CO_2 Heat Pump

A "CO_2 heat pump" uses carbon dioxide (R-744) as the refrigerant. CO_2 is a *natural refrigerant* as opposed to many traditional ones (like HFCs) that have higher global warming potential (GWP of 1) and zero ODP ozone depletion potential. There are a few variants (subcritical, transcritical cycles), and many CO_2 systems are used especially for high-temperature water, industrial process heat, etc.

CO_2 Heat Pump - Transcritical CO_2 Refrigeration

Transcritical CO_2 (R-744) refrigeration is a system where carbon dioxide operates above its critical point (31.1 °C/88 °F, 73.8 bar/1070 psi) on the high-pressure side. Above this point, CO_2 is no longer a distinct liquid or gas, so heat rejection occurs in a gas cooler rather than a condenser.

This cycle is widely used in domestic hot water, supermarkets, cold storage, food processing, and industrial refrigeration, and increasingly for heat recovery and district energy.

How the Transcritical Cycle Works

1. **Compression**
   CO_2 vapor is compressed to very high pressure (90–140 bar/1305-2030 psi).
2. **Gas Cooling (Not Condensing)**
   Heat is rejected in a gas cooler; temperature drops but no phase change occurs.
3. **Expansion**
   High-pressure CO_2 expands through an expansion valve, causing a sharp temperature drop.
4. **Evaporation**
   CO_2 absorbs heat from refrigerated spaces.
5. **Return to Compressor**
   Low-pressure vapor returns to the compressor.

Advantages of CO_2 heat pumps vs traditional synthetic-refrigerant heat pumps

Advantage	Details
Lower GWP / environmental impact	CO_2 has a GWP of 1, which is much lower than many common refrigerants (R-410A, R-134a, etc.). If leaks happen, the environmental damage is much less.
Higher output temperatures	CO_2 systems can reach hotter water temperatures, useful for domestic hot water, industrial processes, or retrofits that expect higher supply temperatures.

Advantage	Details
Better performance in cold ambient conditions	Because of the thermodynamic properties of CO_2, these heat pumps can maintain good efficiency when the outside air is cold. Traditional systems tend to lose efficiency sharply at low temp.
Potentially smaller/distribution savings	Because CO_2 systems can have a larger temperature difference (between supply and return), distribution piping, pumps, valves, etc., can sometimes be smaller or less costly. This can reduce capital cost in larger systems.

CO_2 heat pump application

1. **When need high water/supply temperature** (e.g. domestic hot water, industrial process hot water, certain district heating systems).
2. **Cold climate** where low outdoor air temps would degrade traditional heat pump efficiency significantly.
3. **Carbon pricing/regulations favor low GWP refrigerants**, or when want to build for future regulatory compliance.
4. **Large-scale or commercial/institutional installations**, where the savings per unit are large and the system cost is justified.
5. **Incentives/rebates** available for CO_2 or low-GWP systems. **Especially for jurisdictions where there are penalties for commercial buildings in Canada that fail to reduce greenhouse gas (GHG) emissions.**

Why CO_2 is Growing in North America

- Cold climate favors transcritical efficiency.
- Carbon pricing and building GHG regulations.
- Strong adoption by major grocery chains.
- Strong alignment with Canadian and EU climate regulations.
- Increasing incentives and utility support.