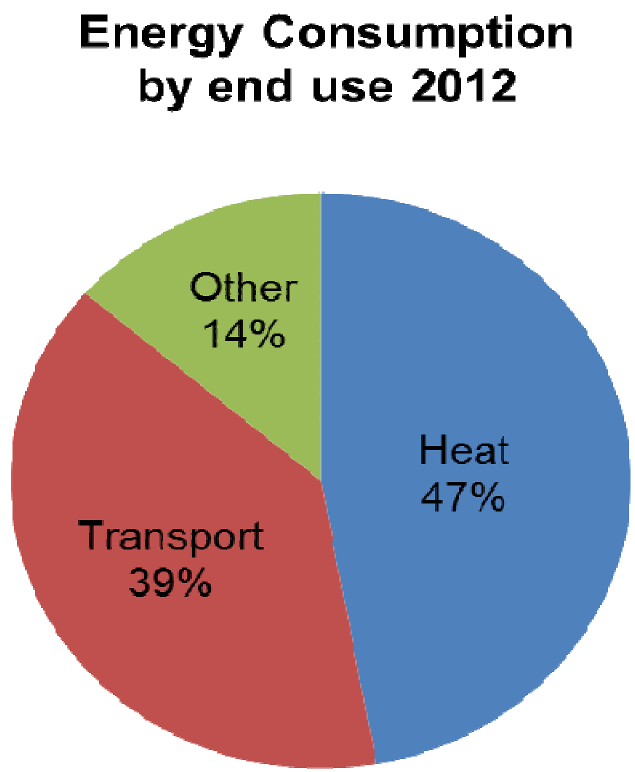
Universities Leading on Low Carbon Heating and Cooling: Past, Present and Future

Context

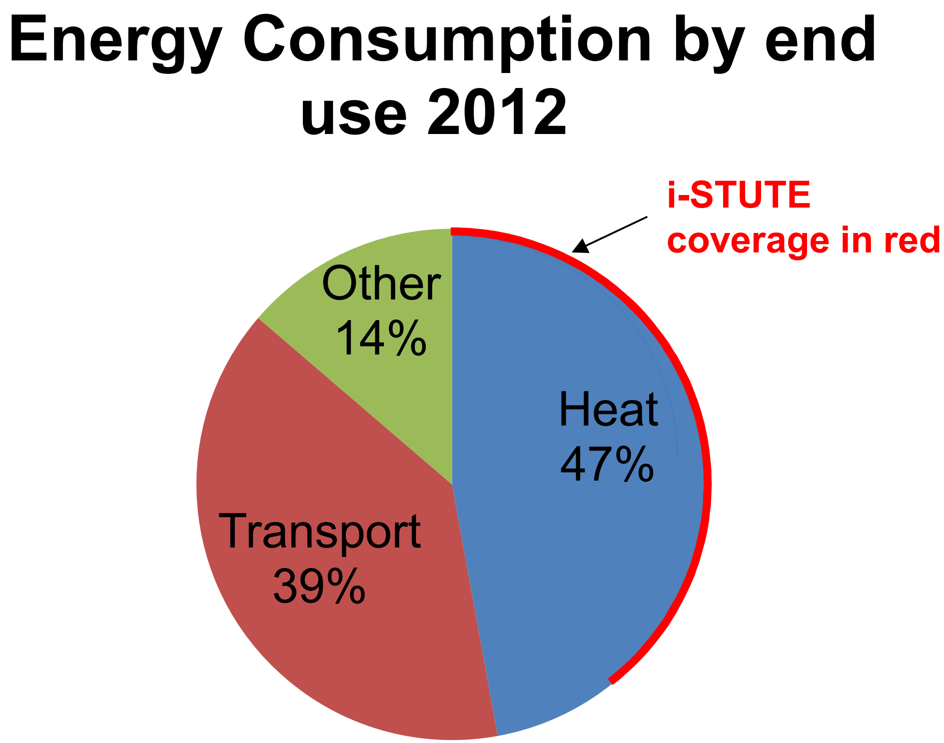
- In 2011, RCUK initiated a call to fund up to six interdisciplinary Centres in 'End Use Energy Demand'. Each Centre would be funded for five years initially with a nominal budget of £5M.
- i-STUTE was awarded one of the centres and funding commenced from April 2013 – its distinctive feature is concentration on heating and cooling.

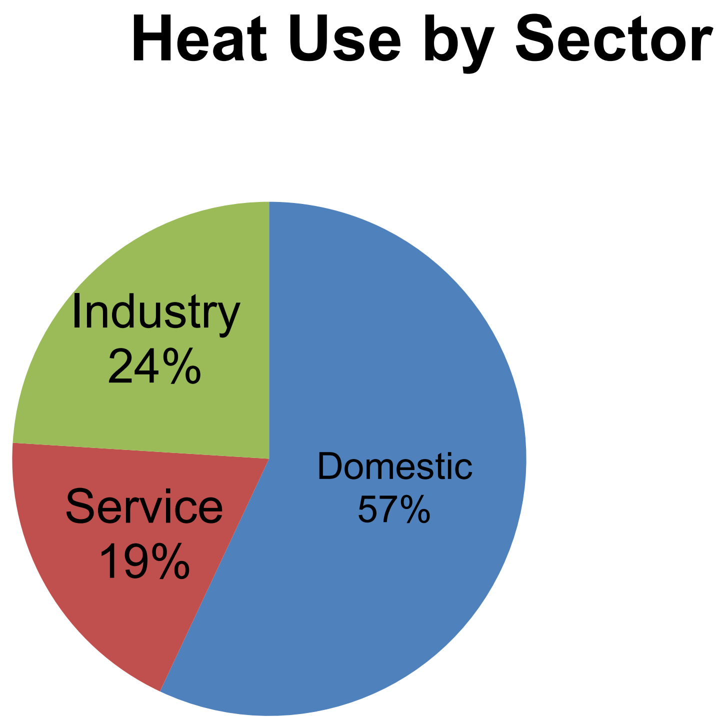
Why heating and cooling?

- 47% of fossil fuels in the UK are burnt for low temperature heating purposes (24% of CO_2 emissions)
- 19% of electricity in the UK used to provide cooling - Worldwide it represents 10% of greenhouse gas emissions

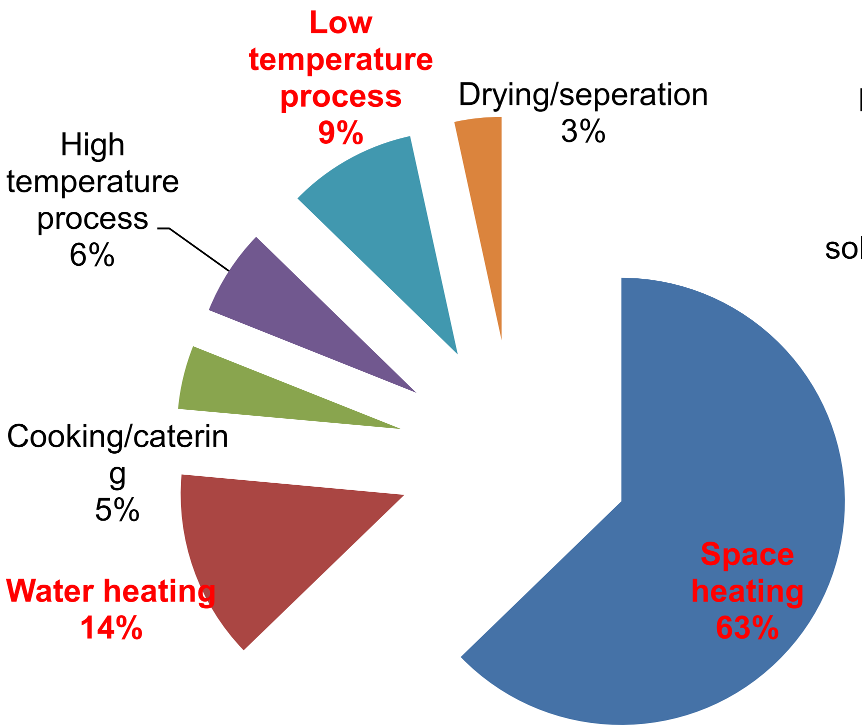


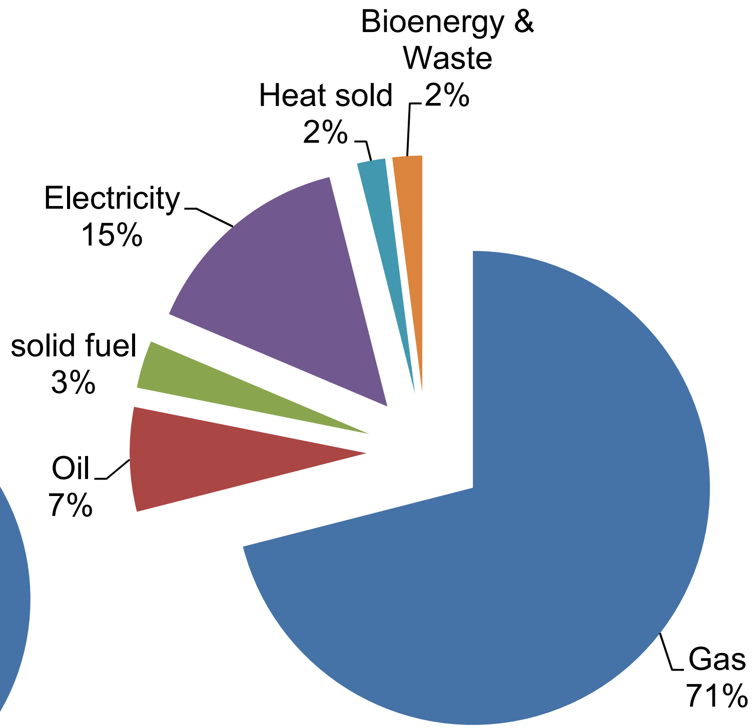
i-STUTE


Energy Consumption by end use 2012
i-STUTE
coverage in red
Other
14%
Heat
47%
Transport
39%


Heat Use by Sector
Industry
24%
Domestic
57%
Service
19%

Heat use by purpose





Breakdown by fuel of total heat use

i-STUTE coverage in red

Who are we, what do we do?

Loughborough University

- Thermal energy storage
- Consumer behaviour

WARWICK
THE UNIVERSITY OF WARWICK

- Thermal heat pumps
- Business models

London South Bank University

- Commercial and industrial refrigeration
- Engagement with SMEs

Ulster University

- Electric heat pumps
- Integration with storage

Work packages in:

- Cooling / refrigeration
- Low temperature heating
- Industrial heat
- Business models
- Consumer behaviour / acceptability

+

- Dissemination

  i-STUTE – www.i-STUTE.org

  SIRACH - (Sustainable Innovation in Refrigeration, Air Conditioning and Heat Pumps) www.sirach.org.uk

Identified savings through new technologies:

- Gas heat pump 1.5-3.0 tCO_2 per year per house, dependent on type.
- Electric heat pump + store 0.6 tCO_2 per year per house
- Supermarkets 2 MtCO2 per year
- Data centres 1.1 $MtCO_2$ per year
- Storage will aid electric heat pump savings – a further 20% CO_2 reduction

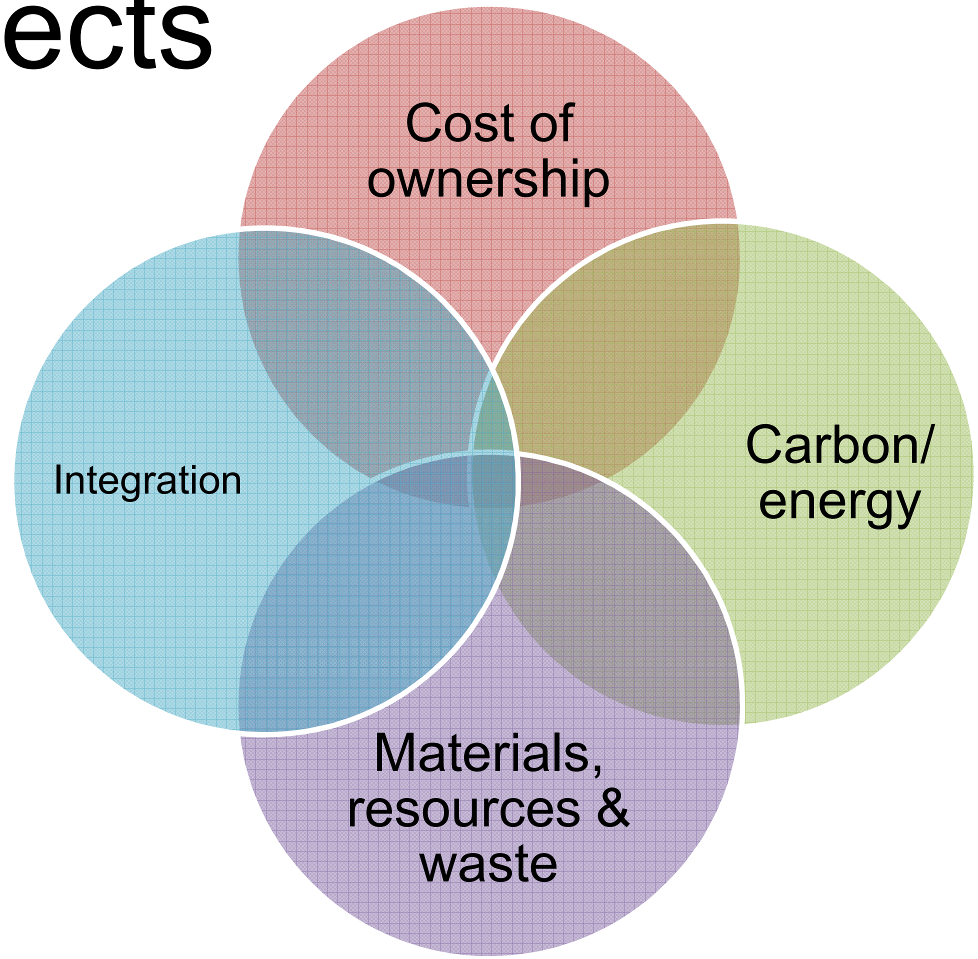
i-STUTE cooling based projects

Supermarket refrigeration

Data centres

Transport refrigeration

Integrated heating and cooling

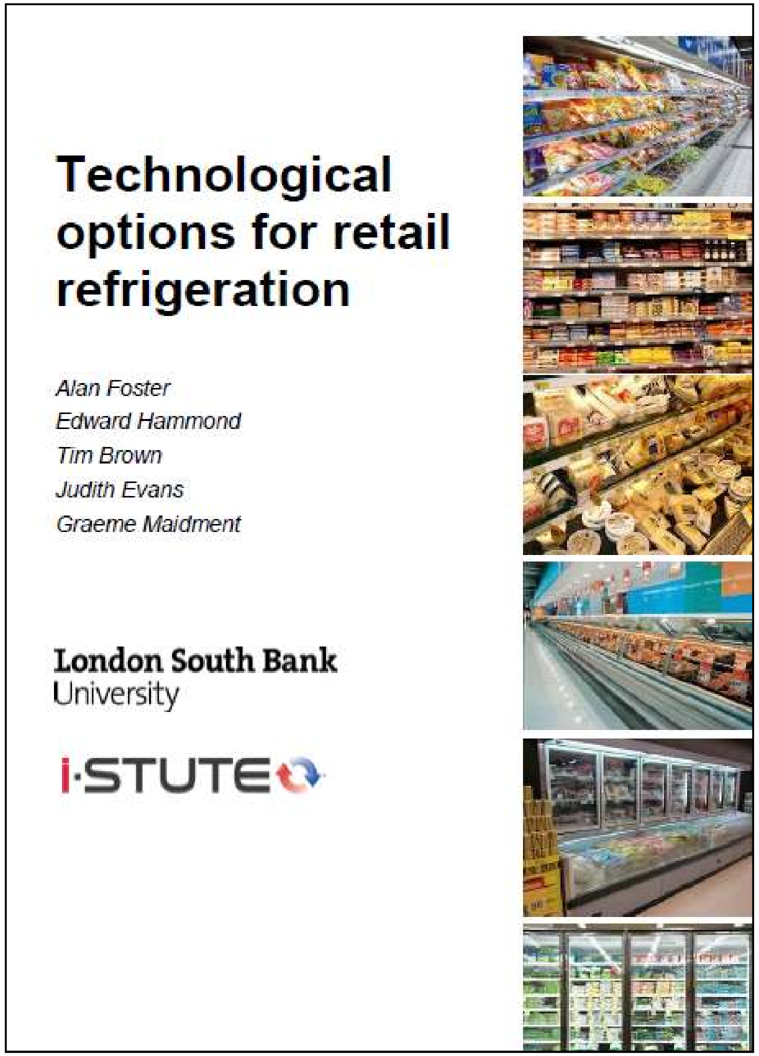


Retail refrigeration

Road map:

1. Review of display cabinet refrigeration technologies
2. Building fabric and construction
3. Review of hot food preparation technologies
4. Review of HVAC technologies
5. Combined Heat and Power (CHP)
6. Lighting
7. Application of refrigeration system technologies to a baseline store
8. Results from refrigeration system modelling

- **Published by IIR**



Retail refrigeration

Proof of concept prototype:

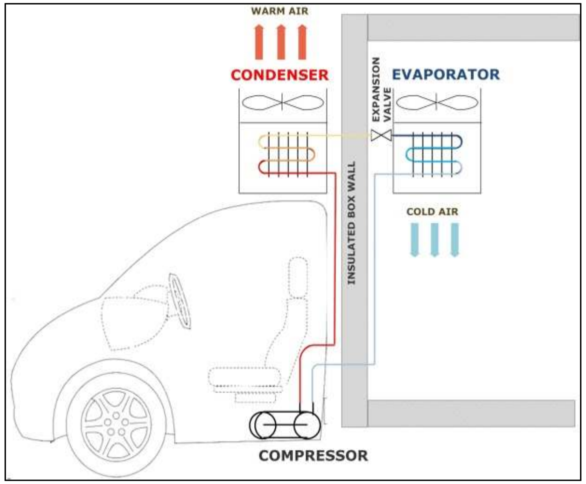
Chilled multi-deck (remote)

George Barker Leo cabinet (standard ASDA cabinet)

Already has EC fans, LED lights, large evaporator, optimised air flow design features

1. **Baseline test (EN23953) completed**
2. **Doors (good fitting doors) sourced from Epta**
3. **AirCell (low temperature range), new high efficiency evaporator, optimised fans and air flow- discussions ongoing with Adande**
4. **Occupancy sensors (lights)**
5. **Low emissivity packaging**

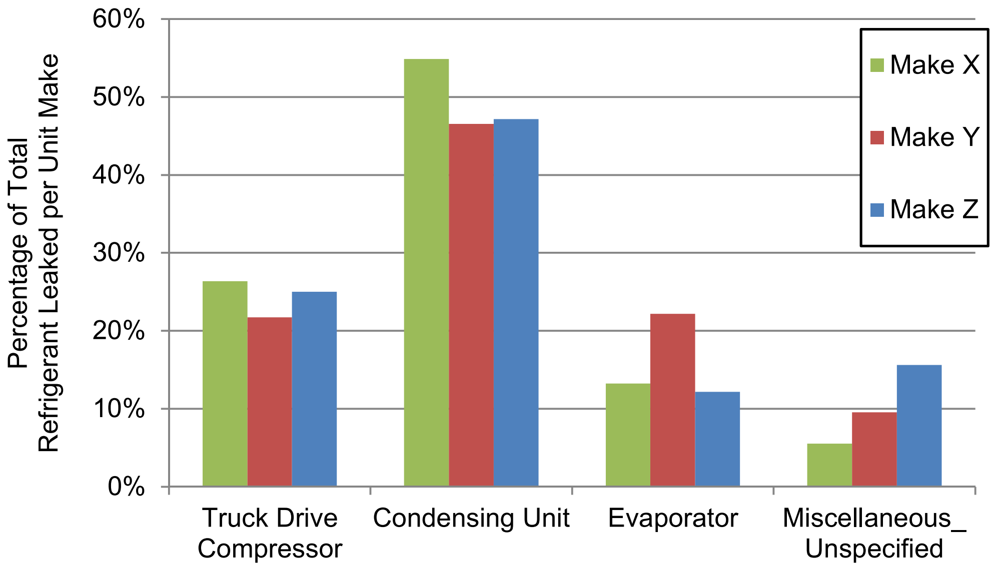
Refrigerated Transport - Leakage

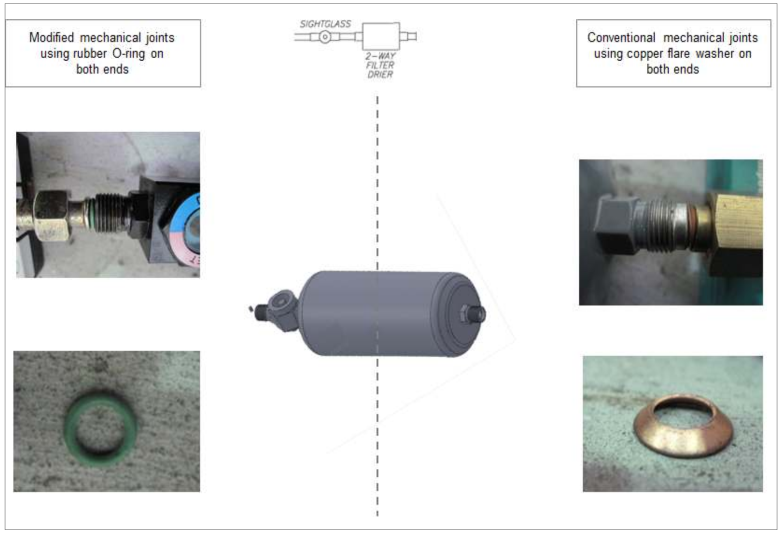


30% annual leak rate for HFC refrigerants

Non-observable faults leak rate 80 g yr^{-1} i.e. 5%

Average of 1.40 kg refrigerant leaked per vehicle

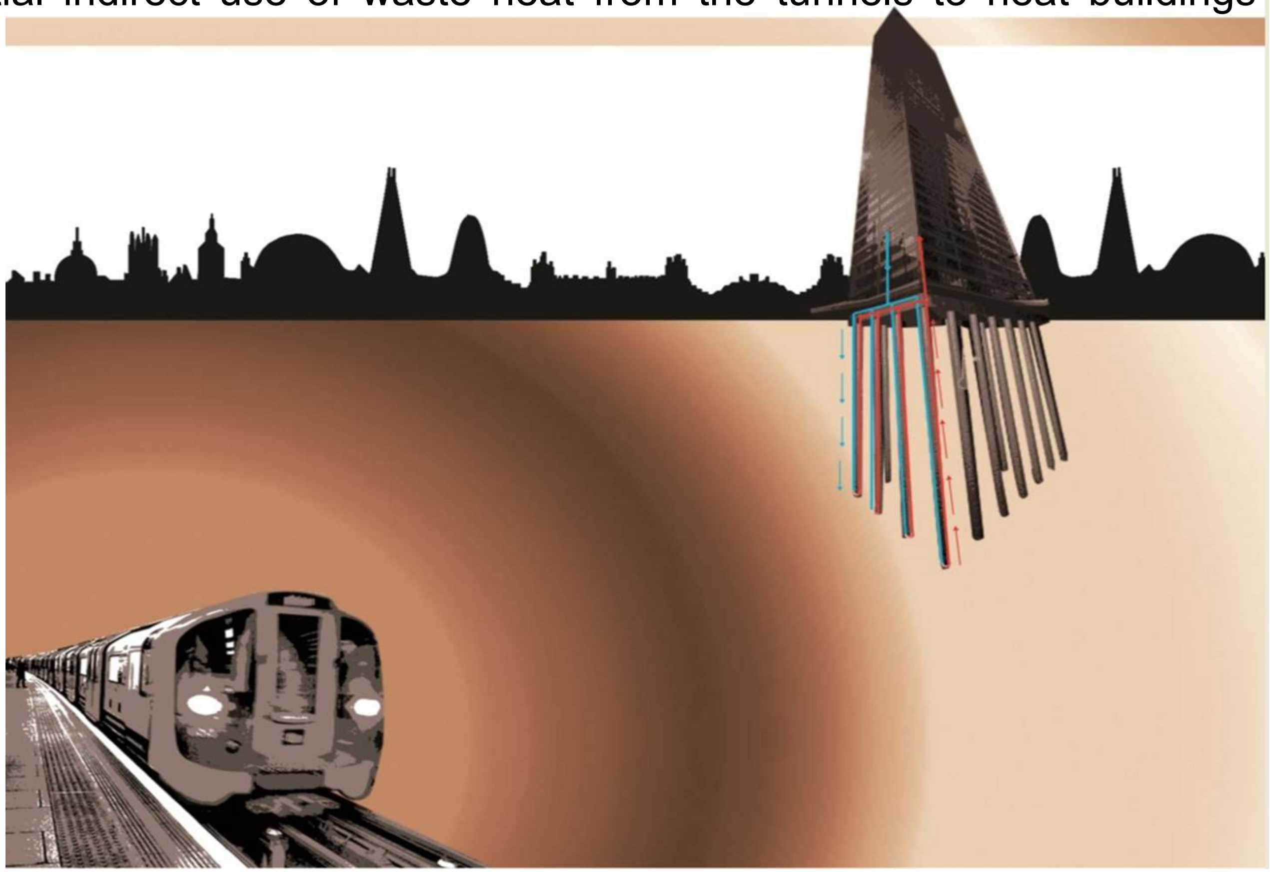




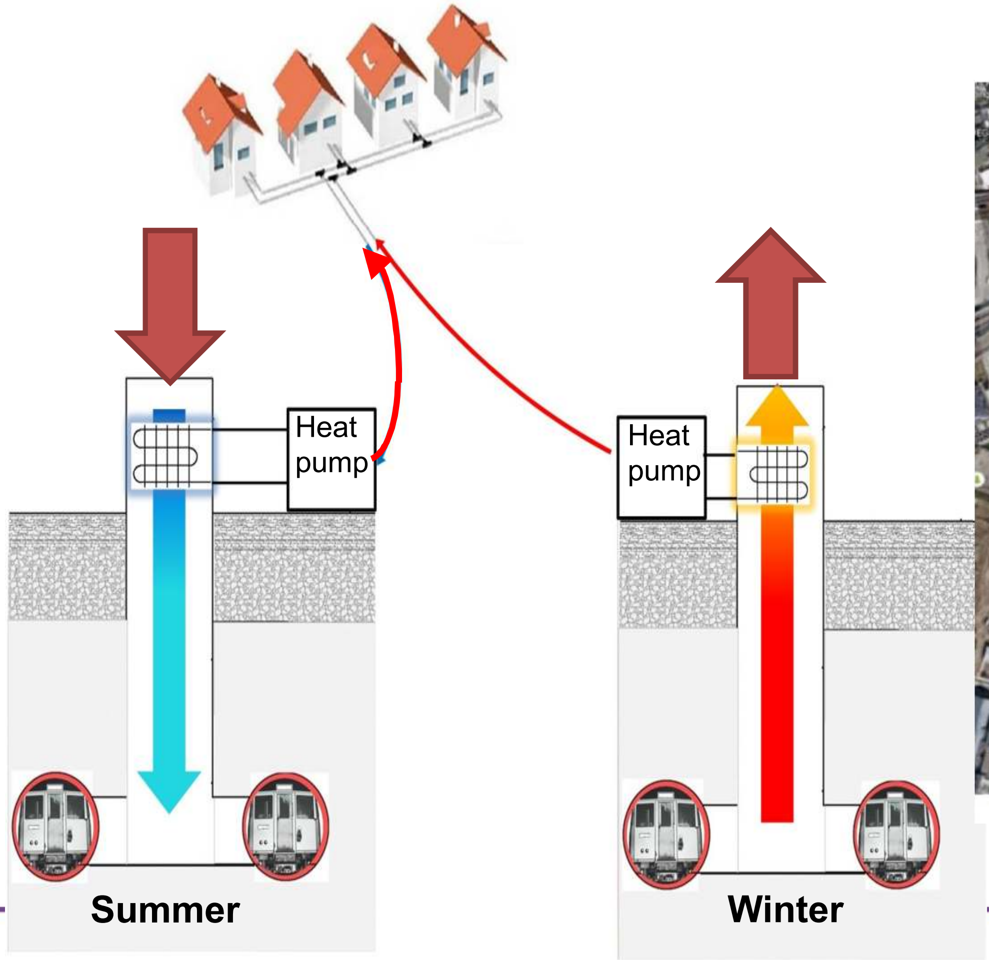
Integrated Heating, Cooling and Storage

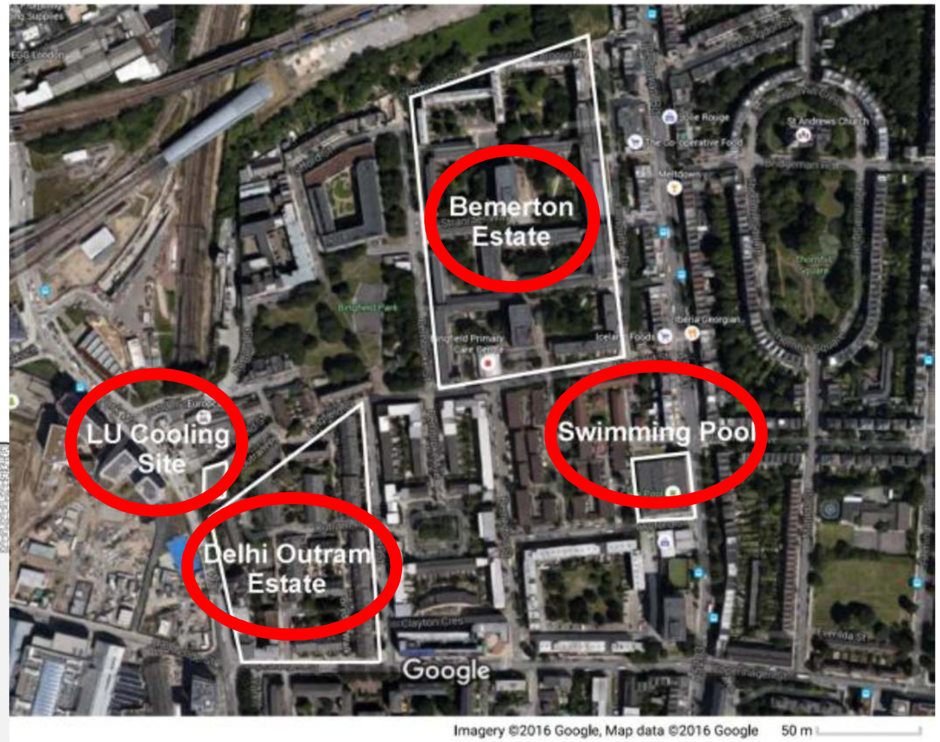
Deliverables

- To investigate the interactions of underground railway tunnels and ground heat exchangers
- To investigate the potential indirect use of waste heat from the tunnels to heat buildings above ground.



Recovering Heat from Vent Shafts





London Urban Sub-Terrain Energy Recovery - LUSTER

LUSTER will investigate the potential of heat energy recovery from urban sub-terrain structures, such as sewers, electricity cable tunnels and underground railway tunnels.

Project lead:
LSBU

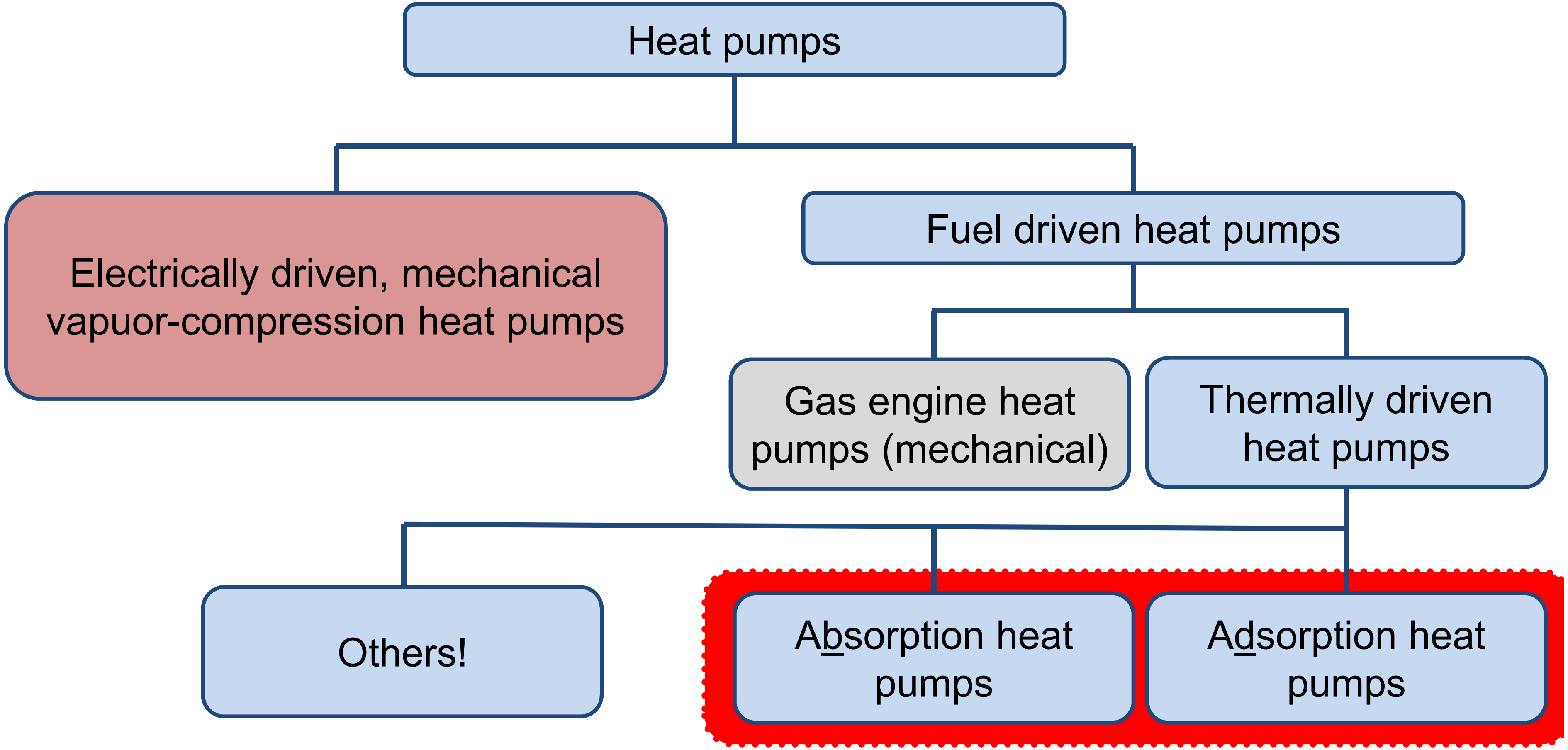
Project start: September 2017

Duration: 18 months

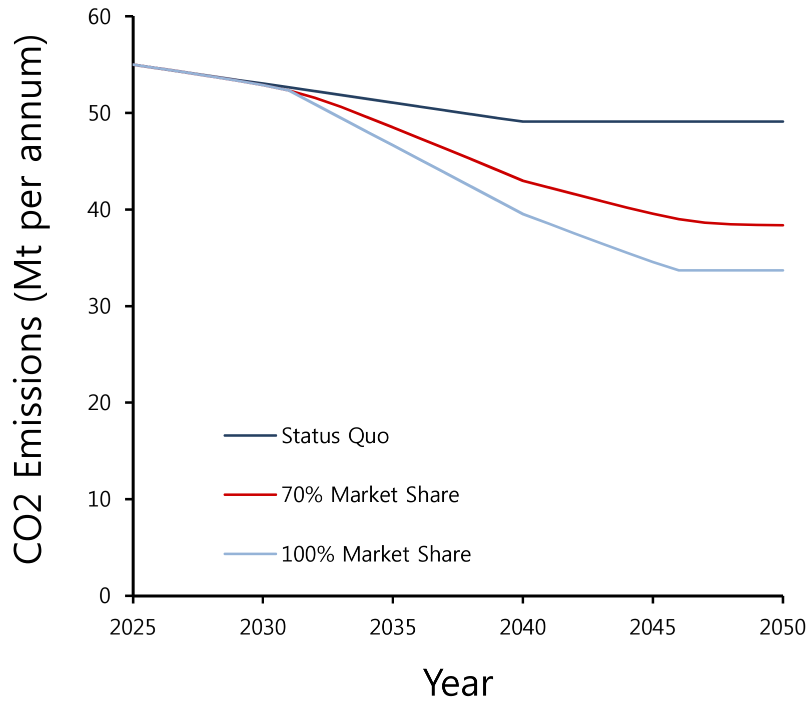
Academic partner:
UCL

Industrial partners:
London Underground Ltd.,
Thames Water Ltd., REHAU,
Energy Innovation Centre

Gas Heat Pump Technologies



Potential impact on emissions in the UK



▶ A 2.6% reduction in UK annual CO_2 emissions by 2040 is possible.

▶ There is a potential for an eventual 4.2% reduction in annual CO_2 emissions if all gas boilers were replaced by gas heat pumps

Individual saving c. 33%

Market Scenarios:

Two scenarios are considered:

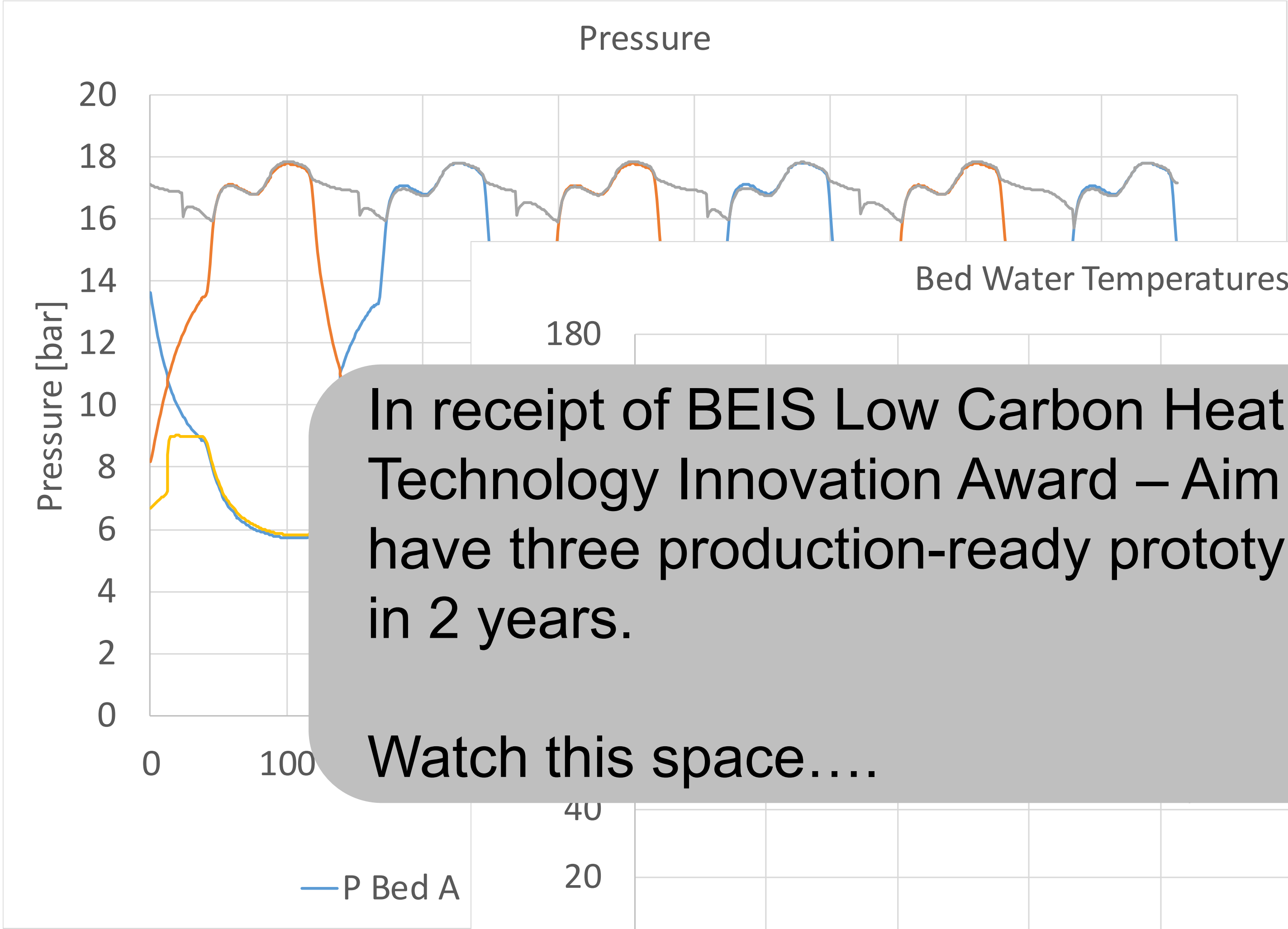
▶ The first assumes that the market for Gas Heat Pumps will saturate at a 70% share of gas heating appliances annual sales after approximately 12 years (the rest of the market remaining as condensing boilers).

▶ The second assumes that after 7 years on the market, the cost of Gas Heat Pumps reaches the point where legislation requiring their use is introduced, in much the same way as was carried out for condensing boilers replacing non condensing boilers.

The vision:

- Box-for-box exchange for conventional gas boiler → Retrofit market (> 90% of annual sales)
- Air source
- 30 - 40% reduction in gas consumption
- 7kW (3 bedroom semi-detached house)

The laboratory



In receipt of BEIS Low Carbon Heating Technology Innovation Award – Aim to have three production-ready prototypes in 2 years.

Watch this space….

Thermal Energy Storage

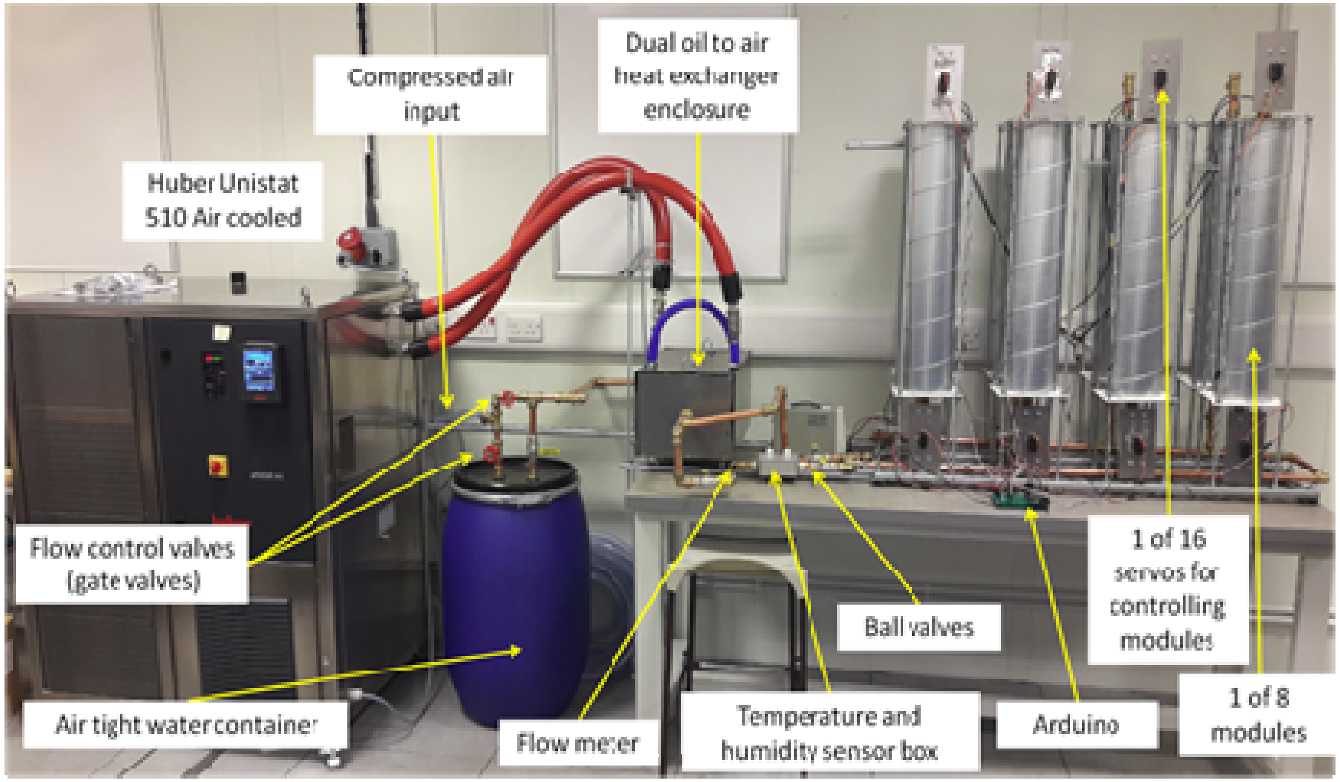
- Compact Chemical Heat Storage
- Compact Latent Heat Storage
- Process Heat Storage

Investigation of the Potential of $MgSO_4$ for Inter-Seasonal Thermochemical Energy Storage

Activities Undertaken

- Analysis of $MgSO_4$ composite material dehydration heating rate effects
- Nitrogen Vapour sorption testing of composite samples
- 200g scale hydration tests
- 3 successful preparation methods for new composites developed
- Design, and construction of a new larger (adjustable) size all-in-one de/hydration chamber at 40kg size complete

Investigation of the Potential of $MgSO_4$ for Inter-Seasonal Thermochemical Energy Storage



- Design, and construction of a new larger (adjustable) size all-in-one de/hydration chamber at 40kg size complete

Thermal Energy Storage for Medium Temperature Industrial Process Heating

- Materials Characterisation:
  Molten salt mixtures of lithium nitrate and sodium nitrate and a wide range of organic PCMs were characterised by DSC and TGA.

- System Development:
  Experimental systems have been designed, fabricated and experimentally characterised.

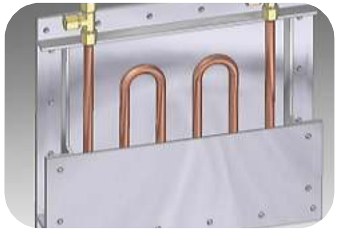
- Thermal performance simulation
  Heat transfer models of the experimental systems have been developed and analysis of some of the factors influencing performance undertaken.

- Levelized cost of energy for a range of storage applications have been evaluated.

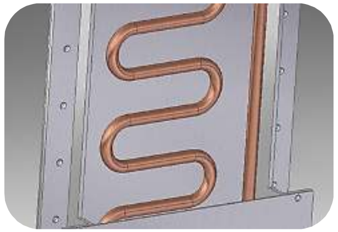
Phase Change Materials for Thermal Energy Storage

- Compact Storage:
  - Higher PCM volumetric Ratios;
    - Larger isothermal power output possible;
    - Higher sensitivity to PCM's thermal conductivity;

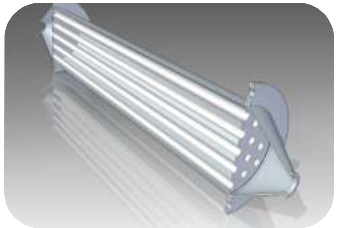
- Encapsulated storage:
  - Lower PCM volumetric Ratios;
    - More sensible heat behaviour;
    - Higher power outputs;
    - Lower sensitivity to PCM's thermal conductivity;



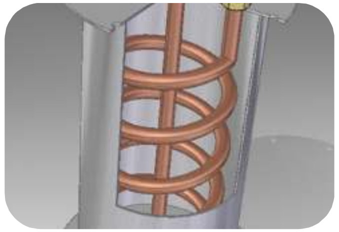
Vertical array



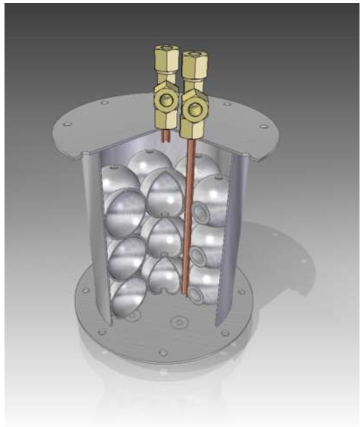
Horizontal Array



Shell and tubes



Coil in tank



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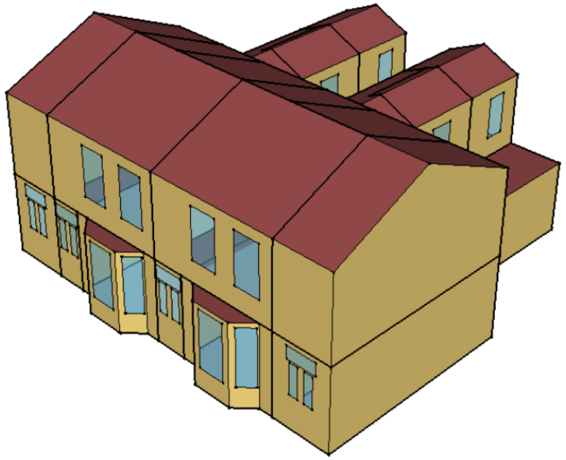
Electric Heat Pumps
Previously

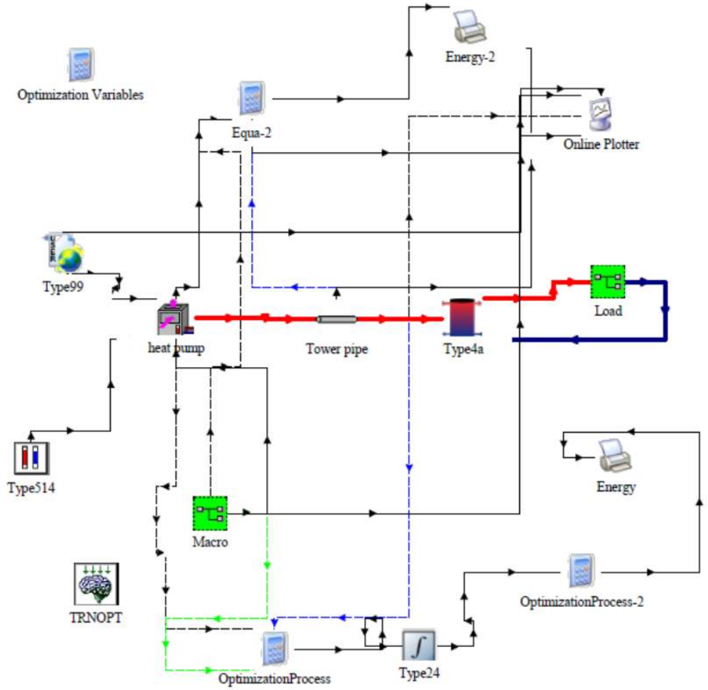
- **Aim**
- High performance heat pumps for domestic and industrial applications
- **Domestic Heat Pump**
- Working with air-source heat pump and thermal storage tank (water)
- **High Temperature Heat Pump**
- R245fa providing heat in a hospital
- Operating with Seasonal Thermal Energy Storage

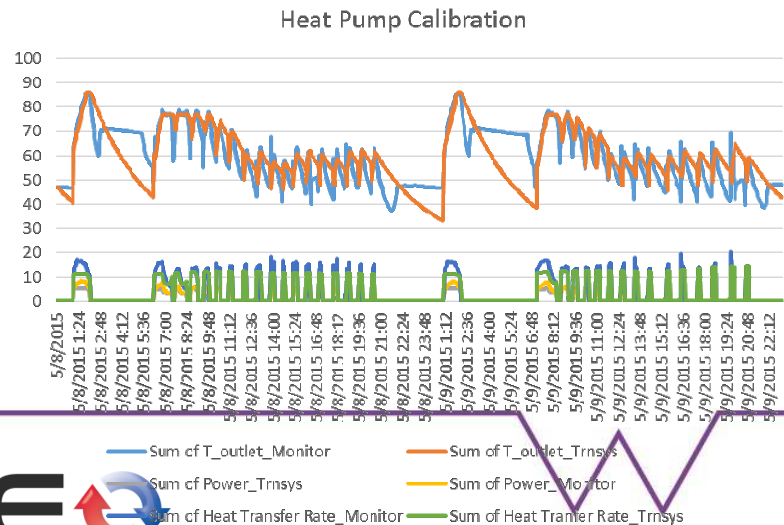
Date	Heating Capacity	Power IN	COP	COPh	η isen	Cr
	kW	kW	kW/kW		%	
01-Dec	40.36	7.82	5.16	6.27	75.48	3.63
09-Jan	28.33	6.12	4.63	4.45	51.64	4.13
18-Feb	38.63	6.97	5.54	6.52	70.15	3.31
19-Feb	37.84	6.76	5.59	6.22	66.67	3.34

Heat Pump + Thermal Store

Ulster's Terrace Street







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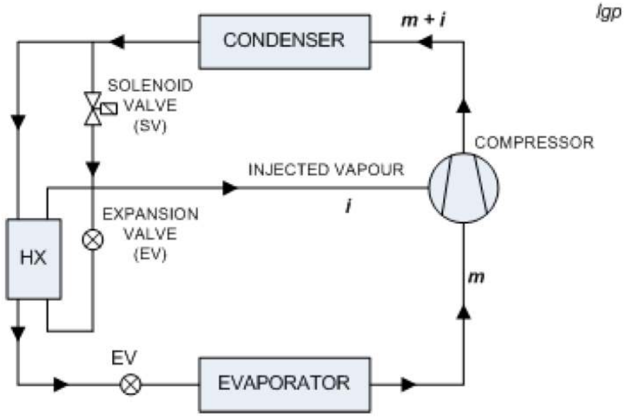
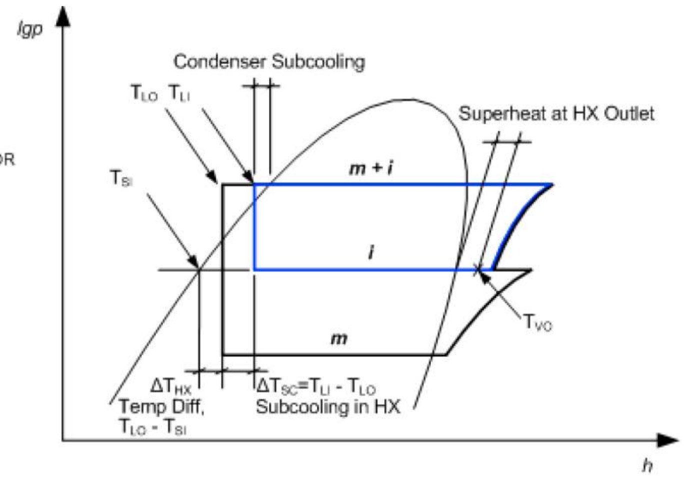
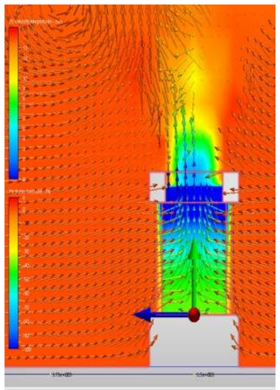
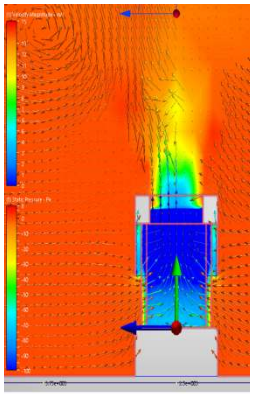
Air source heat pump CoP = 5.1

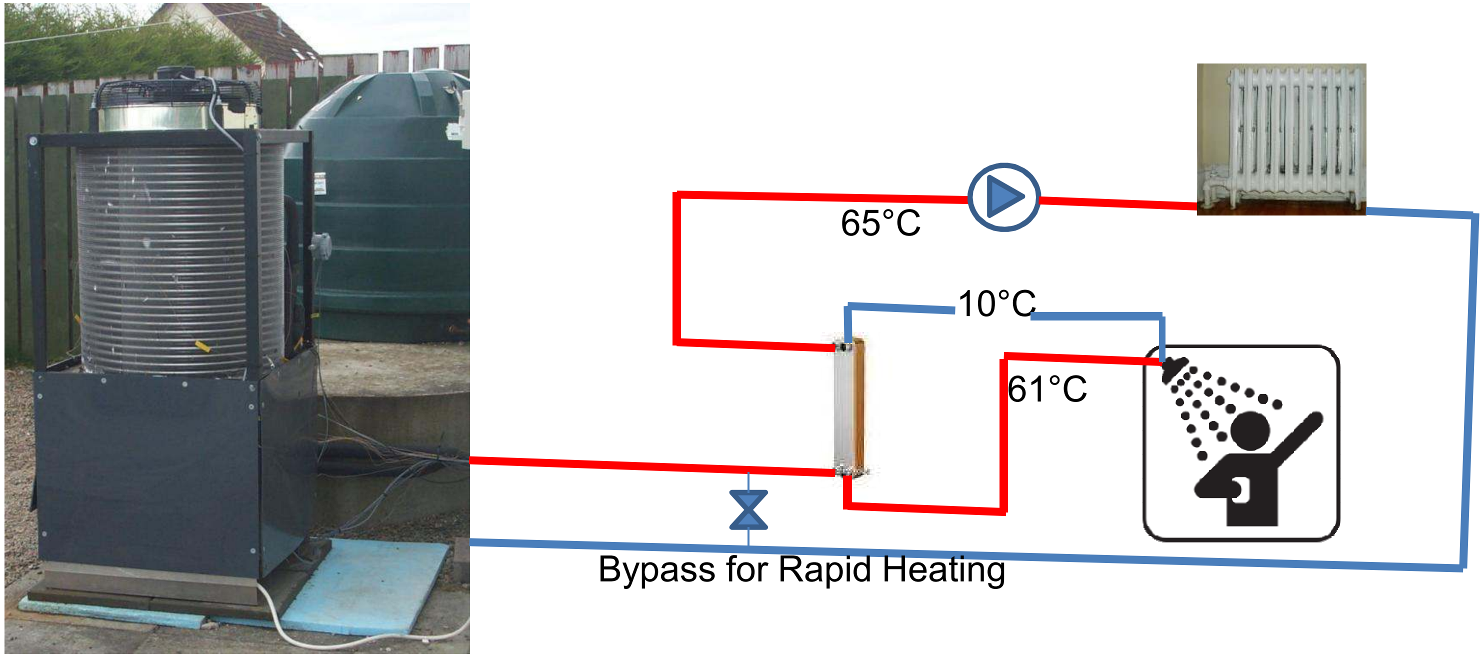








"Combination" Air Source Heat Pump



Consumer / business studies

- **WP1.1: Review and synthesis of existing activities.**
  - A review of how economic, policy and behavioural factors influence the adoption of new technologies relevant to heating/cooling technologies.
- **WP1.2: Business model typology.**
  - What are the existing business models adopted by energy service providers in the UK? What are the new alternatives are under consideration? How do they match the requirements for successful introduction identified in our review?
- **WP1.3: Behavioural Insights – Case studies.**
  - Case studies analysis of where business models succeed or fail to build their understanding of customer needs and behaviours, develop relationships with those customers and provide propositions that customers adopt.
- **WP1.4: Behavioural Insights – Experiments and focus groups.**
  - Experiments & focus groups to provide converging evidence on a range of value propositions, zeroing in on features likely to lead to success or failure.

Where are we going?

- Refrigeration and Data Centre Roadmaps

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- Domestic/Residential SOLUTIONS

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- Specific challenges
  - Gas HP
  - HT Heat Pump
  - Thermal Stores

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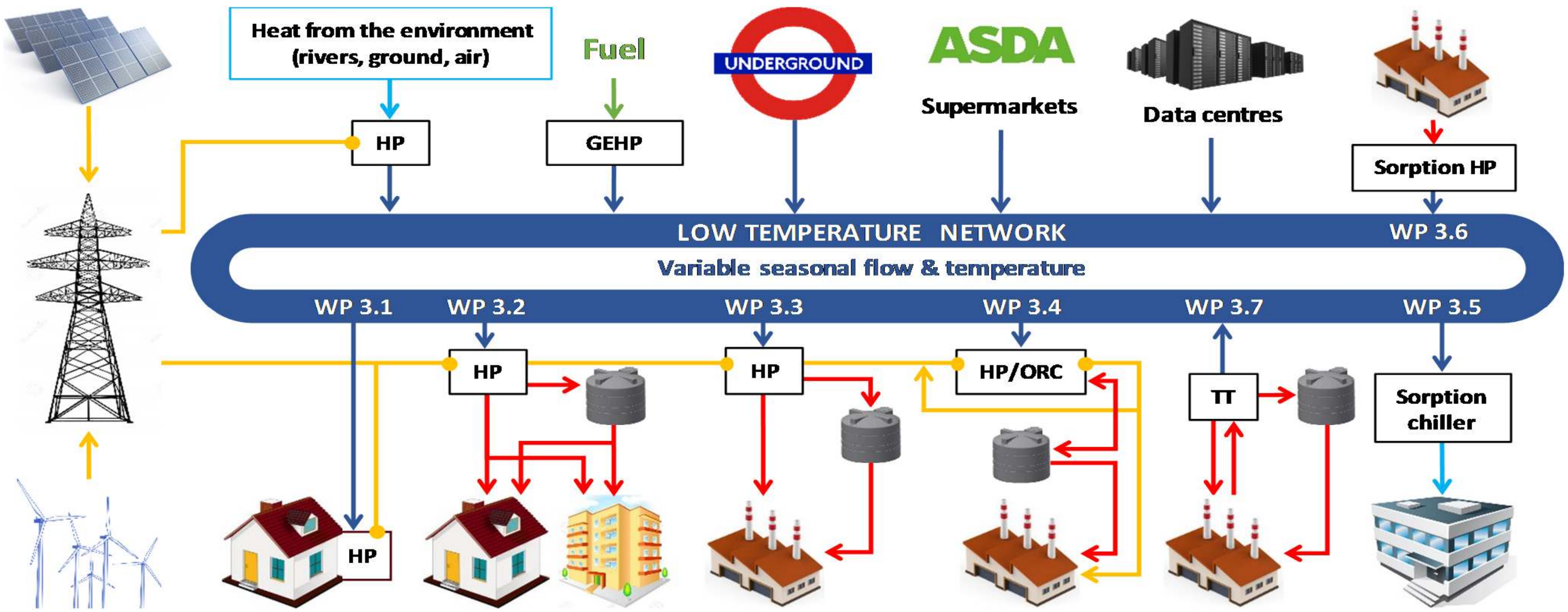
  - Thermal Stores
- Low Temperature Distribution Networks – LoT-NET

LoT-NET

- BEIS estimate that heat networks could supply 20% or more of building heat demand by 2050.

- Heat networks have previously used high temperature hot water to serve buildings and processes but now 4th generation networks seek to use much lower temperatures to make more sources available and reduce losses

- Lot-NET will research integration of low temperature (LT) networks with heat pump and thermal storage technologies to maximise waste and ambient heat utilisation in <u>low or zero-carbon solutions</u>


Heat from the environment (rivers, ground, air)
Fuel
UNDERGROUND
ASDA
Supermarkets
Data centres
HP
GEHP
Sorption HP
LOW TEMPERATURE NETWORK
Variable seasonal flow & temperature
WP 3.6
WP 3.1
WP 3.2
WP 3.3
WP 3.4
WP 3.7
WP 3.5
HP
HP
HP/ORC
TT
Sorption chiller
HP

Thanks for your attention!

Questions??