subcritical mode even during the hottest summer months when the ambient air temperature is 27 to 28°C [81 to 82°F] or more.

In the winter months the system is designed to run in transcritical mode to satisfy the supermarket's need for hot water. To achieve the needed hot water, the system

employs heat recovery, which can recover up to 42kW [12.0TR] in winter, equaling “total” heat recovery, and increasing the system’s COP to 4.2. The capacity of the Milan system is 30kW [8.5TR] for medium temperature, 6kW [1.7TR] for low temperature and 40kW [11.4TR] for high temperature (air conditioning).

[7]**Europe:** Migros Ticino, a cooperative that is part of Swiss retail giant Migros, installed its first transcritical $CO_2$ system in 2009 already. Now the company, which operates 33 grocery stores among other businesses, has taken its commitment to natural refrigerants one step further and installed its first fully integrated $CO_2$ system at a store in Riazzino, Switzerland, in the Italian-speaking section of the country.

The system provides for the store’s refrigeration, winter space heating and summer air-conditioning requirements. The transcritical $CO_2$ compressor rack has subcooling, heat pump and chiller sections, and works with two separate water tanks providing the secondary fluid for the HVAC requirements. The system has been tested down to -5°C [23°F] in winter and up to 42°C [108°F] in late June, meeting the store’s needs in all conditions, according to Rossi.

[8]**Europe:** German retail giant Metro recently replaced an inefficient, 20-year-old R404A refrigeration system at an outlet in Ruse, Bulgaria, with a transcritical $CO_2$ system equipped with ejectors – with zero downtime at the store. This was done in a move towards natural refrigerants and to save electricity. The transcritical $CO_2$ system is Metro AG’s 18th with ejectors.

Metro’s 7,000m$^2$ [75,347ft$^2$] Ruse store opened in 1999 and was due for an upgrade this year to improve its overall efficiency. In only four months (from May until end August), the entire refrigeration system was replaced, and various other improvements were made, including the addition of glass doors to fridges to minimize openings and thus save energy. The new system will realize a projected electricity saving of a minimum 20% for cooling and more than 35% on heating, explained Schulze.

[9]**South Africa:** Local retail/wholesale outlet Evergreens opted for a transcritical $CO_2$ refrigeration system in its brand new 22,000m$^2$ [236, 806ft$^2$] store in Johannesburg, which opened in August. The new store boasts the largest transcritical $CO_2$ installation in the South African commercial sector – and one of the largest commercial systems in the world – with a refrigeration capacity of 1.9MW [540TR] serving 167 loads.

The main distribution board manages the racks as well as the evaporator coils. The racks, each with medium-temperature and low-temperature circuits, cool about 167 points, including various cold and freezer rooms, freezer and cold cabinets, and chillers. Loads range in temperature depending on the product, with the freezer rooms being kept at -20°C [-4°F], the citrus at 2°C to 5°C [36°F to 41°F], and the avocados and bananas at 14°C [57°F]. This is because if it is too hot, it will ripen fruit too fast, and if too cold, will make the fruit go black.

The estimated heat rejection is around 384kW [109.7TR], and this is used to heat water from 20°C to 55°C [68°F to 131°F]. Hot gas defrost has been included instead of the normal element heater that uses a lot of electricity.

**[10]South Africa:** In September 2018, food retailer Pick n Pay (PnP) opened its first transcritical $CO_2$ store, based in Milnerton, Cape Town. Today, it has 16 transcritical stores in South Africa (as per a presentation during ATMOsphere Cape Town 2020) with a projected 32 by end of 2020.

The booster system with parallel compression was manufactured locally and the rack is fitted with 10 compressors, four of which run the medium-temperature side, two doing parallel compression, three running the low temperature, and one satellite low-temperature compressor. The compressors are piped to four circuits: -36°C [-32.8°F] to the fish island freezer; -28°C [-18.4°F] to freezer cabinets and freezer store; and -8°C [17.6°F] to the medium-temperature cabinets. Two compressors are piped to provide parallel compression of flash gas. Included in the rack is a plate heat exchanger to reclaim heat for heating of hot water to 55°C [131°F], which is used for washing and cleaning in the bakery, butchery, food preparation areas, and for staff ablution.

**[11]Australia:** Thanks to its natural refrigeration system, a significant reduction in carbon footprint is projected for the new IGA Supa retail and liquor store, which opened in Creswick, Australia in August 2019. “We will have a 47% reduction in our carbon footprint because we chose natural refrigerants over high-GWP refrigerants, and our emissions will be 6,209 $CO_2e$ tons less per year,” said the owner. They also heat the store and produce hot water from the excess heat generated by the $CO_2$ system, further reducing costs and emissions.”

Other considerations that motivated the business case for a $CO_2$ system were cost savings, energy efficiency and future-proofing the store.

**[12]Australia:** A recently opened Woolworths Supermarket in Burwood, a suburb of Melbourne, Australia, is the first supermarket in the world to become associated with certification from the stringent Living Building Challenge (LBC) performance standard, in part by employing two transcritical $CO_2$ refrigeration systems and doors on all meat and dairy cases.

Three transcritical $CO_2$ refrigeration racks are being used by Woolworths in the shopping center, two for the supermarket’s chillers and freezers, and one for the Dan Murphy’s liquor store (part of the Woolworths group) located inside the center. Both systems include parallel compression. Doors have also been included on all meat and dairy cases, which will reduce the energy consumption by around 30%, by preventing cold air from spilling from the cases, noted Woolworths. Energy is also further reduced by use of waste heat from refrigeration to heat the store and switching off lights after hours.

[13]**New Zealand:** The Fresh Choice Papamoa and Countdown Hāwera food retail stores both opened in 2019, each with an energy efficient transcritical $CO_2$ system. With regards to energy efficiency and savings expected, both stores are expected to typically save "5% to 8% over a new, well-engineered equivalent HFC system."

Countdown Hāwera in Taranaki is New Zealand's first «Be Accessible»-accredited supermarket, designed to be inclusive and accessible to everyone regardless of ability. Fresh Choice Papamoa, part of the Woolworths New Zealand group, boasts a unique heat reclaim system. Instead of having two heat exchangers on the rack, only one heat exchanger was used both for the hot water and the HVAC systems.

[14]**South America:** In 2019, Makro, a division of Dutch conglomerate SHV Holdings, has installed a transcritical $CO_2$ system at its new Valle del Lili supermarket in Cali, Colombia. With more than 3,400m $^2$ [36,597ft $^2$] of sales space, the store has achieved Leadership in Energy and Environmental Design (LEED) certification thanks to the measures put it place to reduce water and energy.

The installation features a transcritical $CO_2$ refrigeration system with parallel compression. The cooling capacity is 130kW [37.1TR] on the medium-temperature side and 4kW [1.1TR] for low temperature. As a special safety feature, the rack has been equipped with a controlled suction-gas super heater, which reduces the "oil throw" in the compressors and ensures the stable operation of the system, even if the cooling cabinets work under discontinued super heating. In addition, the installation includes a gas cooler (cooling capacity: 254kW/72.2TR), electronic expansion valves, and self-service doors – all to maximize energy efficiency and to reduce the store's carbon footprint.

[15]**China:** One of China's first transcritical $CO_2$ systems – installed in a remodeled store – has been installed in 2019. The transcritical $CO_2$ system was installed at a CSF Market store in Beijing in July 2018 as a part of a three-month store renovation project. The system replaced the store's old R22 system.

The transcritical $CO_2$ system installed at the CSF Market store includes a parallel-compression system. All the different configurations and technologies available for transcritical $CO_2$ systems such as ejectors, parallel compression and booster configurations, are directed towards gas cooler outlet temperature control. According to the manufacturer, the customer is very satisfied with the energy savings. The system deploys heat recovery, which made the system save energy compared to the former R22 system.

# REFERENCES

## Chapter two: 'Applications of transcritical $CO_2$


1. Battesti, M. (2018). *Carrefour's first $CO_2$ transcritical convenience store.* Available online at: http://www.r744.com/articles/8184/carrefourandrsquo_s_first_co2_transcritical_convenience_store

2. Williams, A. (2018). *$CO_2$ at heart of new Delhaize convenience store.* Available online at: http://www.r744.com/articles/8422/co2_at_heart_of_new_delhaize_convenience_store

3. Dusek, J. (2014). *Lawson's green flagship convenience store opens in Osaka, pro-*

at: http://www.r744.com/articles/5044/lawson_s_green_flagship_convenience_store_opens_in_osaka_promises_50_energy_reductions

4. Garry, M. (2020). *Transcritical $CO_2$ in Warm, Muggy Florida.* Available online at: http://r744.com/articles/9384/transcritical_co2_in_warm_muggy_florida

5. Garry, M. (2019). *Weis Markets reports dramatic energy savings with transcritical $CO_2$.* Available online at: http://www.r744.com/articles/9096/weir_markets_reports_dramatic_energy_savings_with_transcritical_andnbsp_co2

6. Stausholm, T. (2020). *Italian Supermarket Increases Efficiency of Transcritical $CO_2$ system with Groundwater.* Available online at: http://r744.com/articles/9349/italian_supermarket_increases_efficiency_of_transcritical_co2_system_with_groundwater

7. Stausholm, T. (2019). *Migros Ticino installs its first integrated $CO_2$ system.* Available online at: http://r744.com/articles/9090/migros_ticino_installs_its_first_integrated_co2_system

8. Koegelenberg, I. (2019). *Bulgarian Metro Store Installs Transcritical $CO_2$ system with Zero Downtime.* Available at: http://r744.com/articles/9187/bulgarian_metro_store_replaces_20_year_old_hfc_system_with_zero_downtime

9. Koegelenberg, I. (2020). *1.9MW of $CO_2$ for South African Produce Market.* Accelerate Corporate Edition 2020. Available online at: https://issuu.com/shecco/docs/acorp_sphere

10. Koegelenberg, I. (2019). *Centre Point PnP minimizes environmental impact.* Available online at: https://www.coldlinkafrica.co.za/index.php/projects/412-centre-point-pnp-minimises-environmental-impact

11. Koegelenberg, I. (2019). *Prioritizing Sustainability, IGA Store Chooses $CO_2$.* Available online at: http://www.r744.com/articles/9162/prioritizing_sustainability_iga_store_chooses_co2

12. Koegelenberg, I. (2020). *Meeting the "Living Building Challenge".* Available online at: https://accelerate24.news/regions/australia/meeting-the-living-building-challenge/2020/

13. Koegelenberg, I. (2019). *Quick Adopting New Zealanders Boast Two New $CO_2$ Retail Installations.* Available online at: http://r744.com/articles/9236/_quick_adopting_new_zealanders_boast_two_new_co2_retail_installations

14. Aleu, P. (2019. *Makro Continues $CO_2$ Installations in Latin America.* Available at: http://r744.com/articles/9267/makro_continues_co2_installations_in_latin_america

15. Yoshimoto, D. (2019). *Satisfying Results Observed in China's Second Transcritical $CO_2$ System.* Available online at: http://r744.com/articles/9245/satisfying_results_observed_in_china_s_second_transcritical_co2andnbsp_system

16. Garry, M. (2020). *Hannaford Pioneers Transcritical $CO_2$.* Available online at: http://r744.com/articles/9328/hannaford_pioneers_transcritical_co2_andn-dash_again

17. Yoshimoto, D. (2020). *Japanese Cold Storage Operator Cuts Energy by 35% with $CO_2$.* Available online at: http://r744.com/articles/9392/japanese_cold_storage_operator_cuts_energy_by_35_with_co2

18. Yoshimoto, D. (2019). *Yoshio Ice goes with transcritical $CO_2$ in warm climate.* Available online at: http://r744.com/articles/9048/yoshio_ice_goes_with_transcritical_co2_in_warm_climate

19. Koegelenberg, I. (2020). *Australian Wholesaler Chooses $CO_2$ Over Ammonia and HFCs for Cold Storage.* Available online at: https://accelerate24.news/regions/australia/australian-wholesaler-chooses-co2-over-ammonia-and-hfcs-for-cold-storage/2020/

20. Yoshimoto, D. (2019). *Japanese margarine, beer, ice makers adopting transcritical $CO_2$.* Available online at: http://r744.com/articles/9110/japan_margarine_beer_ice_makers_adopting_transcritical_co2

21. Williams, A. (2018). *Sipping $CO_2$ cooled wine.* Available online at: http://r744.com/articles/8168/sipping_co2_cooled_wine

22. SCM Frigo s.p.A (2020). Available online at: https://www.linkedin.com/posts/scm-frigo-s.p.a._scmfrigo-beijerref-co2leader-activity-6626143937620918272-Er2y/

23. Ackermann, J. (2018). *$CO_2$ transcritical installation- a processing plant first.* Available online at: https://www.coldlinkafrica.co.za/index.php/projects/317-co2-trans-critical-installation-a-processing-plant-first

24. Yoshimoto, D. (2019). *World's largest transcritical $CO_2$ system commissioned in California.* Available online at: http://r744.com/articles/9042/world_s_largest_transcritical_co2_system_commissioned_in_california

25. Jooste, J. (2019). *Transcritical $CO_2$ system pushing boundaries for Meat World.* Available online at: http://www.coldlinkafrica.co.za/index.php/projects/550-trans-critical-co2-system-pushing-boundaries-for-meat-world

26. Aleu, P. (2019). *Hillphoenix supplies 4th transcritical $CO_2$ industrial system in Latin America.* Available online at: http://r744.com/articles/9064/hillphoenix_supplies_4th_transcritical_co2_industrial_system_in_latin_america

27. Yoshimoto, D. (2019). *DFDS Logistics Switches to $CO_2$ Containers for Coastal Shipping Service.* Available online at: http://r744.com/articles/9204/dfds_logistics_switches_to_co2_containers_for_coastal_shipping_service

28. Stausholm, T. (2019). *Fishing Trawler Installs Compact $CO_2$ System to Chill Catch.* Available online at: http://r744.com/articles/9313/u_s_fishing_trawler_installs_compact_co2_system_to_chill_pollock

29. Garry, M. (2020). *Toronto's $CO_2$ System for Outdoor Ice Trail Said to be World's First.* Available online at: https://accelerate24.news/regions/torontos-co2-system-for-outdoor-ice-trail-said-to-be-worlds-first/2020/?mc_cid=8c87020895&mc_eid=f3c3851c70

30. Yoshimoto, D. (2019). *Beijing 2022 Winter Olympics officially announces use of $CO_2$ systems for ice venues.* Available online at: http://r744.com/articles/9053/beijing_2022_winter_olympics_officially_announces_use_of_co2_systems_for_ice_venues

31. Williams, A. (2019). *Norway's first year-round indoor ski arena to use $CO_2$ transcritical.* Available online at: http://r744.com/articles/9050/norwayandrsquo_s_first_year_round_indoor_ski_arena_to_use_co2_transcritical

32. Garry, M. (2019). *GEA to equip two Chinese cruise ships with transcritical $CO_2$.* Available online at: http://r744.com/articles/9128/gea_to_equip_two_chinese_cruise_ships_with_transcritical_co2

33. Koegelenberg, I. (2019). *Burger King Starts Roll Out of $CO_2$ Condensing Units in Spain.* Available online at: http://r744.com/articles/9203/burger_king_starts_roll_out_of_co2_condensing_units_in_spain

34. Williams, A. (2019). *The Natural Refrigerant Treatment.* Accelerate Europe Spring 2019. Available online at: https://issuu.com/shecco/docs/ae_1903_33d31f1e897942/22

35. Garry, M. (2019). *Versatile $CO_2$ Contractor Installs Transcritical at a Supermarket, a Processing Facility and an Ice Rink.* Available online at: https://accelerate24.news/regions/versatile-co2-contractor-installs-transcritical-at-a-supermarket-a-processing-facility-and-an-ice-rink/2019/