Progress Report
WP3.4
January 2014

WP3.4 Next generation gas/heat powered heat pump

Background:

Rationale

- Up to 50% reduction in CO_2 emissions compared with domestic condensing boilers
- Inability of electricity supply system to cope with an ‘all electric’ future with all homes heated by electric heat pumps – gas (inc. biogas) still has a role to play

Technical options

- Engine driven heat pumps
  - Small sizes have maintenance and noise issues
- Sorption cycles [A**b**sorption and A**d**sorption]
  - Very few moving parts
  - Potentially low cost

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Previous research at Warwick:

‘CALEBRE’ project funded by EPSRC/EON:

- Part of funding was for proof of concept gas fired heat pump using a**d**sorption – ammonia refrigerant with active carbon adsorbent
- Specification of first machine was for 7 kW heat output
- University spin-out company (Sorption Energy Ltd) owns IP and hopes to develop a product

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Operating principle

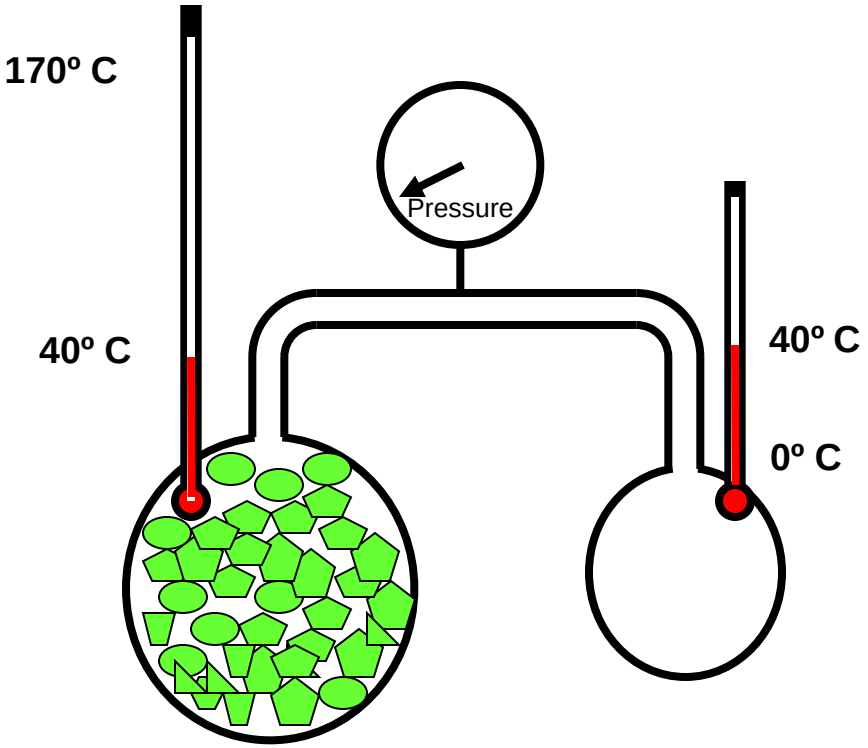
Idealised Adsorption Cycle

Initial State:

Ambient Temperature

Low pressure

High concentration



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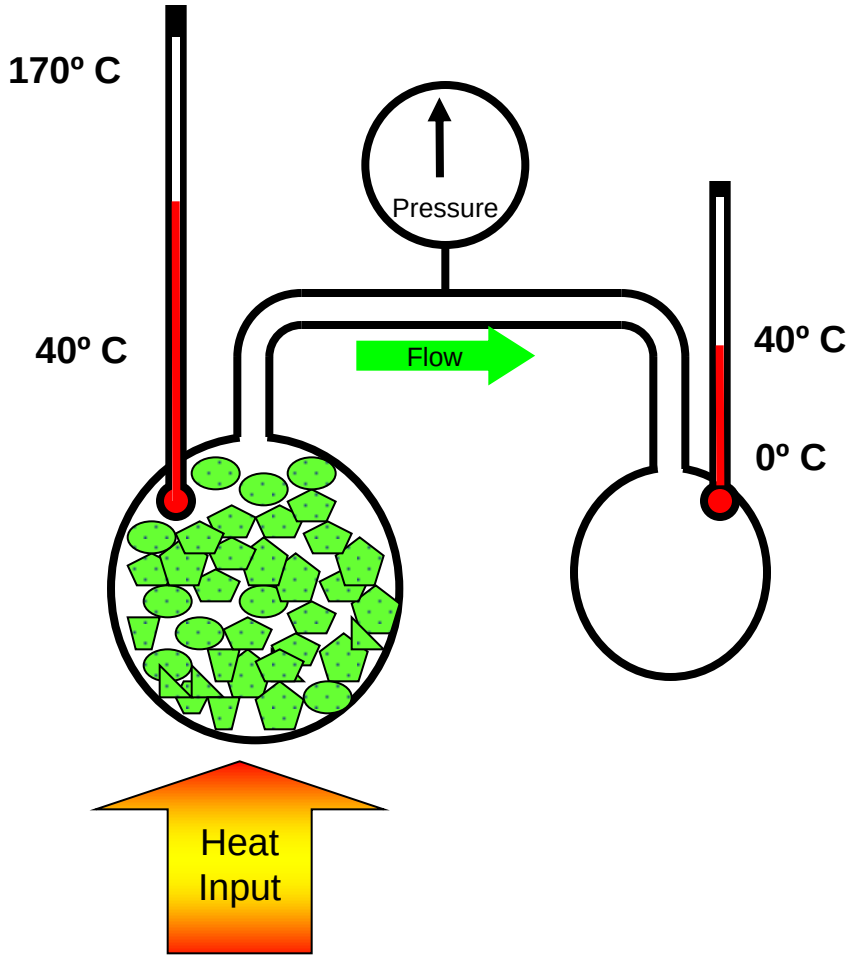
Operating principle

Idealised Adsorption Cycle

Process 1

Carbon bed is heated, ammonia is driven off and pressure increases until…



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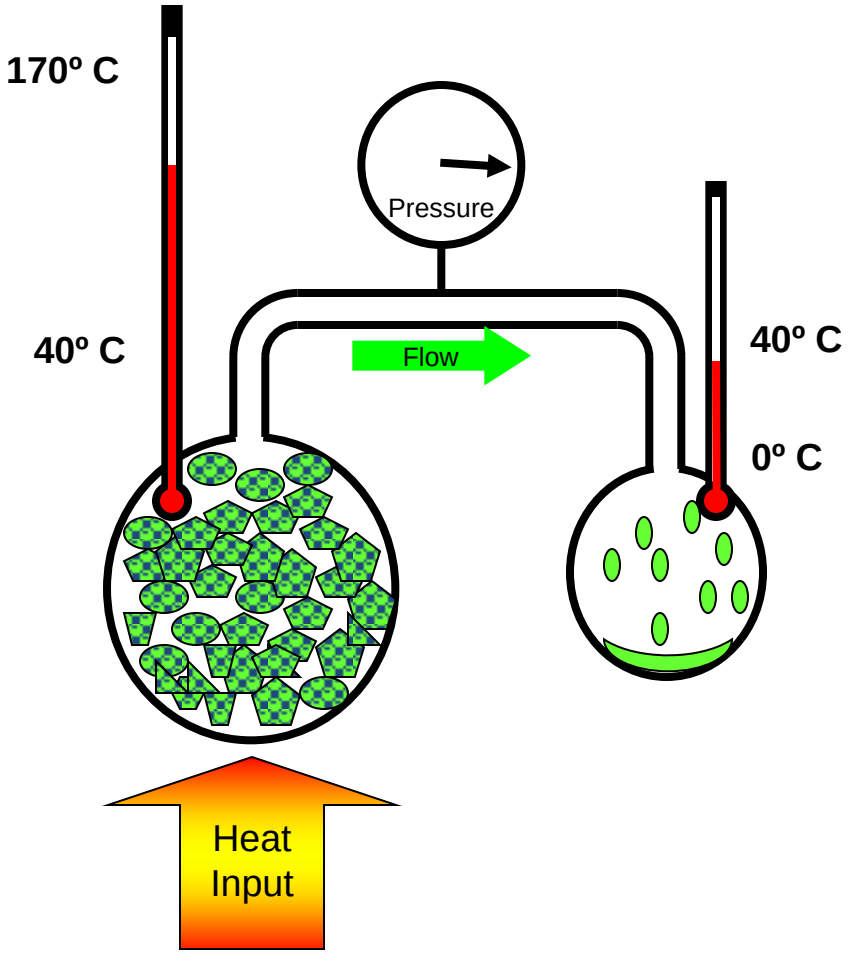
Operating principle

Idealised Adsorption Cycle

Process 2 starts

The saturation pressure is reached and ammonia condenses in the right hand vessel at ambient temperature.



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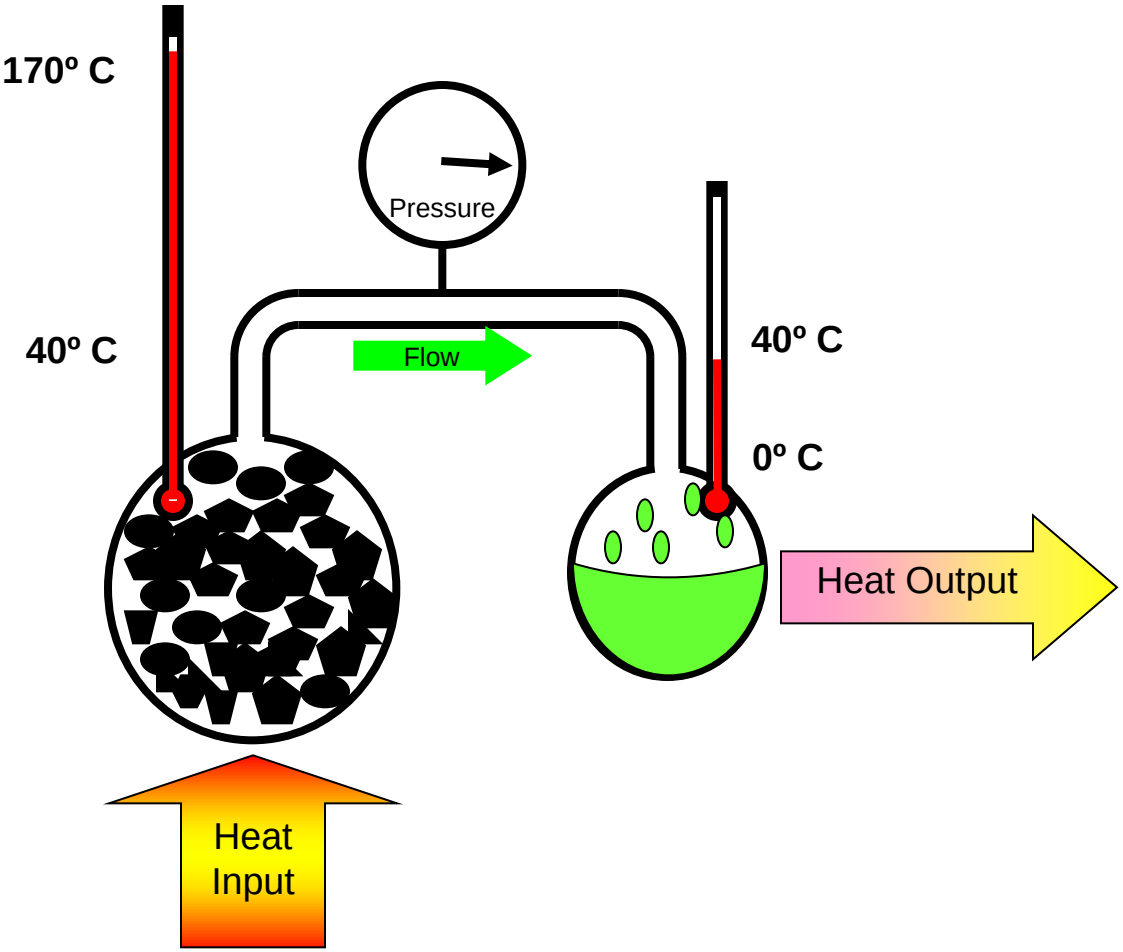
Operating principle

Idealised Adsorption Cycle

Process 2 continues

More ammonia is driven out from the carbon and condensed in the right hand vessel



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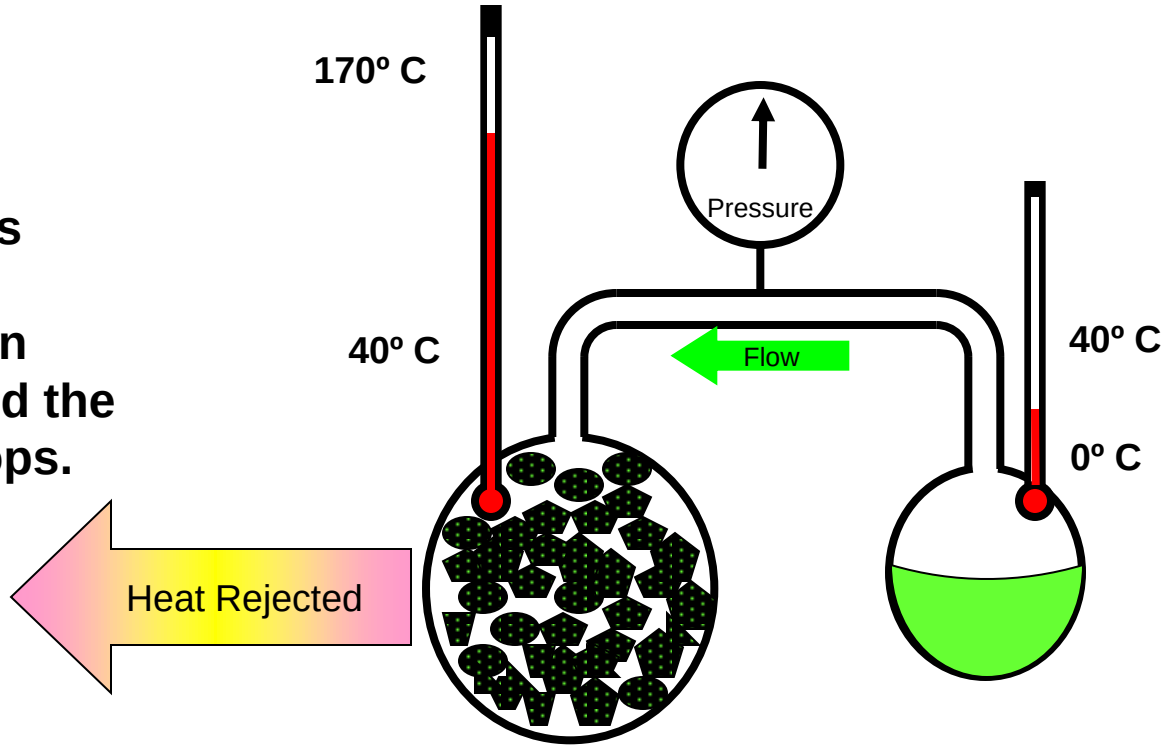
Operating principle

Idealised Adsorption Cycle

Process 3

The carbon is cooled, the concentration increases and the pressure drops.



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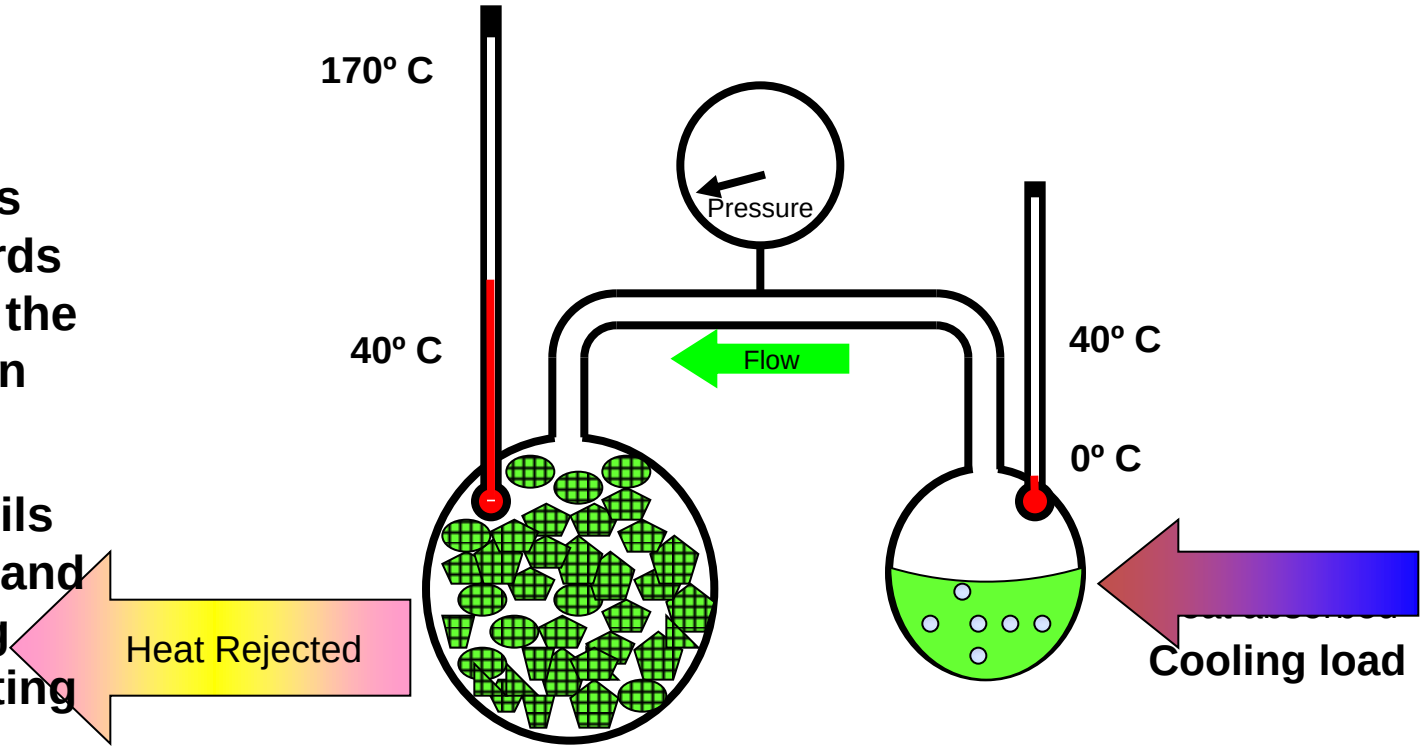
Operating principle

Idealised Adsorption Cycle

Process 4

The carbon is cooled towards ambient and the concentration increases.

Ammonia boils in the right hand vessel giving the refrigerating effect.

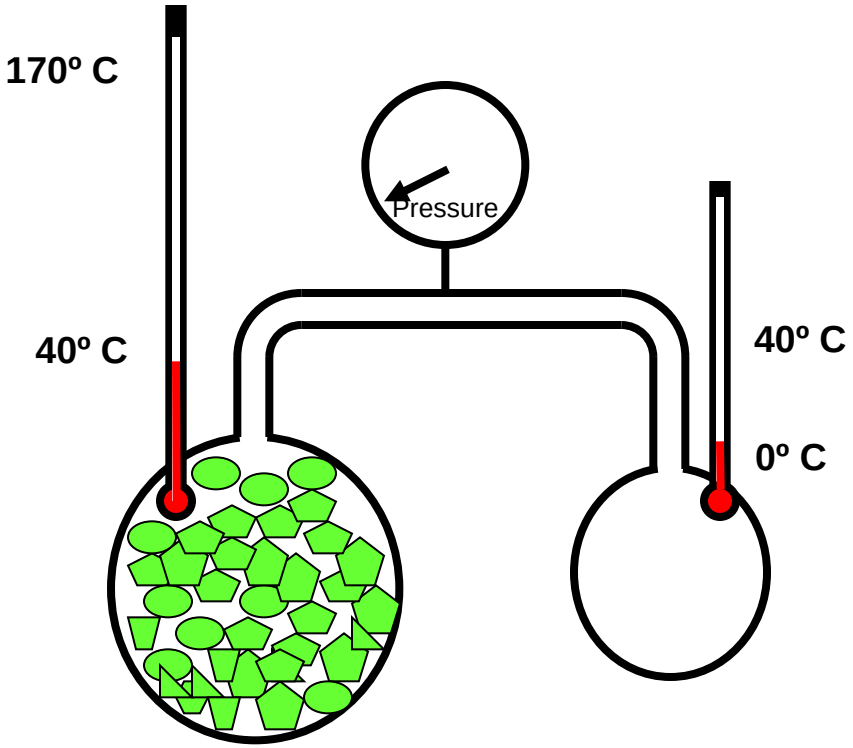


Operating principle

Idealised Adsorption Cycle

End of Process 4:

The system is returned to the starting condition



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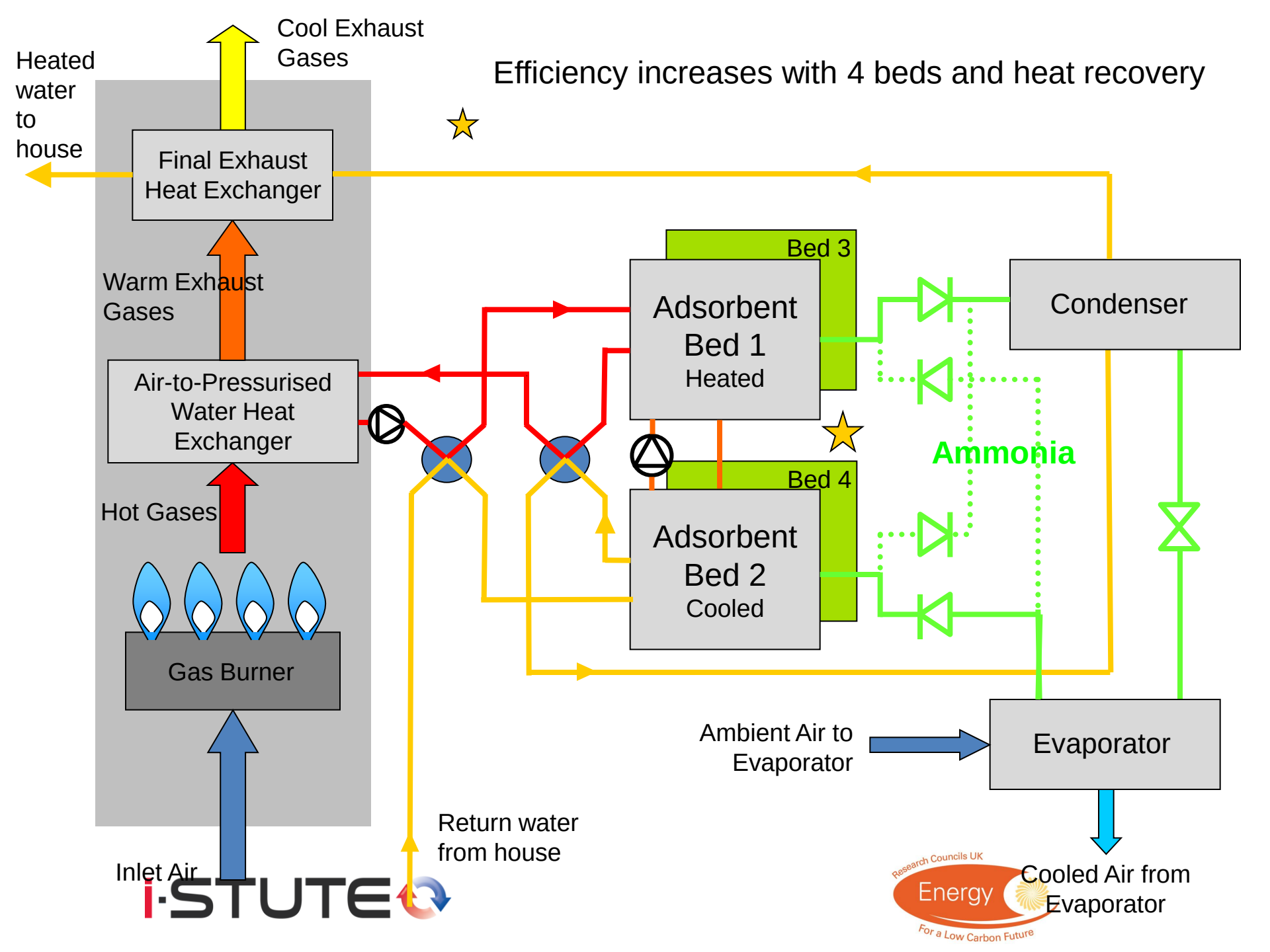
Efficiency increases with 4 beds and heat recovery
Heated water to house
Cool Exhaust Gases
Final Exhaust Heat Exchanger
Warm Exhaust Gases
Air-to-Pressurised Water Heat Exchanger
Hot Gases
Gas Burner
Inlet Air
Bed 3
Adsorbent Bed 1
Heated
Bed 4
Adsorbent Bed 2
Cooled
Condenser
Ammonia
Ambient Air to Evaporator
Evaporator
Cooled Air from Evaporator
Return water from house
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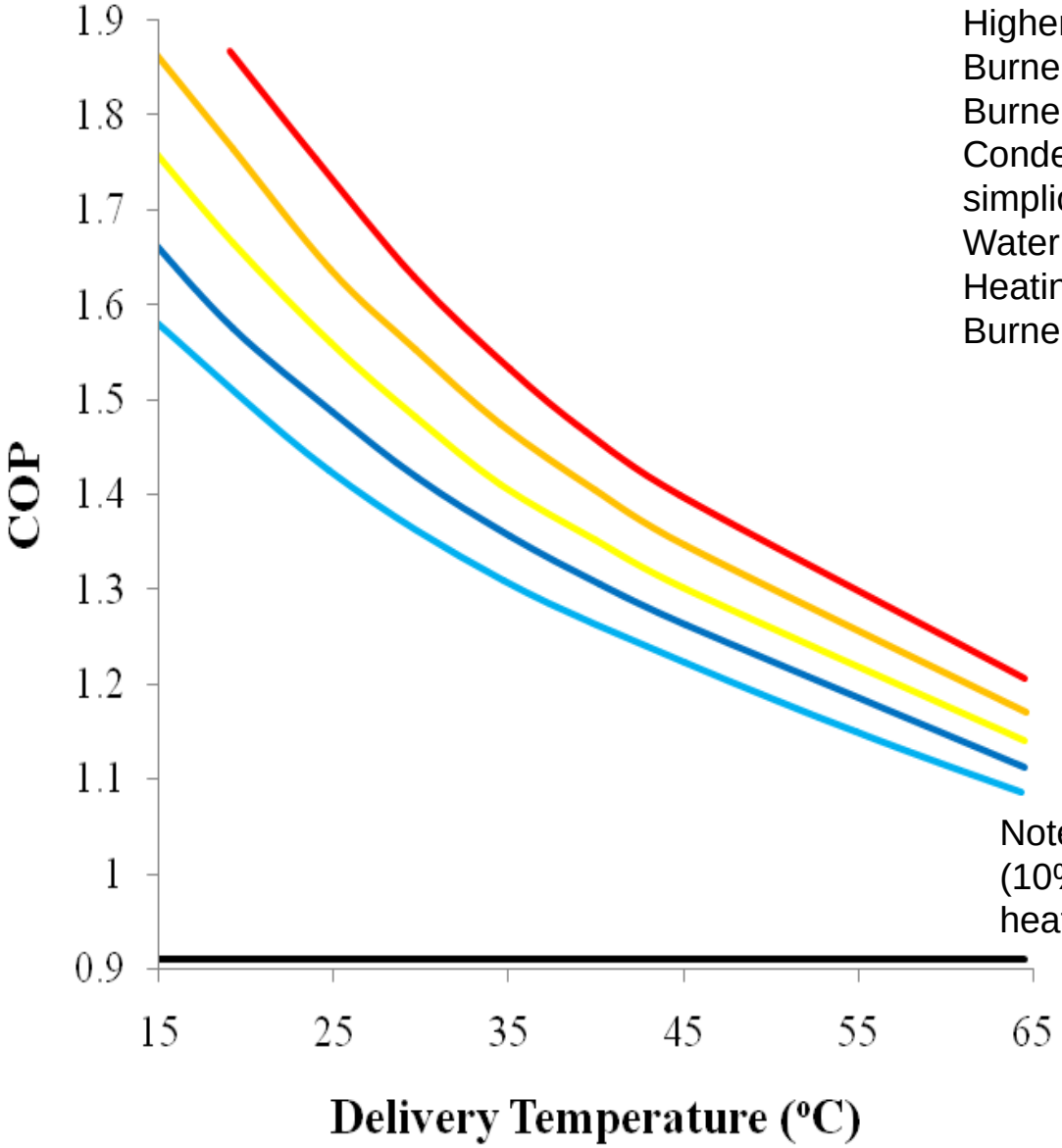

Higher calorific value of natural gas used in all cases
Burner efficiency: 84%
Burner exhaust gas recovery: 5% of gas input
Condensing boiler efficiency (assumed constant for simplicity): 91% (SEDBUK)
Water flow rate: 20 l/min
Heating power: 6-7 kW
Burner water temperature: 120-200°C

Note that the COP should never drop below 1.0 (10% better than condensing boiler), within the heat pump operating range.

Change in product concept over time of project:

Where has the rest of the hardware gone?

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Fits into standard wall-mounted casing

Adsorbent Beds (Generators)

- Box-for-box exchange for old boiler
- Key competitive advantage
  - other gas-fired heat pumps too large for wall mount
- Retrofit market >90% of annual sales

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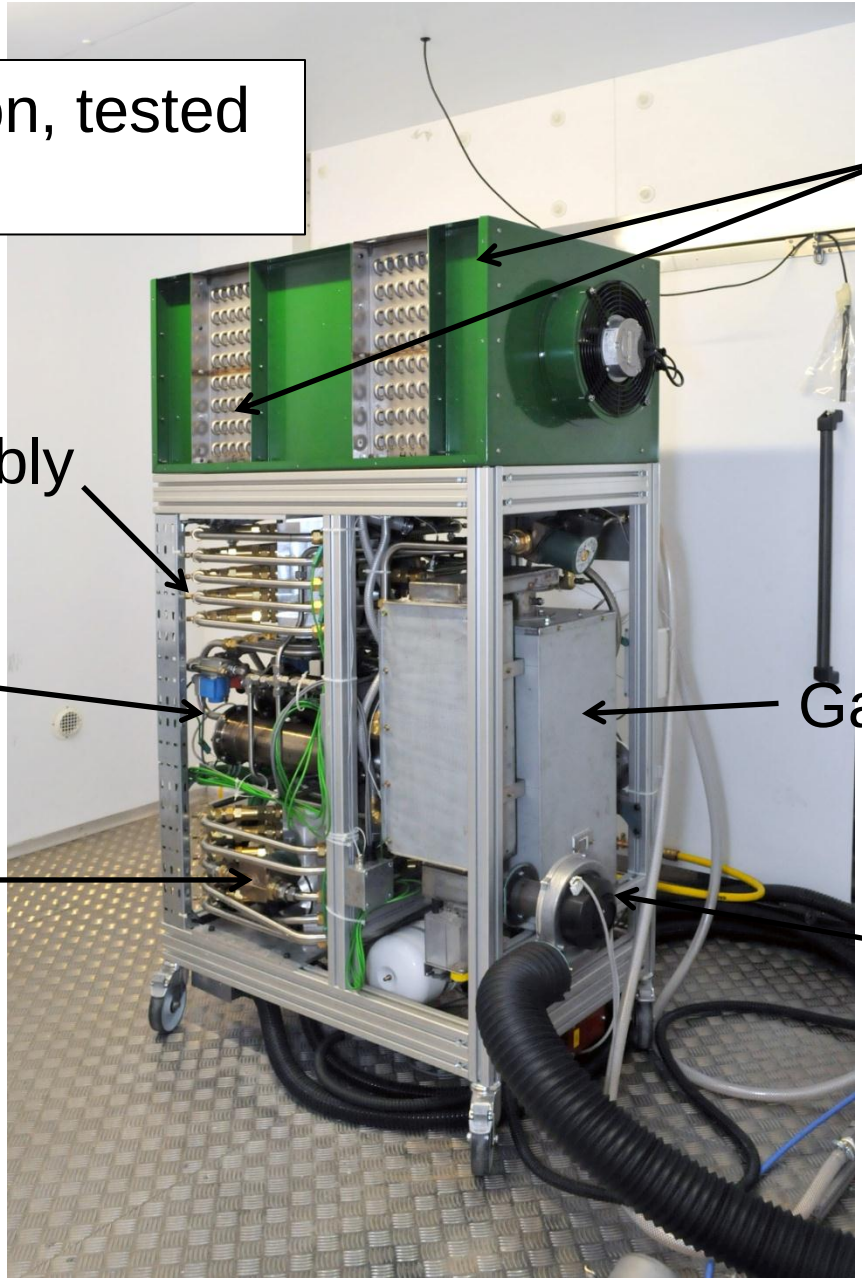
Original version, tested May 2011



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Initial testing:

Initial running successfully produced output water at 60°C.

The machine functioned but **excessive heat losses** and **internal leakage** from valve assemblies lead us to a re-design.

Problems to be solved:

- ‘Production water valve’ [4-pole, 4-way] needed that did not suffer from internal heat and flow leakage.
- Ammonia check valves unreliable.
- Generator heat transfer less than predicted

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Current status:

- Bespoke 4 pole-4 way water valves built and tested.
- Ammonia check valves re-designed
- Larger generators built as a temporary means of testing a 7kW machine.

- Testing imminent

- In depth study of generator heat transfer carried out
- Reports written on ‘Markets, Support Measures and Barriers’ and ‘State of the Art’

So where do we go with i-STUTE?

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Plans October 14 – March 14:

- Carry out tests on thermal compressor
- Evaluate current prototype
- Trial different methods to improve generator heat transfer
- Compare existing and future technologies

- Make recommendations for fruitful lines of research

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Activities:

- Carry out tests on thermal compressor
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Activities:

- Carry out tests on thermal compressor
- Evaluate current prototype

1. Rapid prototyped water distributor failed completely
2. Decision taken to reconfigure as 2-bed machine to maintain industrial interest and to confirm generator characteristics as expected.
3. Target COP (Gas, Gross) of 2-bed system with existing generators ~ 1.1. Power 5-9kW depending on bed conductivity.

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Activities:

Trial different methods to improve generator heat transfer

1. Detailed measurements of thermal conductivity and contact resistance of range of carbon mixes and densities carried out.
2. Results to be presented at ISHP2014
3. Still need to pull conclusions together to aid design.

Plans October 14 – March 14:

- Carry out tests on thermal compressor
- Evaluate current prototype
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- Make recommendations for fruitful lines of research

Still to do…

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Thank you for your attention

- Any questions?