# Section Seven: Heat Pump

## Why Are Heat Pumps Discussed So Much?

Yes — heat pumps are widely promoted because they are considered a "green technology." The main reason is that they reduce carbon emissions from heating, which is one of the largest sources of energy use in buildings.

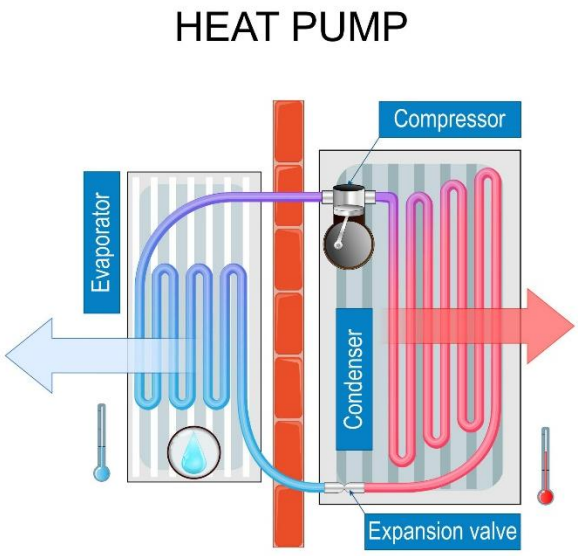
Heating homes with fossil fuels (like gas or oil) produces a lot of $CO_2$ emissions, and governments are trying to reduce this to meet climate targets.

## Why Heating Matters for Climate?

- In many countries, home heating is a major energy use.
- Gas boilers burn fossil fuels directly, releasing carbon dioxide ($CO_2$).
- To reduce emissions, countries are trying to switch to electrified heating systems.

Heat pumps are a leading option because they use electricity and environmental **heat** rather than burning fuel.

## Why Heat Pumps Are Considered Green?




### 1 They Use Renewable Environmental Heat

Heat pumps extract heat from:

- Air
- Ground
- Water

This heat already exists in nature and is free thermal energy.
Example (COP = 3):

- 1 unit electricity
- 2 units heat from environment
- = 3 units heating delivered

So about two-thirds of the heat is renewable.

### 2 No Direct Combustion

Gas boilers burn methane:

$$CH_4 + O_2 \rightarrow CO_2 + H_2O$$

This releases $CO_2$ directly in your home's heating system.
Heat pumps:

- ❌ No combustion
- ❌ No flue gases
- ❌ No direct carbon emissions at the house

### 3️⃣ Electricity Can Become Renewable

Heat pumps run on electricity. Electricity can be produced from:

- Wind
- Solar
- Hydro
- Nuclear
- Fossil fuels

As the electricity grid becomes greener, heat pumps automatically become greener too.
This is a big reason governments promote them.

### 4️⃣ Higher Energy Efficiency

Typical efficiencies:

| System | Efficiency |
|---|---|
| Electric heater | 100% |
| Gas boiler | 85–95% |
| **Heat pump** | **250–450% (COP 2.5–4.5)** |

This means less primary energy is required overall.

### ⚠️ Important Reality Check

Heat pumps are not automatically perfect or green in every situation.
Their environmental benefit depends on:

- Electricity generation mix
- Building insulation
- Proper installation
- Operating temperature

If powered by coal-heavy electricity or poorly installed, benefits decrease.

## Why Governments Promote Heat Pumps?

Many countries want to reach net-zero emissions.
Examples of policies:

- Reduce gas boiler installations
- Provide heat pump subsidies
- Electrify building heating

Heat pumps are one of the main technologies available today to replace fossil heating.

## What Is a Heat Pump?

A heat pump is a device that transfers heat from one place to another using electricity and a refrigeration cycle. Instead of generating heat directly (like a boiler), it moves heat — which makes it very energy-efficient.

👉 Think of it as a reversible air conditioner:

- In winter → moves heat into your home.
- In summer → moves heat out of your home.

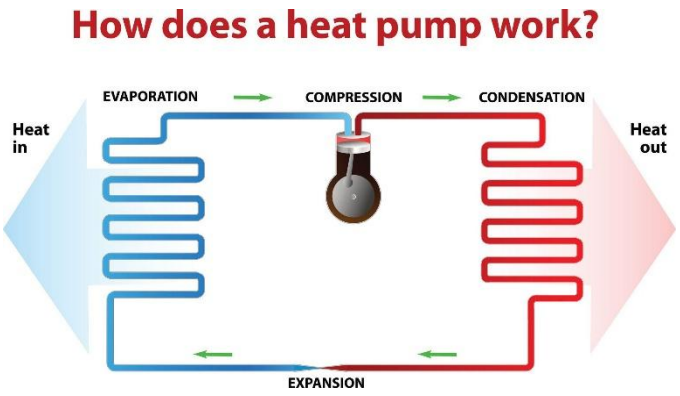
## Key Components

- Compressor – increases refrigerant pressure and temperature
- Evaporator coil – absorbs heat from outside
- Condenser coil – releases heat indoors
- Expansion valve – lowers pressure to restart the cycle
- Refrigerant – fluid that carries heat energy

## Basic Working Principle

1. Refrigerant absorbs heat from a source (air, ground, or water).
2. Compressor raises temperature.
3. Heat is released into the building.
4. Cycle repeats.

This process follows thermodynamics and phase-change heat transfer.



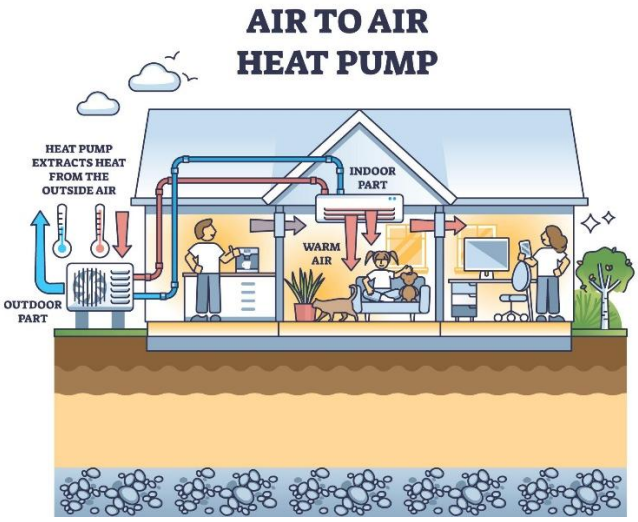

## Types of Heat Pumps

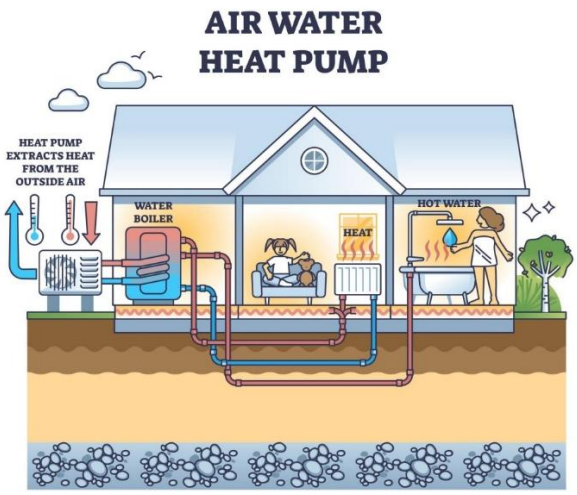
Heat pumps are classified mainly by where they collect heat.

**1. Air Source Heat Pump (ASHP):** Air source heat pumps extract heat from outdoor air — even when it feels cold.

**Subtypes**

- **Air-to-Air**: heats rooms using blown warm air.
- **Air-to-Water**: heats radiators or underfloor heating.




**Advantages**

✅ Lower installation cost

✅ Easier retrofit for existing homes

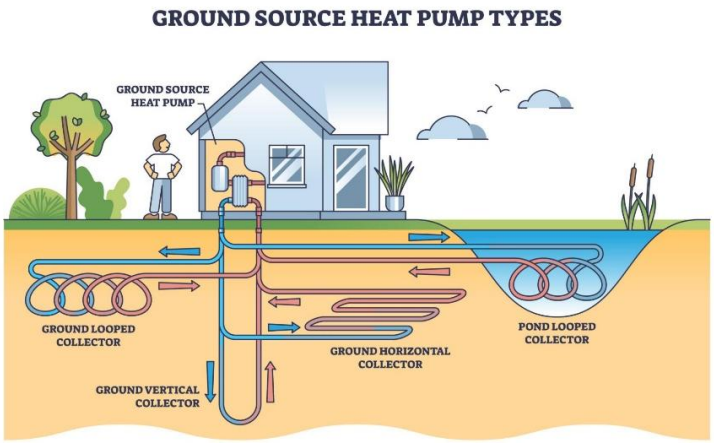
✅ Good for mild climates (like much of the UK)

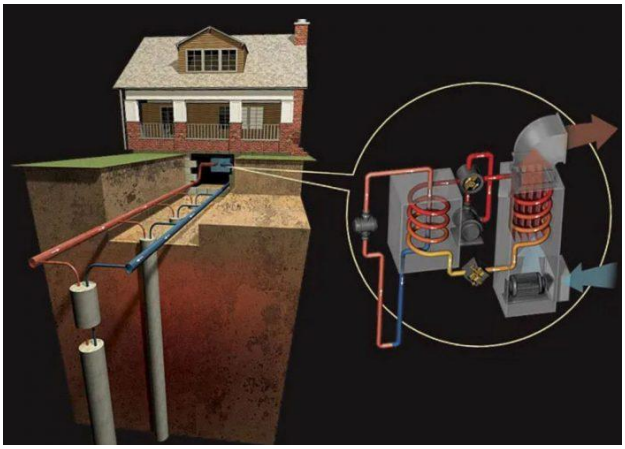
**Disadvantages**

❌ Efficiency drops in very cold temperatures

❌ Outdoor unit noise

**2. Ground Source Heat Pump (GSHP):** Also called geothermal heat pumps, these extract heat from the ground, which stays at a stable temperature year-round.



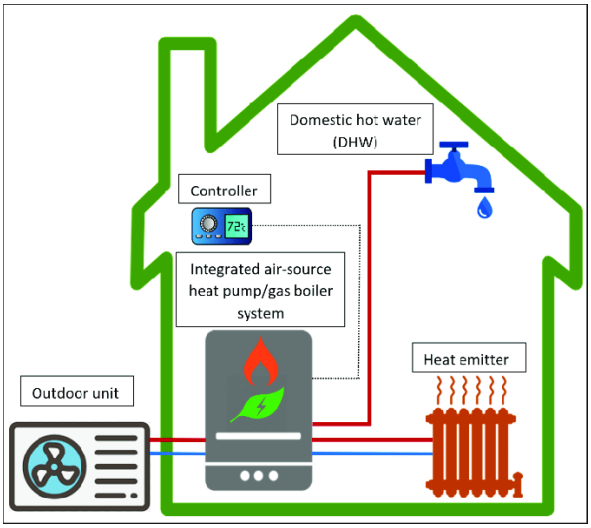
**Loop Types**

- **Horizontal loops** – shallow trenches across land.
- **Vertical boreholes** – deep drilling where space is limited.

**Advantages**

✅ Very high efficiency
✅ Stable performance year-round
✅ Long lifespan

**Disadvantages**
❌ High installation cost
❌ Requires land or drilling




**3. Water Source Heat Pump (WSHP):** These systems use heat from a lake, river, groundwater, or shared water loop.

**Types**

- **Open loop** – pumps water directly.
- **Closed loop** – sealed pipe submerged in water.
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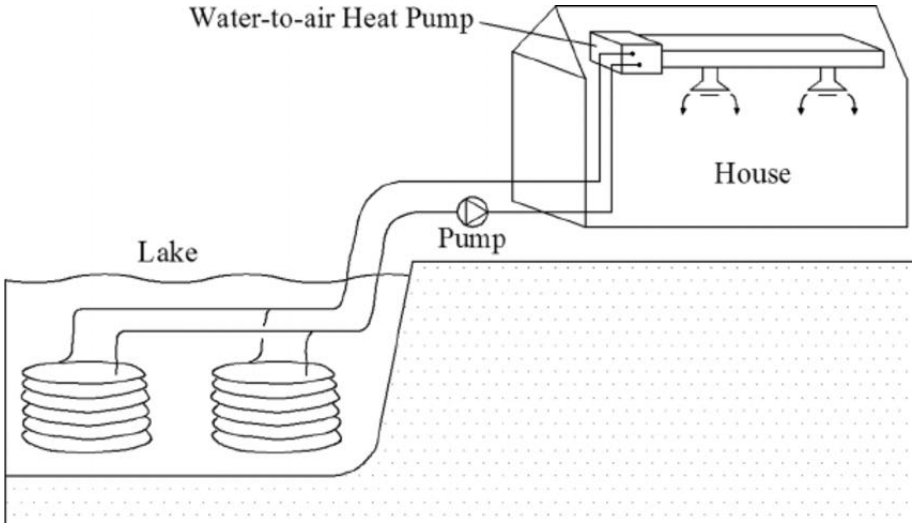


**Advantages**
✅ Extremely efficient if water source available
✅ Stable temperatures

**Disadvantages**
❌ Requires access to suitable water source
❌ Environmental regulations may apply

**4. Hybrid Heat Pumps:** A hybrid system combines a heat pump with a traditional boiler (often gas).

**How It Works**

- Heat pump runs most of the time.
- Boiler turns on during extreme cold or high demand

**Advantages**

✅ Flexible performance
✅ Easier transition from fossil fuels

**Disadvantages**

❌ Still relies partly on gas
❌ More complex controls

## Heat Pump Cycle

Here's a simplified thermodynamic breakdown you can revise:

1. **Evaporation** – Low-pressure refrigerant absorbs heat → becomes gas.
2. **Compression** – Compressor increases pressure → temperature rises.
3. **Condensation** – Heat released into indoor space → refrigerant liquefies.
4. **Expansion** – Pressure drops → refrigerant cools again.

📌 Key concept: Heat pumps use latent heat during phase change — this is why they're efficient.

## 📊 Performance & Efficiency Terms

Important exam or study definitions:

- **COP (Coefficient of Performance)**

$$COP = \frac{\text{Heat Output}}{\text{Electrical Energy Input}}$$

Typical values: 2.5–4.5
A COP between 2.5 and 4.5 means:

- For every 1 kW of electricity, the heat pump delivers about 2.5 to 4.5 kW of heat.

Example:

- COP = 3.0
  → 1 kW electricity in
  → 3 kW heat output

So you're getting **more heat than the electricity you pay for**, because the system is moving heat — not creating it.

**Here's** how to interpret COP ranges:

| COP Value | Performance Level | What It Means |
|---|---|---|
| 1.0 | ❌ Poor | Same as electric heater (no efficiency gain) |
| 2.0–2.5 | ⚠️ Average | Works but not very efficient |
| **2.5–4.5** | ✅ Good / Typical | Normal real-world heat pump performance |
| 5.0+ | ⭐ Excellent | Ideal conditions or advanced systems |

## Why COP Changes

COP is not fixed — it changes depending on conditions:

**Higher COP (better efficiency)**

- Mild outdoor temperatures
- Underfloor heating (low flow temp)
- Well-insulated homes

**Lower COP (worse efficiency)**

- Very cold weather
- High radiator temperatures
- Poor system design

Example:

- Outside 10 °C → COP ≈ 4

- Outside −5 °C → COP ≈ 2.5

## 🔥 Quick Comparison with Other Heating

This helps you see why COP 3–4 is good:

- Electric heater → COP = **1**
- Gas boiler → ~90% efficient (≈0.9)
- Heat pump → COP **3–4** (300–400% effective heat output)

That's why heat pumps can lower energy use.

## 🏠 Applications

- Residential heating & cooling
- Underfloor heating systems
- Commercial HVAC
- Industrial heat recovery

## 🧠 Quick Comparison Table

| Type | Efficiency | Installation Cost | Best For |
|---|---|---|---|
| Air Source | Medium–High | ££ | Most homes |
| Ground Source | Very High | ££££ | New builds, land available |
| Water Source | Very High | £££ | Near water bodies |
| Hybrid | Medium | £££ | Retrofit upgrades |

## Can switching to heat pumps save money?

We mentioned above "heat pumps can lower energy use." But why some UK households have seen higher energy bills after switching from gas boilers to heat pumps?

The key issue isn't that heat pumps "don't work." It's mainly about UK energy pricing + system design + installation quality.

Let's break it down clearly.

### 1️⃣ The UK Electricity vs Gas Price Problem (Main Reason)

In the UK:

- ⚡ Electricity costs 3 to 4 times more per kWh than gas
- 🔥 Gas is relatively cheap per kWh

A typical comparison (rough example):

| Energy Type | Price per kWh (example) |
|---|---|
| Gas | ~7p |
| Electricity | ~27p |

Now look at this carefully:

If a heat pump has:

- COP = 3

That means:

- 1 kWh electricity → 3 kWh heat
- Effective heat cost = 27p ÷ 3 = 9p per kWh of heat

Gas boiler (90% efficient):

- 7p ÷ 0.9 ≈ 7.8p per kWh of heat

👉 Result: Gas can still be slightly cheaper.

So even though heat pumps are more energy efficient, they are not always cheaper to run in the UK because electricity is expensive. This is the biggest reason bills increase.

**2 Poor System Design (Very Common in the UK)**

Heat pumps work best when:

- Flow temperature is LOW (35–45°C)
- Large radiators or underfloor heating are installed
- House is well insulated

But many UK retrofits:

- Keep small radiators
- Run at 55–65°C
- Have poor insulation

This reduces COP from 4 down to 2 to 2.5.

If COP drops to 2:

- 27p ÷ 2 = 13.5p per kWh heat

Now it's much more expensive than gas.

**3 UK Housing Stock Issue**

Many UK homes are:

- Solid brick
- Poorly insulated
- High heat loss
- Designed for high-temperature gas boilers

Heat pumps are low-temperature systems. If the house leaks heat, the heat pump runs constantly.

Result:

- Long runtime
- High electricity use
- Big bills

**4 Cold Weather Performance**

During very cold spells:

- COP drops
- Some systems use electric backup heaters (COP = 1)

If backup heating kicks in frequently, electricity use spikes dramatically. This is often misunderstood by homeowners.

**5 Behaviour Change**

Gas boilers:

- Heat quickly
- Turn on/off

Heat pumps:

- Designed to run longer, steady
- Work best at constant temperature

If users:

- Turn them off during day
- Boost frequently
- Use high setpoints

Efficiency drops and costs increase.

## So Is It a Myth That Heat Pumps Save Money?

Not exactly — but:

In countries where:

- Electricity is cheap (France, Norway)
- Gas is expensive
- Homes are well insulated

Heat pumps save money easily.

**In the UK:**

It depends on:

- Insulation quality
- System design
- Electricity tariff
- Outdoor temperature
- Installer competence

**The Real Summary**

Heat pumps:

- ✅ Use less energy
- ❌ Don't always cost less in the UK (because of electricity pricing)

Energy efficiency ≠ energy cost.
That's the key difference.