



Development of a carbon-ammonia adsorption gas heat pump

**IEA Heat Pump Workshop, London, 13th November,
2012**

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Contents:

Background

Concept design

Technical progress

‘CALEBRE’ project funded by EPSRC/EoN:

- Part of funding is for proof of concept gas fired heat pump
- Funding is to University of Warwick
- University spin-out company (Sorption Energy Ltd) owns IP and hopes to develop a product
- Specification of first machine was for a 7 kW heat output

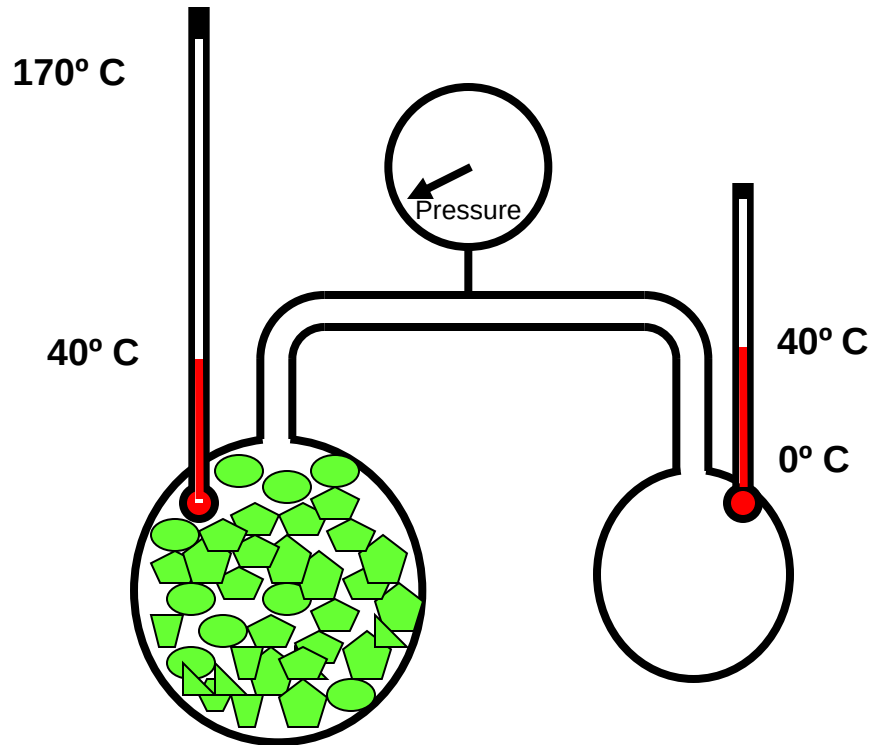
Idealised Adsorption Cycle

Initial State:

**Ambient
Temperature**

Low pressure

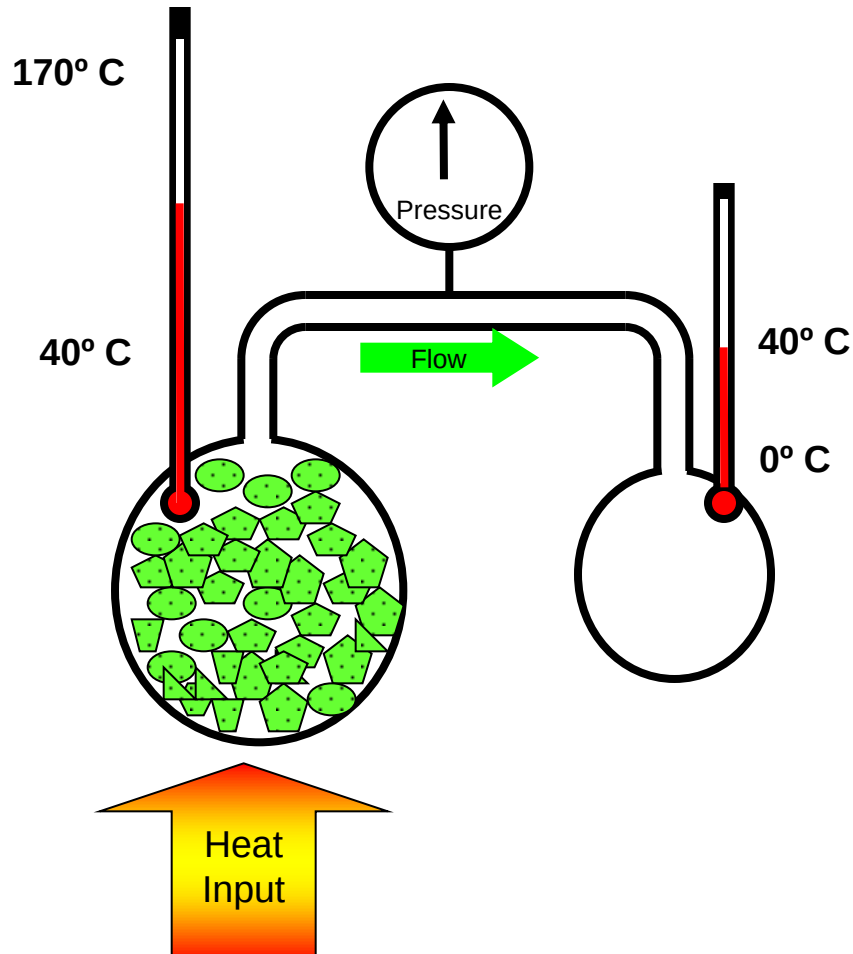
**High
concentration**



Idealised Adsorption Cycle

Process 1

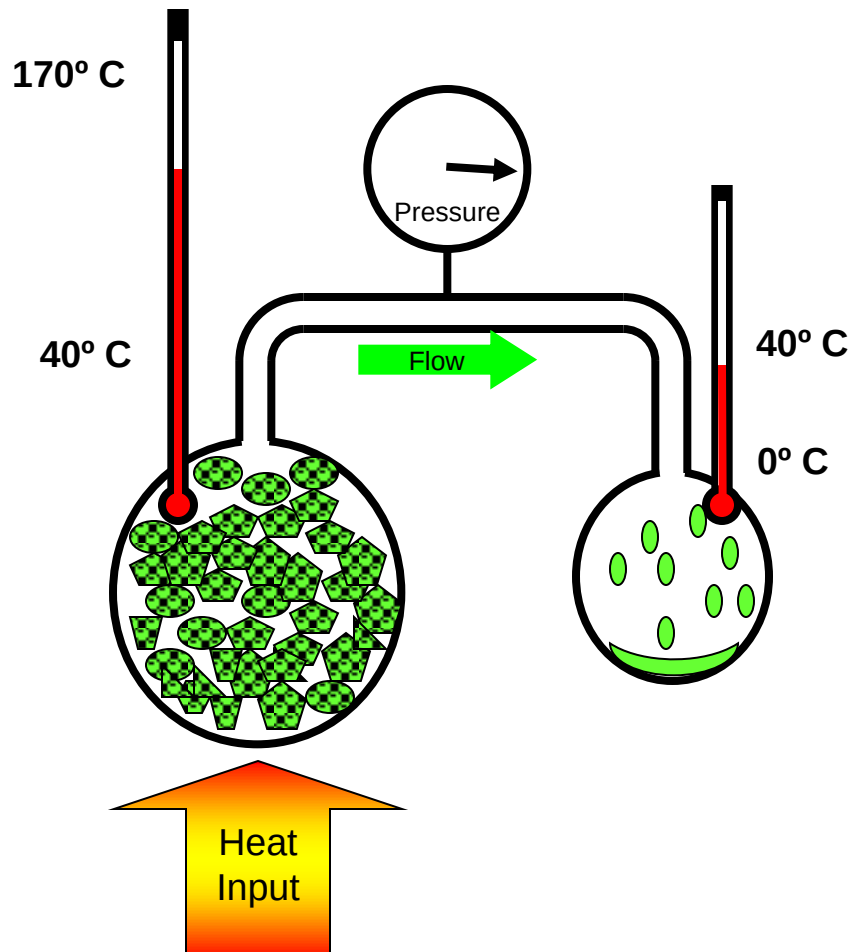
Carbon bed is heated, ammonia is driven off and pressure increases until...



Idealised Adsorption Cycle

Process 2 starts

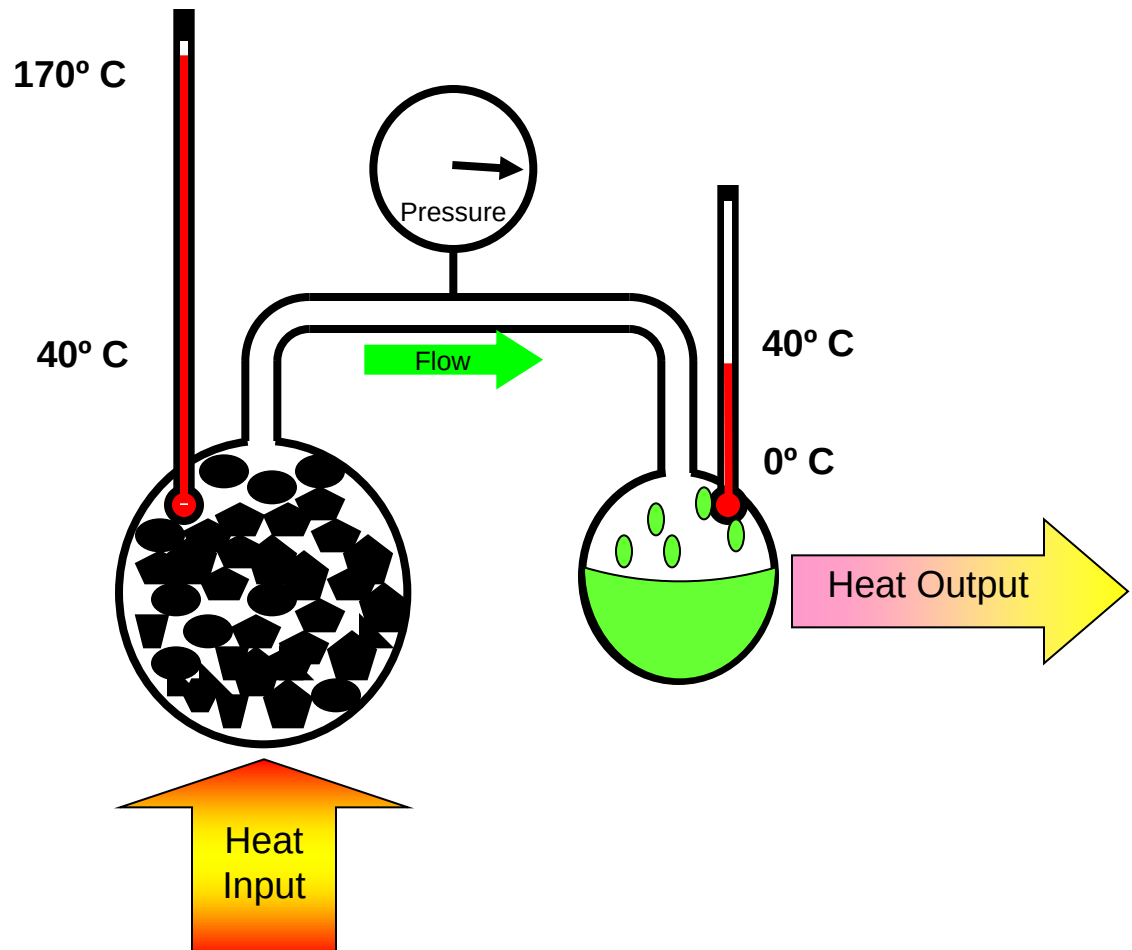
The saturation pressure is reached and ammonia condenses in the right hand vessel at ambient temperature.



Idealised Adsorption Cycle

Process 2 continues

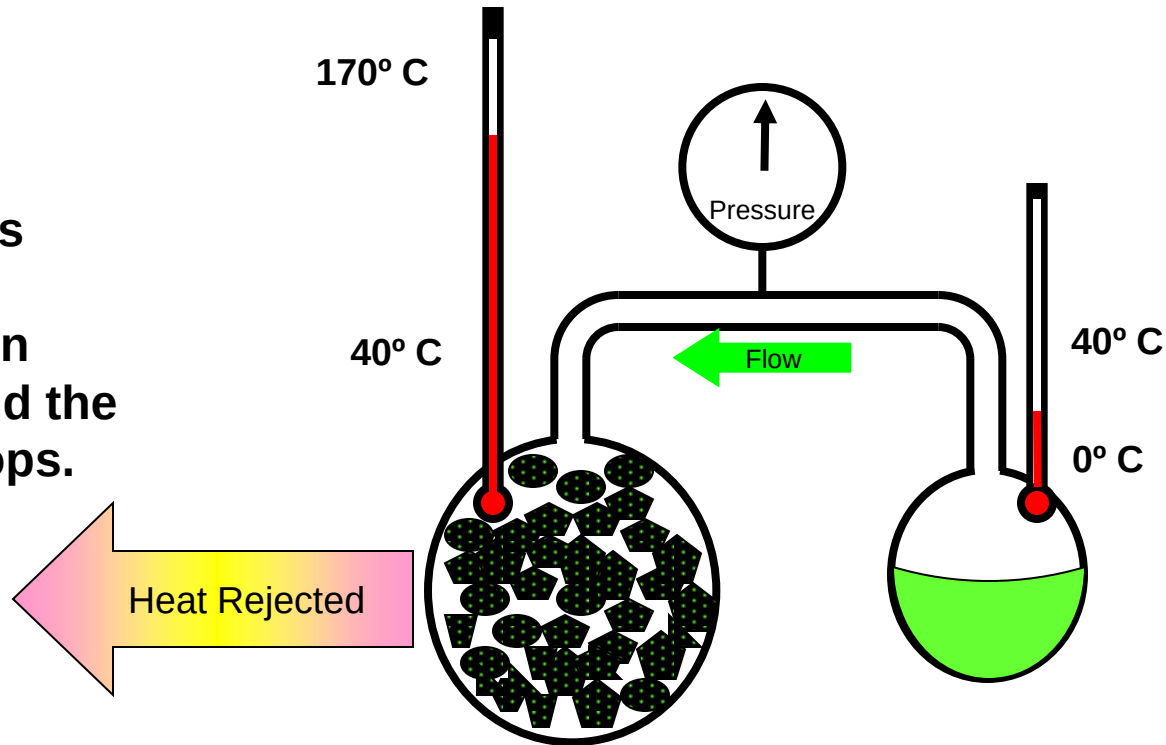
More ammonia is driven out from the carbon and condensed in the right hand vessel



Idealised Adsorption Cycle

Process 3

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

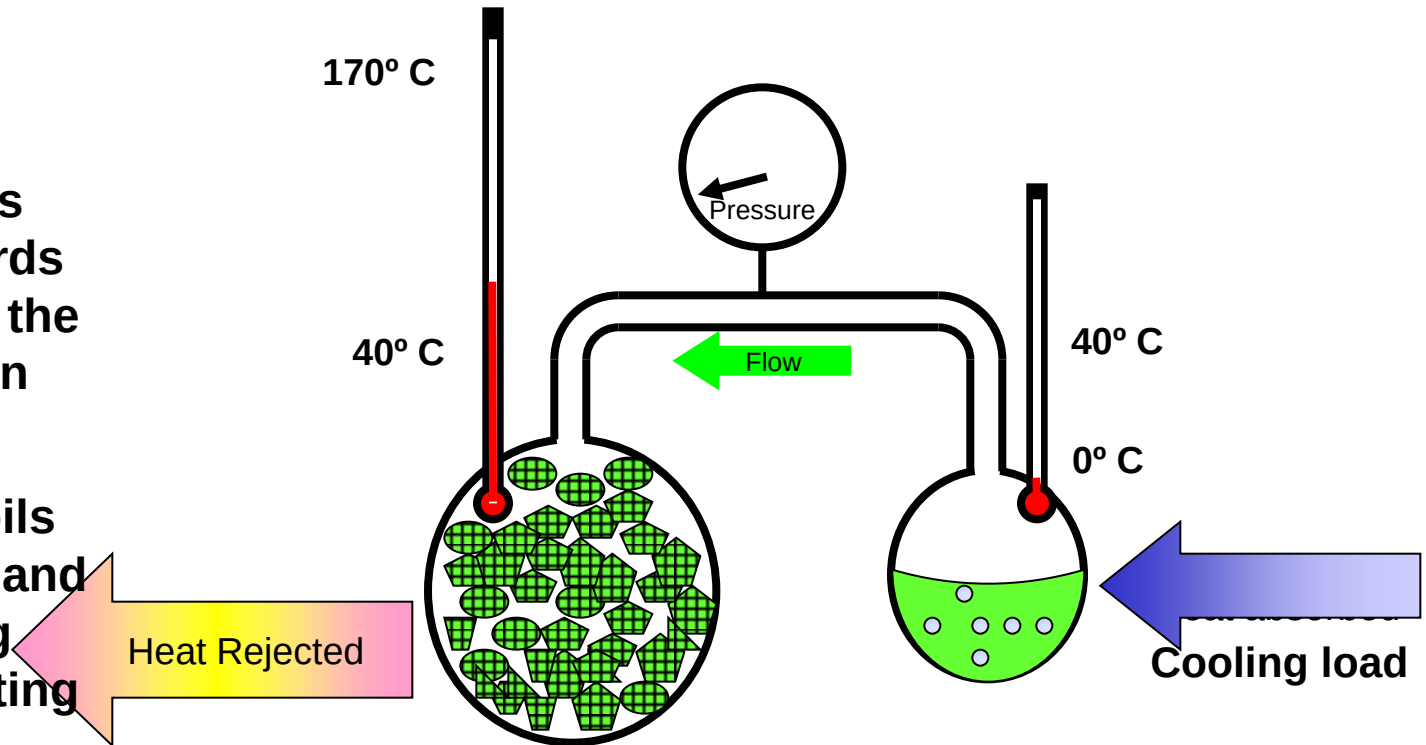


Idealised Adsorption Cycle

Process 4

The carbon is cooled towards ambient and the concentration increases.

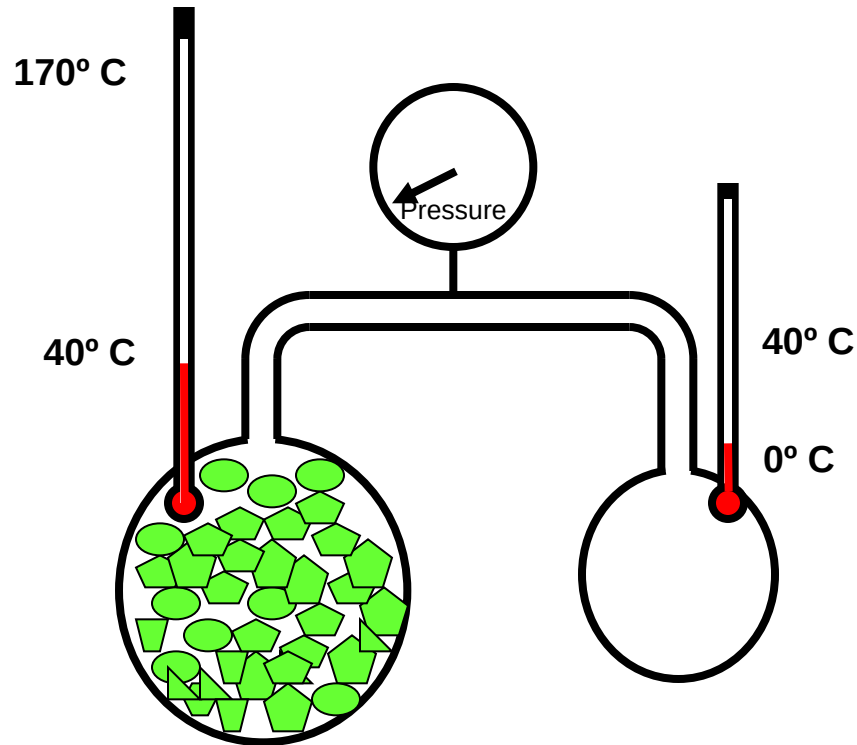
Ammonia boils in the right hand vessel giving the refrigerating effect.



Idealised Adsorption Cycle

End of Process 4:

**The system is returned
to the starting condition**



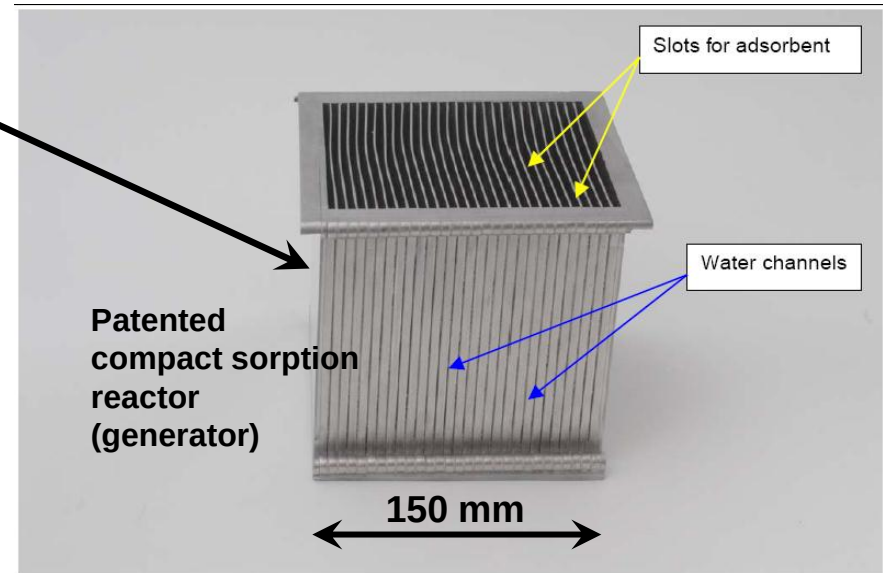
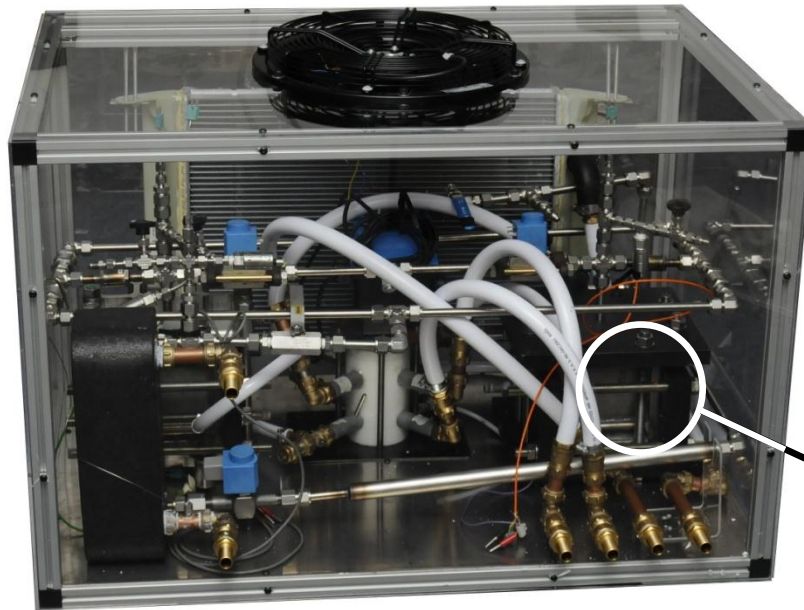
**There are large
capacity adsorption
chillers**

**Mycom Silica-gel water 100 kW
adsorption chiller**



© MYCOM Europe S.A. - ADR-30 chiller at the factory

Our technology is 20x more compact (kW/litre)

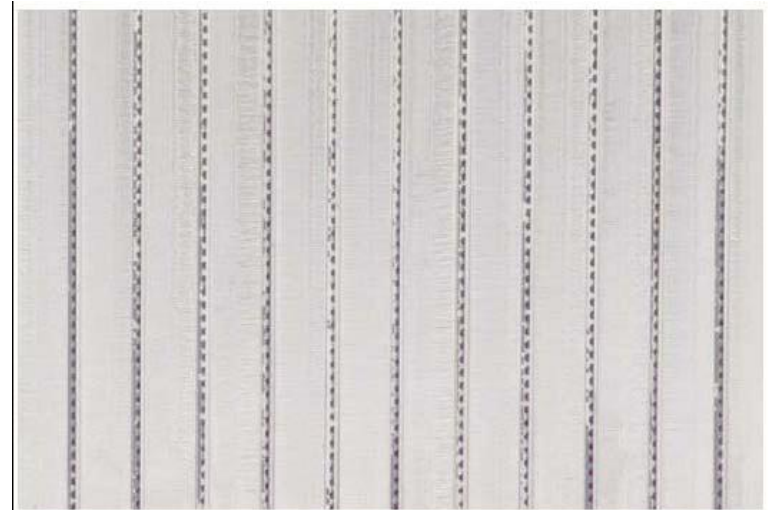


Sorption Generator Design

Nickel Brazed Stainless Steel
Construction

Etched Heat Transfer Fluid
Channels

Carbon Adsorbent Compressed
Into 4 mm Thick Layers

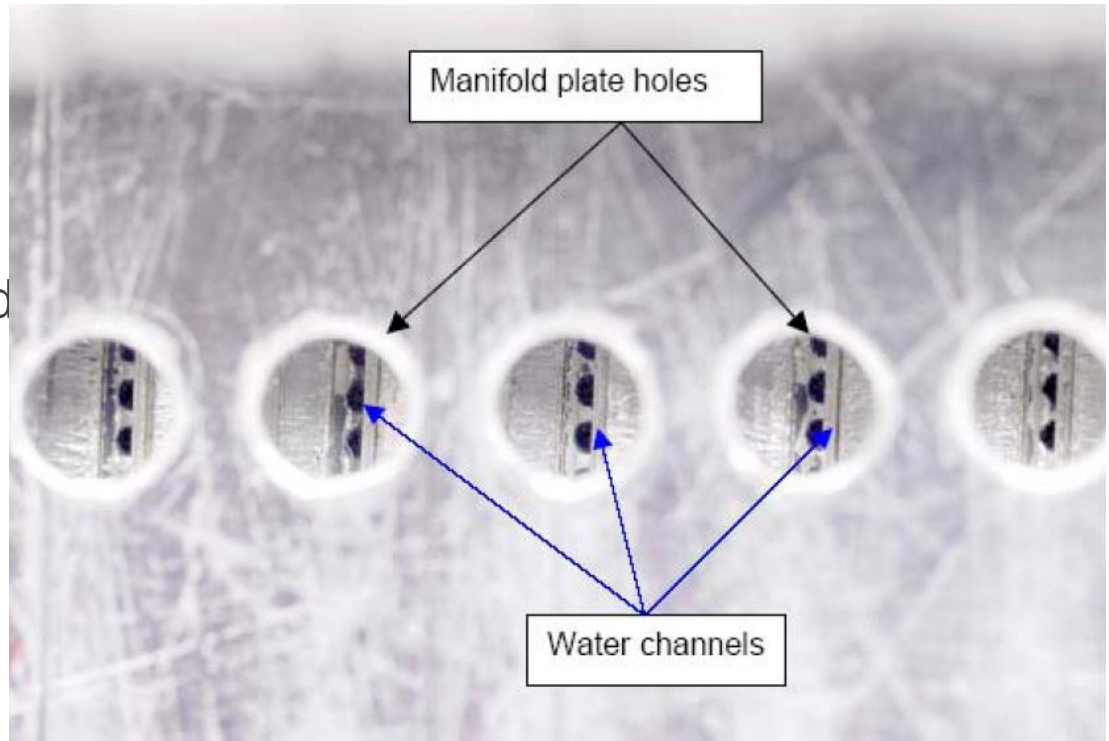


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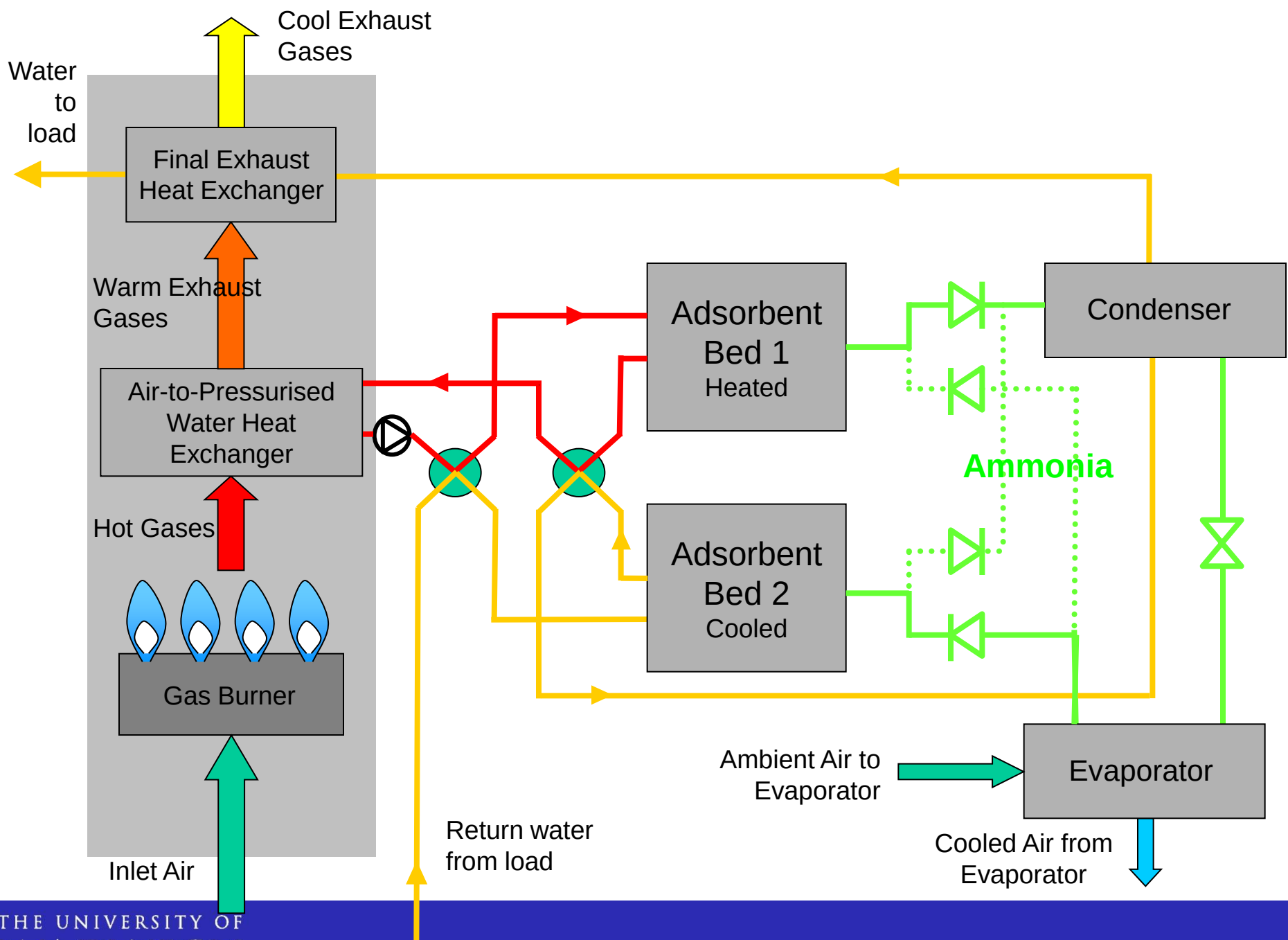
New application – replacement for condensing boilers

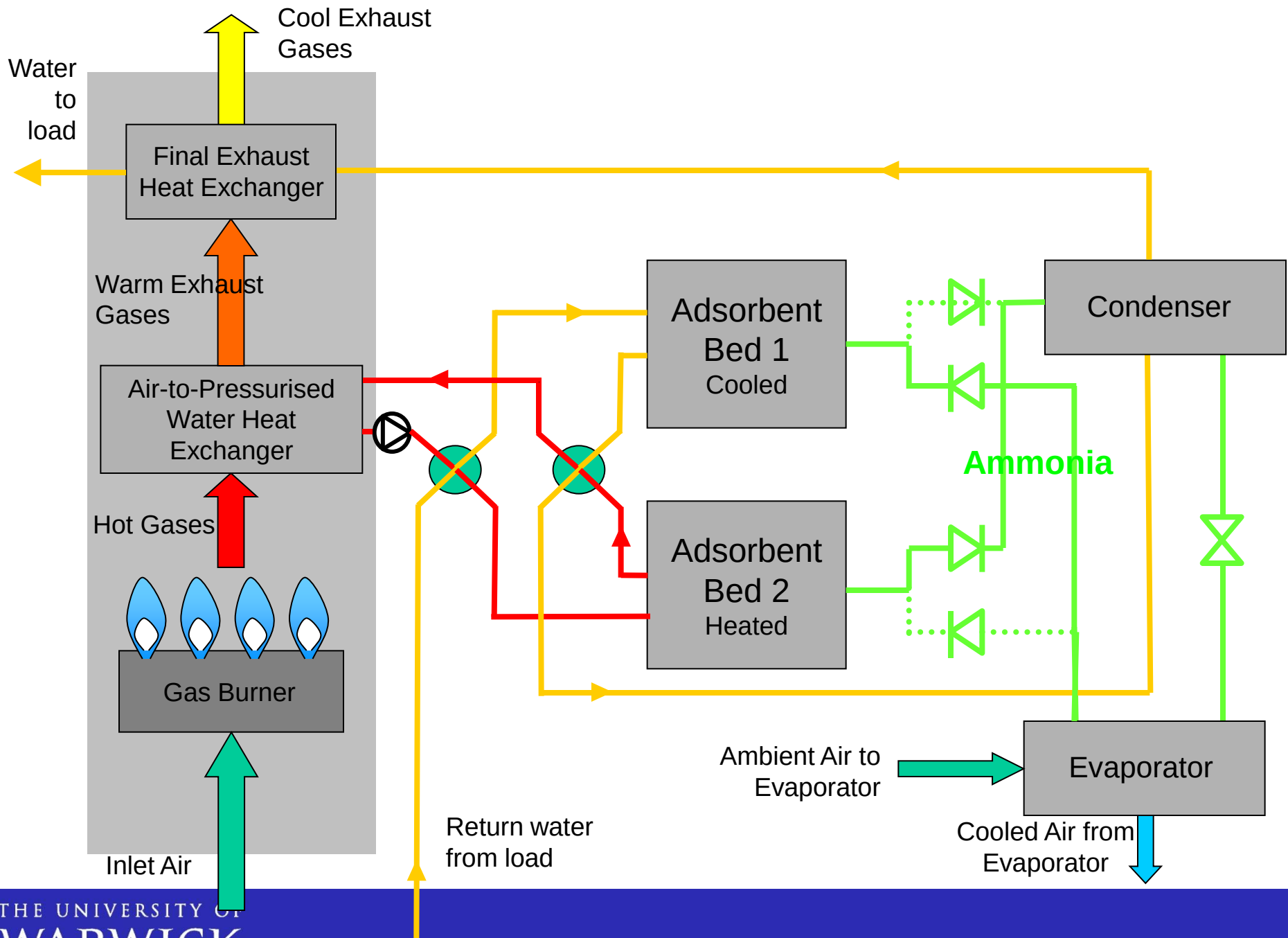
Previous adsorption heating/cooling systems far too large

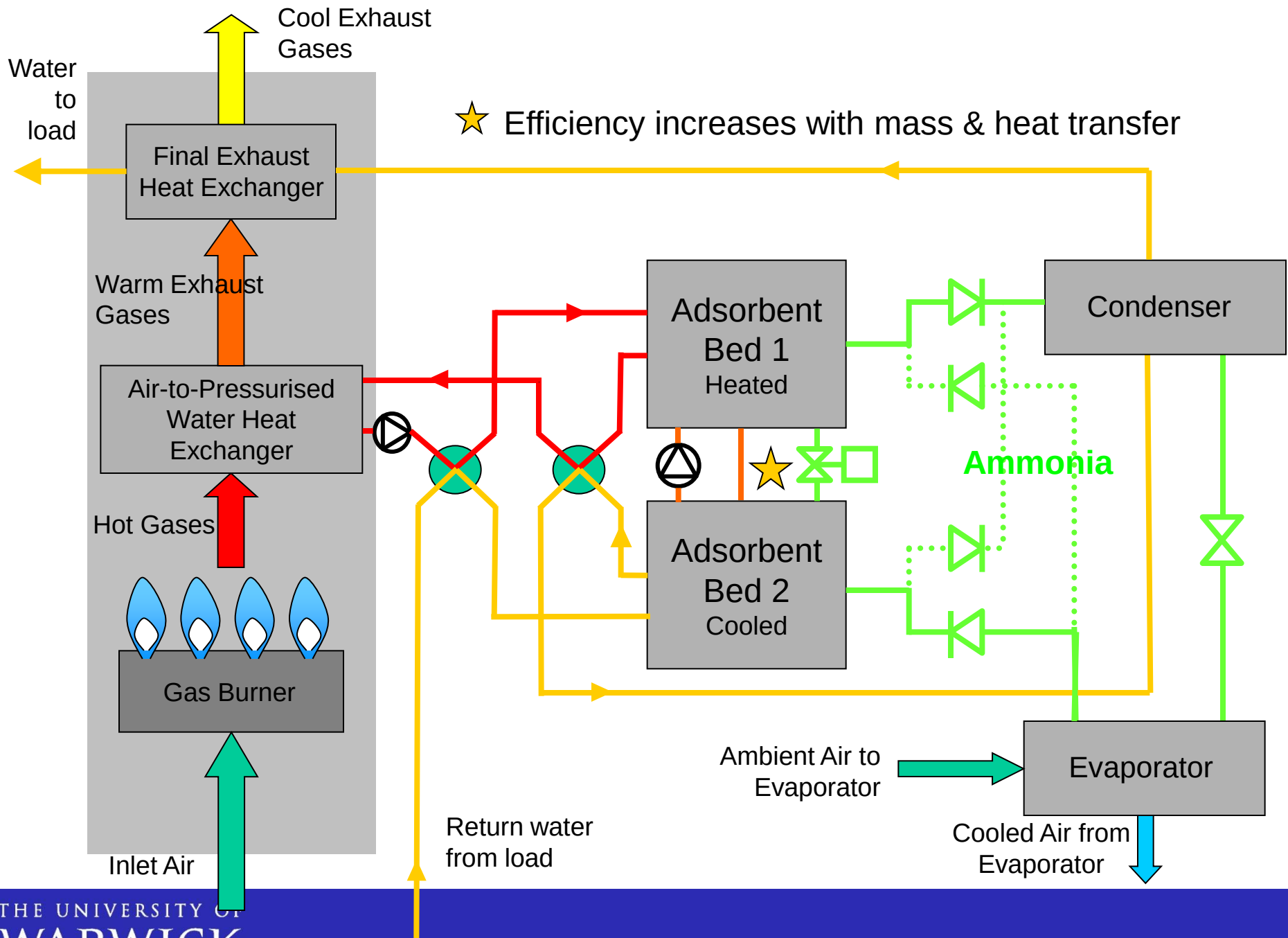
Breakthrough (patented) is in making systems small enough for domestic applications

System to fit in typical homes

Realistic cost and payback







Previous research using shim generator design

Two-bed air-source
compact heat pump
system proven in the
laboratory

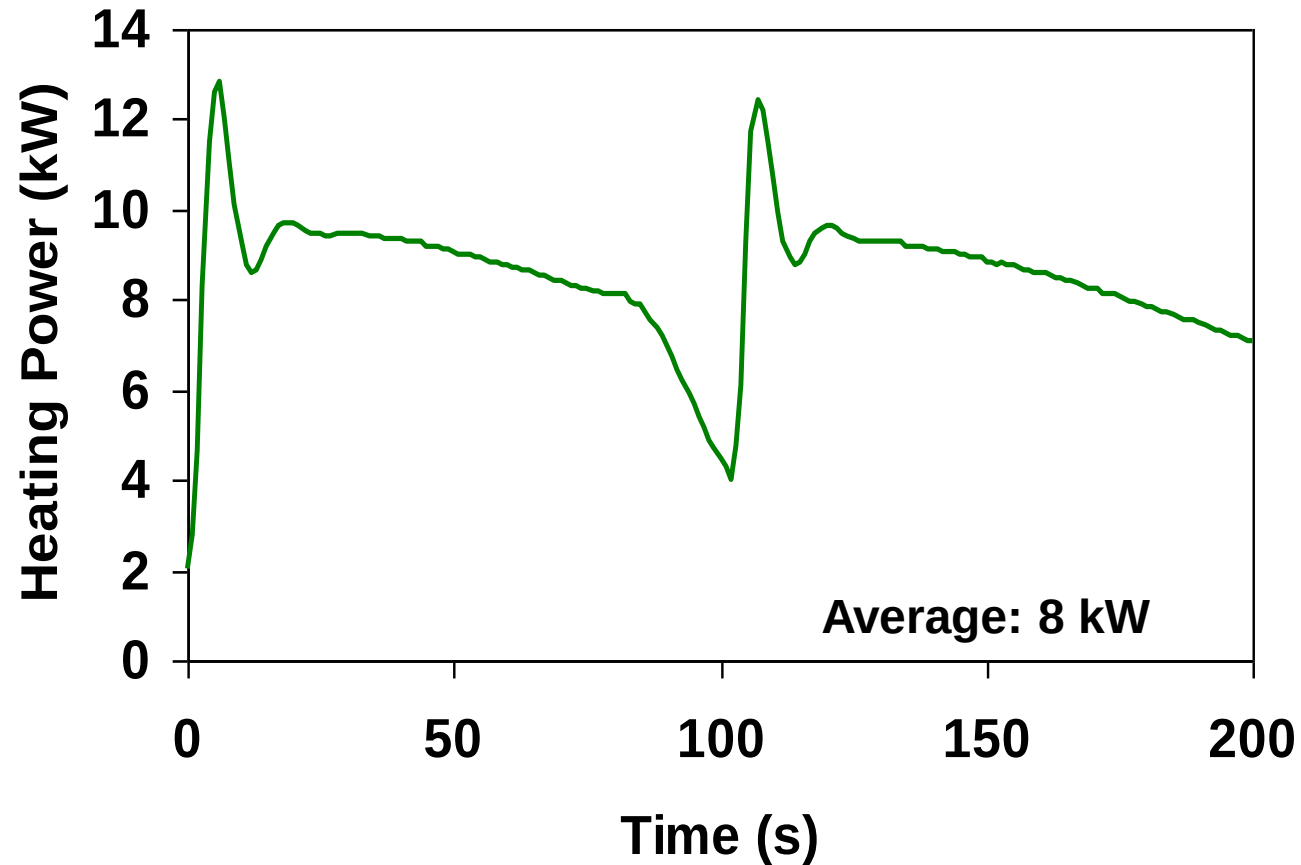
Plate heat exchanger
adsorption generators

Powered by electric heater
7-11 kW heating power

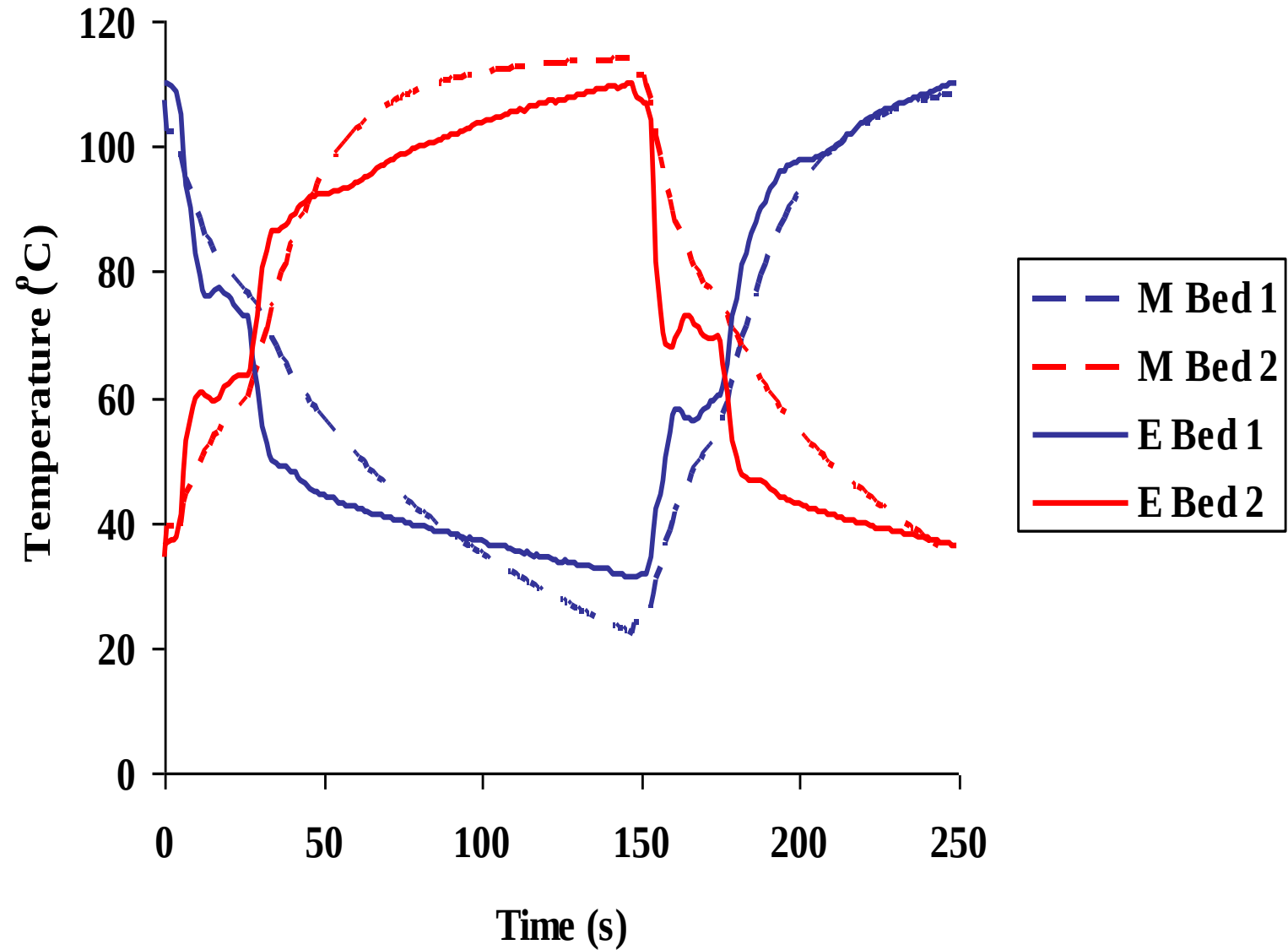
COP 1.6 (heat out /
electrical heat in)



Previous research using shim generator design



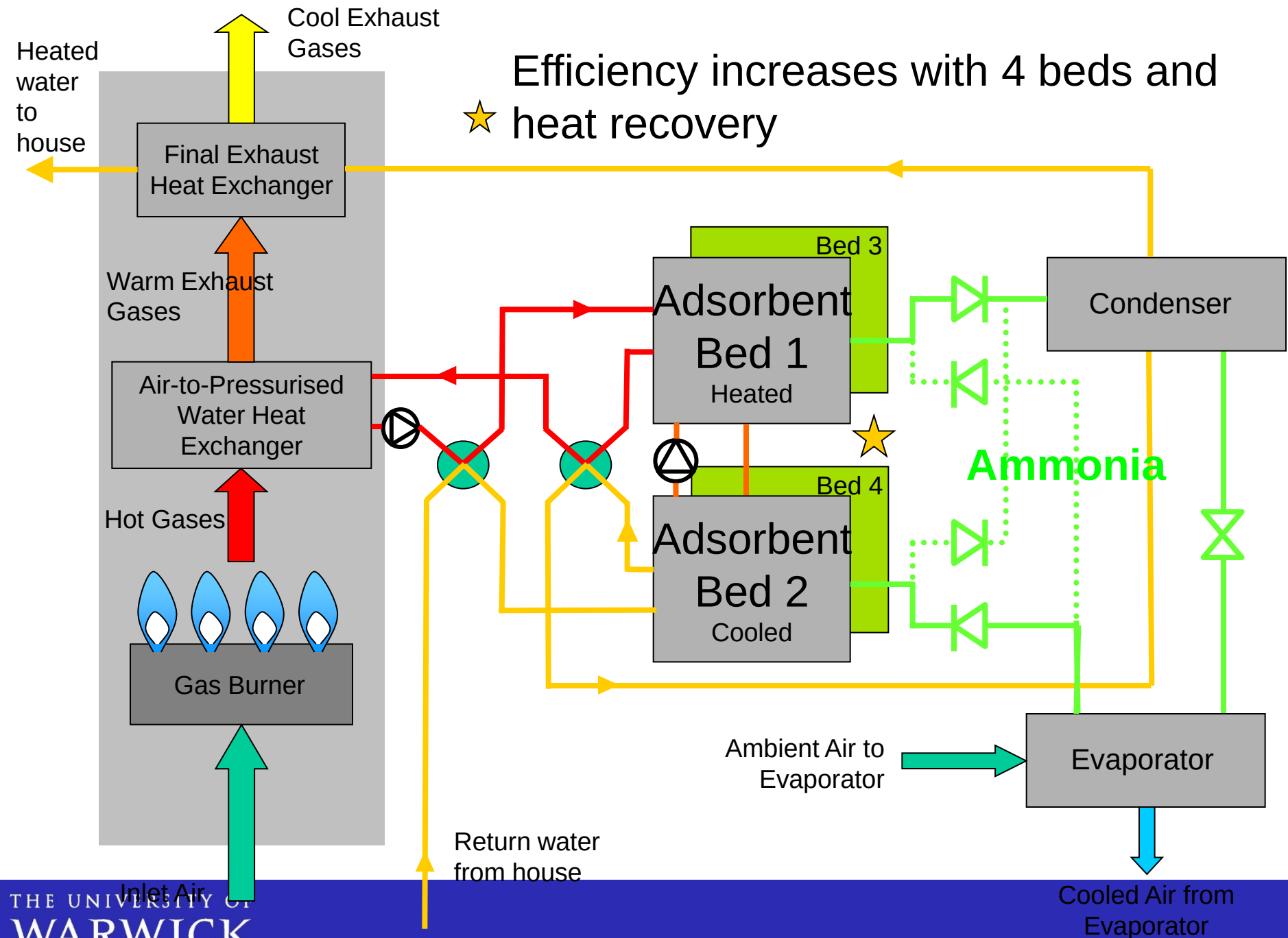
Previous research using shim generator design

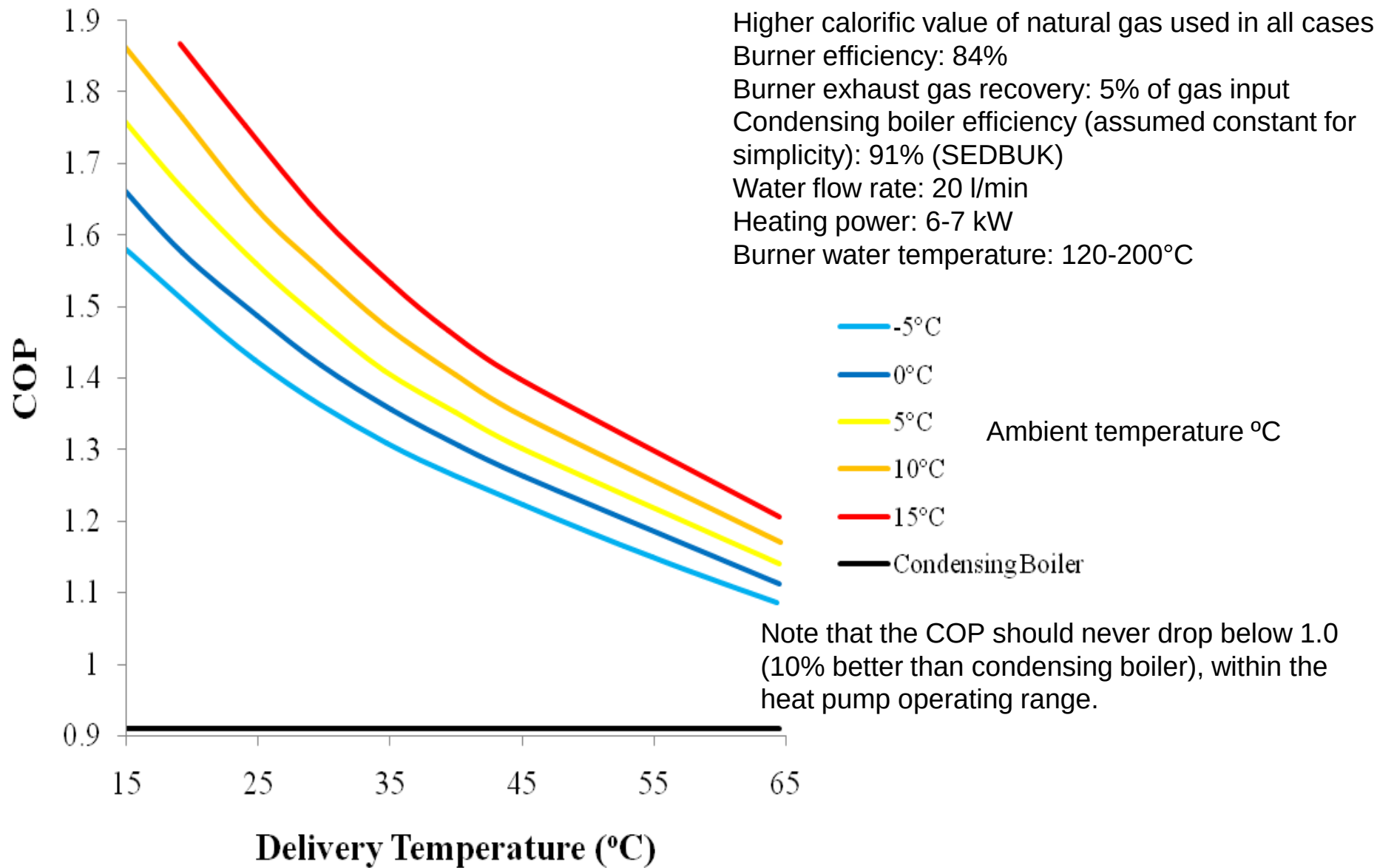


Next step to a commercial product -

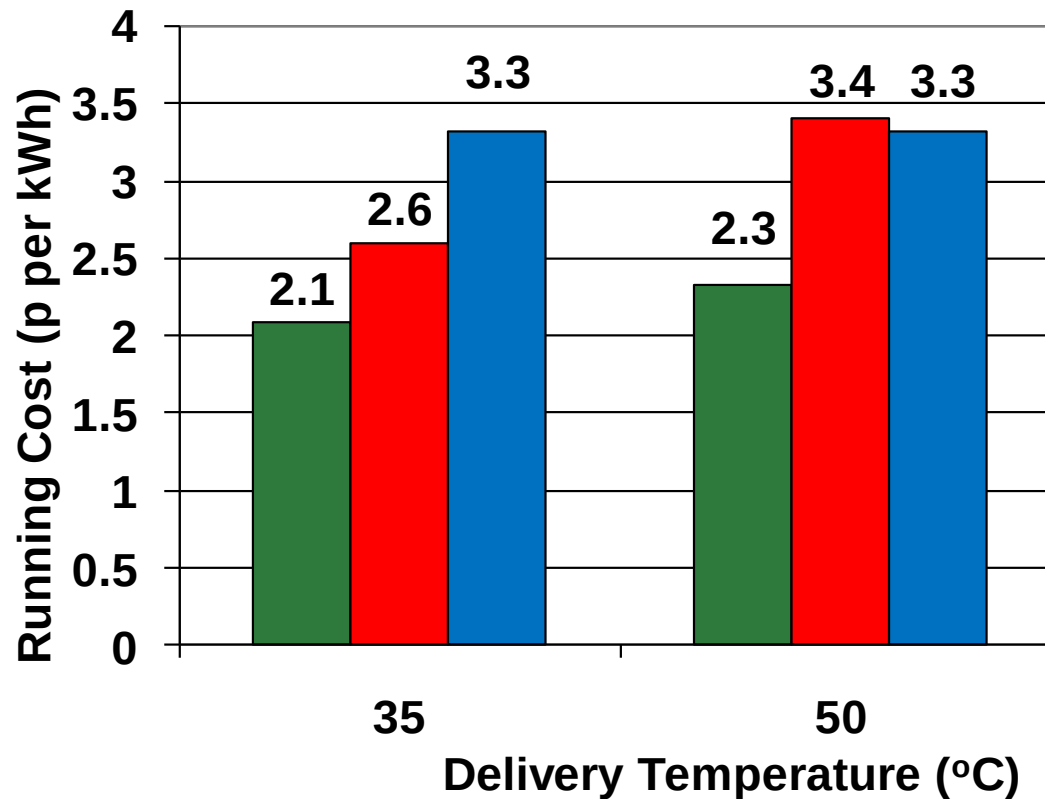
- 4 bed system – 25% more efficient than 2 bed**

★ Efficiency increases with 4 beds and heat recovery





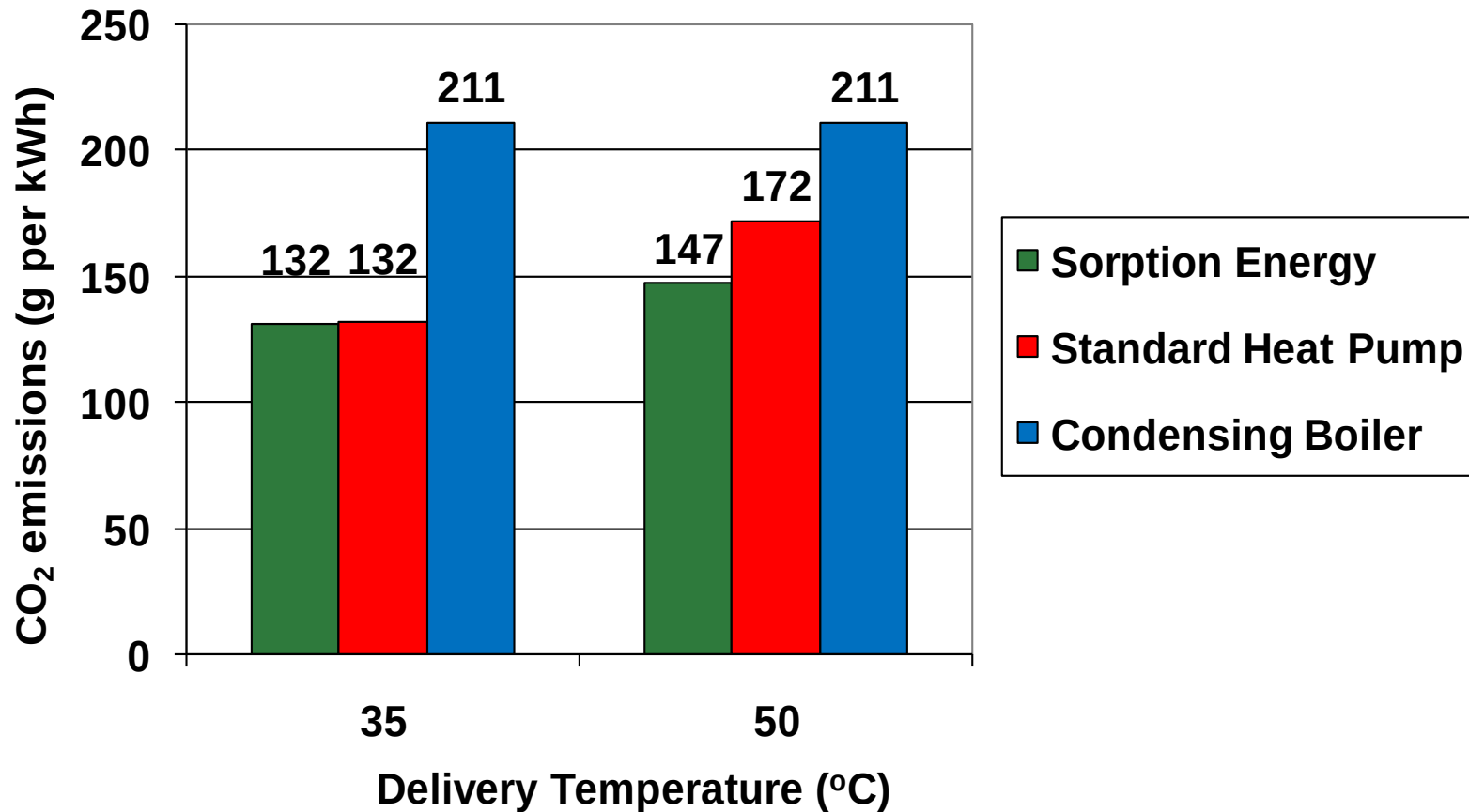
Comparison of Heating Costs (UK)



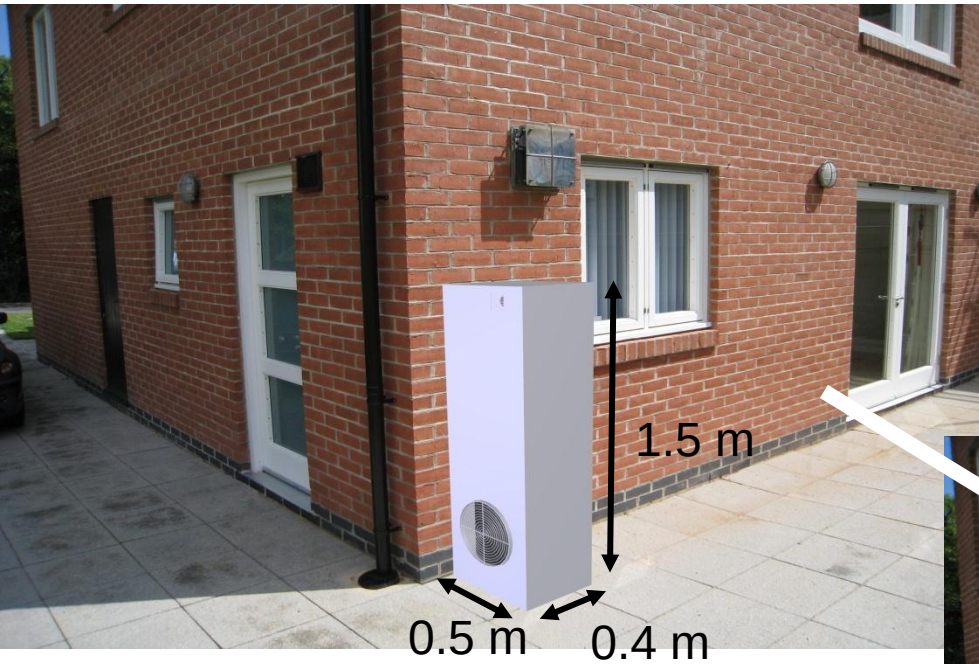
10°C ambient temperature
90% condensing boiler efficiency (HCV)
British Gas gas and electricity prices June 2010
Standard heat pump: Dimplex LI 8 MS

- Sorption Energy
- Standard Heat Pump
- Condensing Boiler

Comparison of CO₂ emissions (UK)



Change in product concept over time of project:



Where has the rest of the hardware gone?

Fits into standard wall-mounted casing



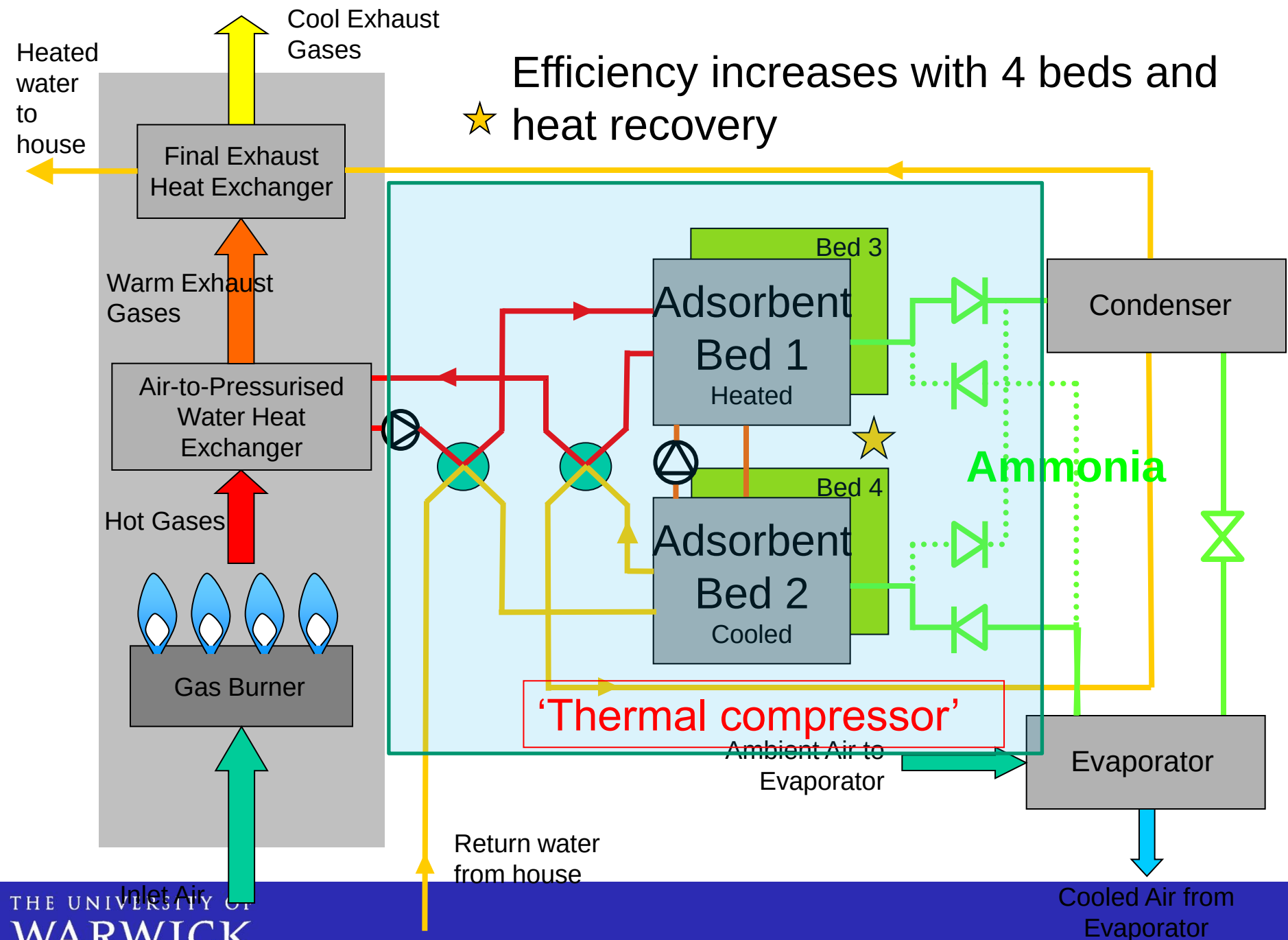
Adsorbent Beds
(Generators)

Box-for-box
exchange for old
boiler

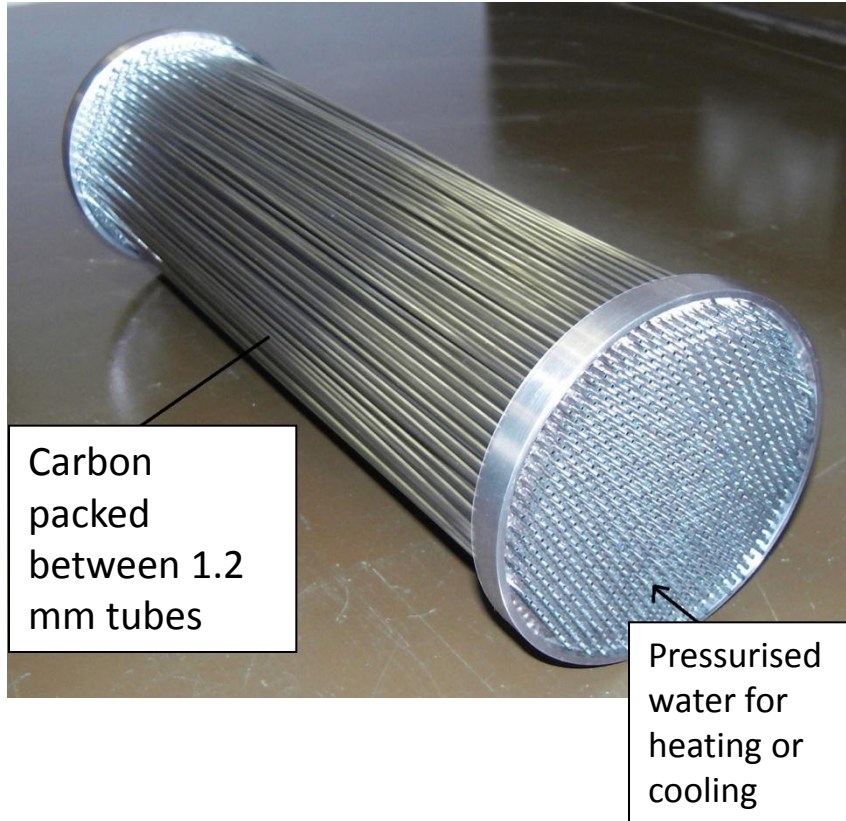
Key competitive
advantage

- other gas-fired heat pumps too large for wall mount

Retrofit market >90%
of annual sales



Generators



Payback within 3 years from fuel savings

About twice cost of condensing boiler

Use existing boiler installers with same trade skills

Similar installation costs inside house

- But have to mount evaporator on outside wall

Fuel savings give pay-back in ~36 months

- Compared to condensing boiler

Original version, tested
May 2011

Top valve assembly

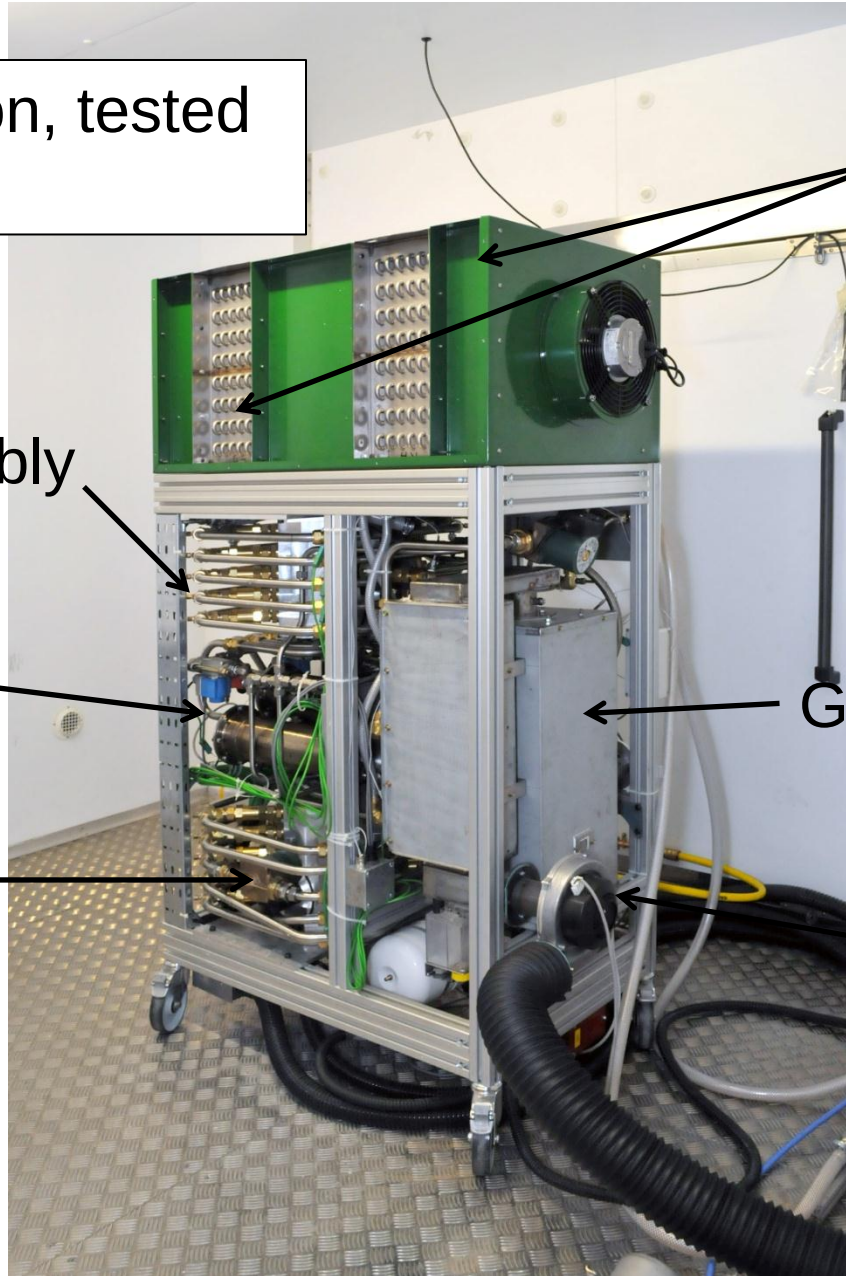
Generators

Bottom valve
assembly

Evaporators

Gas heat exchanger

Burner



Original version, tested
May 2011



Environmental test chambers

Original version, tested
May 2011



Initial testing:

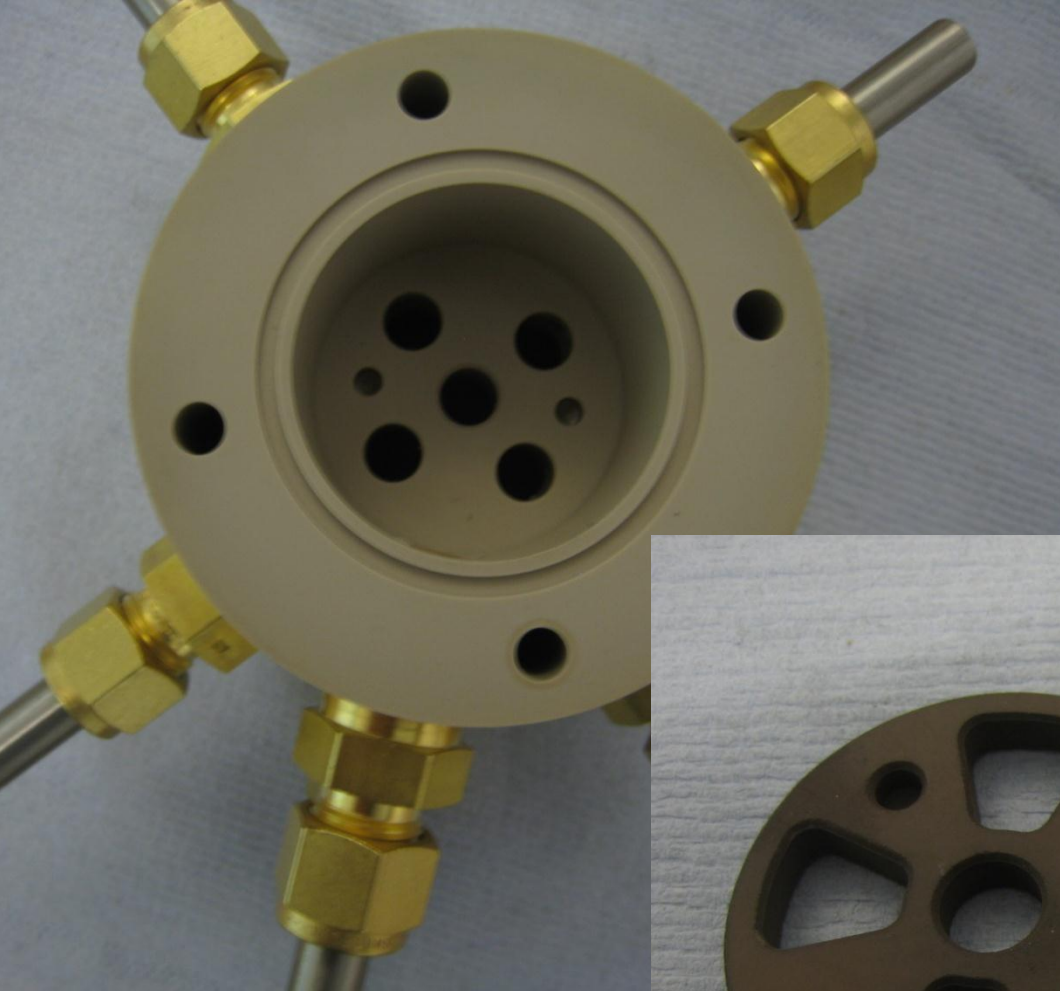
Initial running successfully produced output water at 60°C.

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

- Conclusion was that we needed a 'production valve' and that further testing pointless without it.
- Test module built using existing ceramic discs from a commercial valve.
- Successfully tested in January 2012



Bespoke ceramic discs ordered and new valve body designed. Delivered March 2012.



Performance reduction due to poorer than expected heat transfer in carbon bed

Power, efficiency, size trade offs

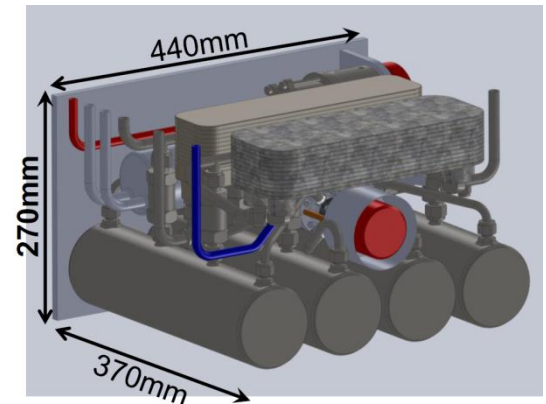
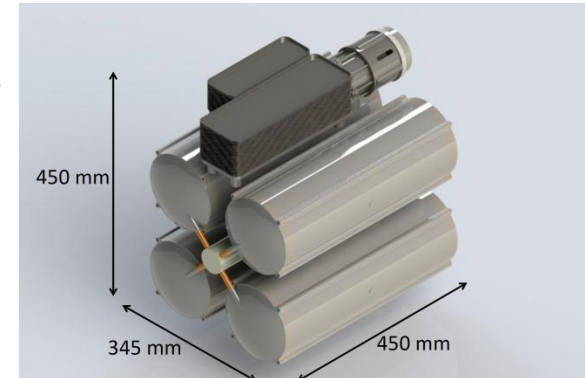
Not achieving efficiency for required size, power

Problem due unexpected low heat transfer in carbon

- Achieving required density
- But accepted density/heat transfer relationship breaking down
- May be due to tube and carbon relative geometries
 - relationship is based on flat plates

Short-term programme

- Build and test larger-size unit rated 7kW
[Early 2013]
- Programme to resolve thermal conductivity issues
 - Identify optimum geometry for maximum effect
- Programme of design-for-manufacture and test of commercial-sized unit
 - grant application



Thank you!