
HEAT PUMP TRAINING PROGRAM

Course 1 – Heat, Energy and Refrigeration Basics

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

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Course 1 — Heat, Energy and Refrigeration Basics

Powered by Sunniva. This is a Level 1 Foundations course for everyone: students, new technicians, plumbers and facility staff. No prior engineering study is needed. After this course you will be able to: (1) explain the difference between heat and temperature and convert between kW, kcal/h, TR and BTU/h; (2) calculate the heat needed to warm water or change its phase; (3) read a refrigerant pressure and know its saturation temperature; (4) explain why a heat pump delivers more heat than the electricity it uses.

1.1 Heat vs temperature: what we are really moving

Key idea: Temperature tells us how hot something is; heat is the energy that flows because of a temperature difference.

Temperature is a measure of how fast the molecules in a substance are moving. We measure it in degrees Celsius (°C) or kelvin (K). A thermometer reads temperature, not heat.

Heat is energy in transit. It always flows from a hotter body to a colder body, on its own. We measure heat in joules (J), kilojoules (kJ) or kilowatt-hours (kWh).

Think of a cup of chai and a full bucket of bath water, both at 60 °C. They have the same temperature. But the bucket holds far more heat, because it has far more water.

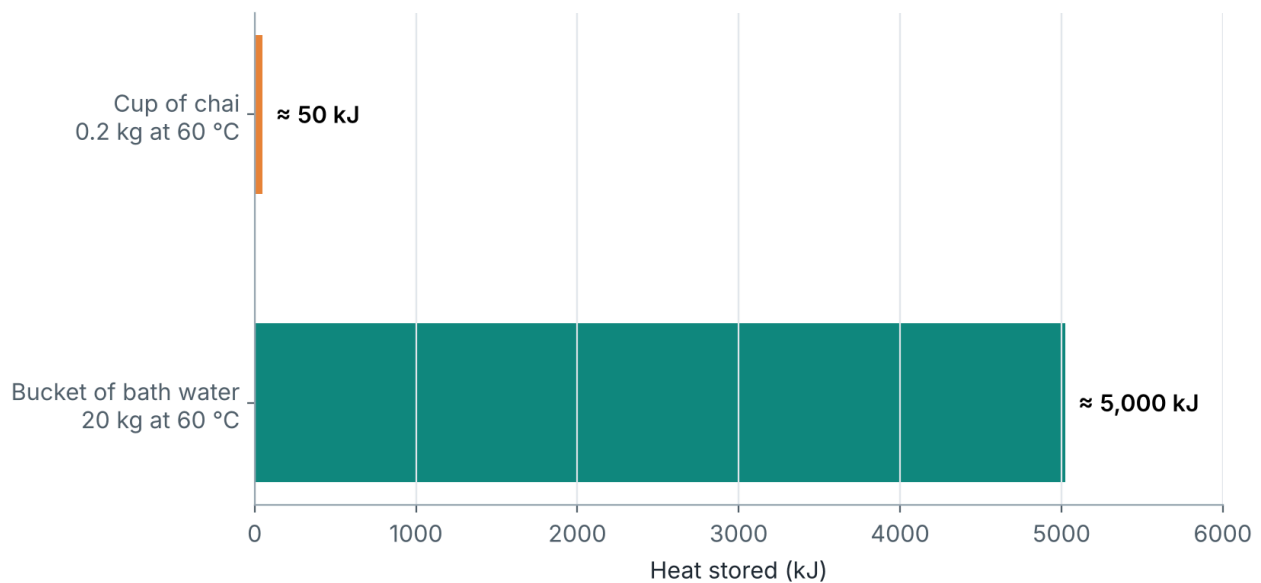
A heat pump does not "make" heat. It moves heat from a cooler place, like outdoor air, into a warmer place, like a hot water tank. That is why we always ask: how much heat, at what temperature?

The kelvin scale starts at absolute zero, the coldest possible temperature. $0\text{ K} = -273.15\text{ °C}$. A temperature *difference* of 1 K is the same size as 1 °C.



Same temperature, very different amounts of heat

Heat stored relative to 0 °C, using $Q = m \times c_p \times \Delta T$. A thermometer reads 60 °C in both. The bucket holds 100 times more heat.



Same temperature, very different amounts of heat

Quantity	What it tells you	Unit (SI)	Measured with
Temperature	How hot or cold	°C or K	Thermometer, sensor
Heat (energy)	How much energy moved	kJ, kWh	Calculated or heat meter
Heat rate (power)	How fast energy moves	kW	Calculated or heat meter

Worked example — heat stored in a bucket vs a cup

$$Q = m \times c_p \times \Delta T$$

- Water specific heat, $c_p = 4.186 \text{ kJ/kg}\cdot\text{K}$ (typical value near room temperature).
- Cup: $Q = 0.2 \times 4.186 \times (60 - 0) = 50.2 \text{ kJ}$.
- Bucket: $Q = 20 \times 4.186 \times (60 - 0) = 5,023 \text{ kJ}$.
- Same temperature, but the bucket holds 100 times more heat.

Remember

- Temperature is a level; heat is a quantity of energy.
- Heat flows naturally from hot to cold only.
- A temperature difference of 1 K equals a difference of 1 °C.
- A heat pump moves heat; it does not create it.

Common mistake: Saying "this geyser has more temperature". Say it has a higher temperature, or more heat stored.

1.2 Units that matter: kW, kcal/h, TR, BTU/h and converting between them

Key idea: All heating and cooling capacities are rates of energy flow, and they convert to kW with a few fixed numbers.

Capacity means how much heat a machine moves per unit time. The SI unit is the kilowatt (kW). One kW means one kilojoule every second.

In India you will still meet older units on nameplates and quotations. Cooling is often quoted in tons of refrigeration (TR). Boilers are often quoted in kcal/h. Imported equipment may use BTU/h (British thermal units per hour).

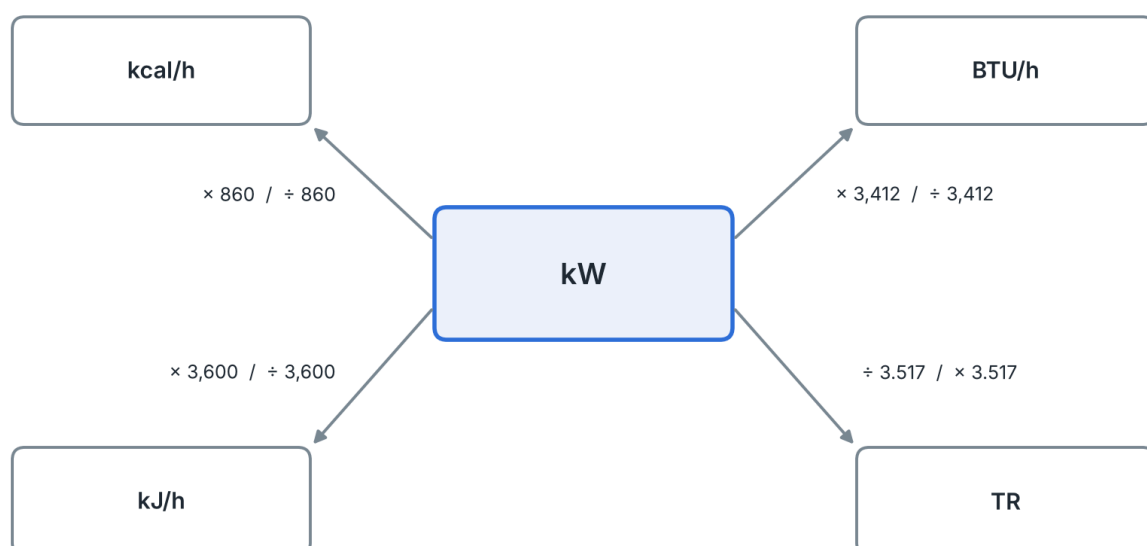
One TR is the heat needed to melt one short ton of ice in 24 hours. It is a cooling rate, not a weight. A "1.5 ton AC" removes about 5.3 kW of heat.

Energy (kWh) and power (kW) are different. Power is the rate. Energy is power multiplied by time. A 2 kW heater running 3 hours uses 6 kWh.

From	To kW multiply by	Notes
1 kcal/h	0.001163	1 kW = 860 kcal/h
1 TR	3.517	1 TR = 12,000 BTU/h = 3,024 kcal/h
1 BTU/h	0.000293	1 kW = 3,412 BTU/h
1 HP (motor power)	0.746	Mechanical/electrical power, not heat capacity

Convert any capacity unit through kW

Multiply going out from kW, divide coming back



Examples: 10 kW = 8,600 kcal/h = 34,120 BTU/h = 2.84 TR. A 1.5 TR AC moves about 5.3 kW.

Convert any capacity unit through kW

Worked example — compare a boiler and a heat pump quote

A hotel in Pune has an old boiler rated 1,00,000 kcal/h. A new quote gives a heat pump in kW. What kW matches?

$$P_{kW} = \frac{P_{kcal/h}}{860}$$

- $P = 1,00,000 \div 860 = 116.3$ kW.
- In TR terms: $116.3 \div 3.517 = 33.1$ TR.
- In BTU/h: $116.3 \times 3,412 = 3,96,800$ BTU/h (about 4 lakh BTU/h).

Remember

- Convert everything to kW first, then compare.
- 1 TR = 3.517 kW; 1 kW = 860 kcal/h; 1 kW = 3,412 BTU/h.
- kW is a rate (power); kWh is an amount (energy).
- HP on a compressor is motor power, not heating capacity.

Field tip: When a customer says "2 ton", ask whether that is cooling capacity or compressor motor HP. They are not the same.



1.3 Sensible and latent heat

Key idea: Sensible heat changes temperature; latent heat changes phase (solid, liquid, gas) without changing temperature.

When you heat water on a stove from 25 °C to 100 °C, the thermometer rises. That heat is called sensible heat, because you can "sense" it on a thermometer.

Once water reaches 100 °C at sea level, it starts boiling. The flame keeps adding heat, but the temperature stays at 100 °C until all the water turns to steam. That hidden heat is called latent heat.

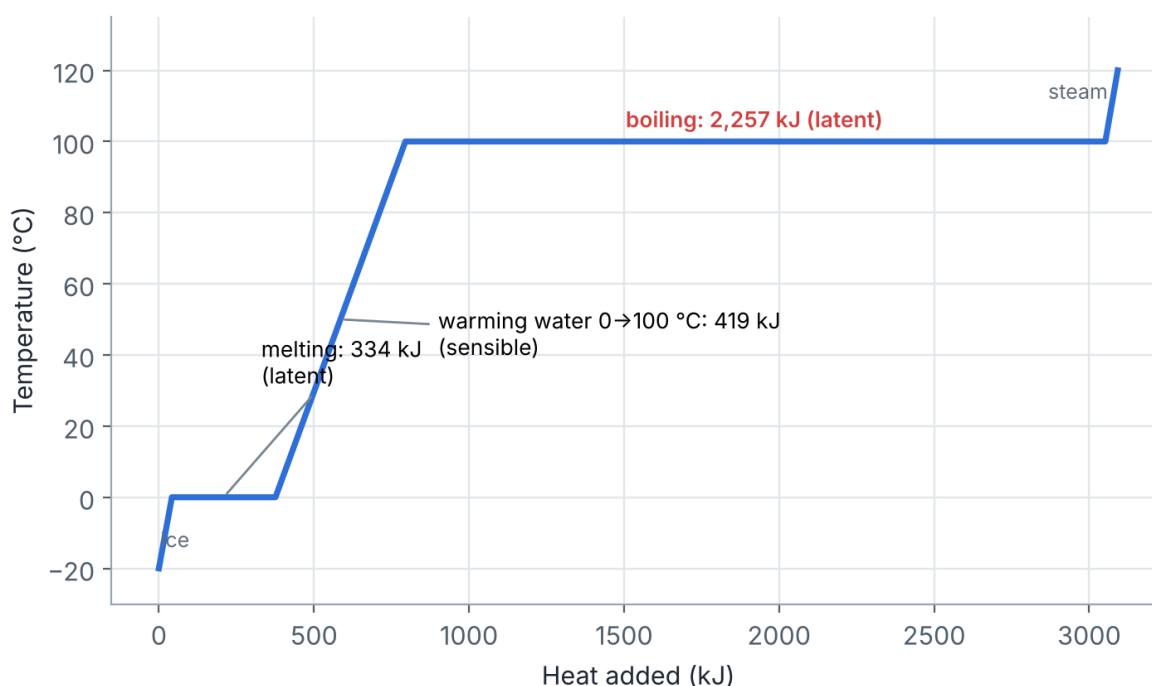
Latent heat is large. Turning 1 kg of boiling water into steam needs about 2,257 kJ. Warming the same kg from 0 °C to 100 °C needs only about 419 kJ.

A clay matka cools water using latent heat. A little water seeps through the clay and evaporates. Evaporation takes latent heat from the remaining water, so it gets cooler.

Refrigeration and heat pumps depend on latent heat. The refrigerant absorbs a lot of heat when it evaporates and gives it back when it condenses.

Heating curve of 1 kg of water at sea level

Sloped parts = sensible heat (temperature rises). Flat parts = latent heat (phase changes, temperature stays).



Heating curve of 1 kg of water

Property of water (typical, 1 atm)	Value
Specific heat of liquid water	4.186 kJ/kg·K
Specific heat of ice	about 2.1 kJ/kg·K
Latent heat of fusion (melting ice)	about 334 kJ/kg
Latent heat of vaporisation at 100 °C	about 2,257 kJ/kg

Worked example — warming a 100 L geyser in Bengaluru

Cold water comes in at 25 °C. We want 60 °C. 100 L of water is about 100 kg.

$$Q = m \times c_p \times \Delta T$$

- $Q = 100 \times 4.186 \times (60 - 25) = 14,651 \text{ kJ}$.
- Convert to kWh: $14,651 \div 3,600 = 4.07 \text{ kWh}$.
- With an electric element (close to 100% efficient) at an example rate of ₹9/kWh: $4.07 \times 9 = \text{about ₹37}$.
- If that same 100 kg were boiled to steam, it would need another $100 \times 2,257 = 2,25,700 \text{ kJ}$ (62.7 kWh). Latent heat is big.

Remember

- Sensible heat shows on a thermometer; latent heat does not.
- $Q = m \times c_p \times \Delta T$ for sensible heat; $Q = m \times h_{fg}$ for latent heat.
- Evaporation absorbs heat; condensation releases it.
- Refrigerants carry heat mainly as latent heat.

Field tip: 1 kWh warms about 860 L of water by 1 K. That is a handy check on any hot water calculation.



1.4 Conduction, convection and radiation

Key idea: Heat travels in three ways: through solids by conduction, with moving fluids by convection, and as infrared waves by radiation.

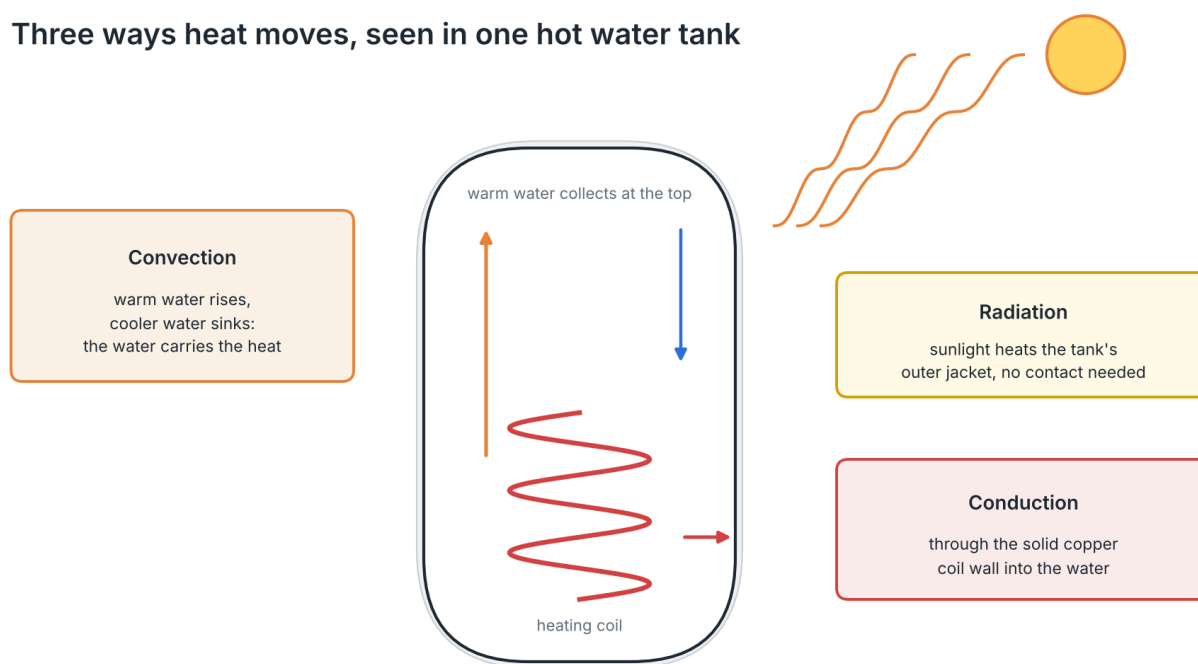
Conduction is heat passing through a material, molecule to molecule. A steel spoon in hot chai gets hot at the handle. Copper and aluminium conduct well, which is why heat exchangers use them.

Convection is heat carried by a moving fluid, such as air or water. Natural convection happens on its own: hot water rises in a geyser tank. Forced convection uses a fan or pump, like the fan on an outdoor unit.

Radiation is heat travelling as infrared waves. It needs no medium. You feel it from the sun on a terrace, or from a hot tandoor wall.

Insulation works by slowing conduction. Materials like PUF (polyurethane foam) and nitrile rubber trap tiny pockets of still gas. Still air and gas conduct heat poorly.

Three ways heat moves, seen in one hot water tank



Conduction, convection and radiation in a hot water tank

Material	Thermal conductivity, W/m·K (typical)	Use
Copper	about 390	Tubes, heat exchangers
Aluminium	about 200	Fins
Carbon steel	about 50	Tanks, pipes
Stainless steel	about 15	Tanks, plate heat exchangers
Water	about 0.6	Heat transfer fluid
Still air	about 0.026	Trapped in insulation
PUF insulation	about 0.022–0.030	Tank and pipe insulation

Worked example — heat loss through a pipe wall vs insulation (conduction)

Compare 1 m² of 2 mm steel with 1 m² of 25 mm PUF, each with a 40 K temperature difference.

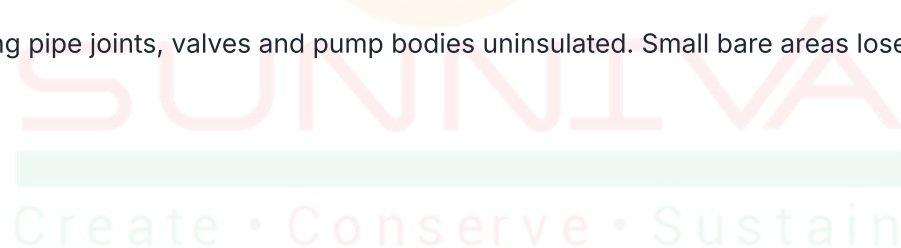
$$Q = \frac{k \times A \times \Delta T}{t}$$

- Steel: $Q = (50 \times 1 \times 40) \div 0.002 = 10,00,000$ W. In practice, the air film outside limits this, but steel offers almost no resistance.
- PUF: $Q = (0.025 \times 1 \times 40) \div 0.025 = 40$ W.
- The insulation cuts conduction by a factor of tens of thousands. This is why uninsulated hot pipes waste so much energy.

Remember

- Conduction: through solids. Convection: by moving fluid. Radiation: by infrared waves.
- Good conductors (copper, aluminium) go where we want heat to pass.
- Insulation works by trapping still gas.
- Fans and pumps turn natural convection into faster forced convection.

Common mistake: Leaving pipe joints, valves and pump bodies uninsulated. Small bare areas lose a surprising share of heat.



1.5 The laws of thermodynamics in plain words

Key idea: Energy is never created or destroyed, and heat only flows from cold to hot if we spend work to push it.

Thermodynamics is the science of heat, work and energy. Four laws are usually listed, numbered zero to three. For heat pump work, the first two matter most.

Zeroth law. If two bodies are each at the same temperature as a third, they are at the same temperature as each other. This is why thermometers work.

First law (conservation of energy). Energy can change form but cannot be created or destroyed. In a heat pump: heat delivered = heat taken from the source + electrical work put in.

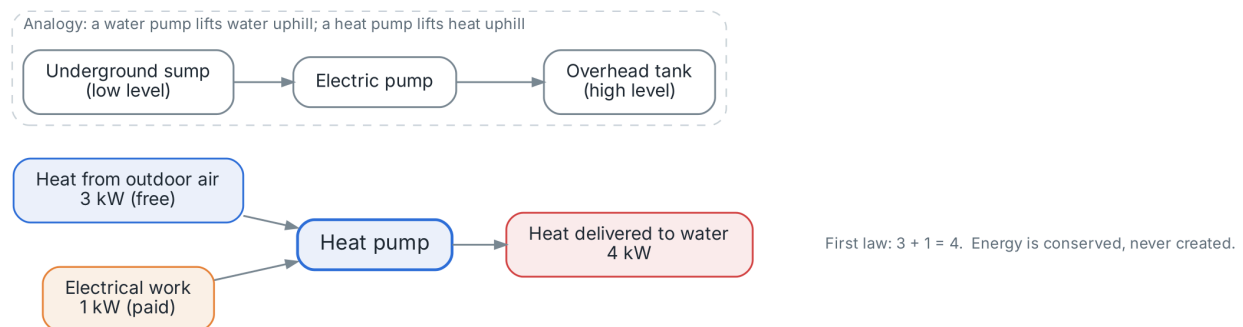
Second law. Heat flows naturally from hot to cold. To move heat from cold to hot, you must supply work. A fridge needs electricity to push heat out of the cold cabinet into the warmer kitchen.

The second law also sets a ceiling. No real machine can beat the ideal Carnot cycle, a theoretical perfect cycle. Real machines reach only part of that limit.

Third law. As a substance approaches absolute zero (0 K), its disorder approaches a minimum. It rarely matters in field work.

Think of a water pump lifting water from a sump to an overhead tank. Water flows down by itself. Lifting it up needs a pump and electricity. A heat pump "lifts" heat in the same way.

Energy balance of a heat pump



Energy balance of a heat pump

Law	Plain words	What it means for a heat pump
Zeroth	Equal temperatures are in balance	Sensors and thermometers can be trusted
First	Energy is conserved	Heat out = heat in + work in
Second	Heat flows hot to cold unless work is added	Compressor work is needed; there is a maximum COP
Third	Absolute zero is a limit	Temperatures in K are always positive

Worked example — ideal (Carnot) heating COP for a Chennai hot water job

Source: outdoor air at 30 °C. Sink: water at 60 °C. Convert to kelvin first.

$$COP_{Carnot,heating} = \frac{T_{hot}}{T_{hot} - T_{cold}}$$

- $T_{\text{hot}} = 60 + 273 = 333 \text{ K}$; $T_{\text{cold}} = 30 + 273 = 303 \text{ K}$.
- $\text{COP}_{\text{Carnot}} = 333 \div (333 - 303) = 333 \div 30 = 11.1$.
- Real air-source heat pumps at these conditions typically reach COP 3.5–4.5, about 30–40% of Carnot.

Remember

- First law: heat delivered = source heat + electrical input.
- Second law: moving heat uphill always costs work.
- Smaller temperature lift means higher possible COP.
- Always use kelvin in Carnot formulas.

Common mistake: Using °C in the Carnot formula. $60 \div 30 = 2$ is wrong; $333 \div 30 = 11.1$ is right.



1.6 Pressure, boiling point and saturation

Key idea: The temperature at which a liquid boils depends on pressure; higher pressure means a higher boiling point.

Pressure is force per unit area. We use bar. Atmospheric pressure at sea level is about 1.013 bar.

Gauges usually read gauge pressure (bar g), which is pressure above atmosphere. Absolute pressure (bar a) is gauge pressure plus atmospheric pressure. Refrigerant tables use absolute pressure.

A pressure cooker is the best example. The weight holds the pressure at about 1 bar above atmosphere. Water then boils at about 120 °C instead of 100 °C, so food cooks faster.

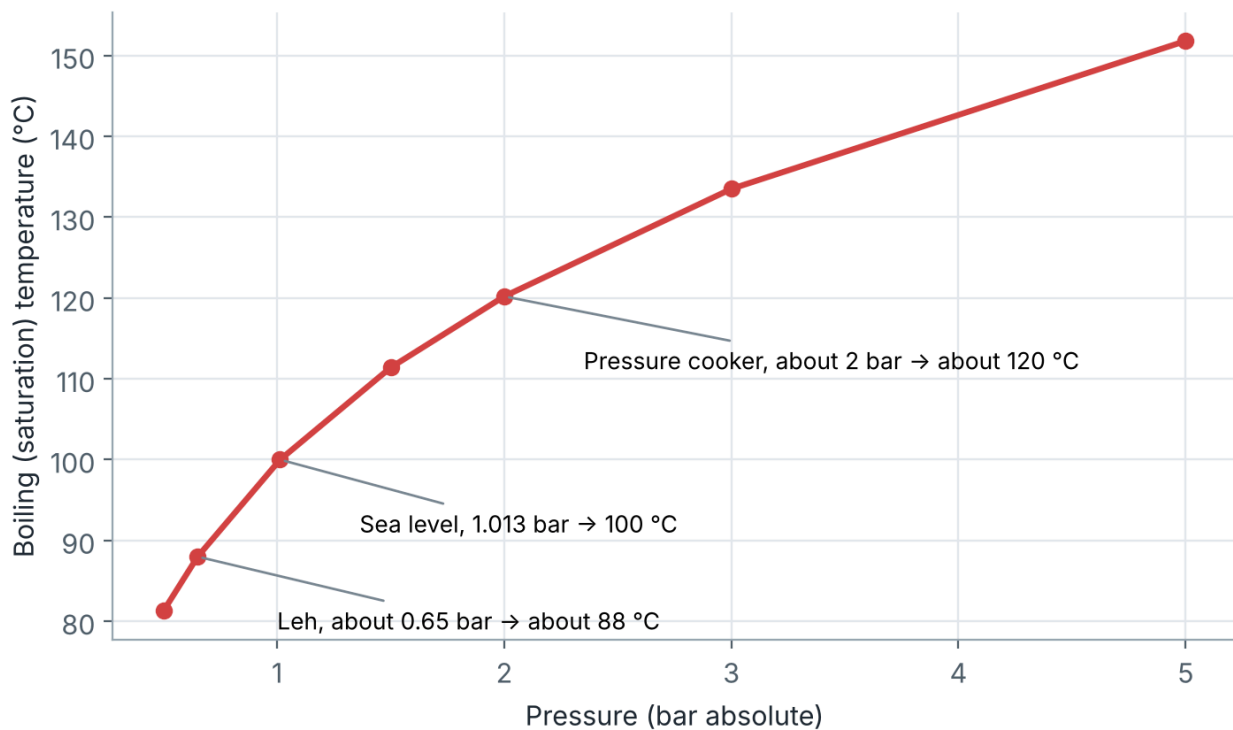
At high altitude, the opposite happens. In Leh (about 3,500 m), air pressure is lower and water boils at about 88 °C (typical). Dal takes longer to cook.

"Saturation" means liquid and vapour are together in balance. At a given pressure, there is only one saturation temperature. If you know one, you know the other. This is the most useful fact in refrigeration.

Below the saturation temperature the liquid is "subcooled". Above it the vapour is "superheated". Technicians measure both to check a system.

Water boils at a lower temperature when pressure is lower

Typical steam-table values. Pressure in bar absolute.



Boiling point of water vs pressure

Situation	Absolute pressure (typical)	Water boils at (typical)
Leh, about 3,500 m	0.65 bar a	about 88 °C
Sea level (Mumbai, Chennai)	1.013 bar a	100 °C
Pressure cooker	about 2.0 bar a	about 120 °C
Small steam boiler	5 bar a	about 152 °C

Worked example — gauge to absolute pressure

A gauge on a system in Kolkata reads 7 bar g. What is the absolute pressure?

$$P_{abs} = P_{gauge} + P_{atm}$$

- $P_{abs} = 7 + 1.013 = 8.01 \text{ bar a}$.
- Use 8.0 bar a when reading a refrigerant pressure–temperature table.

Remember

- Higher pressure raises the boiling point; lower pressure lowers it.
- At saturation, pressure fixes temperature and temperature fixes pressure.
- bar a = bar g + about 1.013 (at sea level).
- Subcooled liquid is below saturation; superheated vapour is above it.

Field tip: Check whether your gauge or app shows bar g or bar a before reading a saturation table.



1.7 Refrigerants and phase change

Key idea: A refrigerant is a fluid chosen to boil at low temperature and condense at high temperature, carrying heat as latent heat.

A refrigerant is the working fluid inside a heat pump or AC. It is picked so that it boils well below room temperature at a moderate pressure. It condenses at a useful high temperature when compressed.

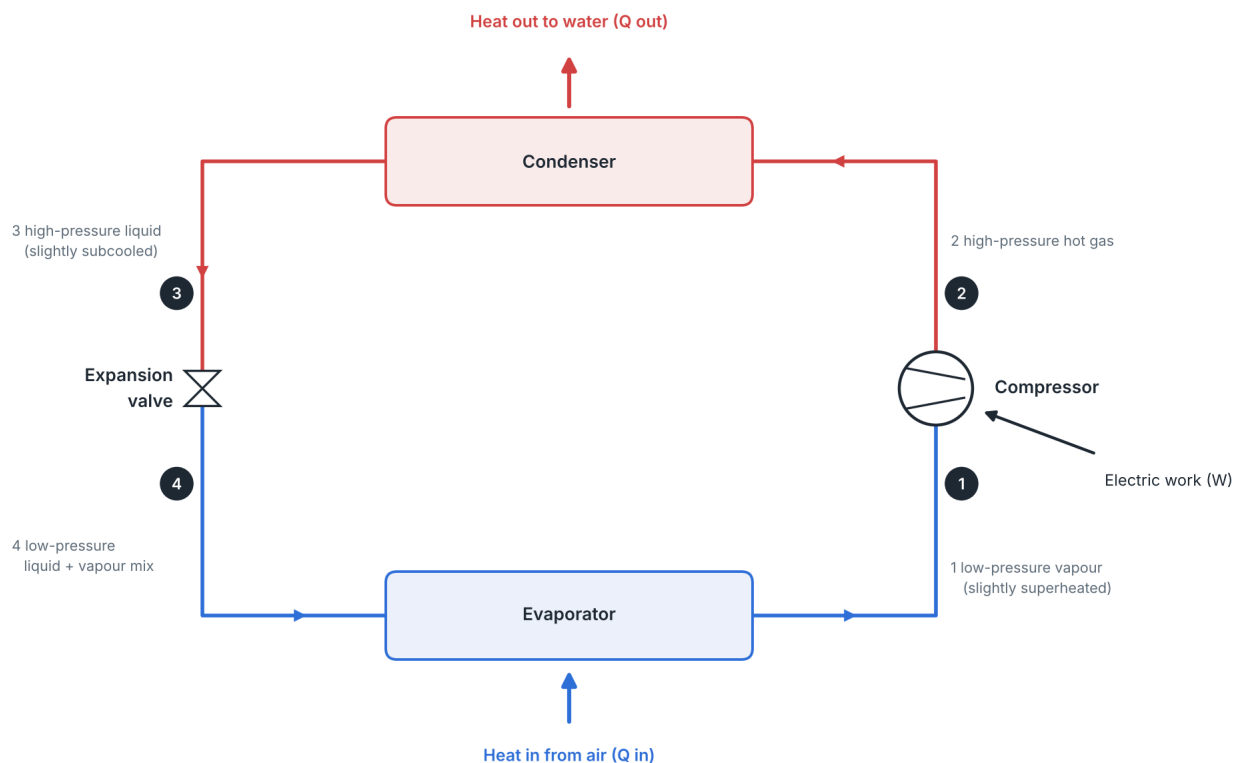
The basic cycle has four parts. The evaporator absorbs heat as the refrigerant boils. The compressor raises its pressure and temperature. The condenser releases heat as it condenses. The expansion valve drops the pressure again.

Think of a fridge. Inside, the refrigerant boils and takes heat from your food. At the back, it condenses and you feel warm air. A heat pump water heater uses that warm "back side" to heat water.

Refrigerants differ in pressure, efficiency, flammability and climate impact. GWP (global warming potential) compares a gas's warming effect to CO₂ over 100 years. Safety class (from ISO 817 / ASHRAE 34) rates toxicity (A low, B high) and flammability (1 none, 2L mild, 2, 3 high).

The vapour compression cycle: four parts, one loop

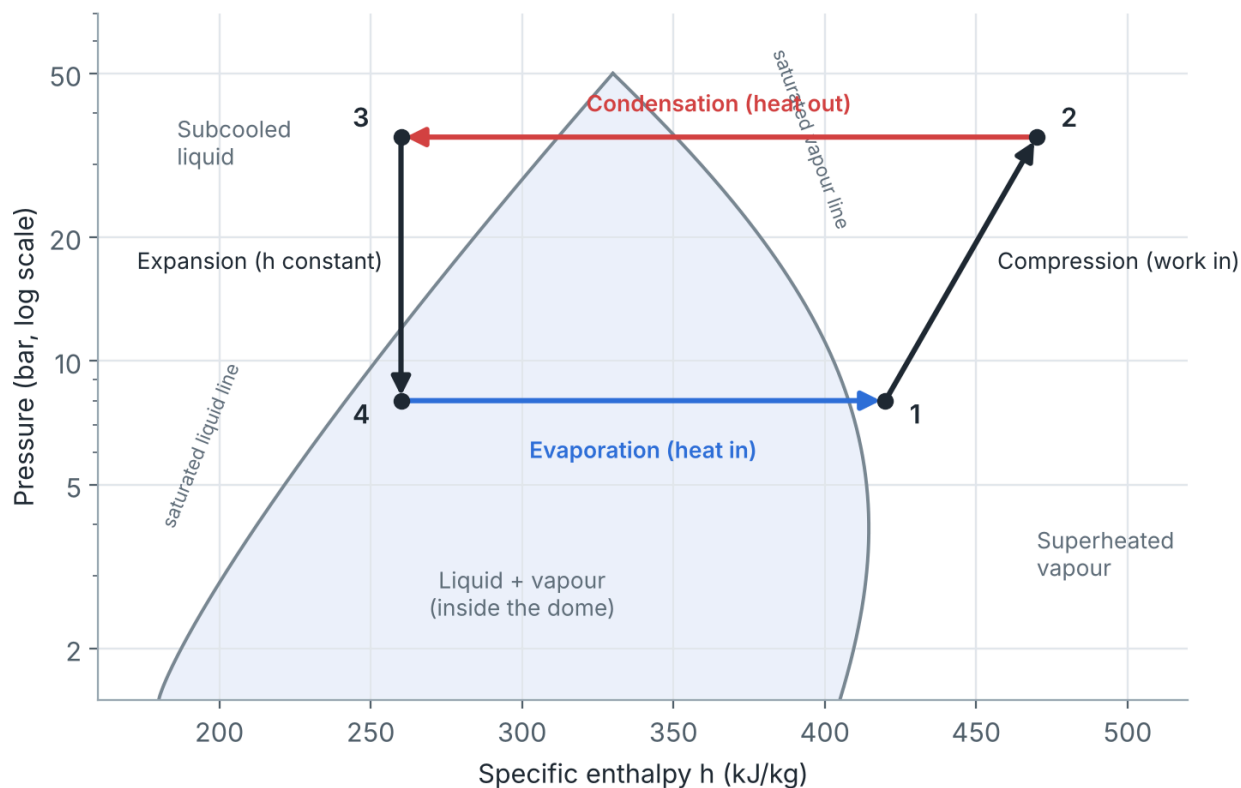
High-pressure side red, low-pressure side blue. Numbers are the four state points.



The vapour compression cycle

The same cycle on a pressure–enthalpy (P-h) diagram

Illustrative values, not tied to one refrigerant



The cycle on a P-h diagram

Refrigerant	Type	GWP (100-yr, IPCC AR4)	Safety class	Sat. pressure at 0 °C (bar a, typical)	Sat. pressure at 40 °C (bar a, typical)
R134a	HFC	1,430	A1	about 2.9	about 10.2
R410A	HFC blend	2,088	A1	about 8.0	about 24.2
R32	HFC	675	A2L	about 8.1	about 24.8
R290 (propane)	Natural (HC)	3	A3	about 4.7	about 13.7
R744 (CO ₂)	Natural	1	A1	about 34.9	Above critical point (31 °C)

Worked example — refrigerant flow needed for 10 kW of heating

In the condenser, each kg of refrigerant gives up heat equal to its enthalpy drop. Assume a typical drop of 200 kJ/kg for this example.

$$\dot{m} = \frac{Q}{\Delta h}$$

- $Q = 10 \text{ kW} = 10 \text{ kJ/s}$.
- $\dot{m} = 10 \div 200 = 0.05 \text{ kg/s}$.
- Per hour: $0.05 \times 3,600 = 180 \text{ kg/h}$ of refrigerant circulating.

Remember

- Evaporator: refrigerant boils and absorbs heat. Condenser: refrigerant condenses and releases heat.
- The compressor sets the two pressures; the expansion valve separates them.
- Low GWP and correct safety class matter as much as efficiency.
- Never mix refrigerants or top up with a different one.

Common mistake: Charging a flammable refrigerant (A2L or A3) with tools and procedures meant only for A1 gases. Use rated tools and follow the safety procedure.



1.8 Air and humidity: dew point, wet-bulb, relative humidity

Key idea: Air always carries some water vapour, and how much it can hold depends on its temperature.

Air is a mix of dry air and water vapour. Warm air can hold more vapour than cold air. This matters for air-source heat pumps, because their outdoor coil works with humid air.

Relative humidity (RH) is how much vapour the air holds compared with the most it could hold at that temperature. 100% RH means the air is saturated. Mumbai in the monsoon often sits near 80–90% RH.

Dew point is the temperature at which air starts to condense water if cooled. A cold glass of water "sweats" because its surface is below the dew point of the room air.

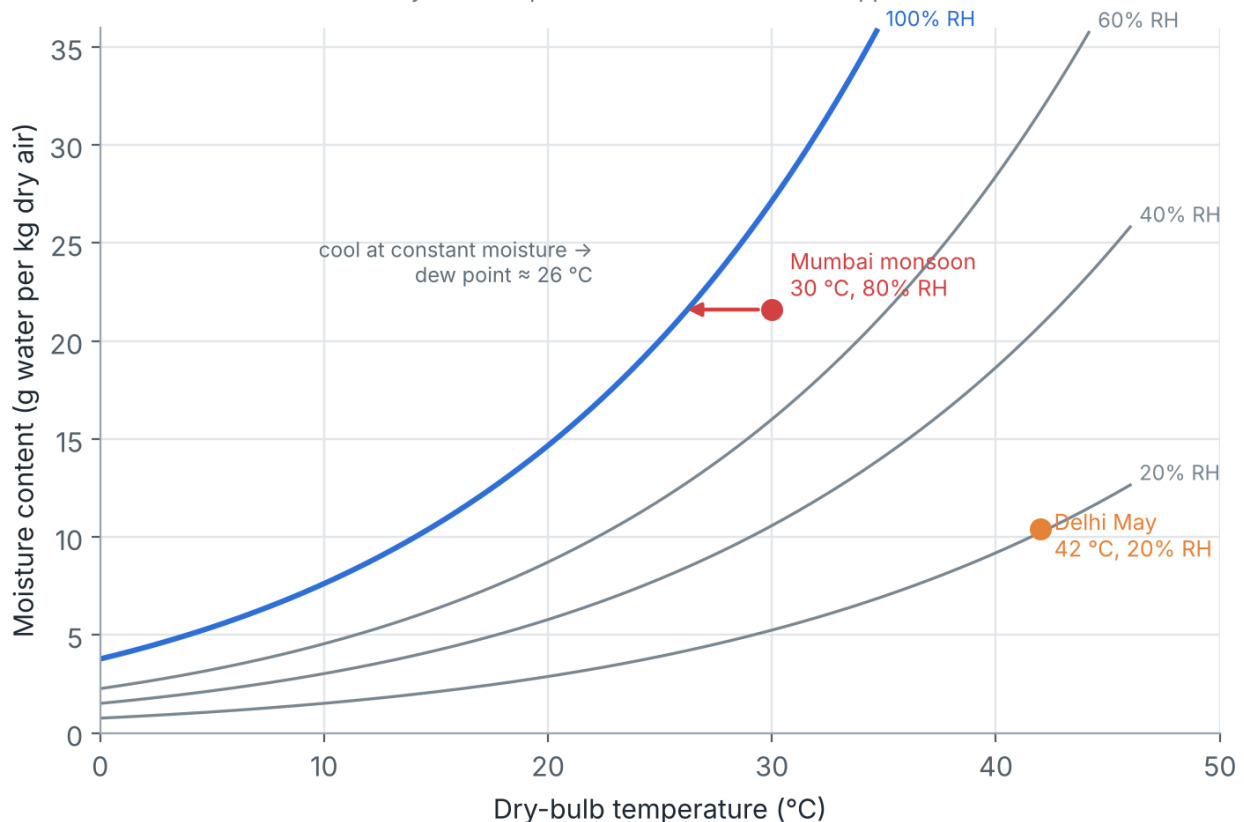
Dry-bulb temperature is the normal air temperature from a thermometer. Wet-bulb temperature is read from a thermometer with a wet wick in moving air. Evaporation from the wick cools it, so wet-bulb is lower unless the air is saturated.

A desert cooler works on this principle. It can cool air close to the wet-bulb temperature. That is why coolers work well in dry Jaipur and poorly in humid Kolkata.

For a heat pump, when the outdoor coil is below the dew point, water drips off it. If the coil surface falls below 0 °C, that water freezes as frost. The unit must then defrost.

Simplified psychrometric chart

Moisture content of air vs dry-bulb temperature at sea level. Values approximate.



Simplified psychrometric chart

Term	Meaning	How measured
Dry-bulb temperature	Normal air temperature	Ordinary thermometer
Wet-bulb temperature	Lowest temperature reachable by evaporating water into the air	Thermometer with wet wick, moving air
Relative humidity (RH)	Vapour held ÷ maximum possible at that temperature, in %	Hygrometer, sensor
Dew point	Temperature at which condensation starts	Calculated, or chilled-mirror meter

Worked example — dew point for Mumbai monsoon air

Air is 30 °C at 80% RH. Use a typical saturation vapour pressure for water at 30 °C of 4.25 kPa.

$$p_v = RH \times p_{sat}(T_{db})$$

- $p_v = 0.80 \times 4.25 = 3.40$ kPa.
- Find the temperature where $p_{sat} = 3.40$ kPa. From steam tables this is about 26 °C.
- So any surface below about 26 °C will drip water. An outdoor coil at 20 °C will condense heavily in Mumbai.

Remember

- Warm air holds more water vapour than cold air.
- RH is a ratio; dew point tells you the actual moisture.
- Wet-bulb $\leq$ dry-bulb, equal only at 100% RH.
- Coil below dew point → condensate; coil below 0 °C → frost.

Field tip: Always plan a condensate drain for air-source heat pumps. In humid coastal cities they can drain several litres per hour (typical).



1.9 Energy, power and efficiency: why COP can exceed 100%

Key idea: A heat pump's COP is heat delivered divided by electricity used, and it exceeds 1 because most of the heat comes free from the air.

Efficiency is useful output divided by input. An electric geyser element turns almost all electricity into heat, so it is close to 100% efficient. A gas burner loses some heat up the flue, so it is typically 80–90%.

A heat pump is different. It does not turn electricity into heat. It uses electricity to move heat from the air into water. So the heat delivered is larger than the electricity used.

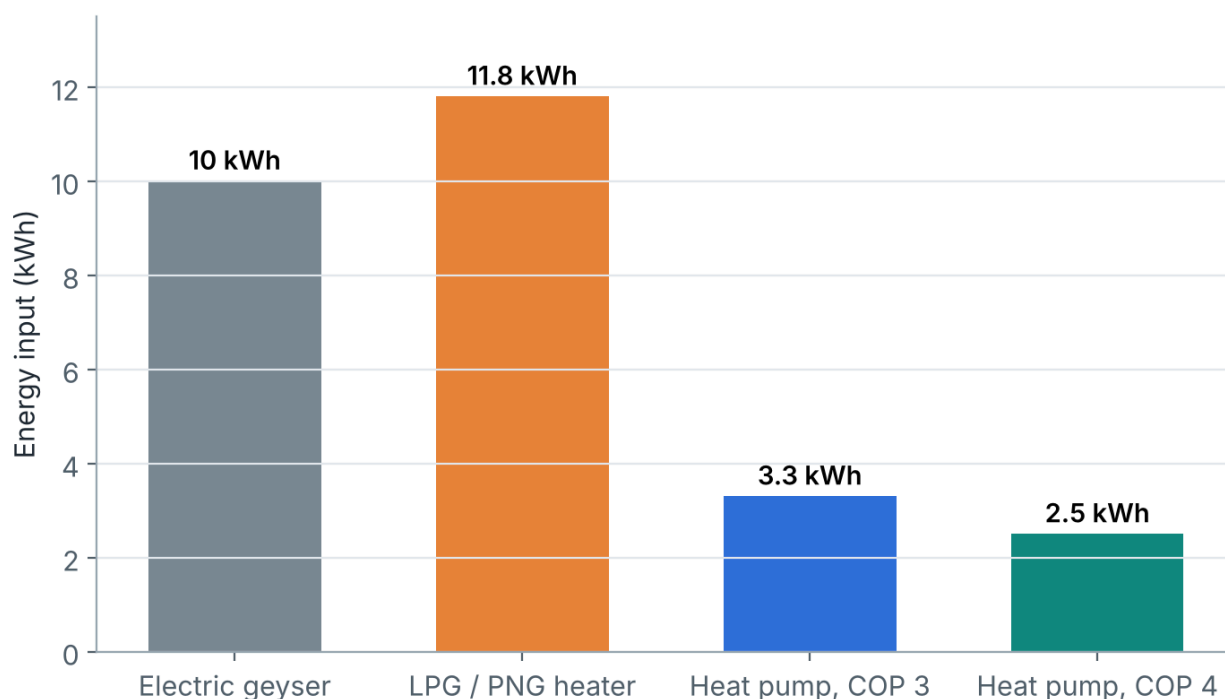
COP (coefficient of performance) is heat delivered ÷ electrical input, both in kW. COP 4 means 4 kW of heat for 1 kW of electricity. Expressed as a percentage, that is 400%.

COP is not fixed. It falls when the source is colder or the water is hotter, because the "lift" is bigger. A heat pump making 55 °C water from 35 °C air in Nagpur will show a higher COP than one making 65 °C water from 10 °C air in Shimla.

No law is broken. By the first law, heat delivered = heat from air + electricity. The extra comes from the environment, which is warmed by the sun.

Energy you pay for to get 10 kWh of hot water

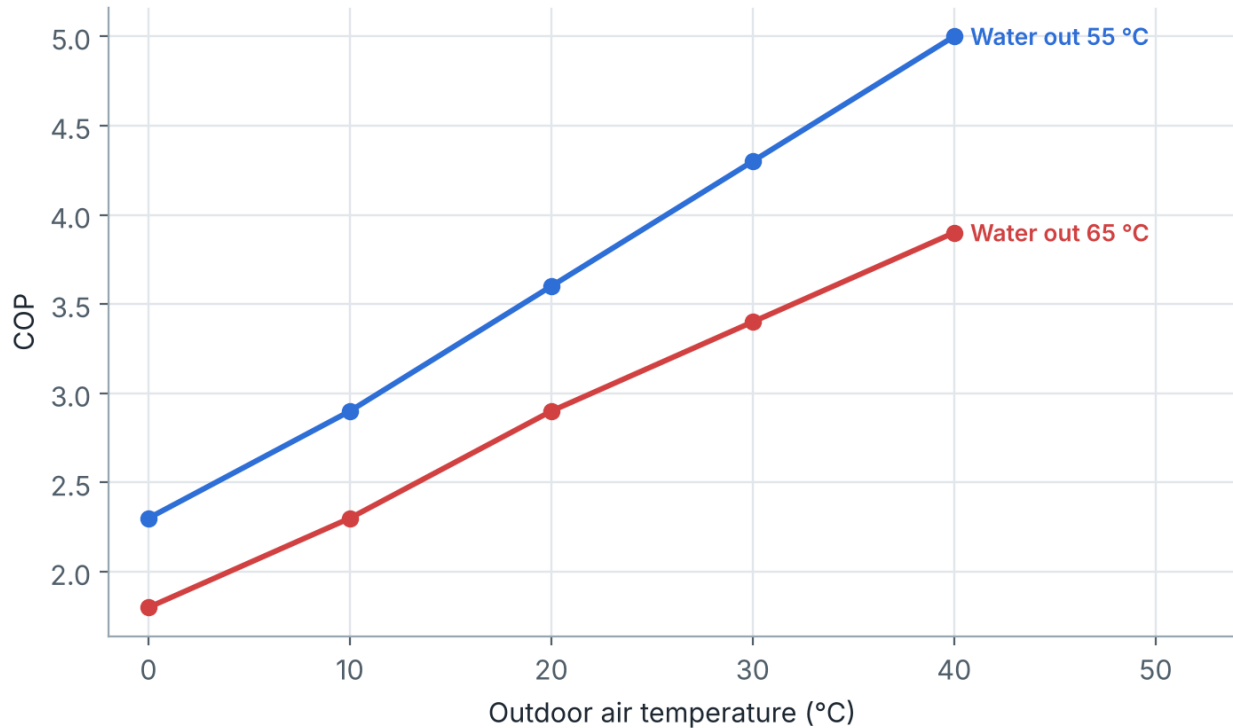
Typical efficiencies: electric 100%, LPG/PNG heater 85%. Heat pump at COP 3 and COP 4.



Energy input for 10 kWh of hot water

COP falls as the outdoor air gets colder

Typical, illustrative values. Real machines vary; use the datasheet.



COP vs outdoor air temperature

Heating method	Efficiency or COP (typical)	Heat delivered per 1 unit of input
Electric geyser element	about 95–100%	about 1 kWh
LPG or PNG water heater	about 80–90%	about 0.8–0.9 kWh of fuel energy
Diesel boiler	about 80–88%	about 0.8–0.88 kWh of fuel energy
Air-source heat pump, hot water at 55–60 °C	COP about 3–4.5	about 3–4.5 kWh

Worked example — daily cost to heat 1,000 L for a hostel in Hyderabad

Heat 1,000 L from 25 °C to 60 °C. Example rates: electricity ₹9/kWh, LPG ₹100/kg. LPG energy content about 12.8 kWh/kg (typical net value); burner efficiency 85% (typical).

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

- $Q = 1,000 \times 4.186 \times 35 = 1,46,510 \text{ kJ} = 1,46,510 \div 3,600 = 40.7 \text{ kWh}$ of heat.
- Electric geyser (about 100%): $40.7 \text{ kWh} \times ₹9 = ₹366$ per day.
- LPG: fuel energy = $40.7 \div 0.85 = 47.9 \text{ kWh}$; LPG mass = $47.9 \div 12.8 = 3.74 \text{ kg}$; cost = $3.74 \times ₹100 = ₹374$ per day.
- Heat pump at COP 4: electricity = $40.7 \div 4 = 10.2 \text{ kWh}$; cost = $10.2 \times ₹9 = ₹92$ per day.
- Saving vs electric geyser: about ₹274 per day, about ₹1 lakh per year at 365 days.

Remember

- $COP = \text{heat delivered (kW)} \div \text{electrical input (kW)}$.

- COP above 1 does not break physics; the extra heat comes from the air.
- COP falls as the temperature lift grows.
- Always compare running cost on the same heat demand in kWh.

Common mistake: Quoting one COP figure without its conditions. Always state source temperature and water outlet temperature with the COP.



Quiz 1

1. A cup of tea and a bucket of water are both at 60 °C. Which statement is true?

- A. Both hold the same heat
- B. The bucket holds more heat
- C. The cup holds more heat
- D. Neither holds any heat

2. 1 TR is approximately equal to:

- A. 1 kW
- B. 2.5 kW
- C. 3.517 kW
- D. 12 kW

3. A boiler rated 86,000 kcal/h has a capacity of about:

- A. 10 kW
- B. 100 kW
- C. 860 kW
- D. 1,000 kW

4. While water is boiling at a steady 100 °C, the heat being added is called:

- A. Sensible heat
- B. Radiant heat
- C. Latent heat
- D. Specific heat

5. Hot water rising to the top of a storage tank is an example of:

- A. Conduction
- B. Natural convection
- C. Radiation
- D. Forced convection

6. Which law says heat cannot flow from cold to hot without work?

- A. Zeroth law
- B. First law
- C. Second law
- D. Third law

7. A gauge reads 5 bar g at sea level. The absolute pressure is about:

- A. 4 bar a
- B. 5 bar a
- C. 6 bar a
- D. 10 bar a

8. In the vapour compression cycle, where does the refrigerant release heat?

- A. Evaporator

- B. Condenser
- C. Expansion valve
- D. Suction line

9. Water drips from an outdoor coil when the coil surface is:

- A. Above the dry-bulb temperature
- B. Above the wet-bulb temperature
- C. Below the dew point
- D. Exactly at 0 °C only

10. A heat pump delivers 12 kW of heat using 3 kW of electricity. Its COP is:

- A. 0.25
- B. 3
- C. 4
- D. 9

Answer key

1. **B** — Same temperature, but the bucket has far more mass, so far more heat.
2. **C** — 1 TR = 12,000 BTU/h = 3.517 kW.
3. **B** — $86,000 \div 860 = 100$ kW.
4. **C** — Heat that changes phase without changing temperature is latent heat.
5. **B** — Warm water is lighter and rises on its own; no pump is involved.
6. **C** — The second law sets the direction of heat flow and the need for work.
7. **C** — $5 + 1.013 \approx 6$ bar a.
8. **B** — The refrigerant condenses in the condenser and gives up its latent heat.
9. **C** — Condensation starts when a surface is below the dew point of the air.
10. **C** — $\text{COP} = 12 \div 3 = 4$.



Glossary

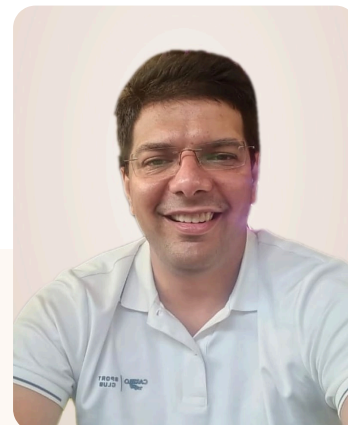


Term	Meaning
Absolute pressure (bar a)	Pressure measured from a perfect vacuum; gauge pressure + atmospheric pressure
BTU/h	British thermal units per hour; 1 kW = 3,412 BTU/h
Carnot COP	Highest COP possible in theory between two temperatures, using kelvin
Condensation	Change from vapour to liquid; releases latent heat
Condenser	Heat exchanger where refrigerant condenses and gives heat to water or air
Conduction	Heat transfer through a solid, molecule to molecule
Convection	Heat carried by a moving fluid (natural or forced)
COP	Coefficient of performance: heat delivered ÷ electrical input
Dew point	Temperature at which air starts to condense water when cooled
Dry-bulb temperature	Normal air temperature read on a thermometer
Enthalpy	Total heat content of a fluid per kg, in kJ/kg
Evaporation	Change from liquid to vapour; absorbs latent heat
Evaporator	Heat exchanger where refrigerant boils and absorbs heat
Expansion valve	Device that drops refrigerant pressure between condenser and evaporator
Gauge pressure (bar g)	Pressure above atmospheric pressure
GWP	Global warming potential, compared with CO ₂ over 100 years
Heat	Energy that flows because of a temperature difference (kJ, kWh)
kcal/h	Kilocalories per hour; 1 kW = 860 kcal/h
Kelvin (K)	Absolute temperature scale; 0 K = -273.15 °C
kW / kWh	Power (rate of energy) / energy (power × time)
Latent heat	Heat that changes phase without changing temperature
P-h diagram	Pressure–enthalpy chart used to draw a refrigeration cycle
Radiation	Heat transfer by infrared waves, needing no medium
Refrigerant	Working fluid that boils and condenses to carry heat in a cycle
Relative humidity (RH)	Water vapour in air as a % of the maximum it can hold at that temperature
Saturation temperature	Boiling/condensing temperature at a given pressure
Sensible heat	Heat that changes temperature
Specific heat (c _p)	Heat needed to raise 1 kg by 1 K; water ≈ 4.186 kJ/kg·K
Subcooling	Liquid cooled below its saturation temperature
Superheat	Vapour heated above its saturation temperature
Temperature	Measure of how hot or cold something is (°C or K)
TR (ton of refrigeration)	Cooling rate of 3.517 kW (12,000 BTU/h)
Wet-bulb temperature	Temperature of a wetted thermometer in moving air; ≤ dry-bulb

ABOUT THE AUTHOR

Kashyap Anandpara

Founder Director, Sunniva Encon LLP



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

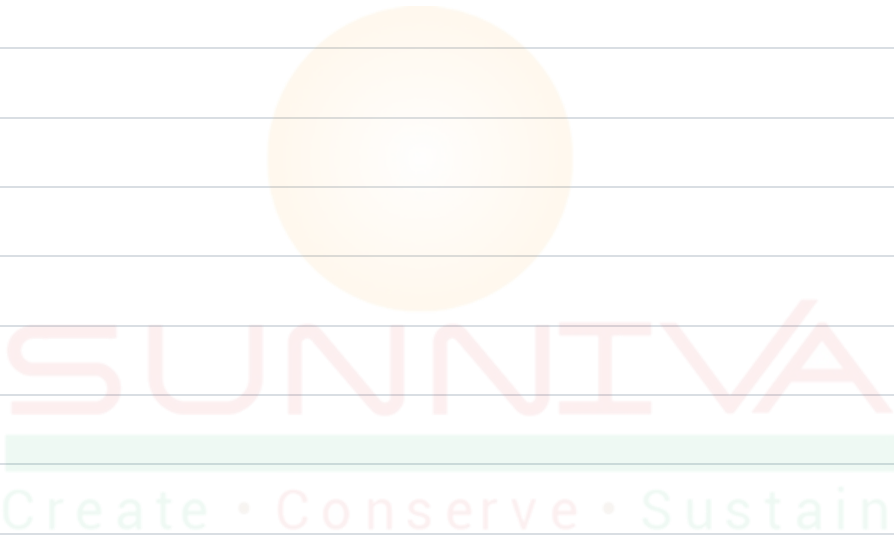
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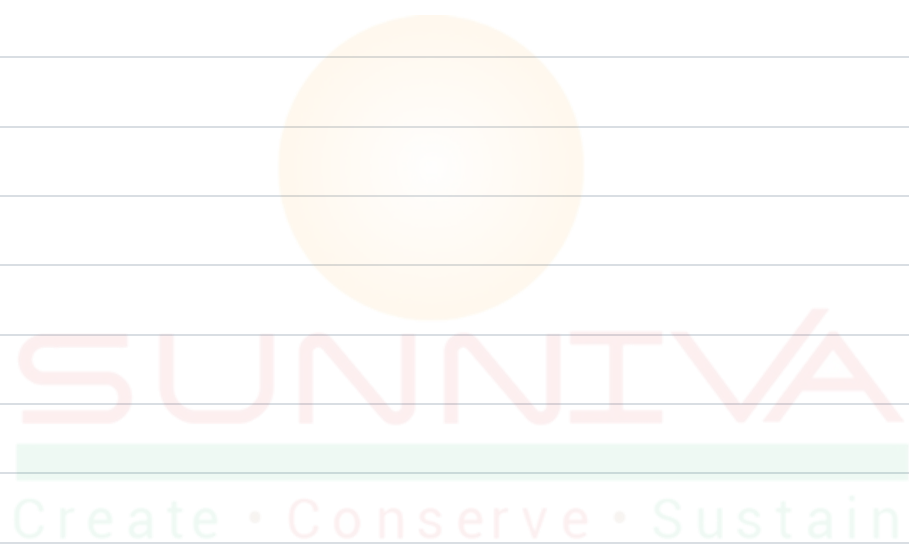
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NOTES



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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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