COLDMATCH GROUP · ENTERPRISE BUYER GUIDE

Ammonia (NH_3) vs CO_2 (R744) Refrigeration for Industrial Cold Storage

A vendor-neutral buyer comparison of the two natural refrigerants dominating new industrial cold storage: energy efficiency (COP), safety, refrigerant cost, climate suitability and CAPEX. Use it to shortlist the right technology before you brief suppliers.

Both ammonia and CO_2 are natural refrigerants with GWP ≤ 1, neither is subject to F-Gas or Kigali phase-down, and both are the strategic long-term choice for large-scale commercial cold storage investors. The right one depends on plant size, climate zone, operator availability and the safety envelope acceptable on site.

Side-by-side matrix

Criterion	Ammonia (NH_3)	CO_2 (R744)
GWP	0	1
ODP	0	0
COP @ –10 °C SST	3.2 – 4.2	2.6 – 3.6
CAPEX vs HFC baseline	+15–30%	+20–40%
Refrigerant cost	USD 3–6 / kg	USD 8–15 / kg
System pressure	10–15 bar (typical)	80–120 bar (transcritical)
Safety regulation	EN 378 / ATEX / OSHA PSM >4.5 t	Pressure vessel code
Operator qualification	Certified NH_3 engineer	Standard refrigeration tech
Best plant size	>200 kW industrial	50 kW – 2 MW
Ambient sensitivity	Stable across ambient	Drops >30 °C without ejector
Regulatory future	Not phased down	Not phased down

Decision dimensions

Energy efficiency (COP)

Ammonia COP is 3.2–4.2 at –10 °C SST vs CO_2 transcritical 2.6–3.6 — a 12–18% energy advantage that widens above 30 °C ambient. Modern CO_2 with parallel compression and multi-ejector closes the gap to 3–7% in temperate climates and 8–12% in hot ones.

Safety

Ammonia is toxic at 25 ppm (OSHA PEL) and mildly flammable — requires ATEX / IIAR-2 machinery rooms, leak detection, ventilation and, above 4.5 t charge in the US, OSHA Process Safety Management. CO_2 is non-toxic below 5,000 ppm and non-flammable, so it can sit inside occupied buildings with standard pressure-vessel controls.

Refrigerant cost

Ammonia is USD 3–6 / kg — the cheapest industrial refrigerant on the market. CO_2 is USD 8–15 / kg. Neither is exposed to F-Gas quotas or Kigali phase-down. Phasing-down HFC blends (R-404A, R-448A) sit at USD 40–120 / kg and are the real financial risk to avoid.

Climate suitability

Ammonia holds efficiency across ambient temperatures and is the default for hot climates (GCC, Africa, LATAM, South-East Asia) above 200 kW. CO_2 transcritical loses 15–25% COP above 30 °C without ejectors or parallel compression. Cascade CO_2/NH_3 or CO_2/HFC restores efficiency in warm regions.

CAPEX & plant size

Below 200 kW, CO_2 almost always wins on TCO — you avoid the fixed cost of an ammonia-safe machinery room (€80–200k) and PSM compliance. Between 200 kW and 2 MW the two converge within ±5% on 15-year TCO in temperate climates. Above 2 MW and/or in hot climates, ammonia pulls ahead by 8–15%.

Applications & operators

CO_2 dominates new supermarket, convenience-retail and urban distribution builds where the plant sits close to people. Ammonia dominates meat, fish and dairy processing, ice plants, ports and 3PL distribution above 200 kW where certified refrigeration engineers are available.

Advantages & limitations

ADVANTAGES

Ammonia (NH_3)

- Highest COP of any commercial refrigerant
- Zero GWP, zero ODP — no phase-down risk
- Very low refrigerant cost per kg (USD 3–6)
- Mature technology with 100+ years of industrial deployment

ADVANTAGES

CO_2 (R744)

- No toxicity, no flammability — installable in occupied buildings
- Standard-qualified technicians can service the plant
- Natural refrigerant with zero phase-down risk
- Excellent heat-recovery temperatures (>90 °C hot water)

LIMITATIONS

Ammonia (NH_3)

- Toxic at concentrations >25 ppm — safety architecture required
- Flammable at 15–28% concentration in air
- PSM compliance mandatory above 4.5 t charge (US)
- Requires qualified operators — labour scarcity in some regions

LIMITATIONS

CO_2 (R744)

- Efficiency degrades sharply above 30 °C ambient without ejectors
- High-pressure components (80+ bar) increase CAPEX
- Cascade with NH_3 or HFC needed for large low-temp plants in hot climates

Decision guidance

Choose ammonia if your plant is above 200 kW, sits in a hot climate, and you have (or can hire) certified refrigeration engineers. Choose CO_2 transcritical if your plant is 50 kW – 2 MW, in a mild climate (<32 °C ambient), or in a location without qualified NH_3 operators. Above 1 MW in a warm climate, CO_2/NH_3 cascade or pure NH_3 typically wins on lifetime cost.

Frequently asked questions

Is ammonia safe to use inside a food factory or distribution centre?

Ammonia is toxic (OSHA PEL 25 ppm) and mildly flammable, but modern plants keep the charge inside a dedicated, ventilated machinery room and distribute cold with a secondary glycol or CO_2 loop. With a low-charge packaged chiller (20–100 kg NH_3), residual risk to occupied areas is very low. Above ~4.5 t charge in the US, OSHA PSM and EPA RMP apply.

Can CO_2 really be installed inside occupied buildings?

Largely yes — this is CO_2's biggest advantage over ammonia. CO_2 is non-flammable and only an asphyxiation hazard above 40,000 ppm, versus 25 ppm for NH_3. You still need leak detection and pressure-relief routed outside, but avoid ammonia-safe machinery rooms, evacuation zones and PSM paperwork.

Which carries the lower insurance and permitting burden?

CO_2 almost always wins. NH_3 typically attracts a 15–35% property + BI loading once charge exceeds ~1 t, plus a documented emergency plan with local fire services. For a mid-size (500–1,500 kW) plant this can be worth €30–120k / year in premium and 3–6 months of permitting time.

How much does ambient temperature change the decision?

It is the single biggest variable. CO_2's critical point is 31 °C, so plants that cannot reject below ~28 °C flip into transcritical mode and COP drops 15–25%. In Gulf, sub-Saharan Africa, South Asia or Australian summer conditions, a plain CO_2 transcritical plant burns 20–30% more electricity per year than a well-designed NH_3 plant.

Do CO_2 ejectors and parallel compression close the efficiency gap?

In moderate climates (annual average <20 °C) — yes, almost entirely (within 3–7% of NH_3). In hot climates the gap narrows from 20–25% down to 8–12%. Trade-off: €40–90k CAPEX adder per 100 kW of MT duty and a smaller pool of qualified commissioning contractors.

Which has the lower lifetime TCO for a mid-size project?

For 200–2,000 kW industrial cold storage in temperate climates, CO_2 transcritical lands within ±5% of NH_3 on 15-year TCO once insurance, permitting and machinery-room build-out are included. Below 200 kW CO_2 wins. Above 2 MW and/or in hot climates, NH_3 pulls ahead 8–15%.

Are there subsidies or green-finance instruments that shift the decision?

Yes — worth 8–20% of CAPEX. EU Taxonomy alignment unlocks green-loan pricing 50–120 bps below vanilla senior debt for both refrigerants. Natural-refrigerant grants (US EPA GreenChill, IRA §179D, Germany's Kälte-Klima-Richtlinie up to 35% of eligible CAPEX, UK IETF) apply to NH_3 and CO_2 but generally not to HFC/HFO. Model after-subsidy CAPEX before finalising.