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COURSE 2 OF 10
FIRST EDITION 2026

HEAT PUMP TRAINING PROGRAM

Course 2 — How a Heat Pump Works

One of ten vendor-neutral courses, with worked examples, P&IDs, a quiz and a glossary, written for Indian conditions.

Values marked "typical", "approximate" or "illustrative" are not test data; check them against manufacturers' manuals and current standards before use.

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LEVEL 1 · FOUNDATIONS

Course 2 — How a Heat Pump Works

Powered by Sunniva. This is a Level 1 Foundations course for everyone: technicians, engineers, sales staff, consultants and curious owners. No prior refrigeration knowledge is needed. After this course you will be able to:

- explain in plain words how a heat pump moves heat from a cold place to a warm place;
- name every main part of the refrigerant circuit and say what it does;
- read a pressure–enthalpy (P-h) diagram and estimate COP from it;
- explain why COP falls as temperature lift rises, and why air-source units need defrost.

2.1 Moving heat uphill: the core idea

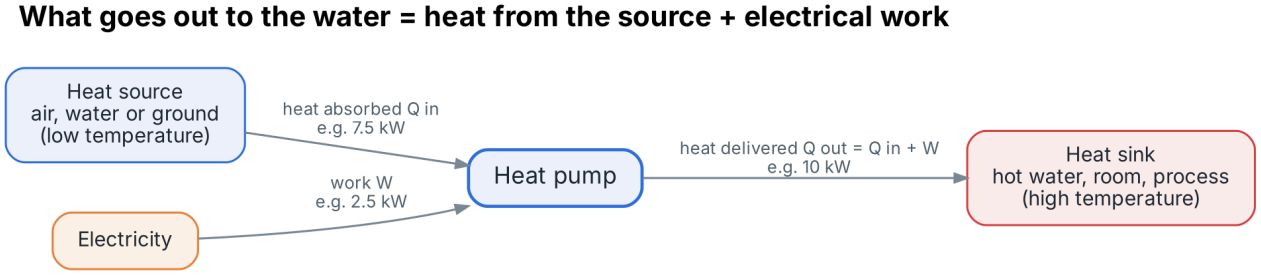
Key idea: A heat pump does not make heat; it moves heat that already exists from a colder place to a warmer place, using a small amount of electricity to do the work.

Heat flows naturally from hot to cold. A cup of chai cools down in a room; it never heats itself up. To make heat flow the other way, "uphill", we must spend work. A water pump does the same for water: it lifts water from a sump to an overhead tank.

Your home fridge is a heat pump. It pulls heat out of the food and throws it out at the back grille. Touch that grille and you feel the heat. A water heating heat pump does the same job, but we keep the warm side and use it.

Air at 25 °C in Chennai still holds a lot of heat. Even air at 0 °C in Shimla holds heat, because "cold" only means "less heat". The heat pump collects this low-grade heat and lifts it to a useful temperature, such as 55 °C for bathing water.

Coefficient of performance (COP) is the useful heat delivered divided by the electricity used. An electric geyser element has a COP of about 1. A heat pump typically delivers a COP of 3 to 5 for water heating.



Energy flow through a heat pump

Heating method	Typical efficiency or COP	Energy bought for 10 kWh of heat
Electric geyser (resistance element)	about 1.0	about 10 kWh electricity
LPG water heater	about 0.8–0.9 (typical)	about 0.9 kg LPG per 10 kWh (typical)
Heat pump (water heating)	about 3–5 (typical)	about 2–3.3 kWh electricity

Worked example — heating 500 L of water in Pune from 25 °C to 55 °C.

$$Q = m\,c_p\,\Delta T \qquad E_{elec} = \frac{Q}{COP}$$

- Mass of water m = 500 kg. Specific heat c_p = 4.186 kJ/kg·K. ΔT = 55 − 25 = 30 K.
- Q = 500 × 4.186 × 30 = 62,790 kJ. Divide by 3,600 to get kWh: Q ≈ 17.4 kWh.
- Electric geyser (COP ≈ 1): 17.4 kWh × ₹9/kWh (example rate) ≈ ₹157.
- Heat pump at COP 3.5: 17.4 ÷ 3.5 ≈ 5.0 kWh × ₹9 ≈ ₹45.
- Heat taken free from the air: 17.4 − 5.0 = 12.4 kWh.

Remember

- A heat pump moves heat; it does not create it.
- Heat out = heat from source + electrical work.
- COP = useful heat ÷ electricity used.
- Even cold air contains usable heat.

Field tip: When explaining to a customer, point to the hot grille behind their fridge. It is the easiest demonstration you have.

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2.2 The vapour compression cycle, step by step

Key idea: A refrigerant boils to absorb heat at low pressure, is compressed, then condenses to release heat at high pressure, and the cycle repeats.

A **refrigerant** is a fluid chosen because it boils at a low temperature. Water boils at 100 °C at sea level. In a pressure cooker, the higher pressure makes water boil at about 120 °C. Pressure sets the boiling point. A heat pump uses this rule: low pressure for boiling cold, high pressure for condensing hot.

The cycle has four parts. Follow one kilogram of refrigerant around the loop.

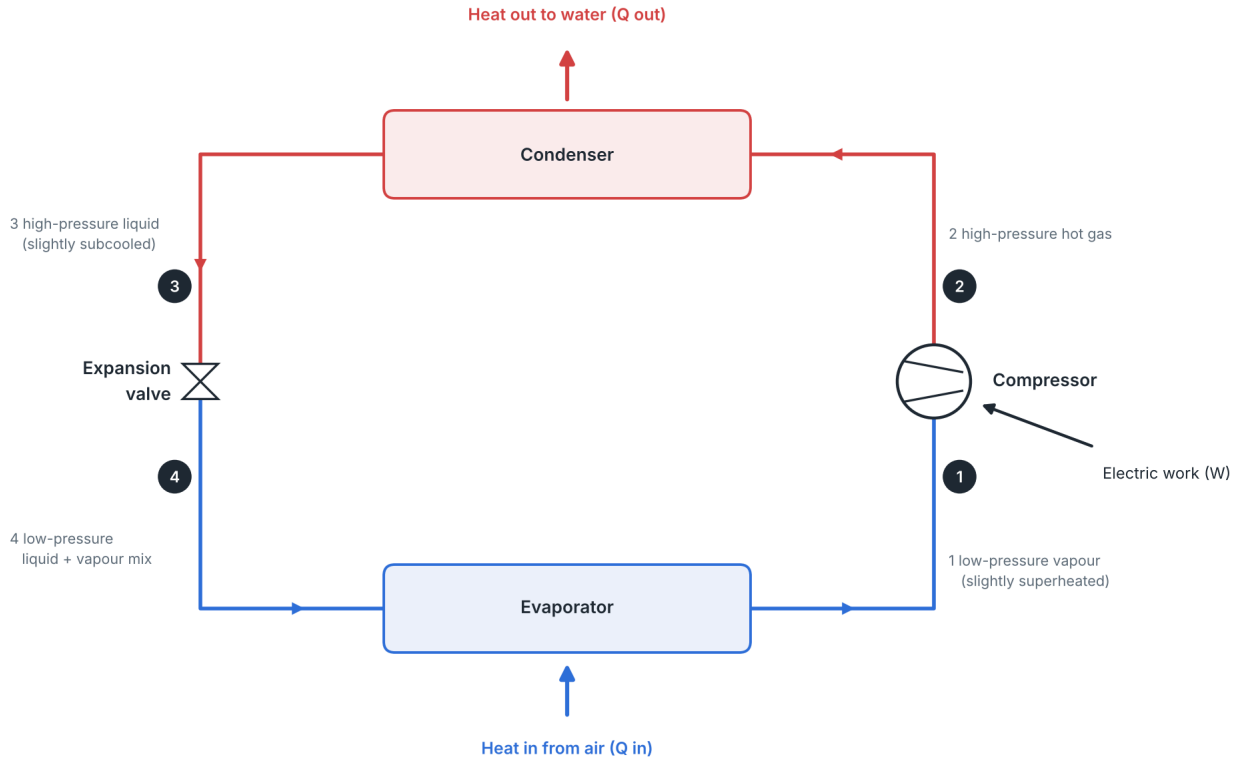
1. **Evaporation (1 ← 4).** Cold, low-pressure liquid enters the **evaporator**. It boils by taking heat from outdoor air or water. It leaves as a slightly **superheated** vapour, meaning a few degrees warmer than its boiling point.
2. **Compression (1 → 2).** The **compressor** squeezes the vapour. Pressure and temperature rise sharply. Hot gas at perhaps 70–100 °C (typical) leaves the compressor.
3. **Condensation (2 → 3).** The hot gas enters the **condenser**. It gives its heat to the water and turns back into liquid. It leaves slightly **subcooled**, meaning a few degrees below its condensing point.
4. **Expansion (3 → 4).** The liquid passes through an **expansion device**. Pressure drops suddenly. Part of the liquid flashes to vapour and the mix becomes very cold. It returns to the evaporator.

Sweat cools your skin the same way: as it evaporates, it takes heat from you. Evaporation always absorbs heat.

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The vapour compression cycle, step by step

High-pressure side red, low-pressure side blue. Numbers are the four state points.



The vapour compression cycle

Point	Location	Pressure	Phase	Typical temperature (water heating, 25 °C air)
1	Compressor suction	Low	Superheated vapour	about 15–20 °C
2	Compressor discharge	High	Hot superheated gas	about 70–100 °C
3	Condenser outlet	High	Subcooled liquid	about 50–55 °C
4	Evaporator inlet	Low	Cold liquid-vapour mix	about 10–15 °C

(Values are typical and depend on refrigerant and conditions.)

Worked example — energy balance on a unit.

$$Q_{cond} = Q_{evap} + W_{comp}$$

- A unit draws W = 3 kW at the compressor.
- Its evaporator absorbs Q_{evap} = 9 kW from air.
- Condenser output Q_{cond} = 9 + 3 = 12 kW.
- COP = 12 ÷ 3 = 4.0.

Remember

- Pressure controls the boiling point of the refrigerant.
- Low side absorbs heat; high side rejects heat.
- Four parts: evaporator, compressor, condenser, expansion device.
- Superheat protects the compressor; subcooling protects the expansion device.

Common mistake: Calling the hot discharge gas "the water temperature". Discharge gas is much hotter than the water it heats.

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2.3 Compressors: rotary, scroll, reciprocating, screw, inverter

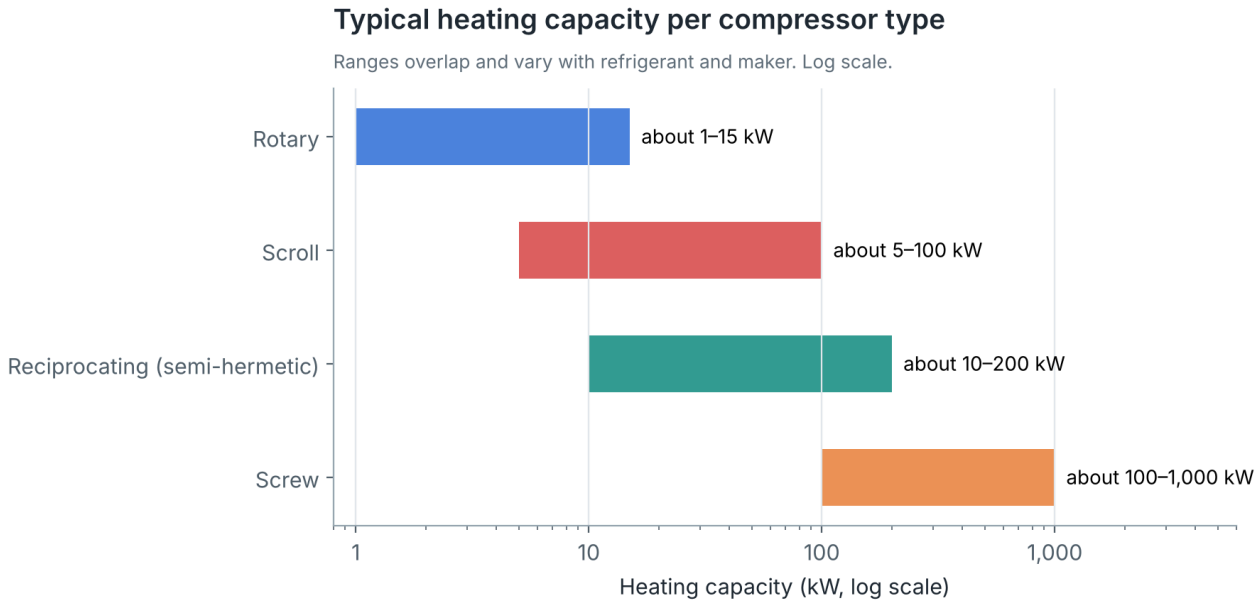
Key idea: The compressor is the heart of the heat pump; its type sets capacity range, efficiency, noise and how well it handles part load.

The compressor raises the refrigerant's pressure. Most heat pump compressors are **hermetic**, meaning motor and pump are sealed in one welded shell. The motor is cooled by the suction gas flowing over it.

Rotary compressors use a rolling piston inside a cylinder. They are small, cheap and common in split ACs and small heat pumps. **Scroll** compressors use two spiral scrolls, one fixed and one orbiting. Gas is trapped and squeezed toward the centre. Scrolls are quiet, efficient and reliable in the mid range.

Reciprocating compressors use pistons, like a car engine. They are rugged and easy to repair but noisier. **Screw** compressors use two meshing rotors. They suit large industrial capacities.

Inverter is not a separate pump type. It is a drive that changes the motor speed. Rotary and scroll compressors are often inverter-driven. A fixed-speed compressor runs at full speed or stops. An inverter compressor slows down to match the load, like a car cruising instead of braking and accelerating.



Typical capacity range per compressor type

Type	Typical capacity per compressor	Strengths	Limits	Common use
Rotary	about 1–15 kW	Compact, low cost	Less efficient at large sizes	Domestic water heaters, splits
Scroll	about 5–100 kW	Quiet, efficient, few moving parts	Not field-repairable (hermetic)	Domestic to commercial units
Reciprocating	about 10–200 kW	Rugged, repairable (semi-hermetic)	Noise, vibration, valve wear	Older and industrial plants
Screw	about 100 kW and above	Large capacity, continuous duty	High cost, oil management	Industrial process heat
Inverter drive (on rotary/scroll)	—	Matches load, soft start, better part-load COP	Electronics sensitive to voltage and heat	Variable-load applications

Remember

- Most heat pump compressors are hermetic and suction-gas cooled.
- Rotary for small, scroll for mid, screw for large.
- Inverter is a speed control, not a pump design.
- Liquid entering the compressor ("slugging") can break it; superheat prevents this.

Field tip: Check supply voltage at the compressor terminals under load. Low voltage in rural feeders is a common cause of trips and burnt windings.

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2.4 The evaporator: collecting heat

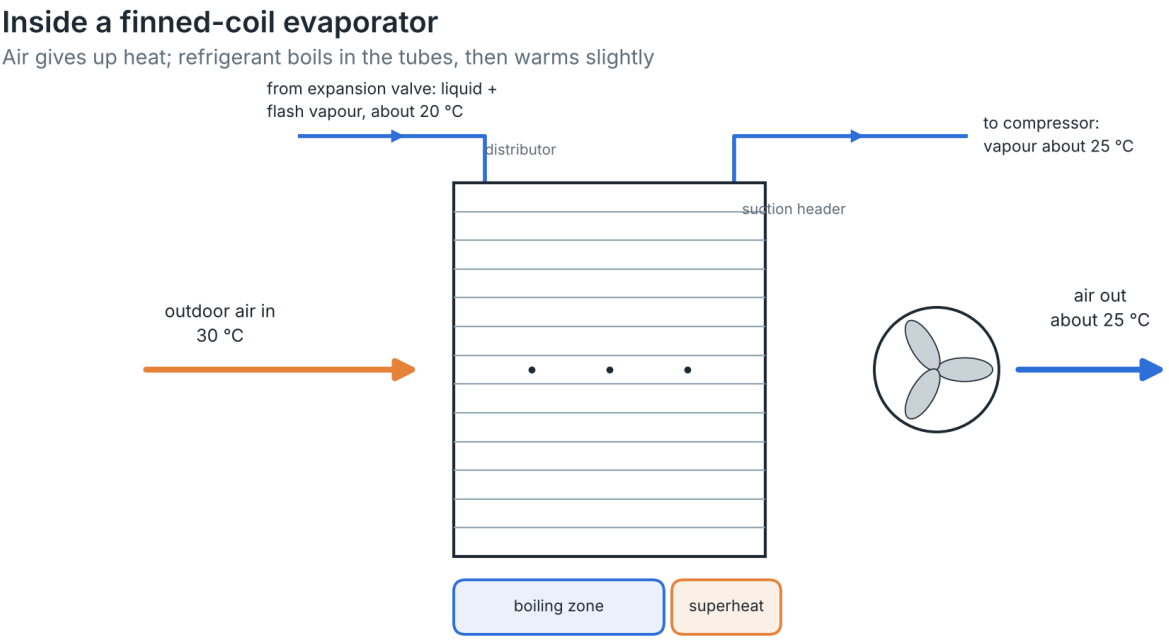
Key idea: The evaporator is where cold boiling refrigerant picks up heat from the source — outdoor air, water or ground loop.

In an **air-to-water** heat pump, the evaporator is a **finned-tube coil**. Copper tubes carry refrigerant; thin aluminium fins add surface area. A **fan** pulls outdoor air through the fins. The air leaves a few degrees colder.

Inside the tubes the refrigerant boils at a nearly constant temperature. This is the **evaporating temperature**, usually several degrees below air temperature. The difference is called the **approach** or temperature difference (TD). Typical air-coil TD is about 6–12 K.

Near the outlet all liquid has boiled away. The vapour then warms a few degrees more. This extra warming is the **superheat**. A small superheat proves no liquid will reach the compressor.

In water-source or ground-source units, the evaporator is a plate or shell-and-tube heat exchanger instead of a coil. The principle is the same.



Inside a finned-coil evaporator

Evaporator issue	Effect	Check
Dusty or blocked fins	Less air, lower evaporating pressure, lower COP	Clean with low-pressure water from inside out
Fan slow or failed	Low suction pressure, frost, LP trip	Fan current, blades, capacitor
Bent fins	Reduced airflow	Comb fins straight
Too little refrigerant	High superheat, low capacity	Superheat and pressures

Worked example — air flow needed for an 8 kW evaporator, air cooled by 5 K.

$$\dot{V} = \frac{Q}{\rho \, c_p \, \Delta T}$$

- Q = 8 kW. Air density ρ ≈ 1.2 kg/m³. c_p ≈ 1.005 kJ/kg·K. ΔT = 5 K.
- V = 8 ÷ (1.2 × 1.005 × 5) = 8 ÷ 6.03 ≈ 1.33 m³/s.
- In m³/h: 1.33 × 3,600 ≈ 4,780 m³/h.

Remember

- The evaporator absorbs heat by boiling refrigerant.
- More surface and more airflow mean higher evaporating temperature and better COP.
- Superheat at the outlet protects the compressor.
- Keep coils clean, especially in dusty or coastal Indian sites.

Common mistake: Installing the outdoor unit in a closed duct or pit. The cold discharge air recirculates and the unit "breathes its own exhaust".

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2.5 The condenser and heat exchangers: plate, shell-and-tube, tube-in-tube, coil-in-tank

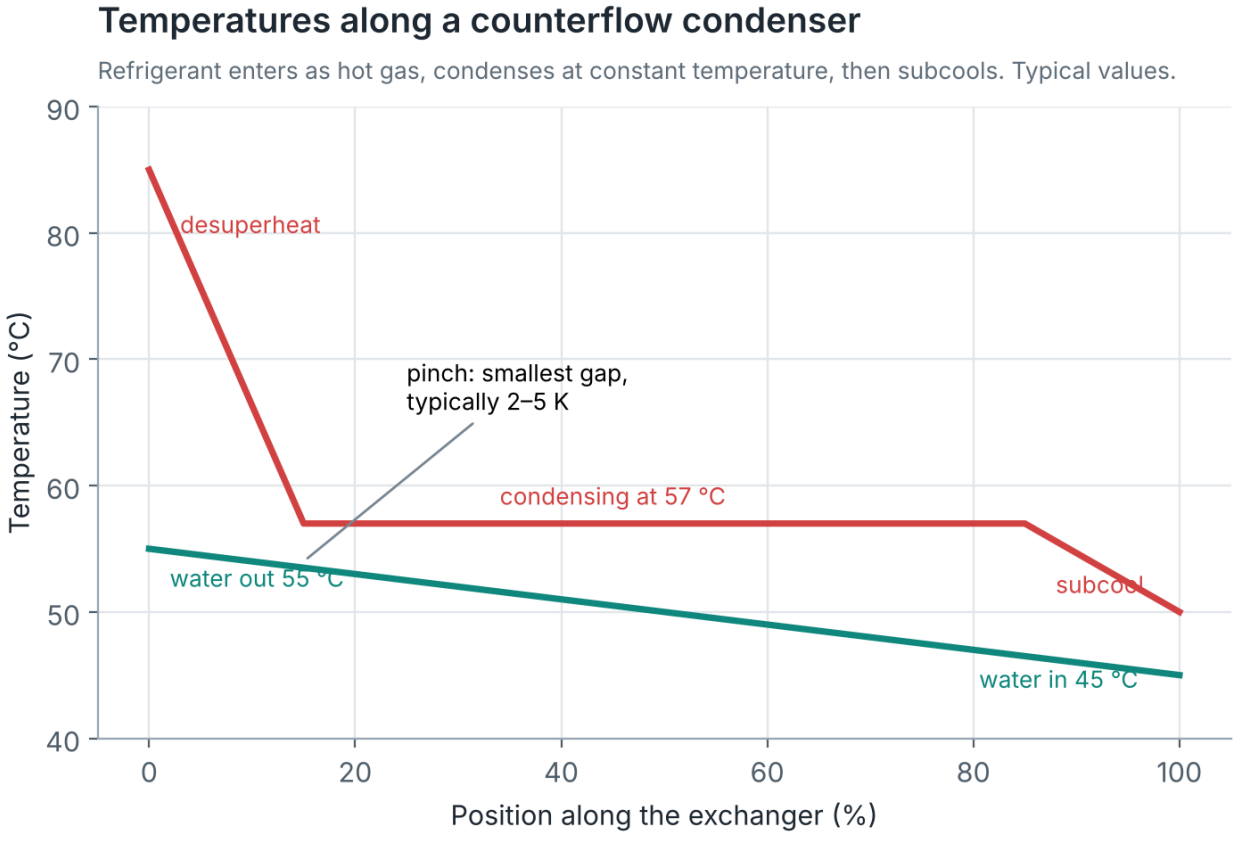
Key idea: The condenser hands the refrigerant's heat to the water; its type decides size, water-side pressure drop and how well it tolerates scale.

In the condenser, hot refrigerant gas gives up heat in three zones. First it **desuperheats** (hot gas cools to condensing temperature). Next it **condenses** (gas turns to liquid at constant temperature). Last it **subcools** (liquid cools a few degrees more).

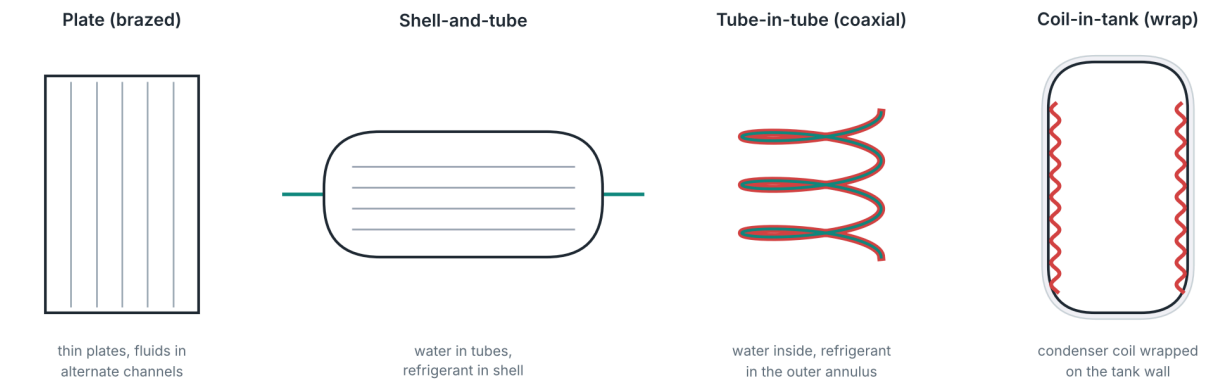
Water and refrigerant should flow in opposite directions. This is **counterflow**. It lets the water leave hotter and keeps the temperature difference even along the length.

Four types are common:

- **Brazed plate heat exchanger (BPHE):** stacked stainless plates brazed together. Very compact and efficient. Narrow channels can scale or block with hard water.
- **Shell-and-tube:** water in tubes, refrigerant in the shell (or the reverse). Bulky but tolerant of dirt and easy to clean mechanically.
- **Tube-in-tube (coaxial):** one tube inside another. Simple and robust, often used in pool heaters and small units.
- **Coil-in-tank:** a copper coil wrapped on or immersed in the storage tank. No water pump needed. Slower heat transfer.



Temperatures along a counterflow condenser



Four common heat exchanger types

Type	Compactness	Scale tolerance	Cleaning	Typical use
Brazed plate	Very high	Low	Chemical descaling only	Domestic, commercial, process
Shell-and-tube	Low	High	Mechanical (rod) and chemical	Large commercial, industrial
Tube-in-tube	Medium	Medium	Chemical	Pool heaters, small units
Coil-in-tank	— (part of tank)	Medium	Hard to reach	Small domestic all-in-one

Worked example — water flow through a 10 kW condenser with 5 K rise.

$$\dot{m} = \frac{Q}{c_p \, \Delta T}$$

- Q = 10 kW. c_p = 4.186 kJ/kg·K. ΔT = 5 K.
- m = 10 ÷ (4.186 × 5) = 0.478 kg/s.
- 0.478 kg/s × 3,600 ≈ 1,720 kg/h ≈ 1,720 LPH.

Remember

- Condensers work in three zones: desuperheat, condense, subcool.
- Counterflow gives the best temperatures.
- Plate exchangers are compact but scale-sensitive.
- Water flow must match the design ΔT.

Field tip: Many Indian borewell and municipal supplies are hard. Use a strainer and softener, and descale plate exchangers on schedule.

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2.6 Expansion devices: capillary, TXV, EEV

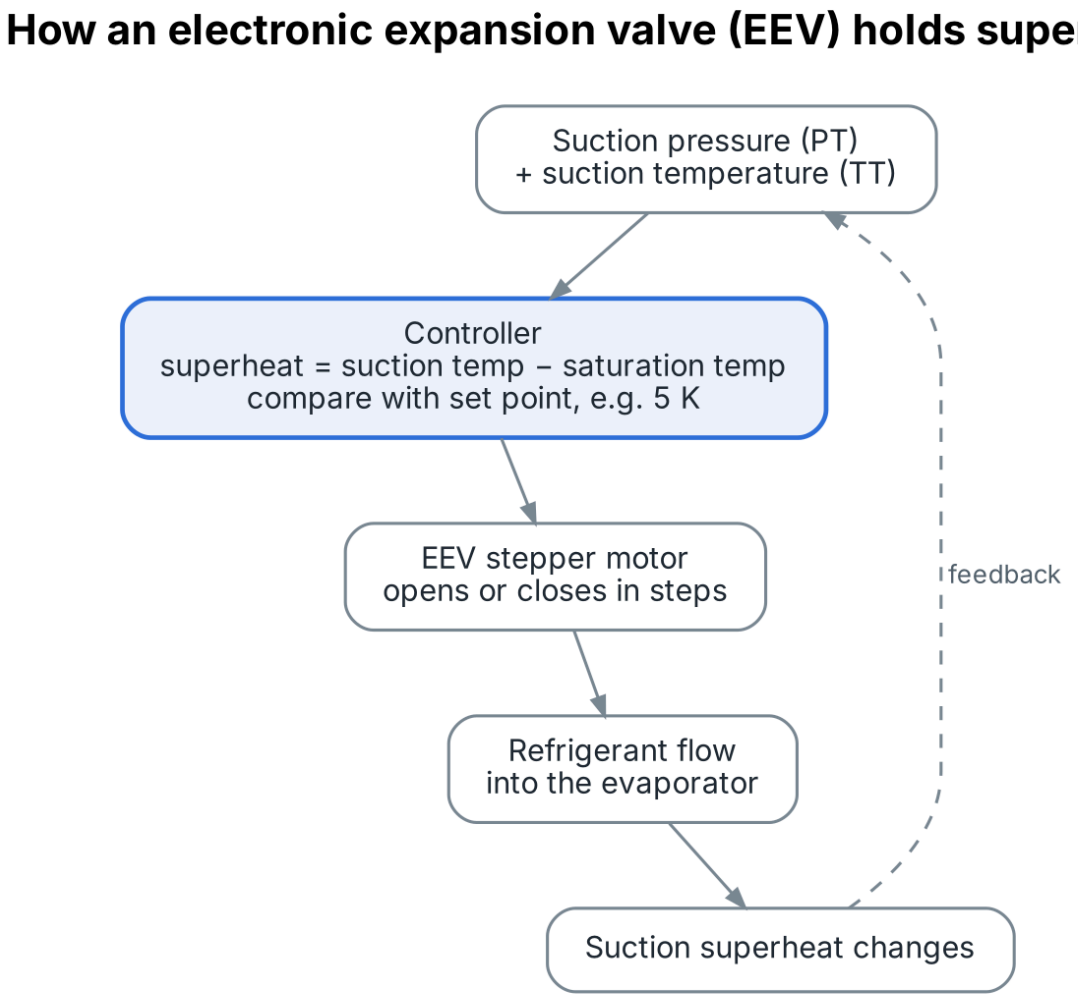
Key idea: The expansion device drops the refrigerant from high to low pressure and meters just enough flow to keep the evaporator full without flooding the compressor.

The expansion device sits between condenser and evaporator. It works like the nozzle on a garden hose. A small opening holds back pressure and lets a controlled flow through.

Capillary tube: a long thin copper tube with a fixed bore. Cheap, no moving parts. It cannot adjust to changing load, so it suits small units with steady conditions, like fridges.

Thermostatic expansion valve (TXV): a mechanical valve with a **sensing bulb** clamped on the suction line. If superheat rises, the bulb pressure opens the valve more. If superheat falls, it closes. It self-adjusts within its design range.

Electronic expansion valve (EEV): a valve moved by a **stepper motor**. A controller reads suction temperature and pressure, calculates superheat and sets the valve position. It responds fast and works over a wide range. Most inverter heat pumps use an EEV.



EEV superheat control loop

Device	Adjusts to load?	Cost	Typical use
Capillary tube	No (fixed)	Lowest	Small fixed-speed units
TXV	Yes, mechanically	Medium	Fixed-speed commercial units
EEV	Yes, electronically, wide range	Highest	Inverter units, wide operating range

Worked example — measuring superheat in the field.

$$SH = T_{suction\ line} - T_{sat}(P_{suction})$$

- Suction gauge reads a pressure whose saturation temperature (from the refrigerant P-T chart) is 2 °C.
- Clamp thermometer on suction line near the compressor reads 8 °C.
- Superheat = 8 − 2 = 6 K. This is within a typical target of about 4–8 K.

Subcooling is measured the same way on the liquid line: saturation temperature at discharge pressure minus liquid line temperature.

Remember

- The expansion device creates the low-pressure side.
- Capillary is fixed; TXV and EEV adjust.
- EEVs control superheat using sensors and a controller.
- Superheat too low risks liquid return; too high wastes evaporator surface.

Common mistake: Judging refrigerant charge from pressure alone. Always check superheat and subcooling too.

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2.7 Controls, sensors and safety devices

Key idea: Sensors tell the controller what the circuit is doing, and safety devices stop the unit before anything is damaged.

The **controller** is the unit's brain, usually a microprocessor board. It reads sensors, runs the compressor, fan, pump and valves, and logs faults.

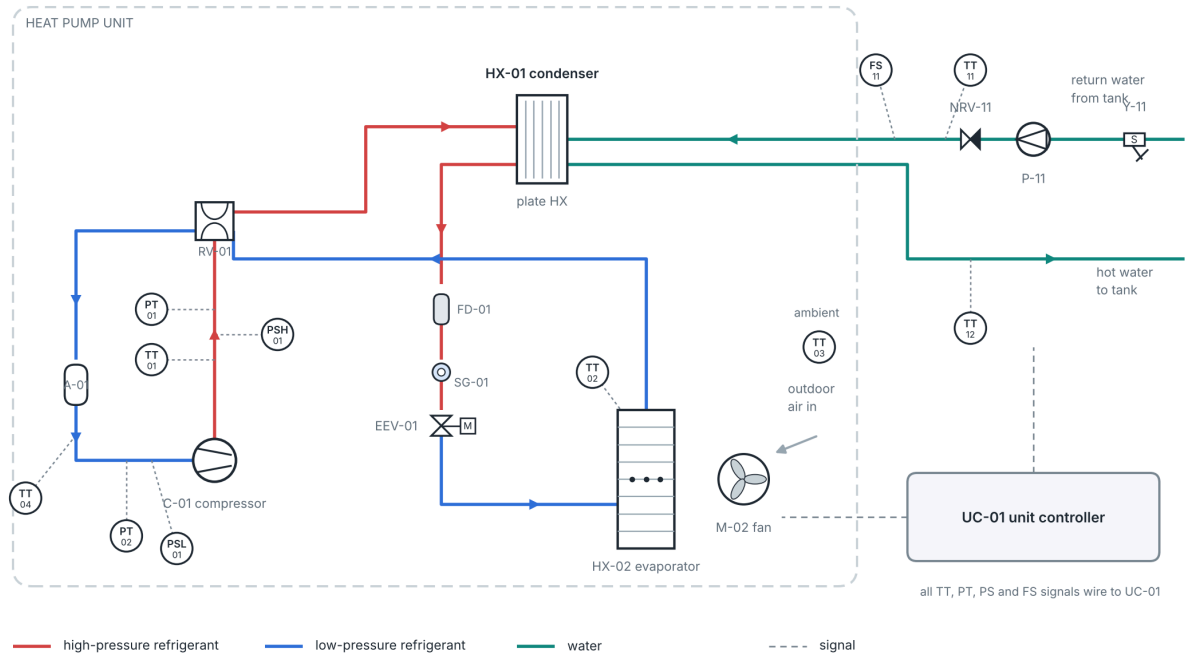
Temperature sensors are usually **NTC thermistors**. NTC means negative temperature coefficient: resistance falls as temperature rises. They are placed on water inlet and outlet, discharge, suction, coil and outdoor air.

Pressure transmitters give a continuous pressure reading. **Pressure switches** are on–off safety devices. The **high-pressure switch (HP)** opens if discharge pressure is too high, for example when water flow stops. The **low-pressure switch (LP)** opens if suction pressure is too low, for example on gas leak or heavy frost.

The **4-way reversing valve** swaps the roles of the two heat exchangers. It is used for defrost and, in some units, for cooling mode. A **flow switch** proves water is flowing before the compressor may start.

Air-to-water heat pump: refrigerant circuit P&ID

Heating mode. Hot side red, cold side blue, water teal, dashed = signal to controller UC-01



P&ID: refrigerant circuit of an air-to-water heat pump

Device	Tag	What it protects or measures	Typical action
High-pressure switch	PSH	Overpressure on discharge side	Stops compressor; often manual reset
Low-pressure switch	PSL	Low suction pressure (leak, frost, low airflow)	Stops compressor; auto reset with lockout after repeats
Discharge temp sensor	TT	Compressor overheating	Reduces speed or stops compressor
Water flow switch	FS	No-flow condition in condenser	Prevents compressor start
Coil temp sensor	TT	Frost on evaporator	Starts and ends defrost
Water outlet sensor	TT	Setpoint control, anti-freeze	Modulates or stops
Crankcase heater	—	Refrigerant migrating into oil when off	Heats compressor sump

Pressure switch set-points depend on refrigerant and design. Always use the value on the unit nameplate or service manual.

Remember

- Sensors measure; switches protect; the controller decides.
- HP switch trips are usually caused by no or low water flow.
- LP switch trips are usually caused by leaks, frost or poor airflow.
- Never bypass a safety switch to "get the unit running".

Field tip: Before replacing a "faulty" NTC sensor, measure its resistance and compare with the table in the service manual at the actual temperature.

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2.8 Reading a pressure–enthalpy (P-h) diagram

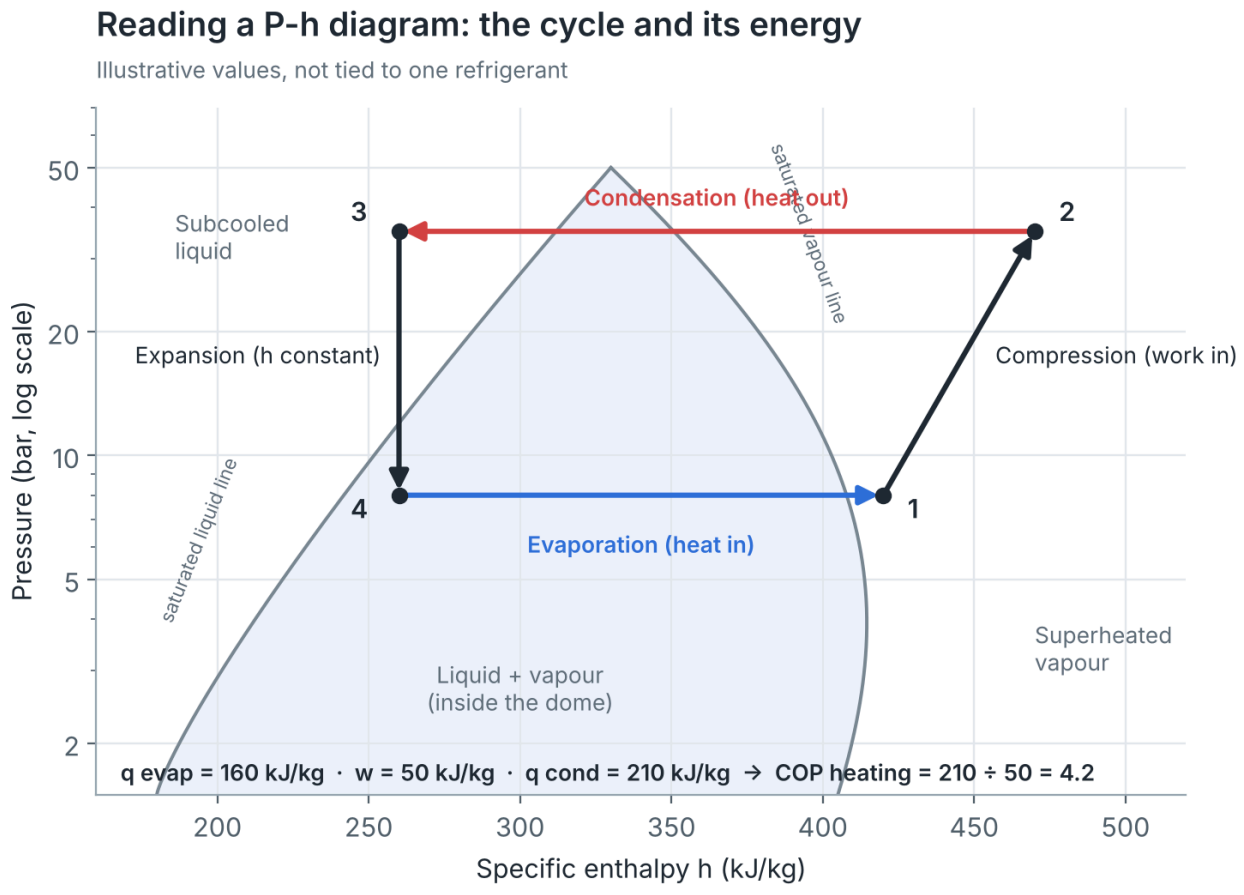
Key idea: The P-h diagram is a map of the refrigerant; the cycle drawn on it shows every state and lets you read heat and work directly as horizontal distances.

Enthalpy (h) is the heat content of one kilogram of refrigerant, in kJ/kg. On a P-h diagram, enthalpy runs along the bottom (x-axis). Pressure runs up the side (y-axis), usually on a log scale.

A dome-shaped curve sits in the middle. Left of the dome is liquid. Inside it is a liquid–vapour mix. Right of it is vapour. The left edge is the **saturated liquid line**; the right edge is the **saturated vapour line**.

The cycle draws as a rough box:

- **4 → 1, evaporation:** horizontal line at low pressure, moving right. The length is heat absorbed.
- **1 → 2, compression:** a line going up and to the right. The horizontal shift is compressor work.
- **2 → 3, condensation:** horizontal line at high pressure, moving left. The length is heat delivered.
- **3 → 4, expansion:** a vertical line straight down. Enthalpy does not change.



P-h diagram with the cycle and its energy

Worked example — COP from a P-h diagram (illustrative enthalpies).

$$COP_{heating} = \frac{h_2 - h_3}{h_2 - h_1}$$

- Read from the diagram: h1 = 420 kJ/kg, h2 = 470 kJ/kg, h3 = h4 = 260 kJ/kg.
- Heat delivered q_{cond} = 470 − 260 = 210 kJ/kg.
- Compressor work w = 470 − 420 = 50 kJ/kg.
- COP = 210 ÷ 50 = 4.2.
- Check: q_{evap} = 420 − 260 = 160 kJ/kg, and 160 + 50 = 210. The balance holds.

Mass flow for a 12 kW unit: m = 12 ÷ 210 ≈ 0.057 kg/s.

Remember

- Horizontal = pressure constant; vertical = enthalpy constant.
- Evaporation and condensation are horizontal lines.
- Expansion is vertical: no energy added or removed.
- COP = condenser enthalpy change ÷ compressor enthalpy change.

Field tip: Keep a P-h chart and P-T chart for each refrigerant you service. Gauge readings mean nothing without them.

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2.9 What drives COP: temperature lift and operating conditions

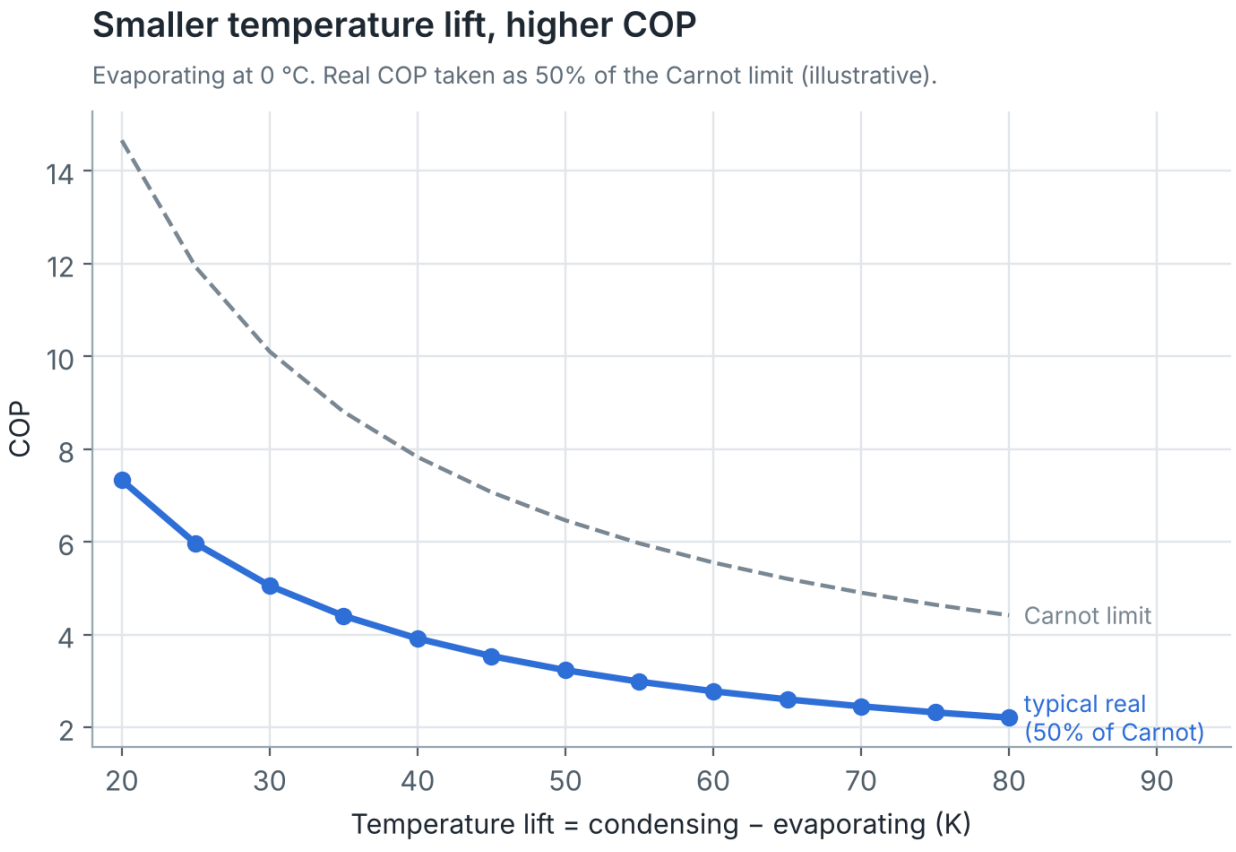
Key idea: COP depends mostly on temperature lift — the gap between the source temperature and the delivery temperature; the smaller the lift, the higher the COP.

Temperature lift is condensing temperature minus evaporating temperature. A small lift is like pumping water up one floor. A big lift is like pumping it up to the tenth floor. The higher the climb, the more work per litre.

Physics sets a ceiling called the **Carnot COP**. It uses absolute temperatures in kelvin (°C + 273.15). Real heat pumps typically reach about 40–60% of Carnot COP, because of compressor losses, heat exchanger temperature differences and pressure drops.

So COP rises when:

- the source is warmer (summer air in Chennai beats winter air in Delhi);
- the delivery water is cooler (45 °C needs less lift than 65 °C);
- heat exchangers are clean and correctly sized (smaller approach temperatures);
- water and air flows are correct.



COP vs temperature lift

Temperature lift (K)	Condensing temp (°C)	Carnot COP	Approx. real COP (50% of Carnot)
20	20	14.7	7.3
30	30	10.1	5.1
40	40	7.8	3.9
50	50	6.5	3.2
60	60	5.6	2.8
70	70	4.9	2.5

All rows assume an evaporating temperature of 0 °C, so condensing temperature equals the lift.

Worked example — same unit, Chennai summer vs Delhi winter, water at 55 °C.

$$COP_{Carnot} = \frac{T_{cond}}{T_{cond} - T_{evap}} \quad (T \text{ in kelvin})$$

- Assume condensing at 60 °C (5 K above water) = 333.15 K.
- Chennai, air 32 °C, evaporating about 24 °C = 297.15 K. Lift = 36 K. Carnot COP = 333.15 ÷ 36 ≈ 9.3. Real at 50% ≈ 4.6.
- Delhi winter, air 8 °C, evaporating about 0 °C = 273.15 K. Lift = 60 K. Carnot COP = 333.15 ÷ 60 ≈ 5.6. Real at 50% ≈ 2.8.
- Daily 17.4 kWh of heat (from lesson 2.1): Chennai 17.4 ÷ 4.6 ≈ 3.8 kWh ≈ ₹34; Delhi 17.4 ÷ 2.8 ≈ 6.2 kWh ≈ ₹56 (₹9/kWh example rate).

Remember

- Lift is the main driver of COP.
- Lower the delivery temperature whenever the application allows.
- Carnot COP is a ceiling; real units reach about half of it (typical).
- Always quote COP with its test conditions (air and water temperatures).

Common mistake: Comparing two units' COPs measured at different conditions. A COP without its air and water temperatures is meaningless.

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2.10 Defrost and low-ambient operation

Key idea: When outdoor air is cold and humid, frost forms on the evaporator; the unit must periodically melt it, and at very low temperatures capacity and COP both fall.

When the coil surface goes below 0 °C, moisture in the air freezes on the fins. Frost blocks airflow, like ice in an old freezer. Suction pressure falls and capacity drops.

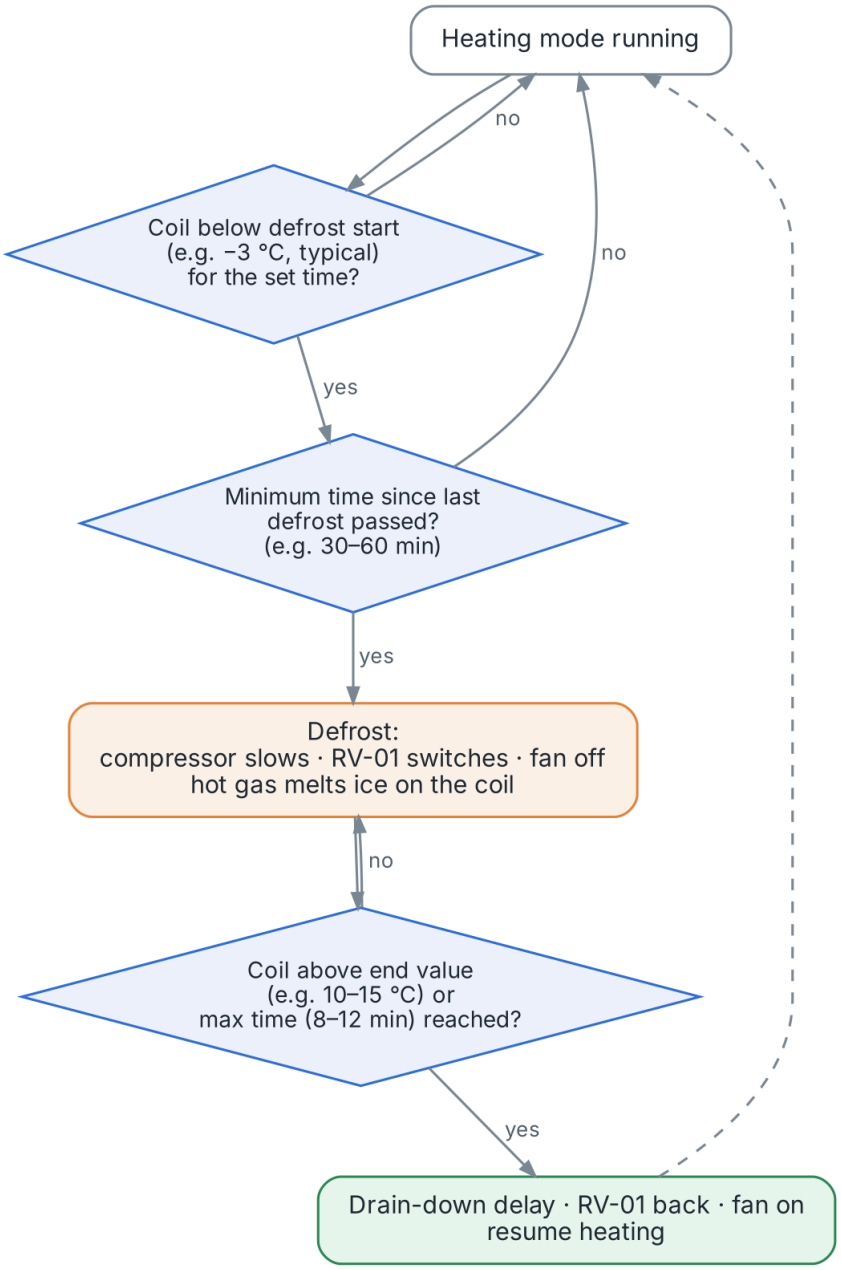
Frosting is worst with outdoor air around −5 °C to +7 °C and high humidity (typical). In very dry, very cold air there is less moisture, so less frost. In India this matters in north Indian winters, hill stations and humid winter mornings; it rarely matters in coastal south India.

Reverse-cycle defrost is the most common method. The 4-way valve switches, so hot gas goes to the outdoor coil and melts the frost. The fan stops so heat stays on the coil. Heat is briefly taken from the water side. **Hot-gas bypass defrost** sends some discharge gas directly to the evaporator without reversing.

The controller starts defrost using coil temperature, time since last defrost, and sometimes the coil-to-air temperature difference. It ends defrost when the coil is warm enough or after a maximum time. Good logic defrosts only when needed.

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How a defrost cycle is triggered and ended (typical settings)



How a defrost cycle starts and ends

Low-ambient challenge	Effect	Design response
Frost on coil	Lower airflow and capacity	Defrost logic, wide fin spacing
Low suction pressure	High compression ratio, hot discharge	EVI (enhanced vapour injection) or two-stage compressor
Refrigerant migration when off	Oil dilution, liquid at start	Crankcase heater
Melt water freezing at base	Ice builds up, blocks drain	Base-pan heater, raised mounting
Water pipes freezing	Burst pipes, damaged exchanger	Anti-freeze pump run, glycol, trace heating

Enhanced vapour injection (EVI) injects extra vapour mid-way through compression. It cools the compressor and restores capacity at low ambient.

Remember

- Frost forms when the coil is below 0 °C and the air is humid.
- Reverse-cycle defrost uses the 4-way valve to send hot gas to the coil.
- Defrost uses energy, so it should run only when needed.
- Capacity and COP fall as outdoor air gets colder.

Field tip: Mount outdoor units on a stand above snow and melt-water level, and keep the drain path clear of ice.

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Quiz 2

1. A heat pump delivers 12 kW of heat and draws 3 kW. What is its COP?
    - A) 0.25
    - B) 3
    - C) 4
    - D) 9
2. Where does the refrigerant absorb heat?
    - A) Condenser
    - B) Evaporator
    - C) Compressor
    - D) Expansion valve
3. What happens to the refrigerant in the expansion device?
    - A) Pressure rises
    - B) It condenses
    - C) Pressure drops and part of it flashes
    - D) It is superheated
4. Which compressor type is most common in mid-size units of about 5–100 kW?
    - A) Screw
    - B) Scroll
    - C) Centrifugal
    - D) Capillary
5. "Inverter" in a heat pump means:
    - A) A type of evaporator
    - B) A variable-speed drive for the compressor
    - C) A reversing valve
    - D) A safety switch
6. Suction line is 9 °C and saturation temperature at suction pressure is 3 °C. Superheat is:
    - A) 3 K
    - B) 6 K
    - C) 9 K
    - D) 12 K
7. The most likely cause of a high-pressure switch trip in water heating is:
    - A) Dirty outdoor coil
    - B) Low water flow through the condenser
    - C) Low ambient air
    - D) Too much superheat
8. On a P-h diagram, the expansion process is:
    - A) A horizontal line

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- B) A vertical line
- C) A curve to the right
- D) A loop

9. Which change raises COP the most?
   - A) Raising water set-point from 45 °C to 60 °C
   - B) Lowering temperature lift
   - C) Running the fan slower
   - D) Blocking the coil
10. During reverse-cycle defrost:
   - A) Hot gas is sent to the outdoor coil and the fan stops
   - B) The water pump is switched off permanently
   - C) The compressor runs backward
   - D) Cold air melts the frost

Answer key

1. C — COP = 12 ÷ 3 = 4.
2. B — The evaporator boils refrigerant, absorbing heat from the source.
3. C — The device drops pressure, so some liquid flashes to vapour and cools.
4. B — Scroll compressors dominate the mid range.
5. B — An inverter changes compressor motor speed to match load.
6. B — 9 − 3 = 6 K.
7. B — No or low water flow means heat is not removed, so discharge pressure rises.
8. B — Expansion happens at constant enthalpy, so it is a vertical line.
9. B — COP rises as lift falls; the other options increase lift or reduce heat transfer.
10. A — The 4-way valve sends hot gas to the outdoor coil; the fan stops to keep heat on the coil.

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Glossary

Term	Meaning
Heat pump	Machine that moves heat from a cold source to a warmer sink using work
COP	Coefficient of performance: useful heat ÷ electricity used
Refrigerant	Working fluid that boils and condenses in the circuit
Evaporator	Heat exchanger where refrigerant boils and absorbs heat
Condenser	Heat exchanger where refrigerant condenses and releases heat
Compressor	Pump that raises refrigerant pressure and temperature
Expansion device	Restriction that drops refrigerant pressure (capillary, TXV, EEV)
TXV	Thermostatic expansion valve, controlled by a suction-line bulb
EEV	Electronic expansion valve, moved by a stepper motor and controller
Superheat	Vapour temperature above its saturation temperature
Subcooling	Liquid temperature below its saturation temperature
Saturation temperature	Boiling or condensing temperature at a given pressure
Enthalpy	Heat content per kg of refrigerant, kJ/kg
P-h diagram	Chart of pressure vs enthalpy used to plot the cycle
Temperature lift	Condensing temperature minus evaporating temperature
Carnot COP	Theoretical maximum COP from absolute temperatures
Approach	Temperature gap between refrigerant and air or water in an exchanger
Counterflow	Two fluids flowing in opposite directions in an exchanger
BPHE	Brazed plate heat exchanger
Hermetic compressor	Motor and compressor sealed in one welded shell
Inverter	Variable-speed drive for the compressor motor
4-way reversing valve	Valve that swaps high and low sides for defrost or cooling
NTC thermistor	Temperature sensor whose resistance falls as temperature rises
HP / LP switch	High- and low-pressure safety switches
Defrost	Melting frost from the evaporator coil
EVI	Enhanced vapour injection, improves low-ambient capacity
Crankcase heater	Heater that keeps refrigerant out of compressor oil when off

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> *It started as an instinct. In 2012 I wanted to do something in energy conservation. That was the whole of it. There was no plan to build machines, and no plan to build them in India. Both came later.*

Kashyap founded Sunniva Encon in 2012 to work on energy conservation. The company now designs and builds heat pumps at its own factory in Asangaon, Maharashtra, with its office in Mumbai, and supplies hot water, space heating and process heat systems across India, including remote, high-altitude sites.

Over these years he has seen heat pumps chosen, sized, installed and serviced in every kind of Indian condition, and seen how often good machines are let down by poor selection, rushed installation or missing maintenance. Most of those problems come from knowledge that is not widely taught.

This program is his answer: an open, vendor-neutral course that shares that knowledge with students, technicians, installers, consultants and facility teams. It teaches the technology, not a brand. The lessons carry no product names or sales claims; Sunniva's part is only to make the material available.

- Founder Director, Sunniva Encon LLP, since 2012
- More than 5,000 heat pump installations across India
- Own heat pump factory in Asangaon, Maharashtra, built for 2,000 machines a year
- Nationwide service network reaching sites as remote as Leh
- Published research paper on ScienceDirect (Elsevier, 2015): sciencedirect.com/science/article/pii/S1877050915007735

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THANK YOU.

Thank you for learning with us. Questions, corrections and suggestions for the next edition are welcome.

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