POWER-SAVING MODE IN FLEXIBLE HEAT PUMPS FOR SUSTAINABLE UK HEATING SOLUTIONS

Miryam Essadik[1] (m.essadik.1@research.gla.ac.uk)

Supervised by: Dr. Siming You[1] and Pr. Zhibin Yu[2]

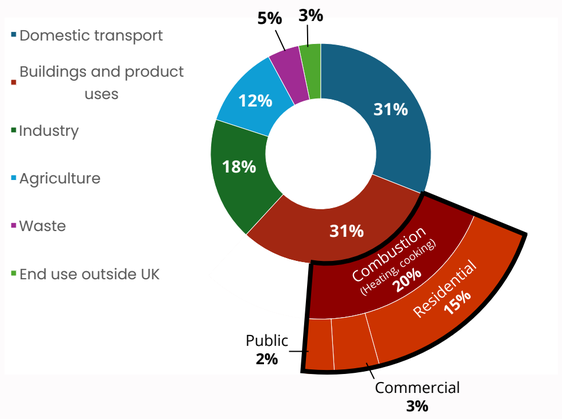
(1) James Watt School of Engineering, University of Glasgow ; (2) School of Engineering, University of Liverpool

1 THE CHALLENGE: HOW CAN WE ACHIEVE NET ZERO AND HEAT THE UK?

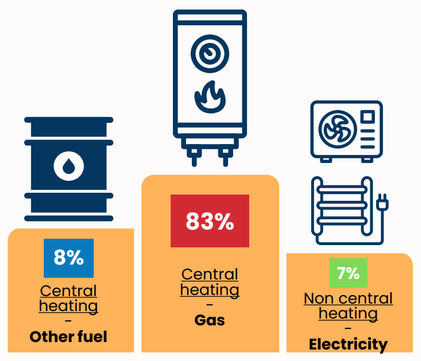
UK Net Zero 2050 Goal:

- **600,000 Heat Pumps/Year** by 2028
- Covers **2.5% of Homes** Annually

Heating in the UK: The Current Landscape

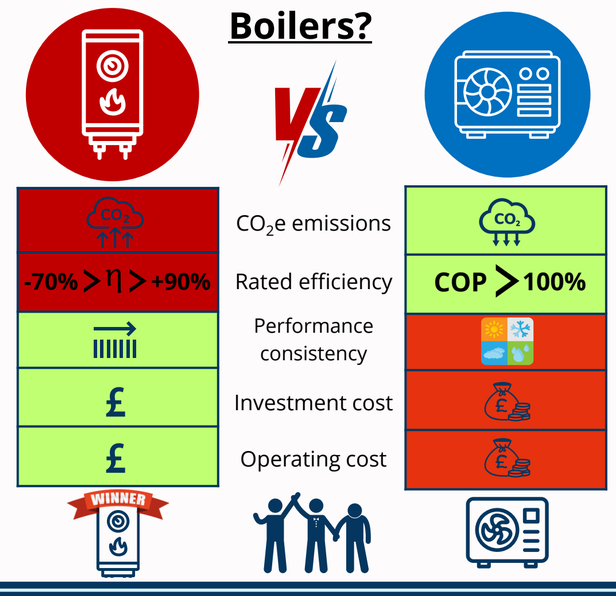


UK greenhouse gas emissions by end user sector in 2022 [1]



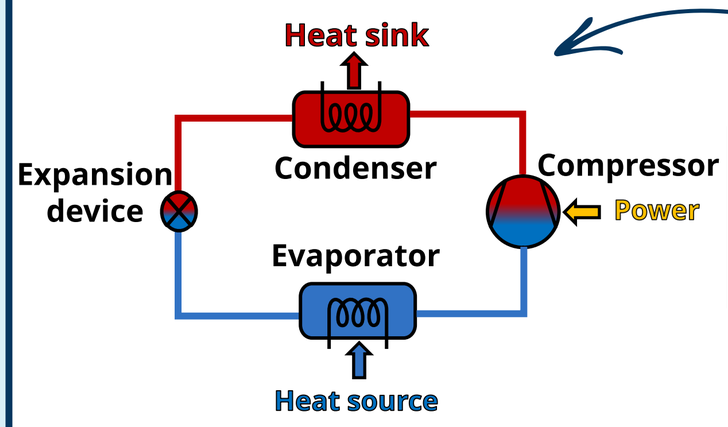
Heating Systems & Fuel Types in UK Households (2017) [2]

Why Heat Pumps Struggle Compared to Gas Boilers?



How Can We Convince People to Make the Big Switch?

2 THE WARM-UP: HEAT PUMP BASICS



A heat pump **transfers heat between a source and a sink**, consuming electricity to power the compressor for **heating or cooling**

Heat pump types vary based on heat source and sink

Source / Sink	Air	Water	Ground
Air			
Water			

- **Air-to-water heat pumps** suit most UK homes without system changes.
- Air-source heat pumps are the **most flexible and affordable**, but their **COP drops in cold and humid weather**.

3 THE NEW CHALLENGER: THE FLEXIBLE HEAT PUMP

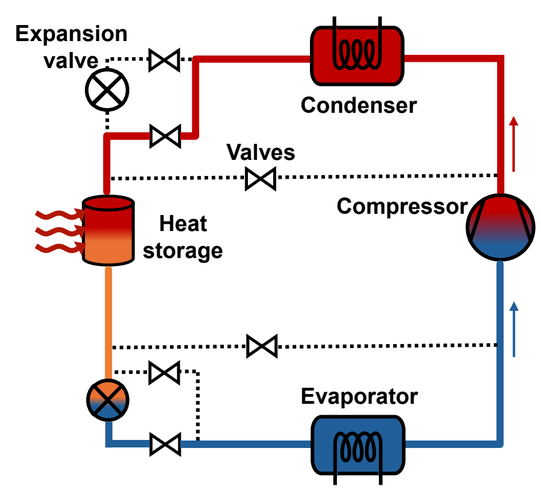
Aims:

1. Make heat pumps the most **cost-effective** heating solution
2. Improve efficiency in **all weather** and **lower operating costs**

→ **Flexible Heat Pump** with multiple operating modes.

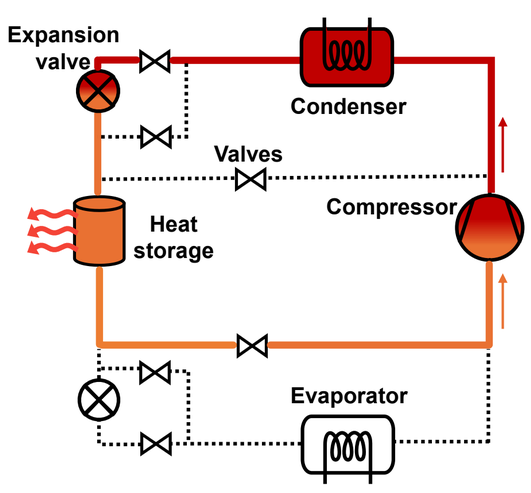
→ **Key modification:** Adding **heat storage** to the refrigerant cycle.

A *Heating/Charging mode*



Recover and store subcooled heat from refrigerant

B *Power-saving/Discharging mode*



Stored heat is used to evaporate refrigerant at a **higher temperature** ➡ **Reduced power consumption**

4 OUR FINDINGS: A CASE FOR A REMATCH?

Methodology

Steady-state thermodynamic, economic, and environmental evaluation

Assess:

Average COP of the Flexible Heat Pump over a full charge/discharge cycle of the heat storage

Compare:

The **performance** of the Flexible Heat Pump with the conventional heat pump

Evaluate:

Environmental impact of heat pumps & gas boiler

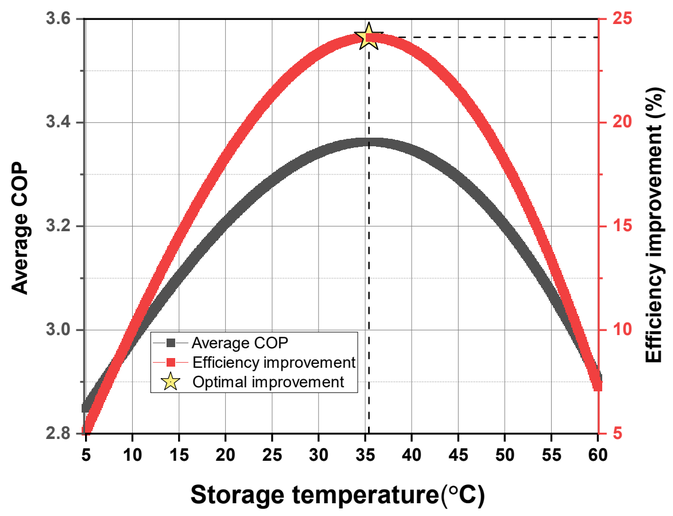
Calculate:

- Upfront equipment costs
- Annual capital & maintenance costs
- **Operational costs**

- Case study to meet an **average annual heating demand** in **Edinburgh**
- **Paraffin** used as a simulated heat storage

Performance analysis

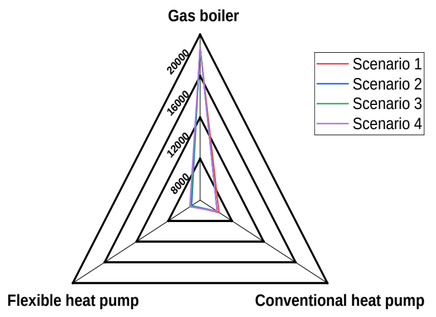
Average COP and improvement depending on storage temperature



The Flexible Heat Pump improves efficiency **by up to 24.1%** (in ideal conditions), achieving an **average COP of 3.36** vs. 2.7 for a conventional heat pump.

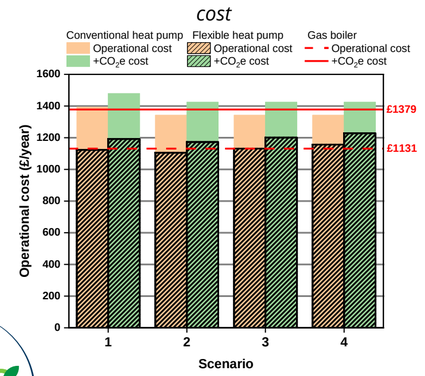
Economic and environmental analysis

Annual energy consumption in kWh/year

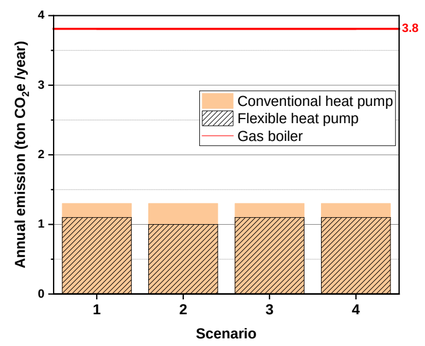


Results in

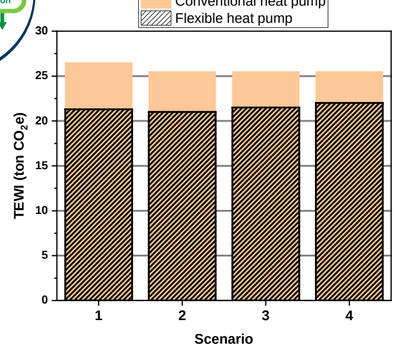
Operational cost per year with and without CO_2e cost



Results in



Annual CO_2e emissions



Total Equivalent Warming Impact (TEWI) over heat pumps lifecycle

Key insights & Outlook:

1. **Lower total annual cost** compared to a conventional heat pump despite higher initial price. **~4 years payback period** compared to a conventional heat pump.
2. **Operating cost was lower or equal to a gas boiler in 3/4 scenarios** and always more economical when factoring in CO_2e costs.
3. Economic viability could improve with **government incentives** and lower electricity prices. Upfront cost could be reduced by using **alternative cheaper heat storage** (e.g. water tank)
4. **16-20% lower TEWI** than conventional heat pump due to reduced power consumption, with further potential as electricity production decarbonises.

UP FOR ROUND 2 ?

References: [1] Department for Energy Security and Net Zero. Final UK greenhouse gas emissions national statistics: 1990 to 2022. (2024)
[2] Department for Business Energy and Industrial Strategy (BEIS). Energy follow up survey: Household energy consumption and affordability. (2021)

Acknowledgements: