LoT-NET

Advisory Board Meeting 10th March 2022
Revised Mid-term Report: Part 1

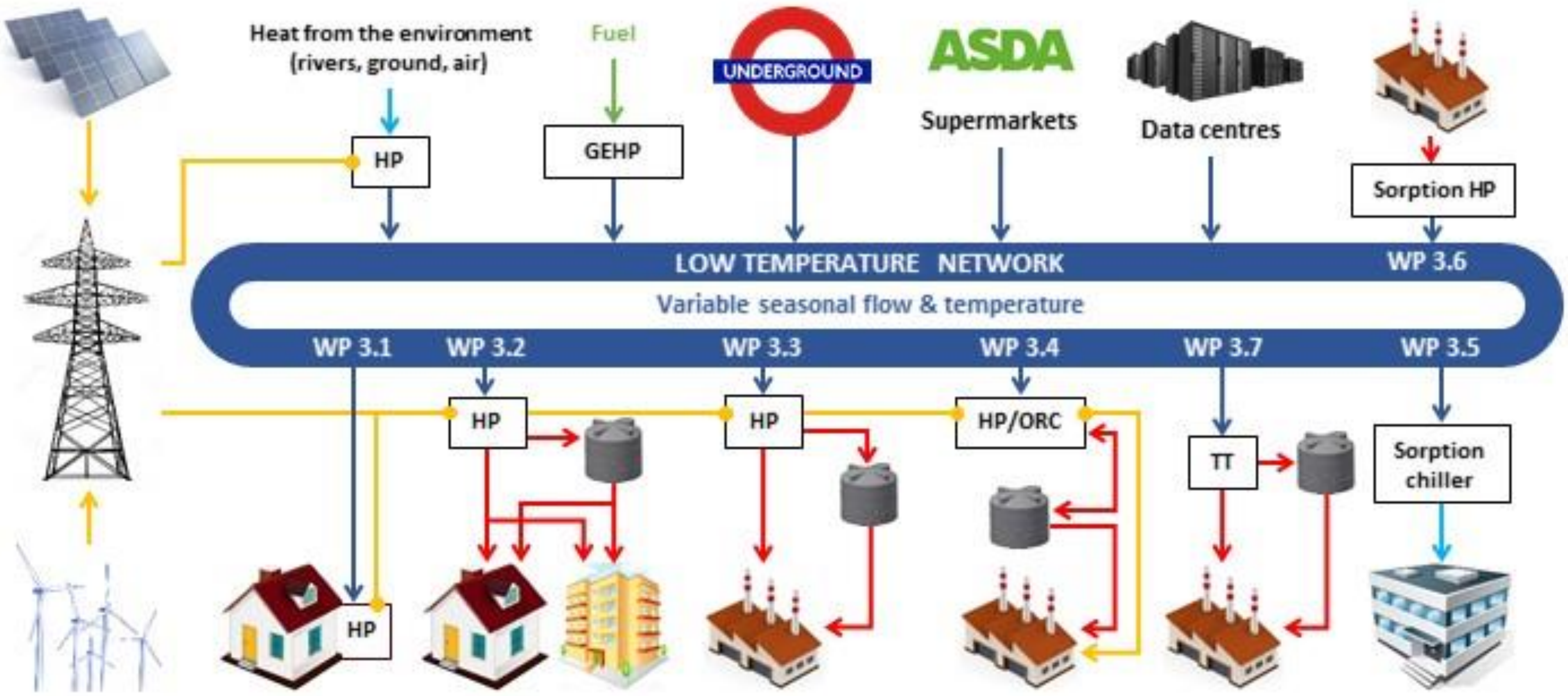
Low Temperature Heat Recovery and Distribution Network Technologies

1. Context
2. Original proposal
3. Original Work packages
4. Dissemination and Engagement
5. Equality, Diversity and Inclusion
6. Early Career Researchers
7. Risk assessment
8. Progress and future plans
9. Integration and Case Studies

1. Context

- LoT-NET is a 5-year, £5.5M FEC project, funded by EPSRC and commencing 1st January 2019
- This updated mid-term report to the AB report has two purposes:
  - Inform the AB (as requested) how the separate research streams will be integrated and present the 'bigger picture'
  - To prepare for the mid-term review that will be required by EPSRC
  - To pave the way towards justifying a possible one-year no extra cost extension
- The report also has sections on, for example, Risk Management and EDI that will be requested by EPSRC

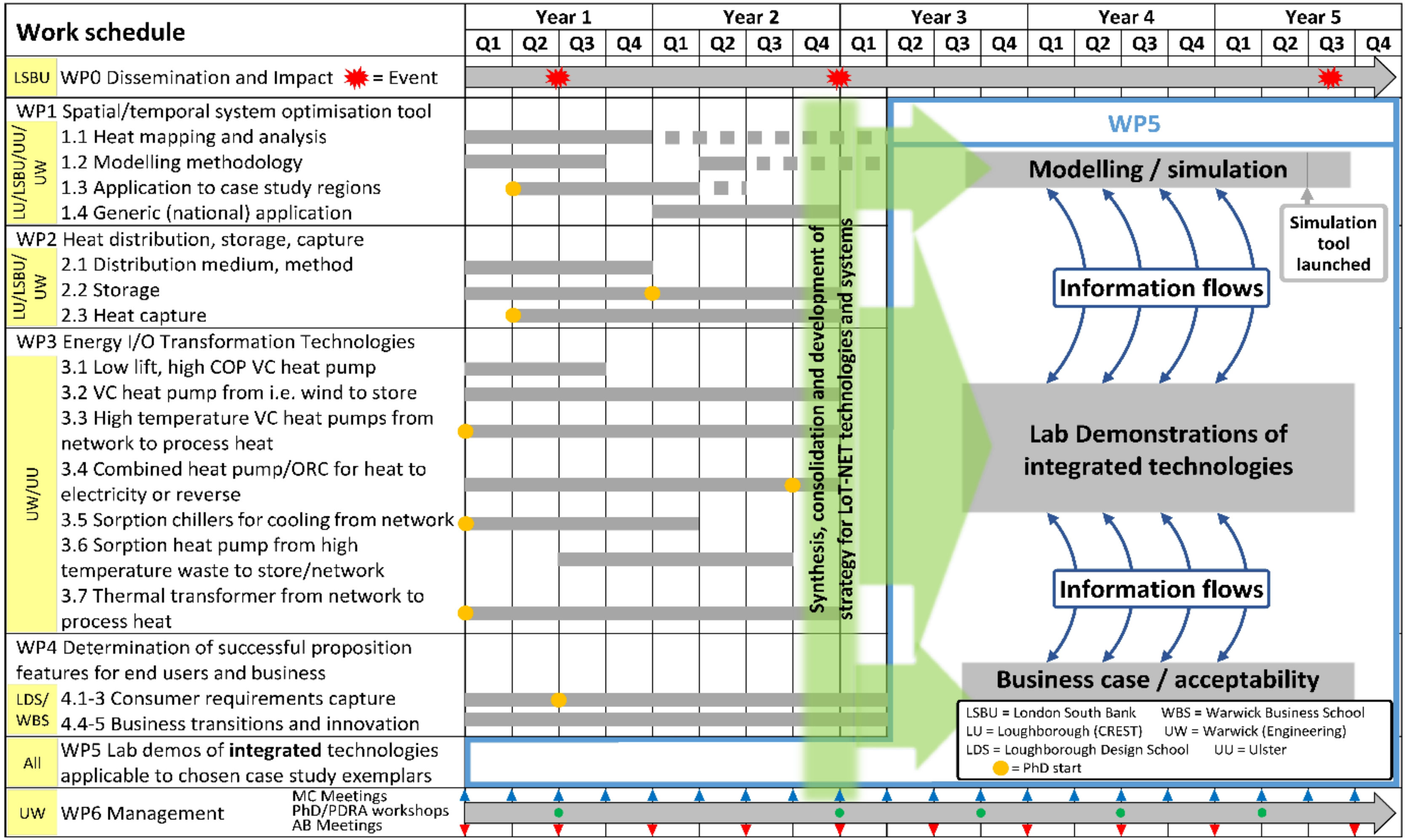
2. Original proposal



2. Original proposal

…to prove a cost-effective near-zero emissions solution for heating and cooling that realises the huge potential of waste heat and renewable energies by utilising a combination of a low-cost low-loss flexible heat distribution network together with novel input, output and storage technologies.

3. Original Work Packages



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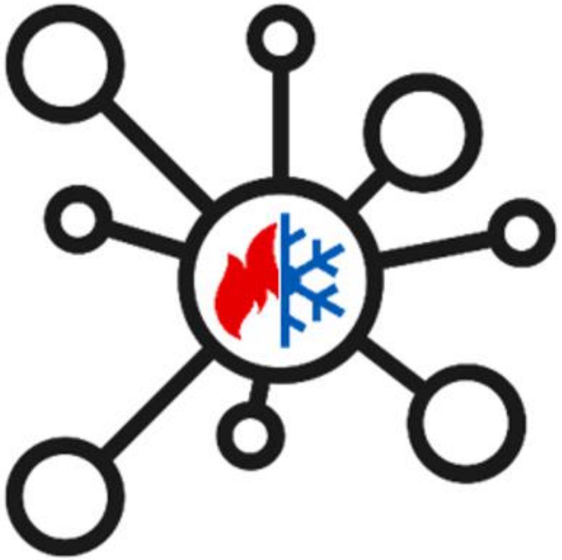
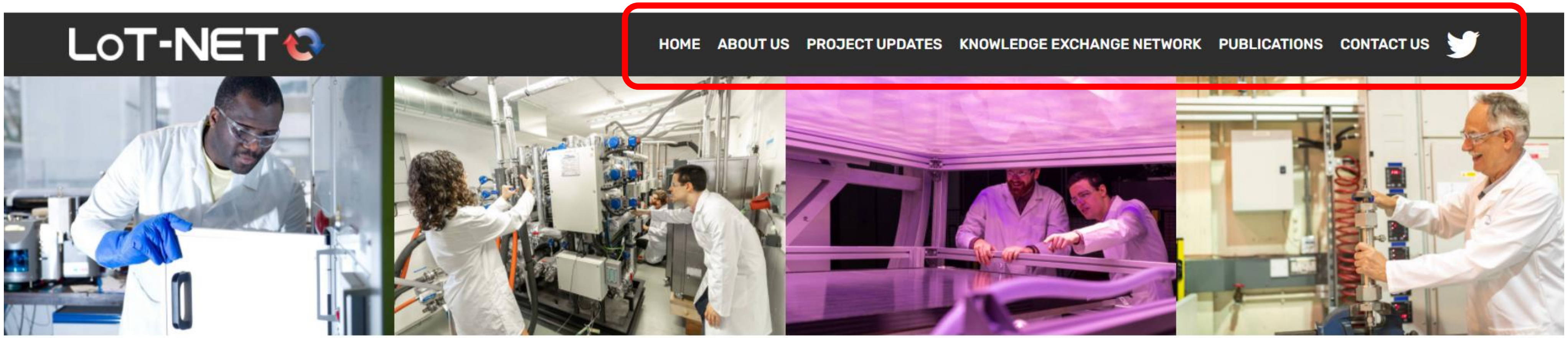
WP0: Dissemination

Aims:

- To be recognised internationally by the district energy community
- To influence Government and funders
- Share key outputs with sister projects
- To publicise and to run events in low-temperature heat/cold networks
- To engage young/early career researchers



REVISED LOT-NET WEBSITE



- New design
- New headings
- New content

ABOUT US

VISION

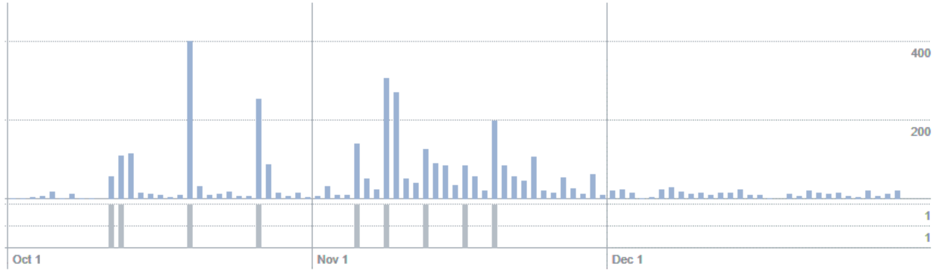
To demonstrate and prove low cost, low carbon, thermal energy networks integrating with electricity and other utilities networks to form flexible and highly efficient smart grids. Transform energy supply and distribution by combining intermittent renewable and waste energy resources with multi-scale thermal and electrical storage, together to provide affordable, secure and sustainable energy to consumers

Make sure to check it out and feel free to share your feedback!

LoT-NET

Social Media

Tweets earned **3.9K impressions** since Oct 1st 2021



Stats since the last update:

Average of **43** impressions per day

Total of **318** engagements

Record of **708** impressions for a single tweet

Glossary

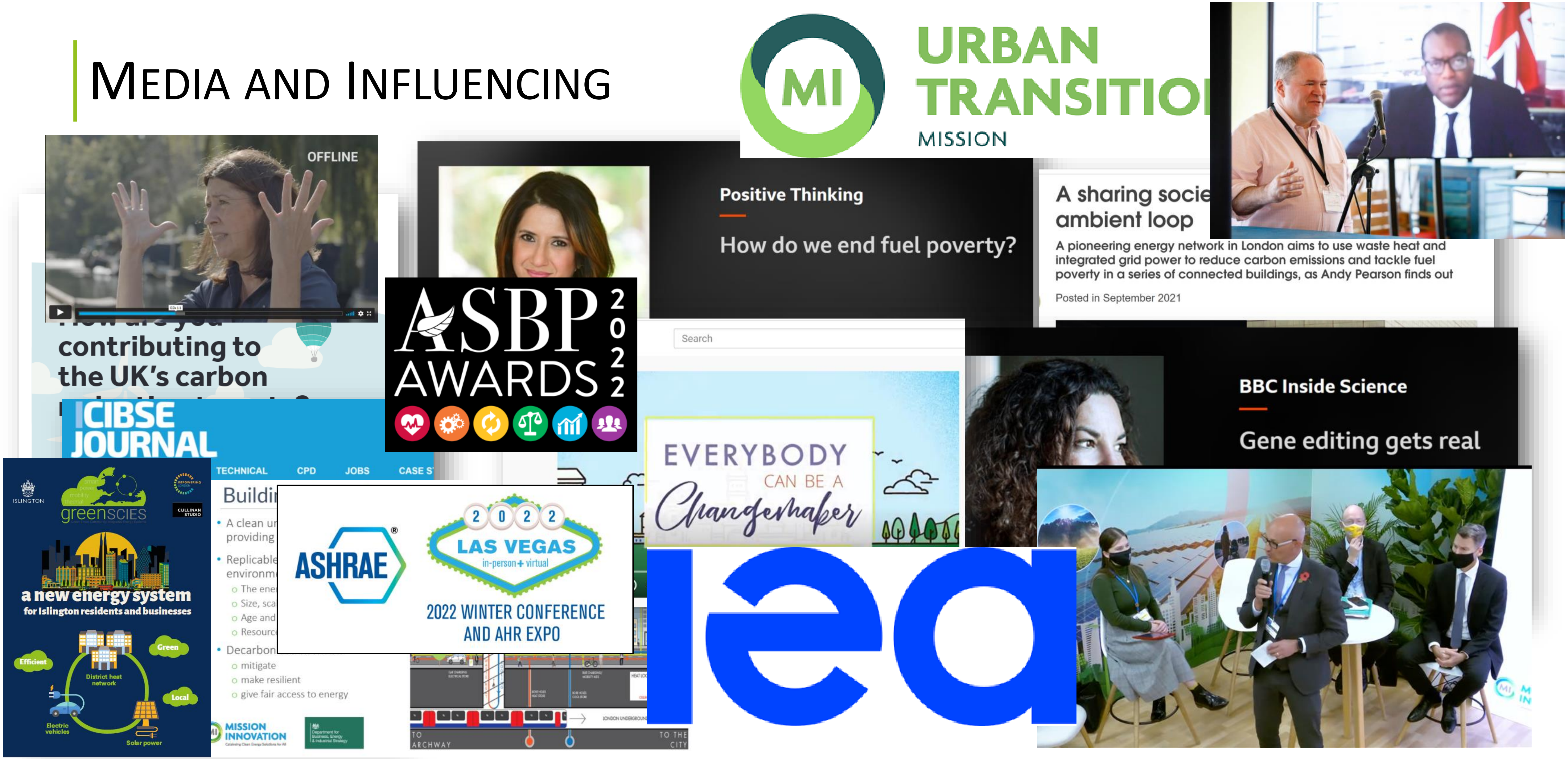
Impression: number of times users saw the tweet on Twitter.

Engagement: number of times users interacted with a tweet, including clicks anywhere on a tweet (username, links, avatar, hashtags), retweets, replies, follows and likes.

Meetings

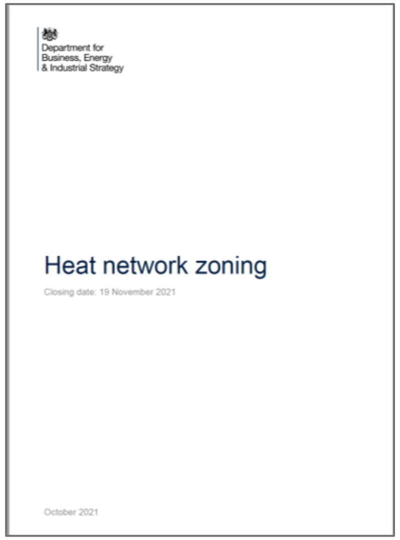
- 13 meeting since January 2019. 53 speakers and 1148 attendees – double pre-Covid attendance
- Student event including 3 minute thesis – 31 July
- 7th July Lessons learned from integration of heat pumps
- 21st September 2021 - SIRACH-Hydrogen for heating and cooling
- 2nd November 2021 – Data centre heat recovery
- 1st December 2021 COP and heating and cooling Feb 2022 - Helping Local authorities on low carbon strategy
- Face to face 2022 in May and June of 2022
- What else?

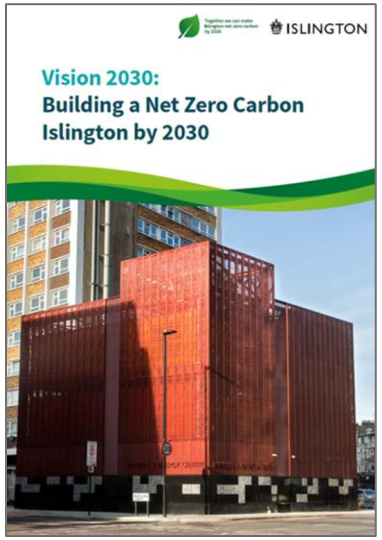
Media and Influencing



Influencing the low carbon agenda

- Responding to, contributing to and mentioned in strategy
- Working with ESC and EnergyRev
- Engaging with international activities ie Mission Innovation Cities Mission
- Presented at COP at UNFCCC Pavilion
- Presenting with BEIS at ASHRAE





4. Dissemination and Engagement: related projects and further successful research awards

- **EnergyREV:** David Elmes has the role of championing heating and cooling in the EnergyREV academic consortium that's part of the Industrial Strategy's Prospering from the Energy Revolution: (PFER) programme.
- PFER Detailed Design Programmes. Team members supported the successful award of two Detailed Design programmes within PFER: the **GreenSCIES** and **Replicating GreenSCIES** project in Islington, London (Maidment, Revesz) and the **Regional Energy System Operator** project in Coventry (Elmes).
- Loughborough, Warwick, Ulster and LSBU are all involved in the EPSRC industrial decarbonisation project **DELTA PHI** (DEcarbonisation of Low TemperAture Process Heat Industry) .
- Warwick, Ulster and Loughborough Design School are collaborating in an EPSRC 'Working with CREDS' project **HP-FITS** researching the combination of electric heat pumps with thermochemical heat stores in demand-side management.

4. Dissemination and Engagement: related projects and further successful research awards

- **Mission Innovation Challenge 7** (Affordable Heating and Cooling) has funded two smaller projects via EPSRC. They are both required to report via LoT-NET:
  - **Sorption Heat Pump Systems** [UW] is an international collaboration on chemisorption heat pumps.
  - **Comfort and Climate Box** [UU] (EPSRC EP/V011340/1 01/06/20 to 31/08/22) is a 26 month project aligned to IEA HPT Annex 55 CCB where global best practice in single family home air source heat pump and thermal storage integration is being assessed.
- Loughborough is involved in the CREDS heat challenge providing inputs in relation to thermal energy storage and awareness of other key developments.
- Loughborough is involved in the Active Building Centre (ABC) project being led by Swansea developing compact thermal energy stores for air source heat pump applications and gaining insight into other aspects of the ABC project.

4. Dissemination and Engagement: updates

- Collaboration between Warwick Estates, WBS and Warwick School of Engineering to assist South Warwickshire Foundation NHS Trust (SWFT NHS) to achieve their decarbonisation goals
- Explore Special Issue (Energies?) on Low Temp Networks
- ASHRAE Winter Meeting - a workshop “Integrated heating and cooling systems”
- Engaging with industrial partners on large-scale energy storage
- GM to give invited talk to CIBSE Technical Symposium, April 2022
- Half day LoT-NET event at CIBSE 2025?? A final major dissemination event

5. Equality, Diversity and Inclusion

- Aim for an inclusive culture within LoT-NET
- Developed an Equality, Diversity and Inclusion plan, using the template from CREDS
- Working group, led by Prof Haines, includes early, mid and established career colleagues, including PGR
- Our four institutions support the gender equality Athena SWAN Charter and hold at least a Bronze award, with the lead University, Warwick, holding a Silver award
- Management Committee have all undertaken ED&I training within their institutions, including addressing unconscious bias and follow good recruitment practice when appointing new researchers to the project
- Establishing a reporting system for any individual associated with the project to report poor practice, e.g. bullying, harassment, lack of inclusion or opportunity relating to protected characteristics

6. Early Career Researchers

As part of LoT-NET, a Knowledge Exchange Network (KEN) has been established, focused on Early Career Researchers. The aims of the network are to:

- Publicise / run event in topics related low-temperature networks
- Develop a scientific knowledge base by pulling together results from LoT-NET and sister projects
- To provide a platform which not only enables ECRS to showcase their research but to collaborate with their peers both from academia and from industry
- Workshop on role models at ASHRAE with CIBSE YEA

Thus far, we have successfully organised three KEN events with large number of attendees from both industry and academia. Our next event is currently being scheduled for May 2022.

7. Risk assessment

Process:

1 risk identification

2 risk analysis

3 risk evaluation and ranking

4 risk mitigation/treatment

5 risk monitoring and review

Review of the risk register is a standing agenda item at each management meeting.

8. Overall Progress

- The Phase 1 focus on capture, storage and conversion technologies and individual work packages has progressed broadly as expected in Y1-3, delayed somewhat by Covid.
- We have developed the modelling environment that will enable the various technologies to be assessed for use and integration into energy systems.
- We also have the intention to expand the modelling capability to include electrical energy demand.
- Overall strategy and phasing as proposed but added research on larger scale real world energy systems. Individual technologies of WP1-3 will continue to be researched, however they will not be integrated as in the original plan.

8. Progress (WP1 – WP3)

WP1

- WP 1.1: Heat Mapping and Analysis
- WP 1.2: Model Development
- WP 1.3: Application to Case Study
- WP 1.4: Generic (national) application

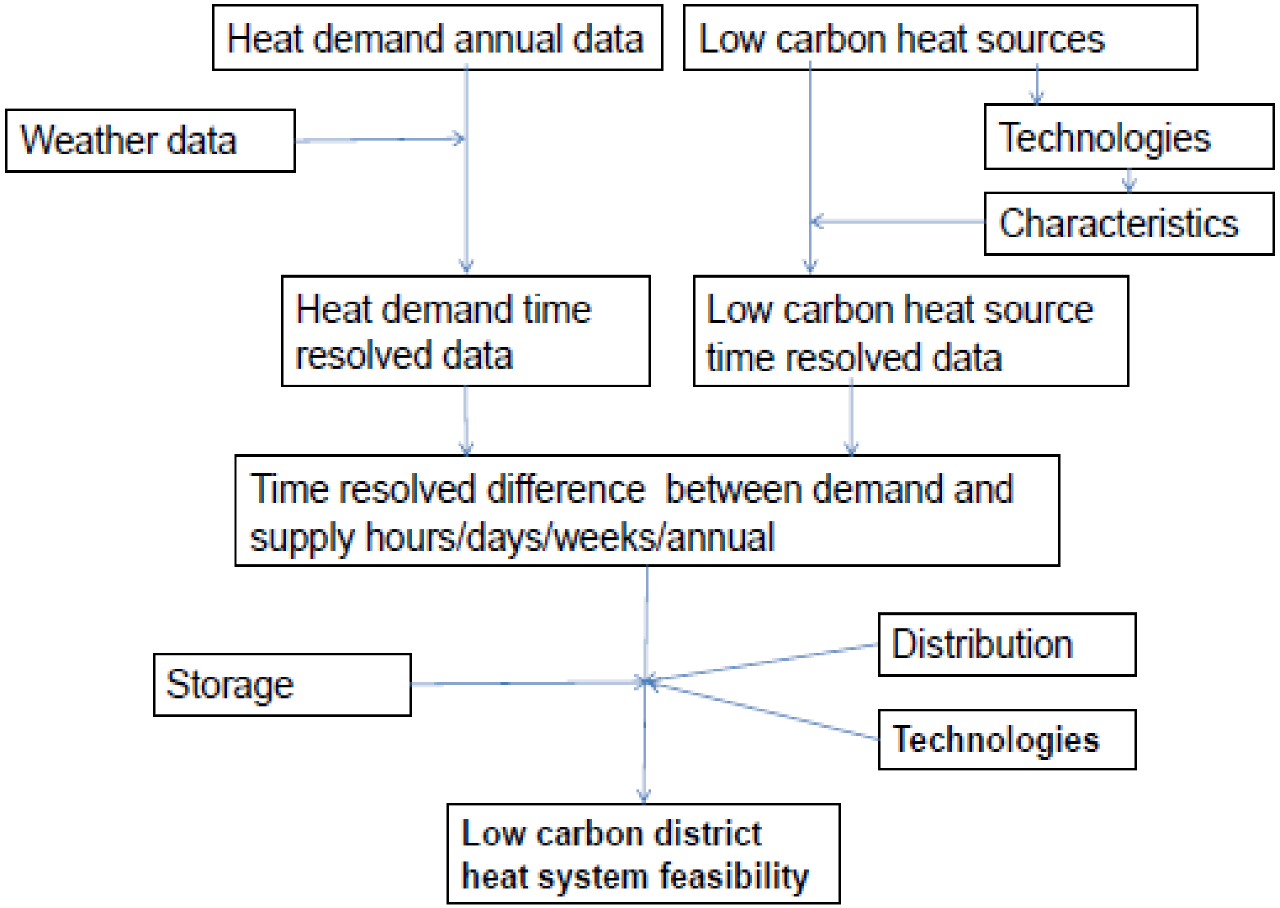
WP2

- WP 2.1: Distribution medium
- WP 2.2: Storage
- WP 2.3: Heat capture

WP3

- WP 3.1: Low temperature lift, high COP VC heat pump
- WP 3.2: VC Heat pump for demand side management
- WP 3.3: High temperature VC heat pumps from network to process heat
- WP 3.4: Combined heat pump/ORC for heat to electricity or reverse.
- WP 3.5: Sorption chillers for cooling from network (commercial use)
- WP 3.6: Sorption heat pump from HT waste to network.
- WP 3.7: Heat transformer from waste heat to process heat and output to network

Work Package 1 – Modelling tool



Work Package 1.1 – Heat mapping and analysis

- Define building types and number in an area
- Define typical building occupancy
- Use hourly weather data and building form and orientation to generate heat gains and heat loads
- Include domestic hot water

	RED AREA	BLUE AREA
Dwelling type		
detached	44.90%	46.20%
semidetached	29.20%	45.10%
terraced	15.70%	7.50%
flat	10.10%	1.20%
Total number of dwellings	89	173
Household type		
One person household	**25.80%**	**17.90%**
Married couple household	**41.60%**	**49.10%**
Same sex couple	**0.00%**	**0.00%**
Cohabiting couple	**13.50%**	**14.50%**
Lone parent	**10.10%**	**16.70%**
Multiperson houshold	**9.00%**	**1.80%**

Table 1. U-values of dwellings' fabric and air changes per hour [24][10].

	Basic U-value (W/m^2K)	Improved U-value (W/m^2K)
External wall	0.45	0.11
Floor	0.60	0.10
Ceiling	0.25	0.13
Glazing	2.94	0.70
Infiltration (air changes per hour, N_{air})	0.50	0.06

Table 1. Basic dwelling geometrical data.

	Floor area (m^2)[10]	Heated volume (m^3)[10]	Total windows area (m^2)[1]	Width (m)[1]
Detached	136	286	34.00	10
Semi-detached	87	186	21.75	10
Terraced	57	142	14.25	10
Flat	56	140	14.00	10

Work Package 1.2 – Model development

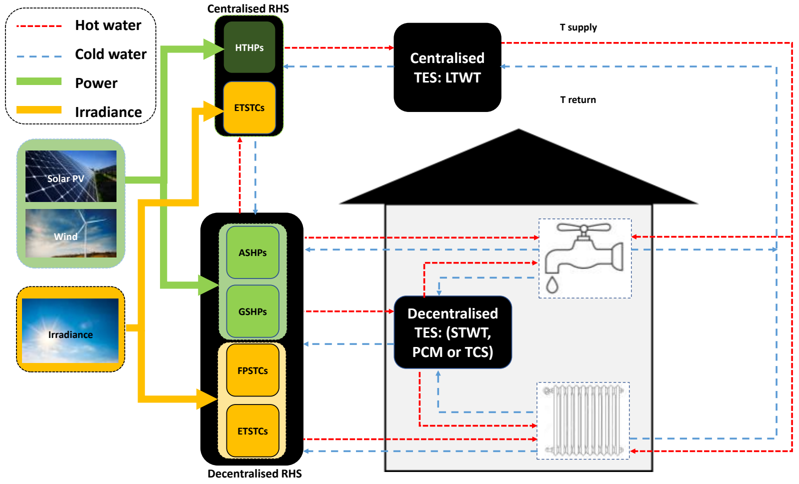
Calculate time varying heat loads.

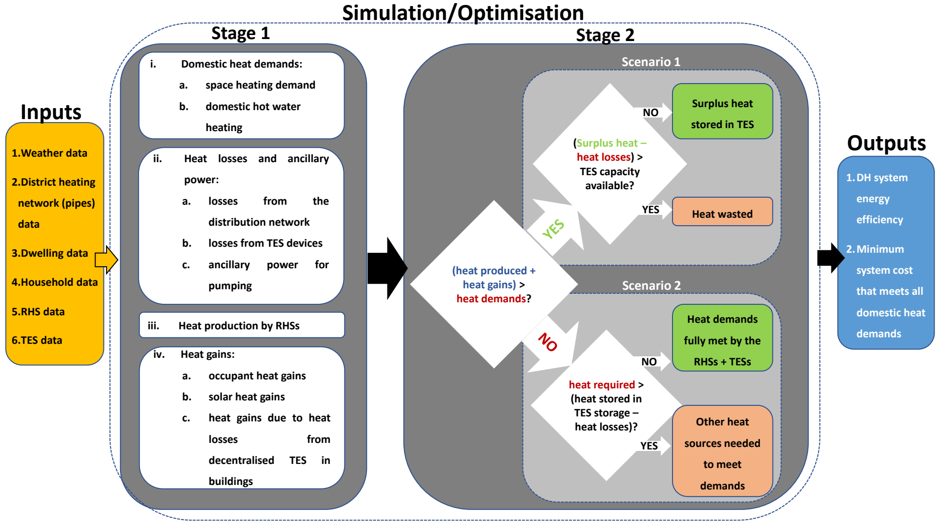
Calculate time varying heat production for different mixes of renewable heat generation.

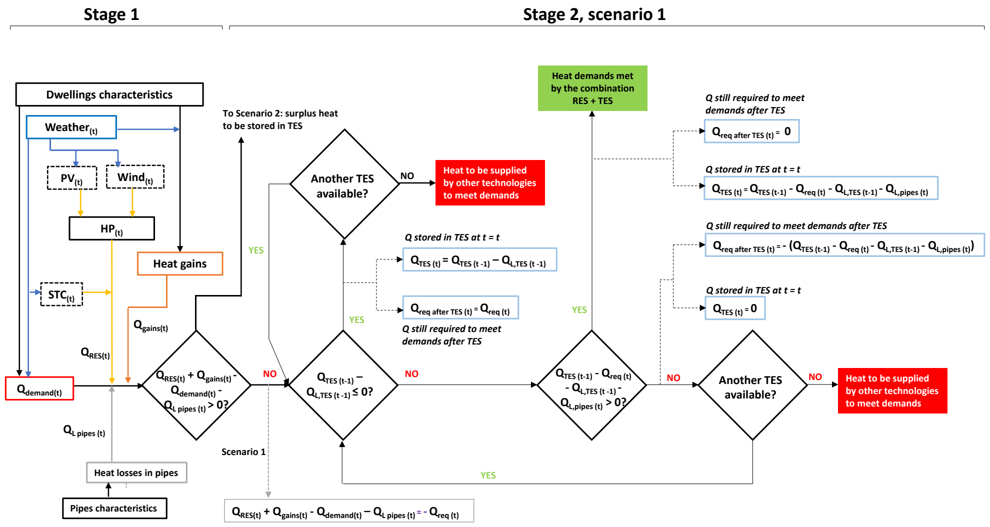
Specify type and distribution of storage.

Specify general operational mode, temperatures, storage priority.

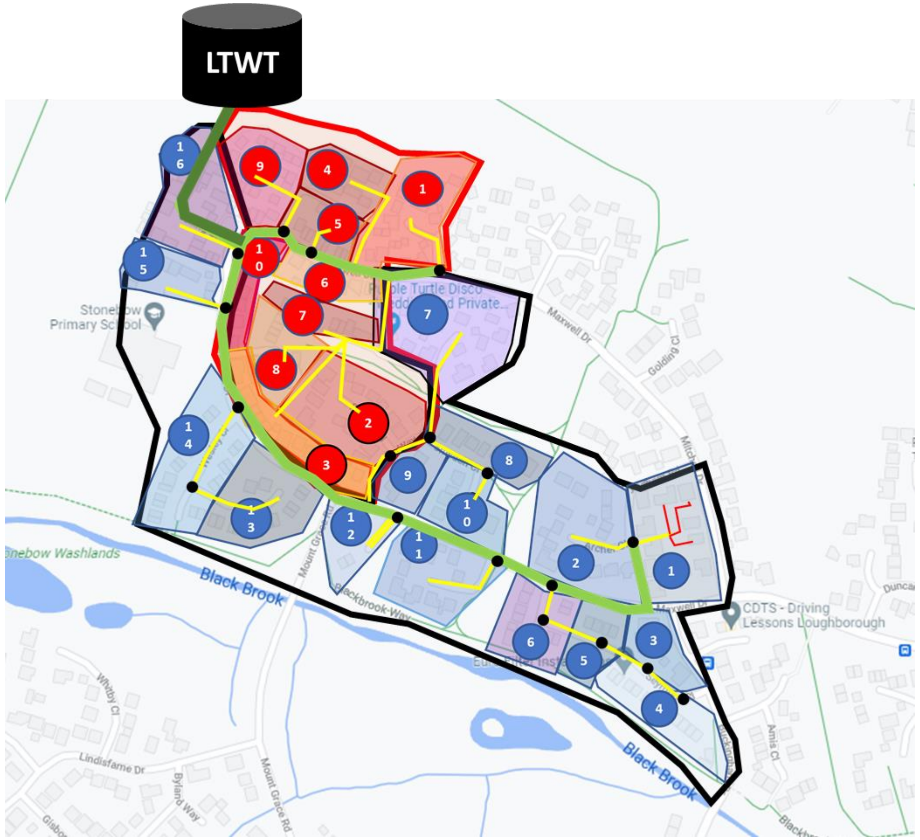
Specify optimisation parameter for example, cost, efficiency.







Work Package 1.3 – Application to case study



Loughborough residential areas

Initial simulations for two different Loughborough residential areas have been performed over a two year period with the condition that the heat source for domestic space and water heating should be 100% renewable with heat demands met for each hourly time period.

Key findings are that air source heat pumps using power generated from wind turbines with large scale thermal storage (up to 20000 m^3) with a storage temperature of 50-90° C is likely to deliver a least cost system.

Work Package 1.3 – Application to case study

- Wind turbines are favoured in the costs analysis compared to PV since generation aligns better with demand.
- Air source heat pumps although with lower COP are significantly cheaper than ground source heat pumps.
- Boosting the storage temperature using high temperature heat pumps greatly increases the heat storage capacity.
- The large store SA/Vol ratio makes long term storage effective due to low heat losses.

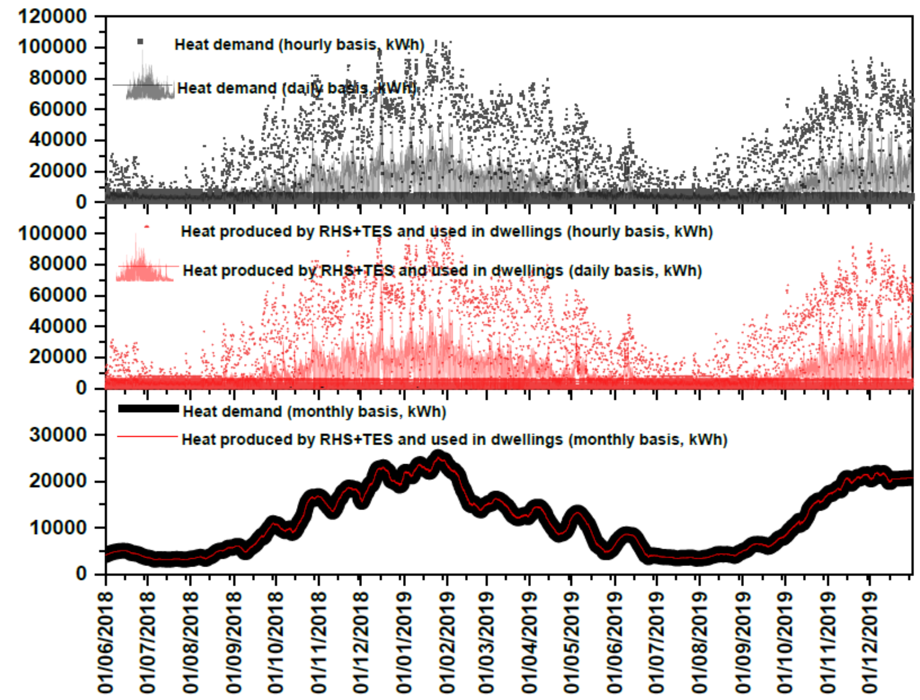


Fig. 1. hourly, daily and monthly total heat demand and heat delivered by a combination of RHS+TES for the town of Loughborough.

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Work Package 1.3 – Application to case study

OPTIMUM CONDITIONS													
Simulation operating conditions						Results							
		System used to lift T before LTWT					RHSss used in dwellings		RHSss used in LTWT				
$T_{charging}$ LTWT	V_{LTWT}	$ETSTC_{LTWT}$	HTHP powered by:		Domestic STCs	η_{DH}	PV $_{DWELLINGS}$	WIND $_{DWELLINGS}$	PV $_{LTWT}$	WIND $_{LTWT}$	HTHP	ETSTC $_{LTWT}$	Cost per dwelling
(°C)	(m^3)		PV	Wind	(m^2 per dwelling)	(yearly average, %)	(MW)	(MW)	(MW)	(MW)	(kW)	(m^2)	(£)
90	10000	NO	NO	YES	2	84.38	0	0.3859	0	0.2023	1160.2	0	13208

A minimum cost of £13,208 per dwelling with efficiency (heat used/heat generated) of 84.38% was found.

Costs in the literature for standard DH systems £11,000 and £11,900 per dwelling [1,2]

To enable a fully renewable network the lowest cost per dwelling is found with a long term water tank storage volume of 10,000m3

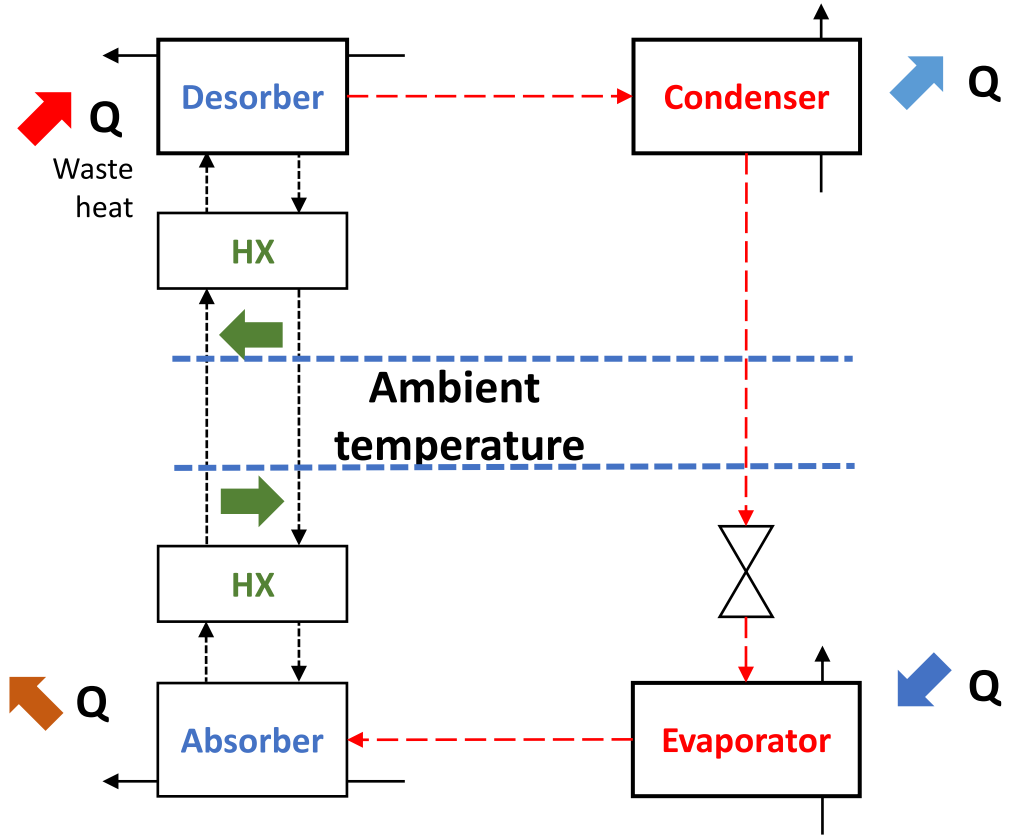
38.2 m3 of storage per dwelling providing 3102kWh of capacity per dwelling, approximately 20% of the annual heat load of 14,000kWh per dwelling

[1] Z. Wang, Heat pumps with district heating for the UK's domestic heating: individual versus district level, Energy Procedia. 149 (2018) 354-362. https://doi.org/10.1016/J.EGYPRO.2018.08.199.

[2] AECOM, Reducing the capital cost of district heat network infrastructure, 2017. https://d2umxnkyjne36n.cloudfront.net/teaserImages/Reducing-the-capital-cost-of-district-heat-network-infrastructure.pdf?mtime=20171103092304.

Work Package 2.1 – Distribution medium

- TC options use fluids at ambient temperature (~zero loss).
  e.g. absorption of water vapour in NaOH
- ‘Low temperature’ (55/45°C) and ‘Ambient’ (14/4°C) loops.
- Characterised both by simple efficiency and by ‘DeltaT H_2O’
  10°C would correspond to a normal LT system with a drop from 55 to 45°C and 100°C would require only 10% of the flow to be pumped compared to a conventional system.
- The main value of a reduction in the flow rate is in the reduced capital cost of trenches etc.
- For LT loops the TC systems could not achieve more than about 75% efficiency with a DeltaT H_2O of around 70°C.
- For ambient loops the efficiencies > 95% and DeltaT H_2O in ‘00s - pipe diameters reduced by a factor of four.

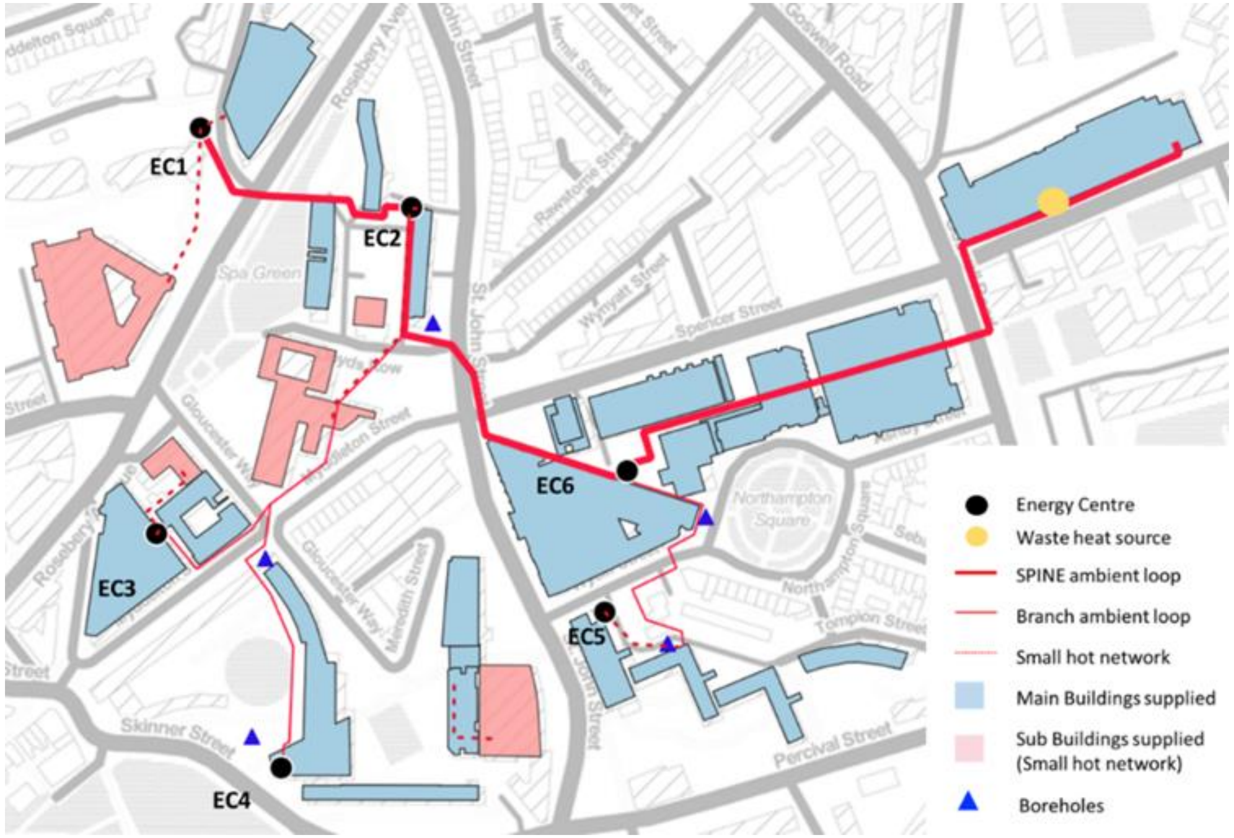


Critoph, R.E.; Pacho, A.M.R. District Heating of Buildings by Renewable Energy Using Thermochemical Heat Transmission. *Energies* **2022**, *15*, 1449. https://doi.org/10.3390/en15041449

Work Package 2.1 – Distribution medium

Future work

- Cost both ambient and low temperature loops against conventional water options in the GreenScies New River project.
- Test NaOH – H_2O absorber, evaporator, condenser in lab.
- Evaluate NaOH – H_2O as an energy storage system.



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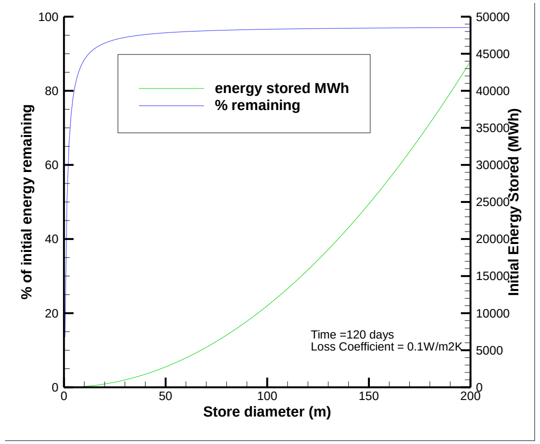
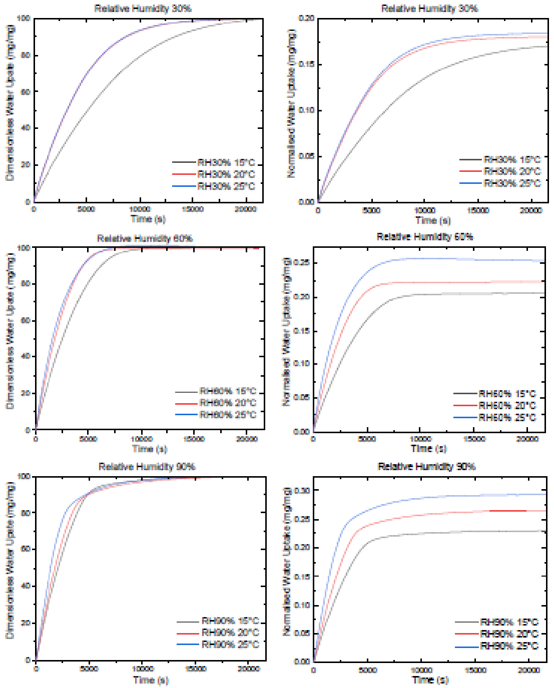
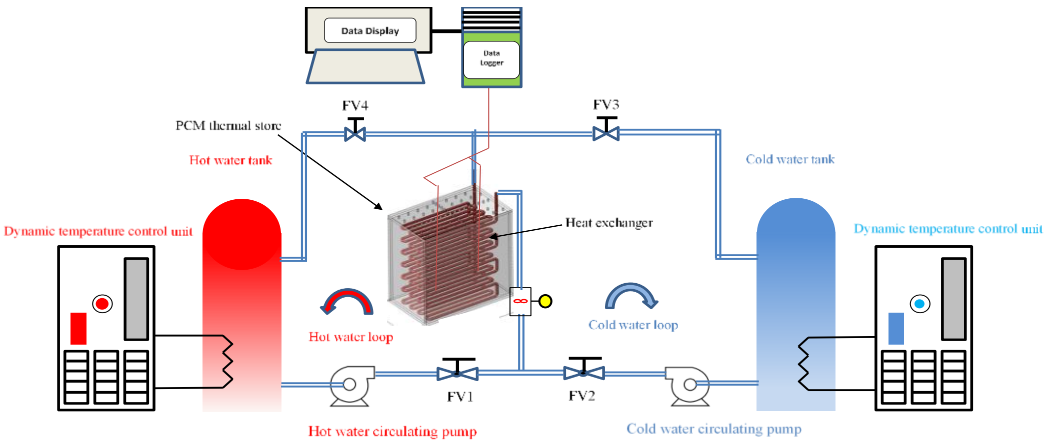
Work Package 2.2 – Storage



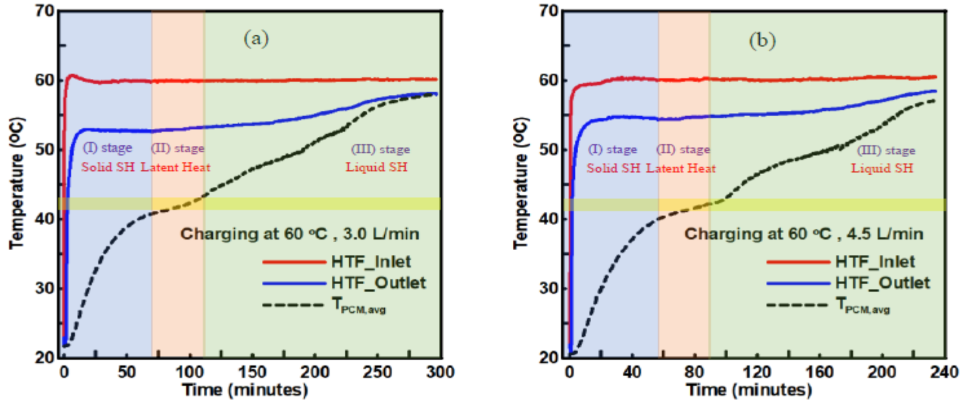
Sensible water based heat storage.
The importance of store size:
H = 20m
Initial store temperature 80°C.



Measurement of hydration of Silica Gel impregnated with 15% MgCl2 for different hydration conditions



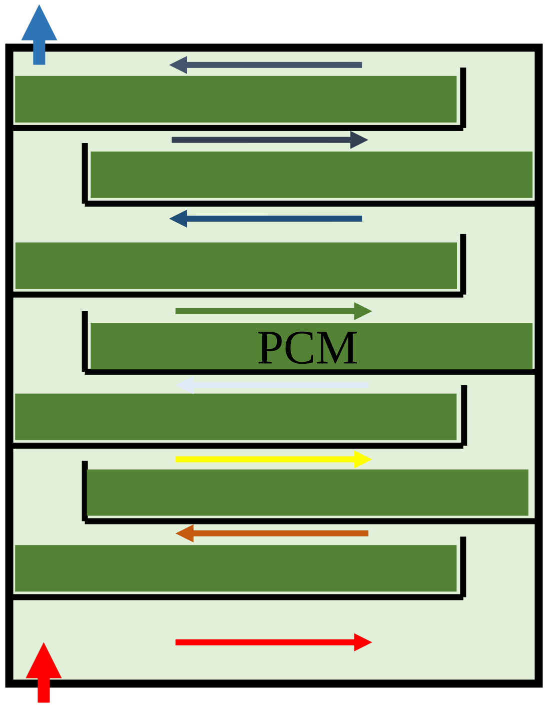
Schematic of lab based latent heat thermal storage test rig (Above)
Examples of experimentally measured store charging process (Below)



Direct contact latent heat thermal energy storage

Storage container design

HTO outlet



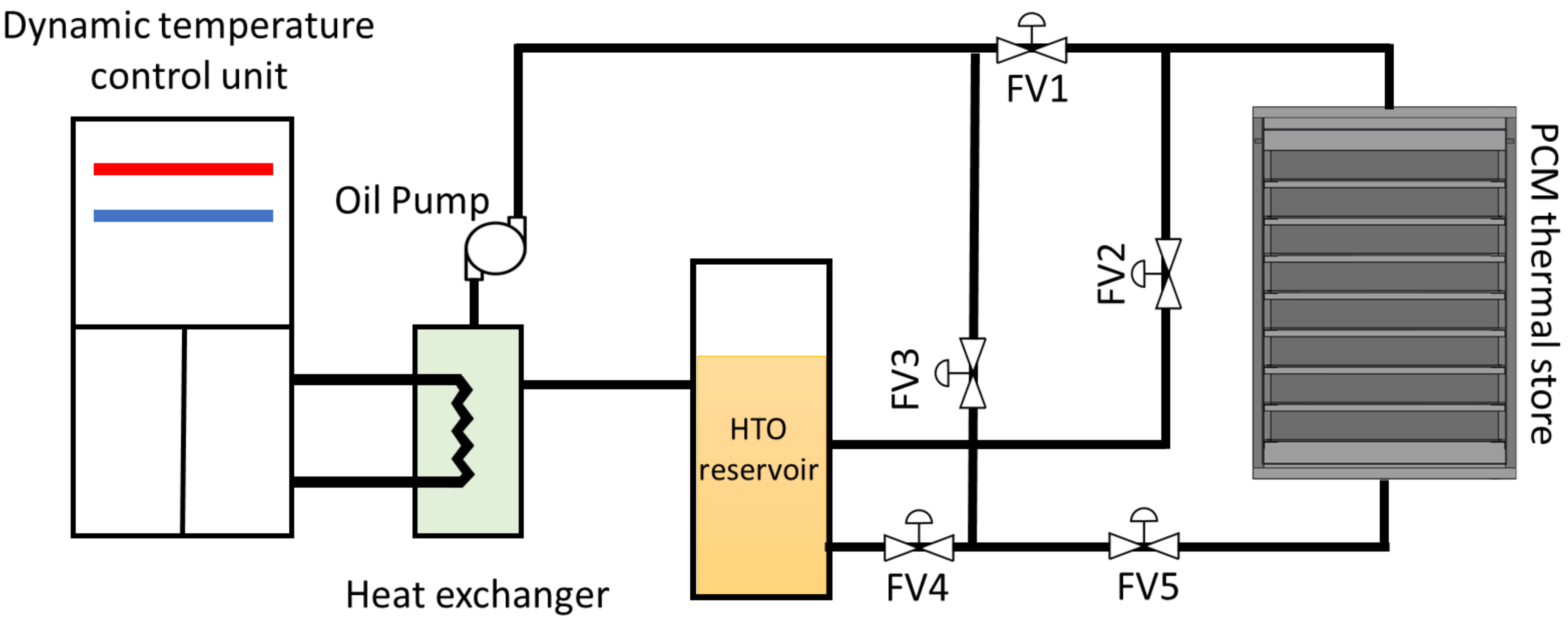
HTO inlet

TES configuration design

Stainless steel frame

Direct contact latent heat thermal energy storage

Test rig for charging and discharging processes



Charge and discharge test setup

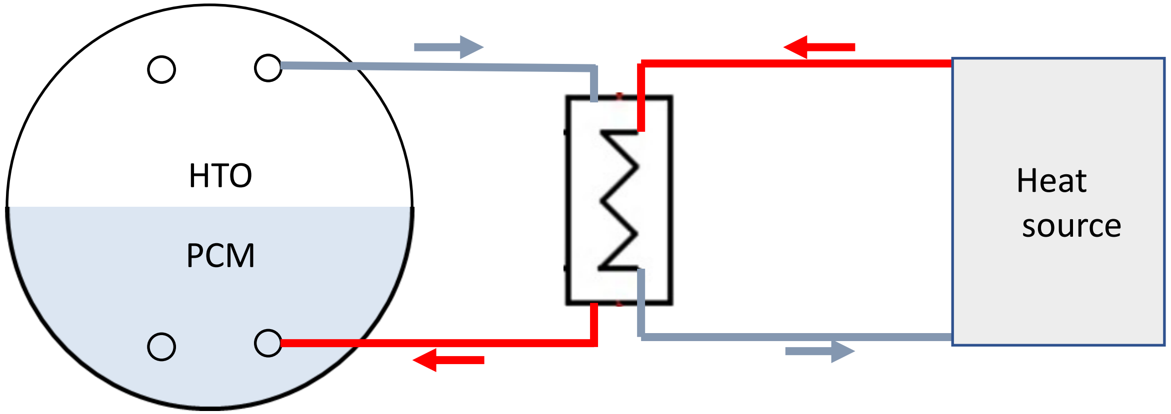
Direct contact latent heat thermal energy storage

Material selection (Phase change material)

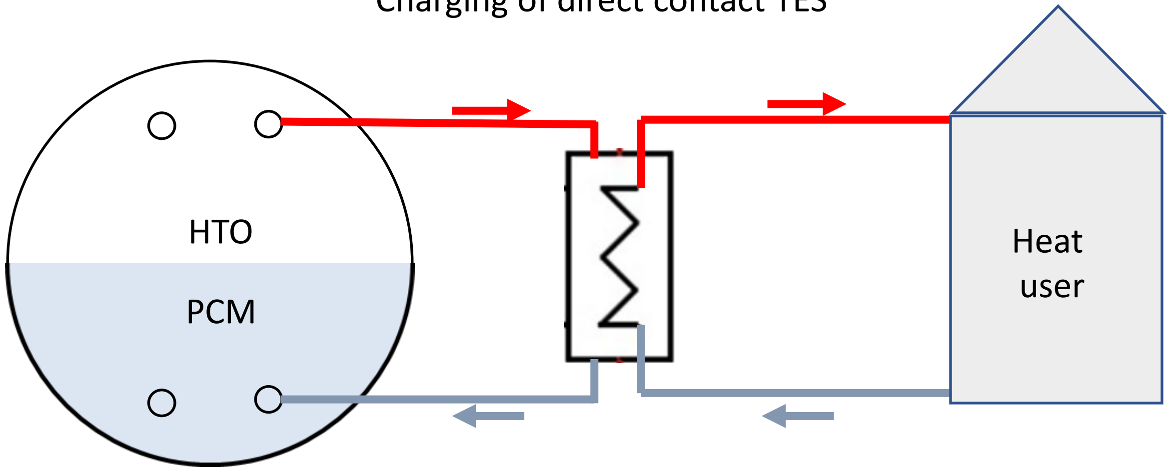
Density	Solid (25°C) 1.2 g/cm^3 Liquid (70°C) 1.1 g/cm^3
Melting point	58-63°C
pH	5.5-6.5
Thermal conductivity	0.2124 $Wm^{-1}K^{-1}$
Boiling point	200°C
Heat of fusion	195 kJ/kg

Polyethylene glycol 6000 properties

Direct contact thermal energy storage

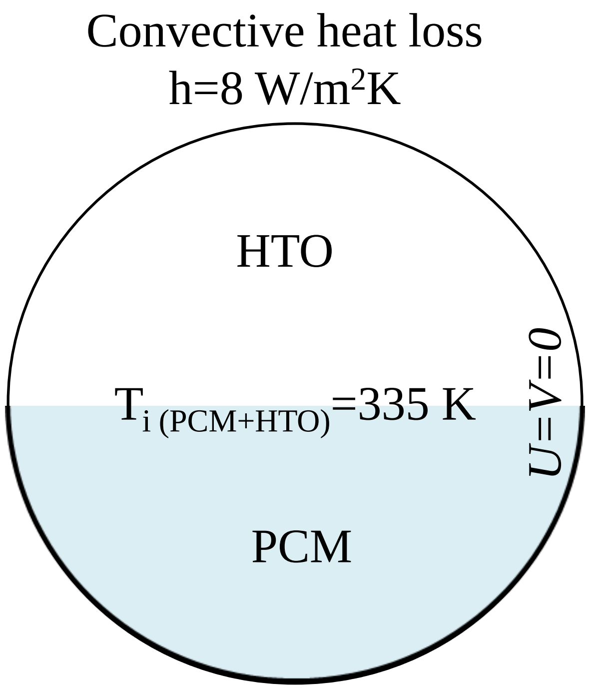


Charging of direct contact TES

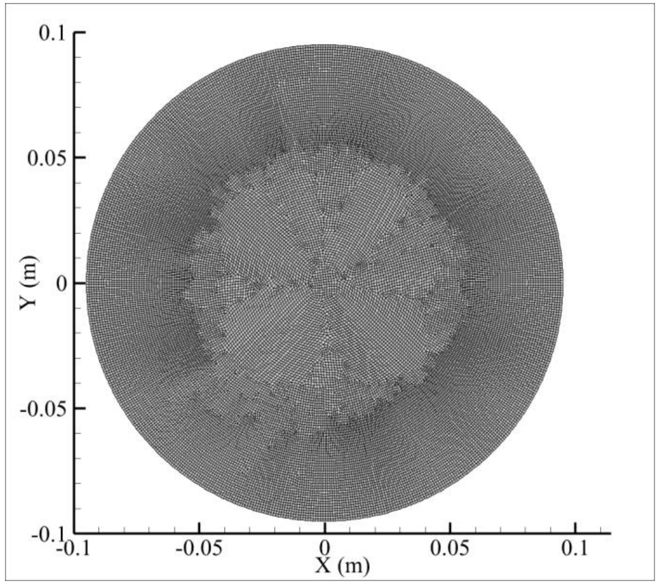


Discharging of direct contact TES

Numerical study on standby heat losses from direct contact thermal energy storage



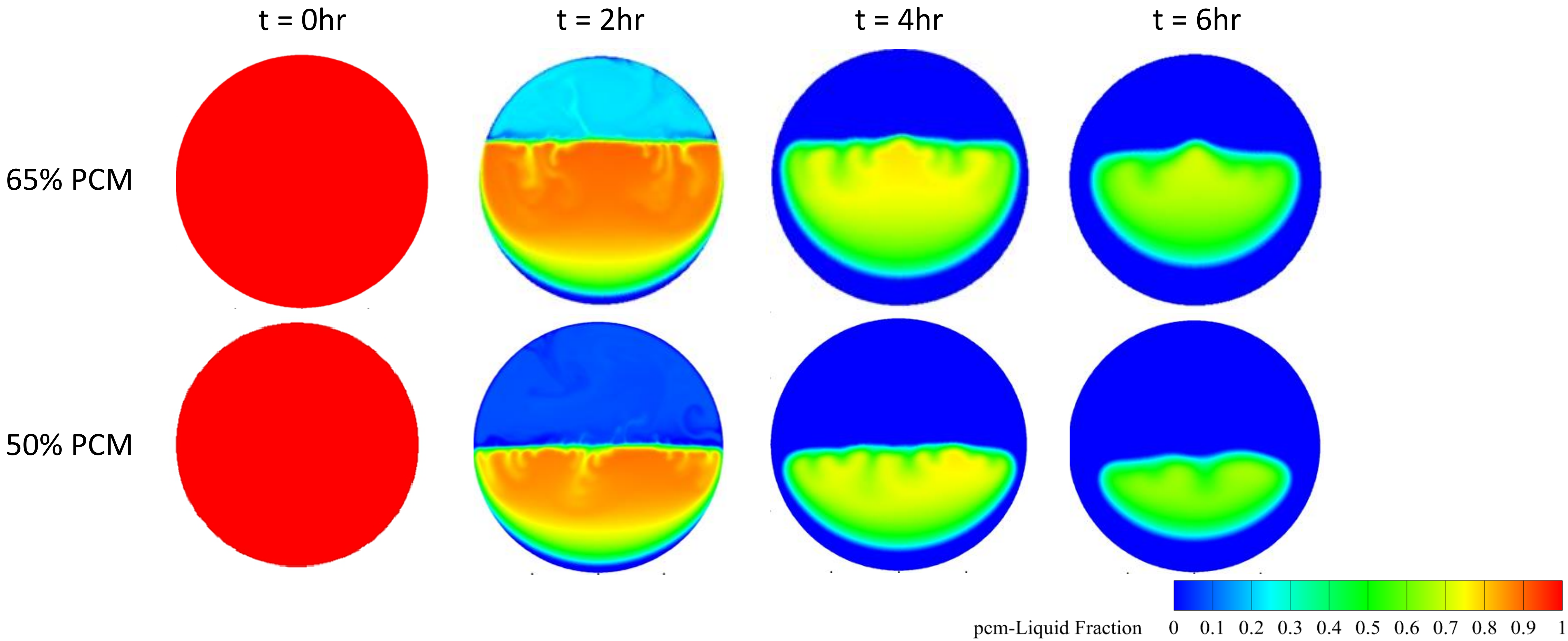
CFD boundary conditions



Mesh configuration

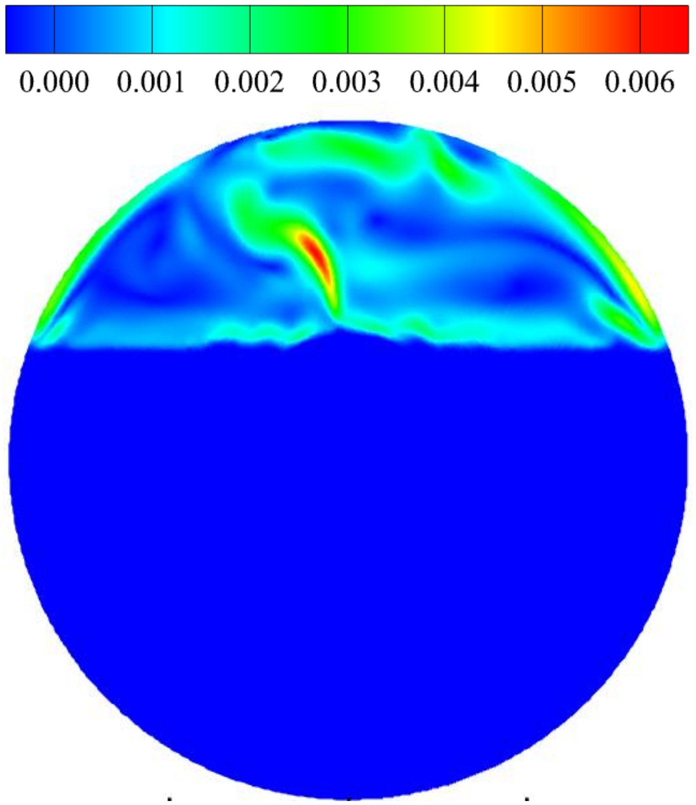
The flow inside the horizontal cylinder was considered to be 2 dimensional and laminar.

Numerical study on standby heat losses from direct contact thermal energy storage

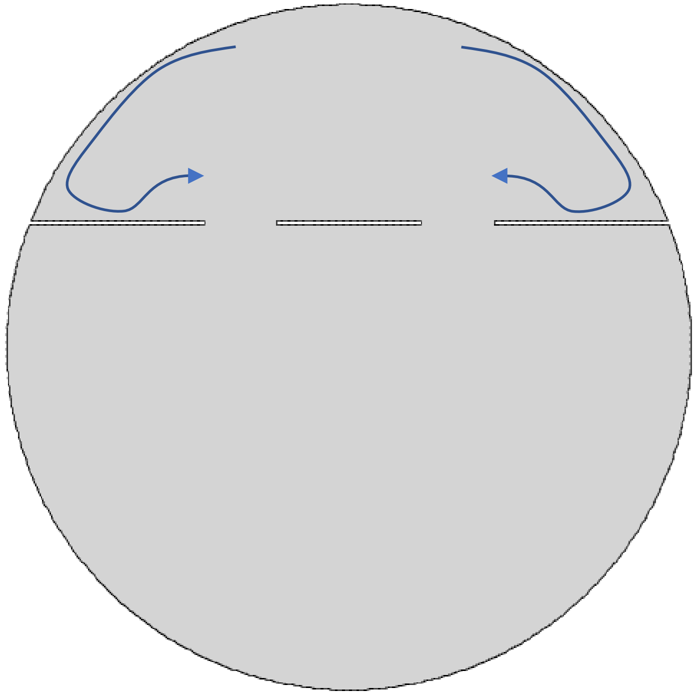


Convective heat loss from PCM

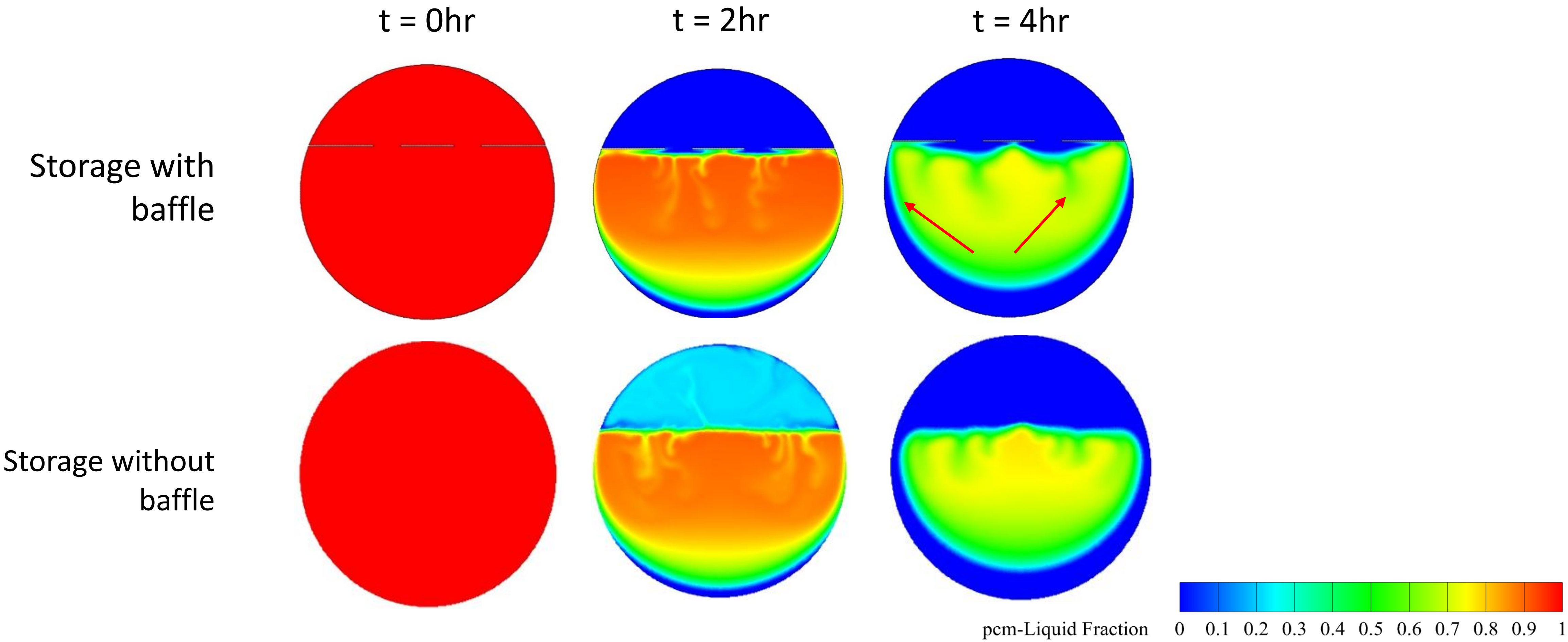
Velocity magnitude m/s



Natural convection can be reduced by using baffle to supress downward flow



Use of baffles to reduce heat losses from direct contact thermal energy storage



Work Package 2.3 – Heat capture opportunities

The different waste heat sources investigated to date are including the following categories:

- Electricity substations, Cable tunnels (Estimated 479 MW)
- Cement/Iron & steel industries (Estimated 68/195 MW)
- Supermarkets (Estimated 959 MW)
- Cold stores (Estimated 416 MW)
- Crematoriums (Estimated 75 MW)
- Data centres (Estimated 1939 MW)
- Paper and pulp (Estimated 10 MW)
- Wastewater treatment plants (Estimated 2929 MW)
- Underground Railways (Estimated 38 MW)

Waste heat - The big questions

- How large?
- Where are they?
- How to capture?
- What's the benefit?
- How do they compare?

Waste heat source	Number of heat sources > 250kW	Waste heat recovery site/medium	Waste heat temperature(s) (°C)	Total thermal energy (heat) output (GWh year^{-1})
Data centres	264	IT server exhaust air	30 to 40°C	16200
		Chilled water heat rejection	10 to 20°C	
Electricity substations	1336	Transformer cooling system	40 to 70°C	4000
Wastewater	985	Final WWTP effluent	12 to 23°C Average 17.6°C	22514
Mine water	18584	Water	12 to 40°C	519644
Supermarkets	3653	Condenser heat rejection	21 to 27°C	7800
		Desuperheater	53°C	
Cold stores	195	Condenser heat rejection	15 to 30°C	3600
		Desuperheater	60 to 90°C	
Underground railway tunnels	65	Ventilation shaft air	11.5°C to 28°C	290
Cremations	269	Combustion exhaust gases	800 to 1000°C	165

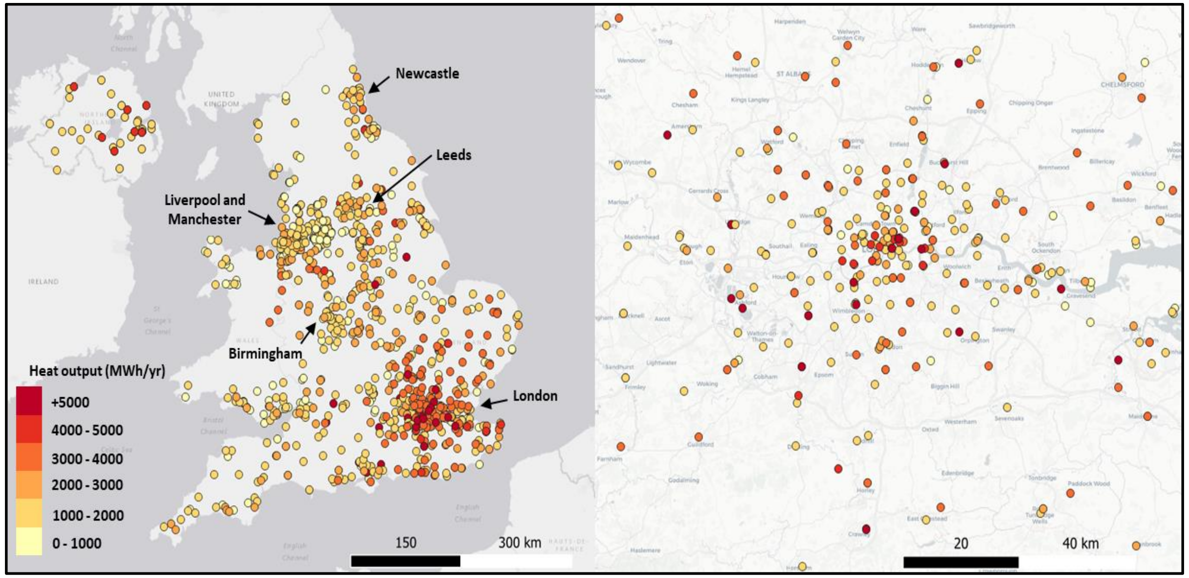
Example : Electrical substation transformers

Headline numbers:

1336 electrical substations of > 60 MVA in England, Wales, N Ireland (excluding Scotland)

Total heat output: 4 TWh/yr

Average waste heat available per site: 3 GWh/yr



(a) (b)

Figure 2 Locations of electrical substations: (a) across the UK (excluding Scotland);
(b) in the Greater London area

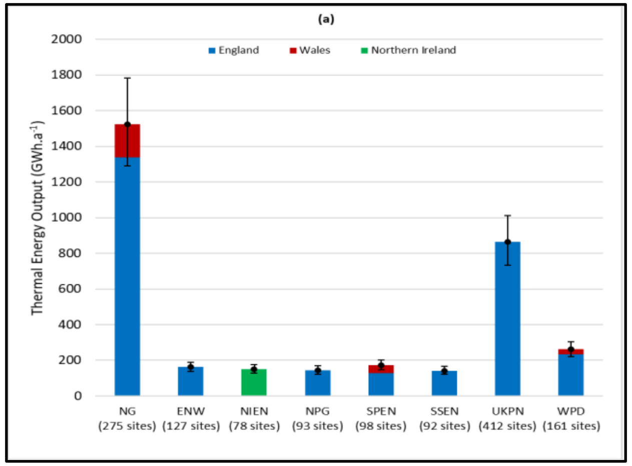
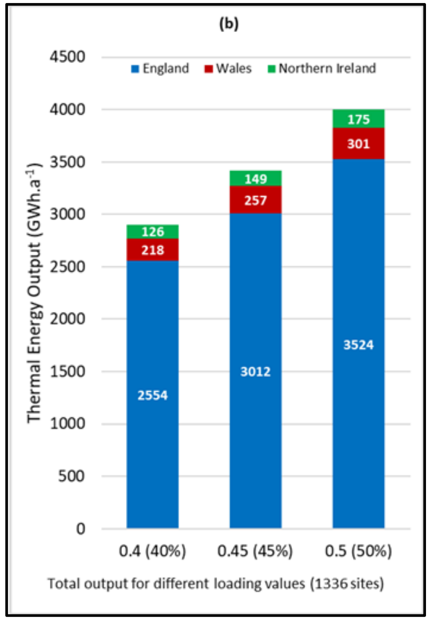


Figure 1 (a) Estimated waste heat from electrical substations for each and total combined waste heat output

Figure 1 (b) Estimated waste heat from electrical substations considering different loading values.



Electrical substation transformers: evidence and methodology

Calculation of heat output from transformers

$$\dot{Q}_{tr} = C \times (0.0065L^2 + 0.0005)$$

Equation relating transformer capacity and loading to heat output (Bowman, 2019)

Reference:

Bowman, J. (2019) *Project SHOES: Secondary Heat Opportunities from Electrical Substations*. MSc Thesis, London South Bank University. London, UK.

UK numbers/types

Main transformer types in UK:

1. Grid Supply Point (GSP) 440 kV to 132 kV; 380 total
2. Bulk Supply Point (BSP): 132 kV to 33 kV; 1000 total
3. Primary substations: 33 kV to 11 kV; 4800 total
4. Secondary substations: 11 kV to 400 V or 240 V; 230,000 total

- Only 2, 3 and 4 in urban areas i.e. appropriately located for heat recovery

Reference:

Northern Power Grid (2015) Adapting to Climate Change

Transformers suitable for waste heat recovery

- Cooling systems generally consist of both an internal and external cooling medium
- Main cooling mediums either oil (O) or air (A), and either natural (N) or forced (F) circulation. Therefore can have ANAN, ANAF, ONAN, ONAF, OFAN, OFAF. Also sometimes use water (W) externally, so can have e.g. OFWF

Assumptions:

- Most useful transformer cooling systems for integrating heat recovery are OFAF or AFWF
- Only transformers of capacity > 60 MVA likely to produce sufficient heat for viable heat recovery system (and use OFAF or OFWF)
- BSP and Primary transformers most appropriate types for waste heat recovery

- 1336 substations identified as potentially suitable for waste heat recovery in UK (excluding Scotland)

Oil forced, air forced transformer cooling OFAF

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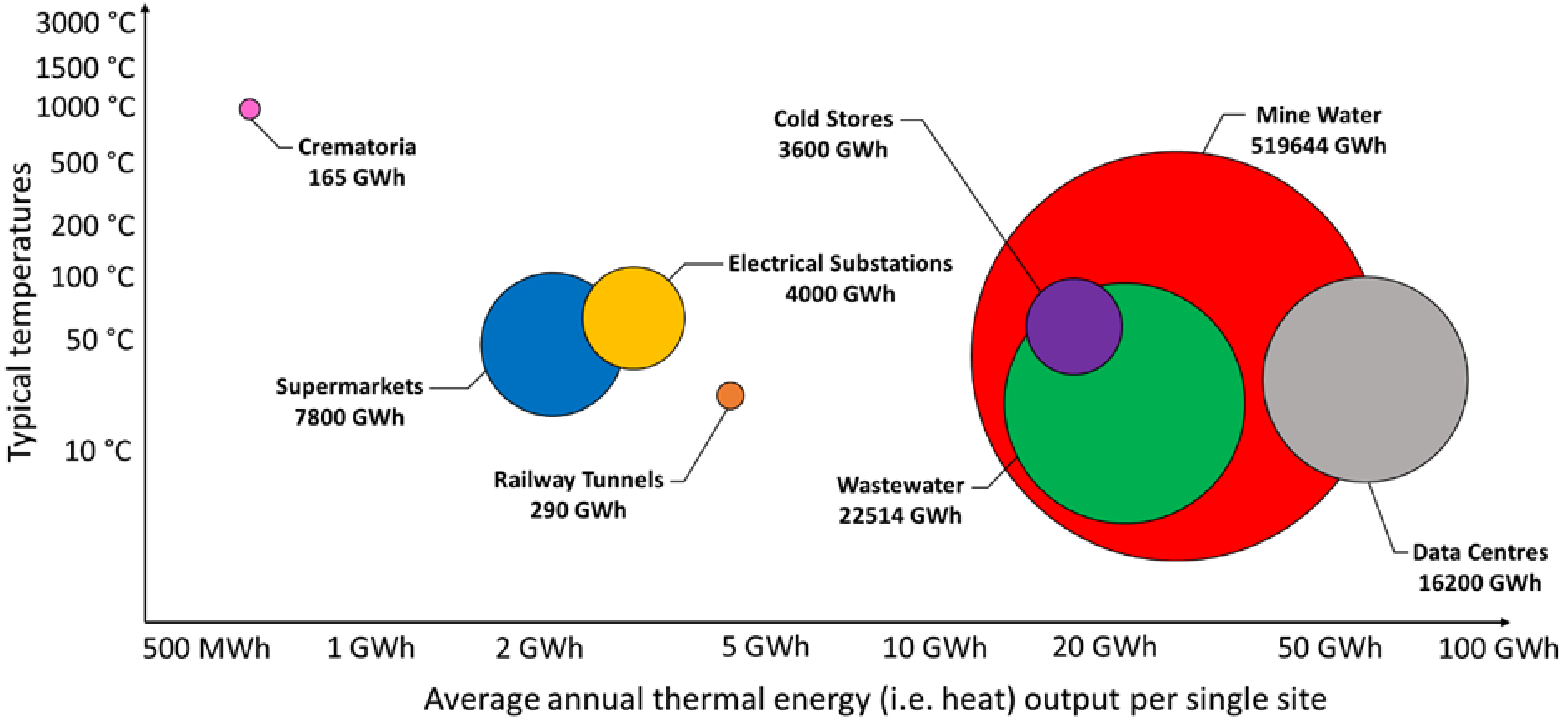
Low temperature secondary waste heat sources in the UK



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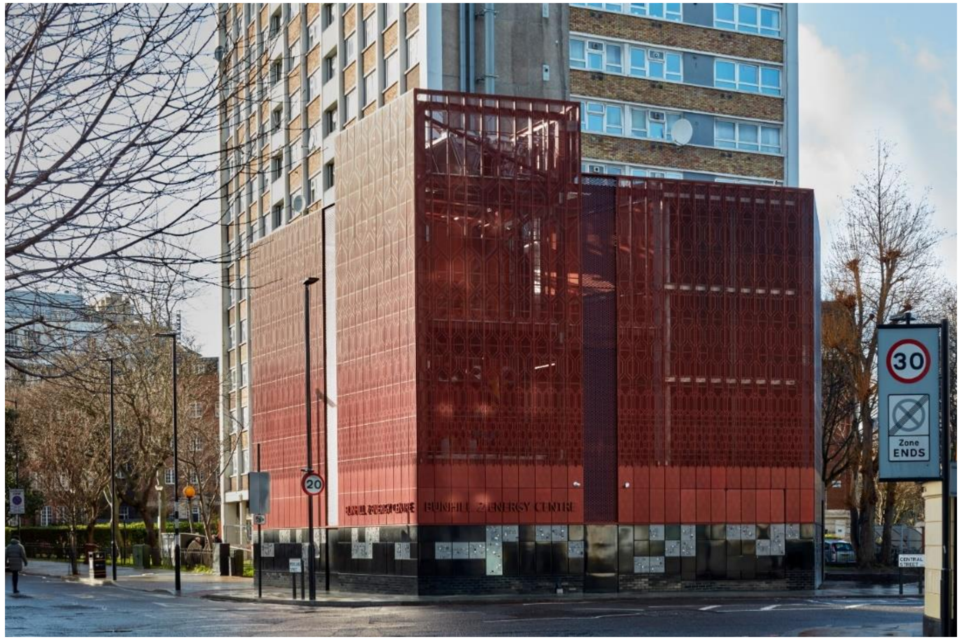
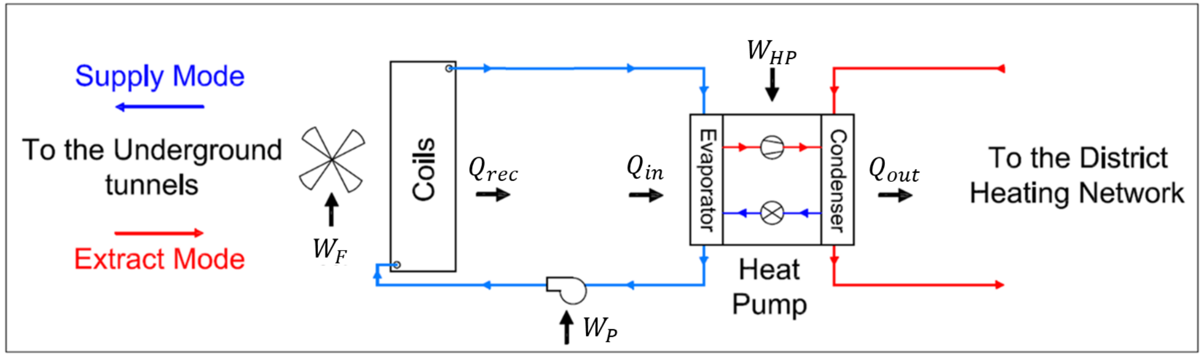
HEAT FUEL PROJECT

- Average of **770 kW** of heat recovered from the London Underground
- Upgraded by a **1 MW** heat pump
- Can also provide cooling when operating in Supply Mode
- Heat FUEL investigates both the heating and cooling benefits based on EES model
- Latest work incorporates flexibility when analysing benefits of waste heat

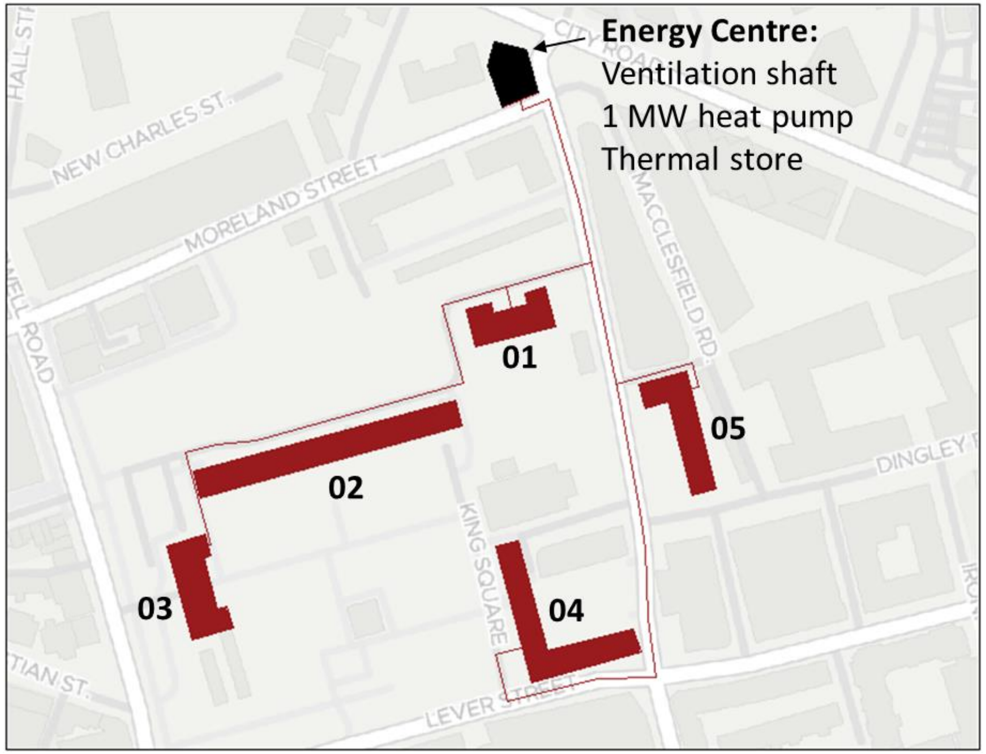




WASTE HEAT AND FLEXIBILITY

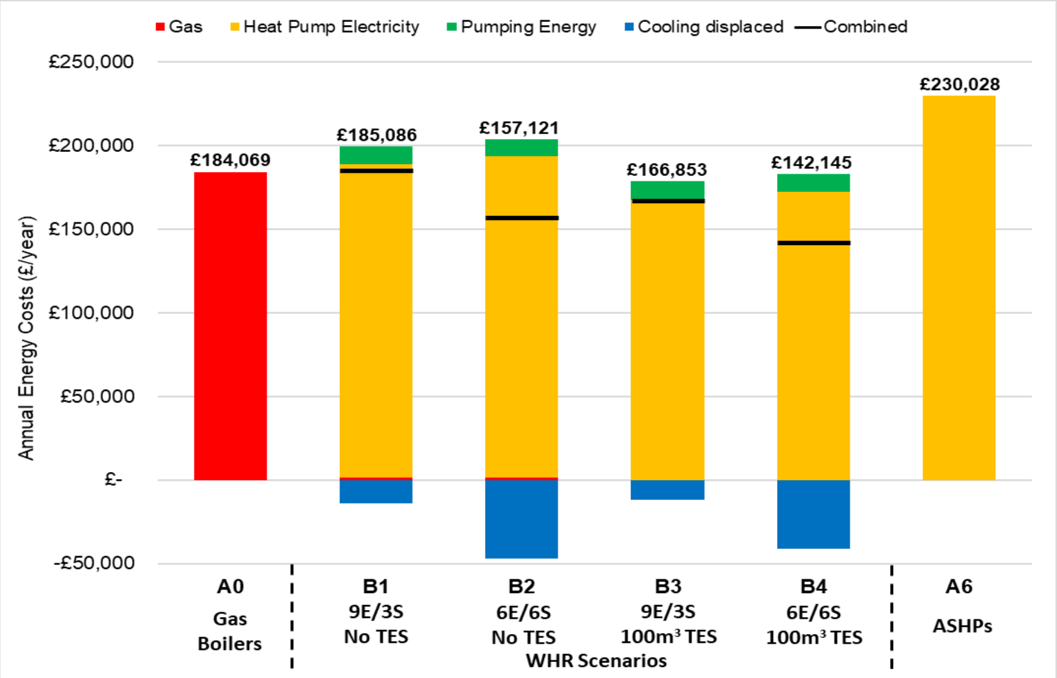
energyPRO model → **Heat demand profiles** + **Ambient and tunnel temps** + **Conversion and storage** + **Energy tariffs**

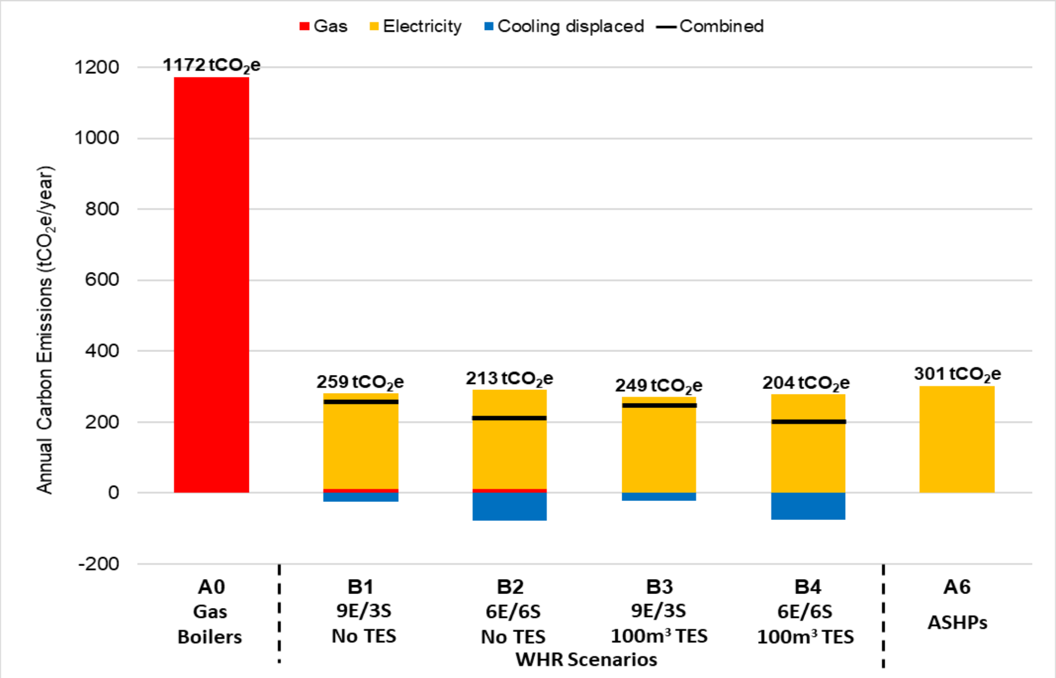
- Benefits of combining WHR system with thermal energy storage (TES) investigated with energyPRO
- Heat network supplied by vent shaft heat pump
- Hourly electricity prices included in the analysis
- Cooling benefit incorporated: chiller displacement
- Comparison against communal gas boilers and air-source heat pumps for each building



CARBON AND COST SAVINGS

WHR could potentially achieve significant savings p.a. against counterfactuals





WHR + 6 months of cooling + flexibility:

23% cost savings against gas

38% cost savings against ASHPs

Waste heat from the Underground:

Average carbon savings of 80% vs. gas boilers

Up to 32% of carbon savings against ASHPs

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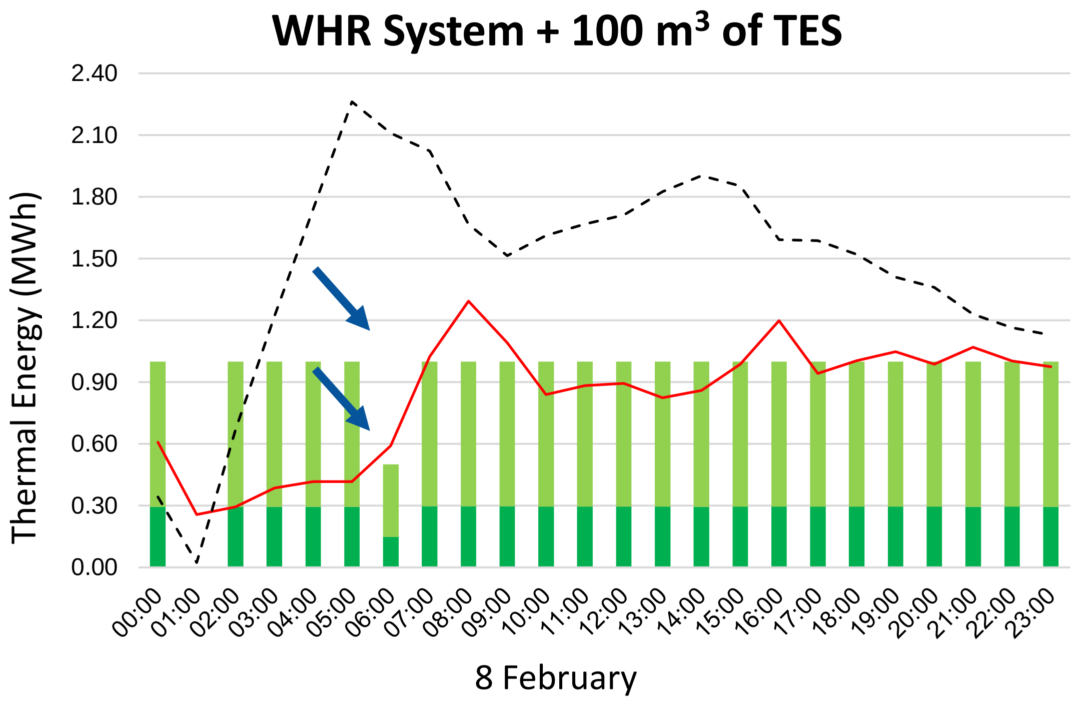
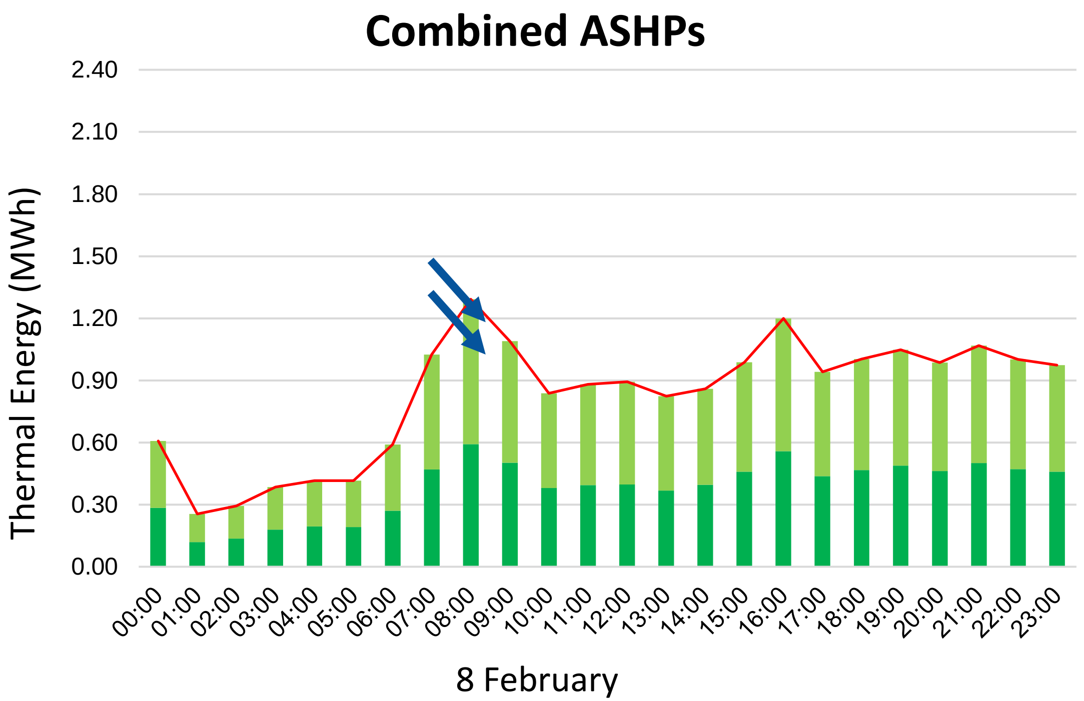
PEAK ELECTRICITY DEMANDS

Wider energy system benefits can also be achieved through lower peak demands





Heat demand profiles during day of **peak hourly demand**

Power demands:

WHR System + TES: 297 kW hourly peak

ASHP Scenario: 593 kW hourly peak

Annual peak demand is reduced by **44%** with **WHR** system

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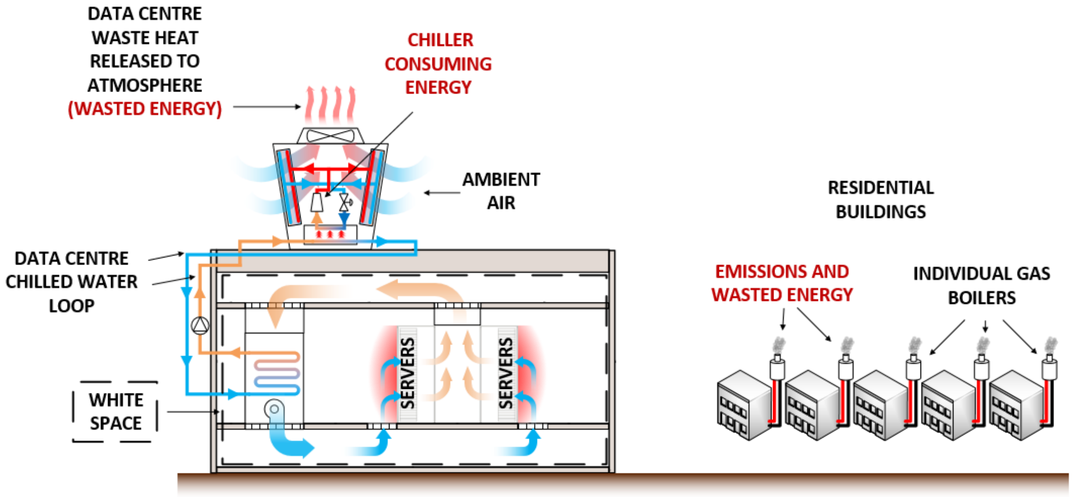
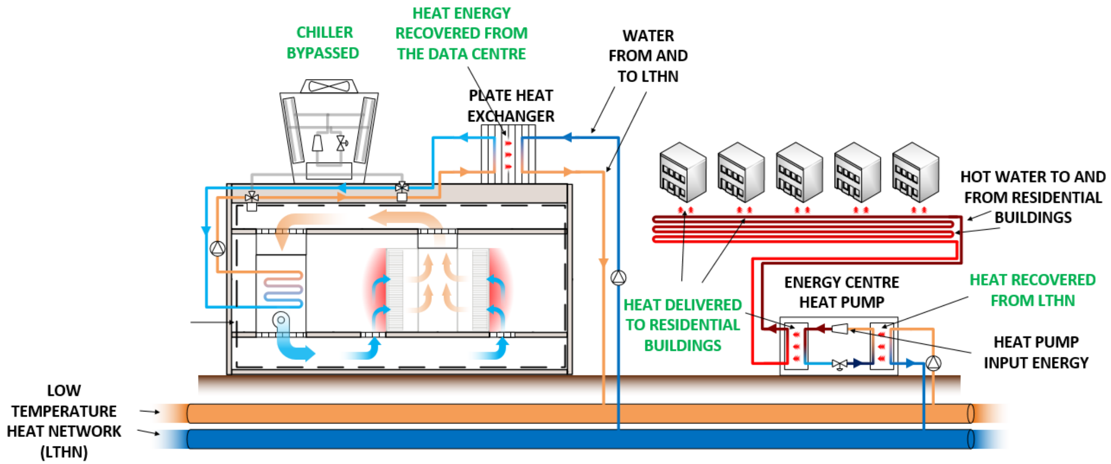
DATA CENTRES

Business as usual:



Heat recovery:

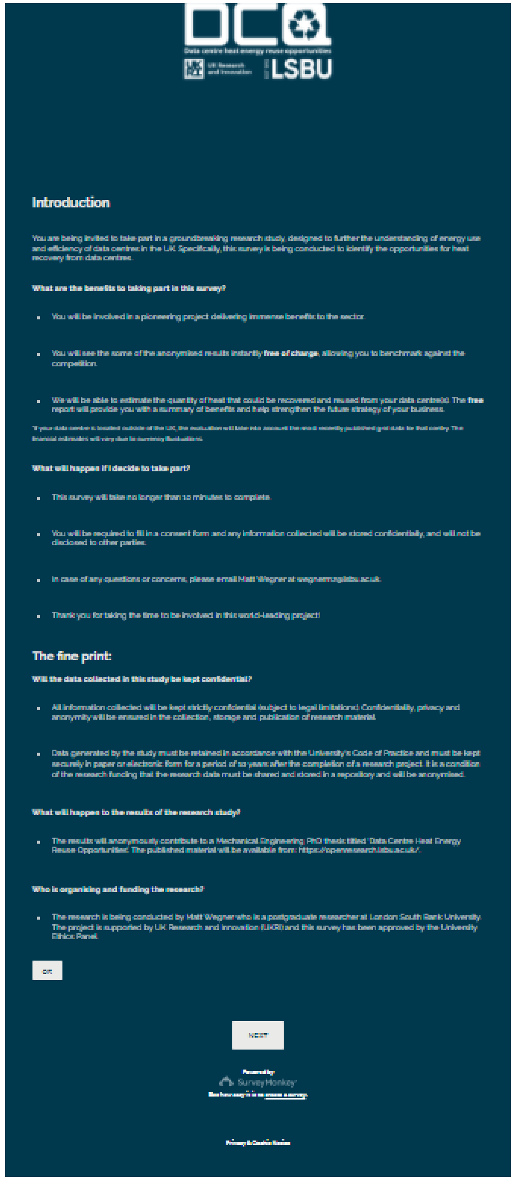


DATA CENTRES

Online survey aims to:

- Overcome the lack of transparency within the sector
- Understand how data centres use energy
- Help establish generic factors between facilities for a more accurate estimate of heat available from the sector
- Invite data centre owners and operators to participate in the project (energy modelling)
- Investigate the industry's attitude towards waste heat recovery and identify enablers

https://www.surveymonkey.co.uk/r/dc-heat


LSBU

Introduction

You are being invited to take part in a groundbreaking research study, designed to further the understanding of energy use and efficiency of data centres in the UK. Specifically, this survey is being conducted to identify the opportunities for heat recovery from data centres.

What are the benefits to taking part in this survey?

- You will be involved in a pioneering project delivering immense benefits to the sector.
- You will see the some of the anonymised results instantly **free of charge**, allowing you to benchmark against the competition.
- We will be able to estimate the quantity of heat that could be recovered and reused from your data centre(s). The **free** report will provide you with a summary of benefits and help strengthen the future strategy of your business.

What will happen if I decide to take part?

- This survey will take no longer than 10 minutes to complete.
- You will be required to fill in a consent form and any information collected will be stored confidentially, and will not be disclosed to other parties.
- In case of any questions or concerns, please email Matt Wegner at wegnerm@lsbu.ac.uk.
- Thank you for taking the time to be involved in this world-leading project!

The fine print:

Will the data collected in this study be kept confidential?

- All information collected will be kept strictly confidential (subject to legal limitations). Confidentiality, privacy and anonymity will be ensured in the collection, storage and publication of research material.
- Data generated by the study must be retained in accordance with the University's Code of Practice and must be kept securely in paper or electronic form for a period of 10 years after the completion of a research project. It is a condition of the research funding that the research data must be shared and stored in a repository and will be anonymised.

What will happen to the results of the research study?

- The results will anonymously contribute to a Mechanical Engineering PhD thesis titled 'Data Centre Heat Energy Reuse Opportunities'. The published material will be available from: https://openresearch.lsbu.ac.uk/.

Who is organising and funding the research?

- The research is being conducted by Matt Wegner who is a postgraduate researcher at London South Bank University. The project is supported by UK Research and Innovation (UKRI) and this survey has been approved by the University Ethics Panel.

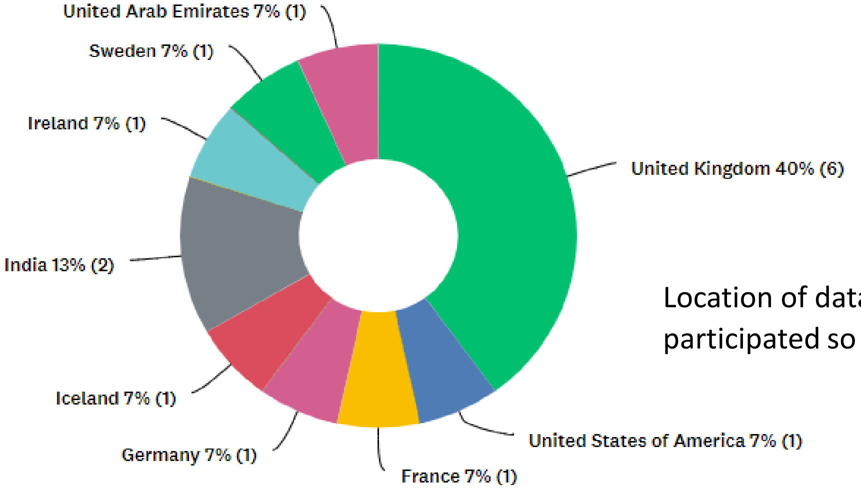
NEXT

SurveyMonkey

DATA CENTRES

Survey update:

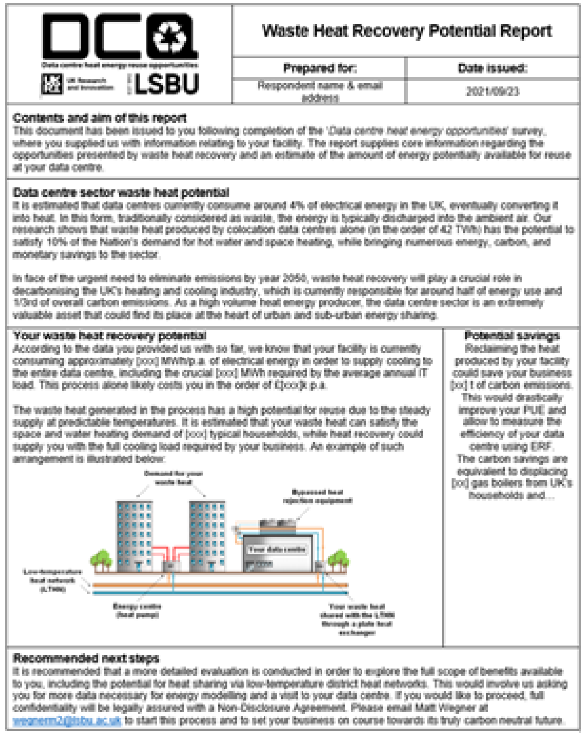
- <30 responses so far, working on many more in 2022
- Arranged participation of a number of telecoms data centres in Q1 2022
- Number of contacts in the industry sharing link to the survey with connections



Location of data centres that participated so far

Participants are offered a free evaluation of heat recovery potential for their data centre, estimating benefits:

- reduced energy consumption
- reduced carbon emissions
- increased efficiency
- displaced gas boilers in neighbouring households/businesses



DCQ
Data centre heat energy reuse opportunities
UK Research and Innovation | LSBU

Waste Heat Recovery Potential Report

Prepared for:	Date issued:
Respondent name & email address	2021/09/23

Contents and aim of this report
This document has been issued to you following completion of the 'Data centre heat energy opportunities' survey, where you supplied us with information relating to your facility. The report supplies core information regarding the opportunities presented by waste heat recovery and an estimate of the amount of energy potentially available for reuse at your data centre.

Data centre sector waste heat potential
It is estimated that data centres currently consume around 4% of electrical energy in the UK, eventually converting it into heat. In this form, traditionally considered as waste, the energy is typically discharged into the ambient air. Our research shows that waste heat produced by colocation data centres alone (in the order of 42 TWh) has the potential to satisfy 10% of the Nation's demand for hot water and space heating, while bringing numerous energy, carbon, and monetary savings to the sector.

In face of the urgent need to eliminate emissions by year 2050, waste heat recovery will play a crucial role in decarbonising the UK's heating and cooling industry, which is currently responsible for around half of energy use and 1/3rd of overall carbon emissions. As a high volume heat energy producer, the data centre sector is an extremely valuable asset that could find its place at the heart of urban and sub-urban energy sharing.

Your waste heat recovery potential
According to the data you provided us with so far, we know that your facility is currently consuming approximately [xxx] MWh/p.a. of electrical energy in order to supply cooling to the entire data centre, including the crucial [xxx] MWh required by the average annual IT load. This process alone likely costs you in the order of £[xxx]k p.a.

The waste heat generated in the process has a high potential for reuse due to the steady supply at predictable temperatures. It is estimated that your waste heat can satisfy the space and water heating demand of [xxx] typical households, while heat recovery could supply you with the full cooling load required by your business. An example of such arrangement is illustrated below:

Potential savings
Reclaiming the heat produced by your facility could save your business [xx] t of carbon emissions. This would drastically improve your PUE and allow to measure the efficiency of your data centre using ERF. The carbon savings are equivalent to displacing [xx] gas boilers from UK's households and...

Recommended next steps
It is recommended that a more detailed evaluation is conducted in order to explore the full scope of benefits available to you, including the potential for heat sharing via low-temperature district heat networks. This would involve us asking you for more data necessary for energy modelling and a visit to your data centre. If you would like to proceed, full confidentiality will be legally assured with a Non-Disclosure Agreement. Please email Matt Wegner at wegnerm2@lsbu.ac.uk to start this process and to set your business on course towards its truly carbon neutral future.

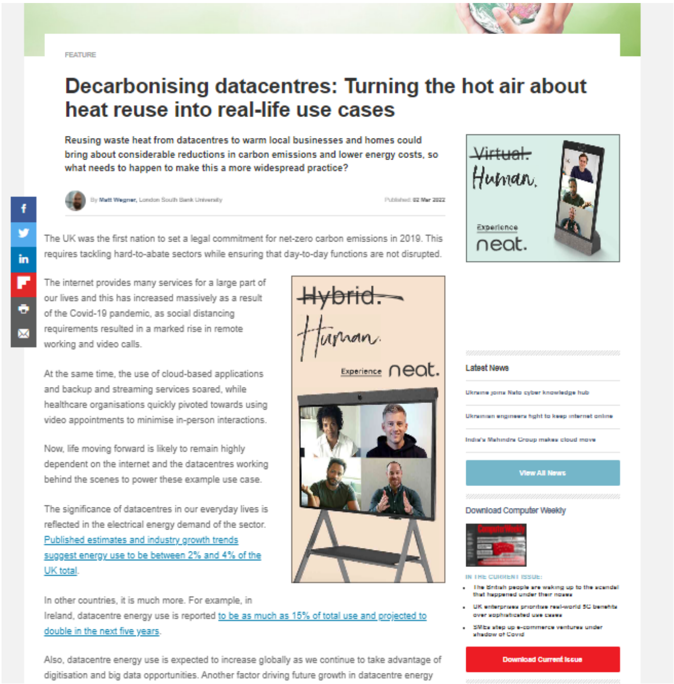
DATA CENTRES

Data Centre World 2022:

- Panel discussion: "Opportunities and blockers for waste heat utilisation"
- Plenty of connections and interest in the survey, new contacts include Colt Data Centres

T-shirts worn by the team at DCW

Exposure via Computer Weekly – article asks data centres for participation in the survey:



FEATURE

Decarbonising datacentres: Turning the hot air about heat reuse into real-life use cases

Reusing waste heat from datacentres to warm local businesses and homes could bring about considerable reductions in carbon emissions and lower energy costs, so what needs to happen to make this a more widespread practice?

By Matt Wegner, London South Bank University — Published: 02 Mar 2022

The UK was the first nation to set a legal commitment for net-zero carbon emissions in 2019. This requires tackling hard-to-abate sectors while ensuring that day-to-day functions are not disrupted.

The internet provides many services for a large part of our lives and this has increased massively as a result of the Covid-19 pandemic, as social distancing requirements resulted in a marked rise in remote working and video calls.

At the same time, the use of cloud-based applications and backup and streaming services soared, while healthcare organisations quickly pivoted towards using video appointments to minimise in-person interactions.

Now, life moving forward is likely to remain highly dependent on the internet and the datacentres working behind the scenes to power these example use case.

The significance of datacentres in our everyday lives is reflected in the electrical energy demand of the sector. Published estimates and industry growth trends suggest energy use to be between 2% and 4% of the UK total.

In other countries, it is much more. For example, in Ireland, datacentre energy use is reported to be as much as 15% of total use and projected to double in the next five years.

Also, datacentre energy use is expected to increase globally as we continue to take advantage of digitisation and big data opportunities. Another factor driving future growth in datacentre energy

https://www.computerweekly.com/feature/Decarbonising-datacentres-Turning-the-hot-air-about-heat-reuse-into-real-life-use-cases

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Conclusions

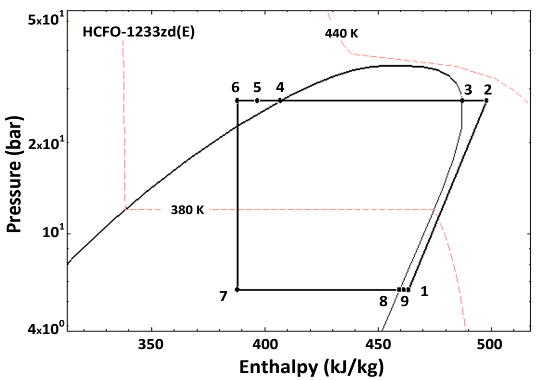
- Comprehensive results – feeding into BEIS NCA, DUKES, ECUK
- Good understanding of waste heat availability across the UK
- Further work in developing practical & optimal solutions
- New studies in industrial cooling and heating being developed
- Good progress with the PhDs
- Lots of publications

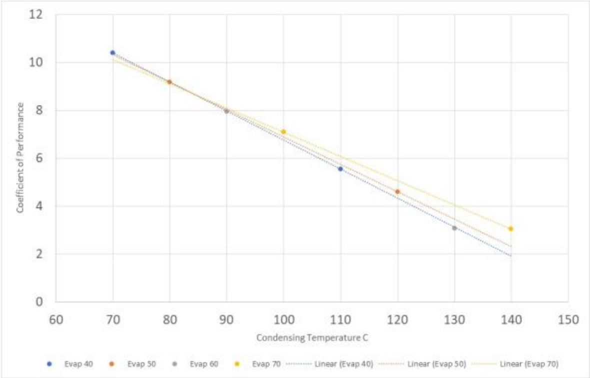
Work Package 3.1 – Low temperature lift, high COP Vapour Compression Heat Pump

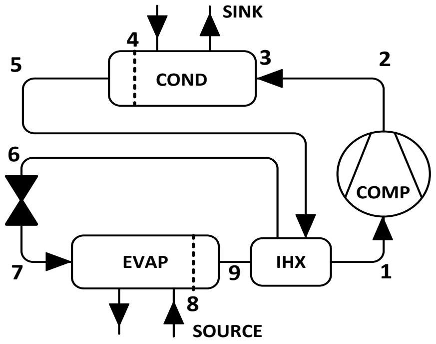
Theoretical Evaluation of Minimum Superheat, Energy, and Exergy in a High-Temperature Heat Pump System Operating with Low GWP Refrigerants, 2022, Adam Y. SULAIMAN, Donal F. COTTER1, Ming J. HUANG1, Neil J. HEWITT, SET2022, Istanbul, Turkey, Sep 2022.

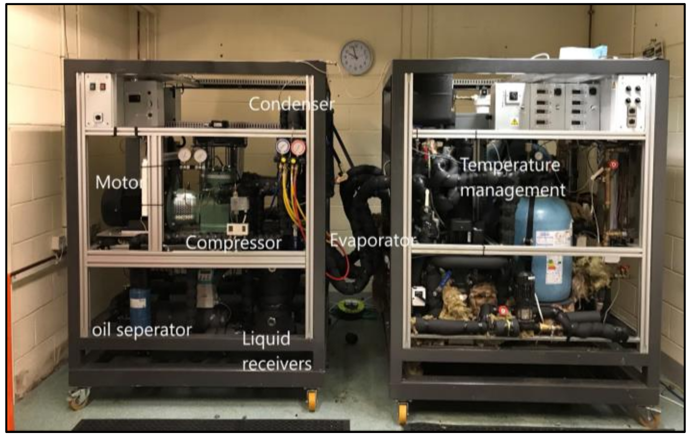
Lubricant Investigation for High Temperature Heat Pump Application, N Shah, D Cotter, M Huang, N Hewitt (2019) 2nd Symposium on High-Temperature Heat Pumps, 249.

Refrigerant Lubricant Interaction in High-Temperature Heat Pump and Organic Rankine Cycle Systems (2020) Donal F. Cotter, Nikhilkumar N. Shah, Ming J. Huang, Neil J. Hewitt, IIR International Rankine Conference - Heating, Cooling and Power Generation – 27-31 July 2020, Glasgow, UK, PAPER ID: 1198.



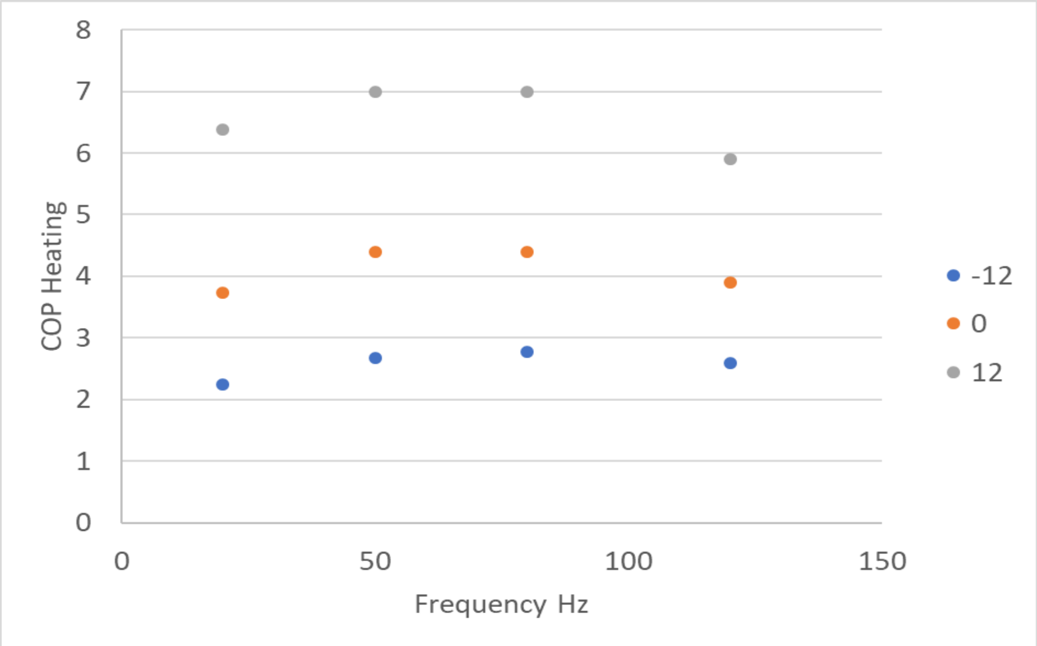






Work Package 3.2 – Vapour Compression Heat Pump for Demand Side Management

- Variable Speed Drive Compressor tested across a range of inlet and outlet temperatures
- Definite peak in performance at 50Hz-60Hz representing design origins at these frequencies
- Loss in performance becomes more pronounced at lower temperature lifts
- Work was carried out using R410a
- Replacement of R410a by R466A provided 5% greater performance
- R466A GWP > 150 (733) compared to R410A of 2,088



Domestic Demand-Side Response: The Challenge for Heat Pumps in a Future UK—Decarbonised Heating Market, NJ Hewitt, N Shah, D Cotter, C Wilson, K Le, R Byrne, P MacArtain (2020) Renewable Energy and Sustainable Buildings, 735-745.

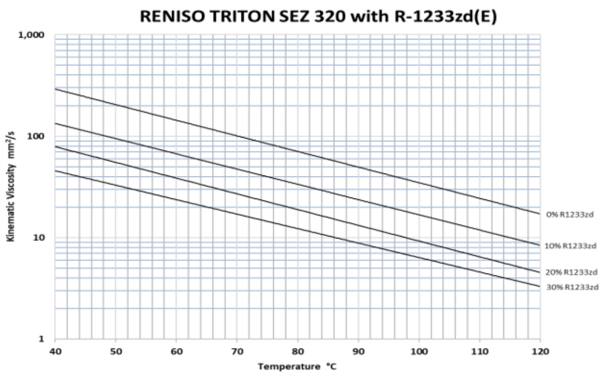
Work Package 3.3 – High Temperature Vapour Compression Heat Pump for Industrial Process Heating

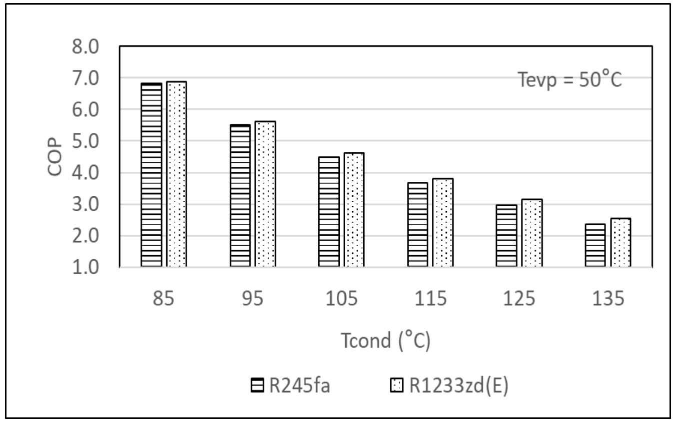
Temperatures up to 140°C can be delivered for R1233zd(E) as a replacement for R245fa.

Compressor lubricants have been tested for solubility and miscibility meets the minimum kinematic viscosity of 20mm^2/s.

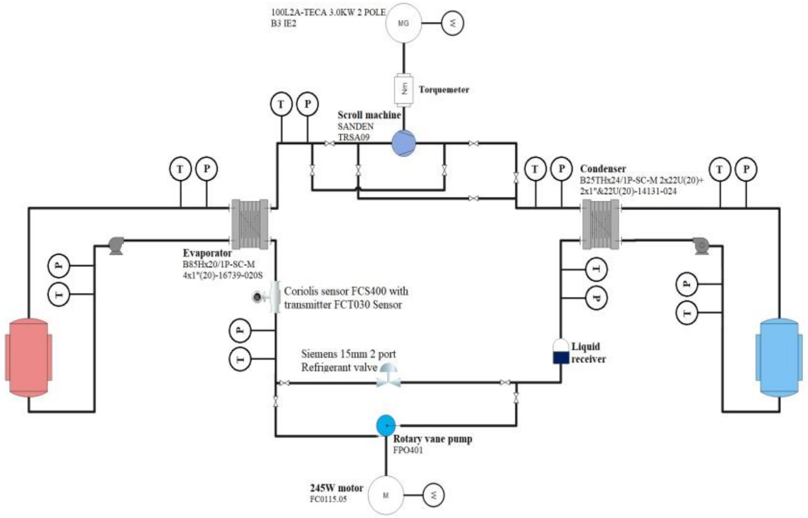
Test best tested both R245fa (baseline) and R1233zd(E) with R1233zd(E) having a superior performance.

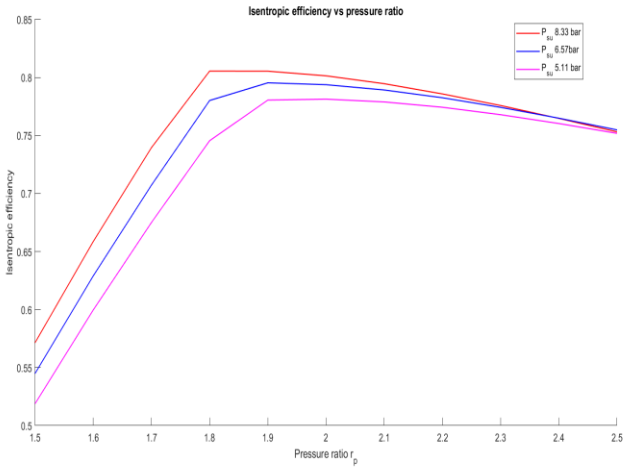
Combining with WP3.1.





Work Package 3.4 – Combined Vapour Compression Heat Pump/Organic Rankine Cycle for Heat or Electricity





Isentropic efficiency vs pressure for SANDEN TRSA09 with R1233zd(E). The parameters obtained for SANDEN TRSA09 with R134a is modified for R1233zd(E).

Work Package 3.5 – Sorption chillers for cooling from network (commercial use)

A few systems available commercially and characteristics known – no research needed prior to application.

Work Package 3.6 –Sorption heat pump from HT waste to network

Similar technology to domestic gas heat pump research already underway at Warwick (BEIS and MI) and can receive results from those projects.

Work Package 3.5 – Sorption chillers for cooling from network (commercial use)

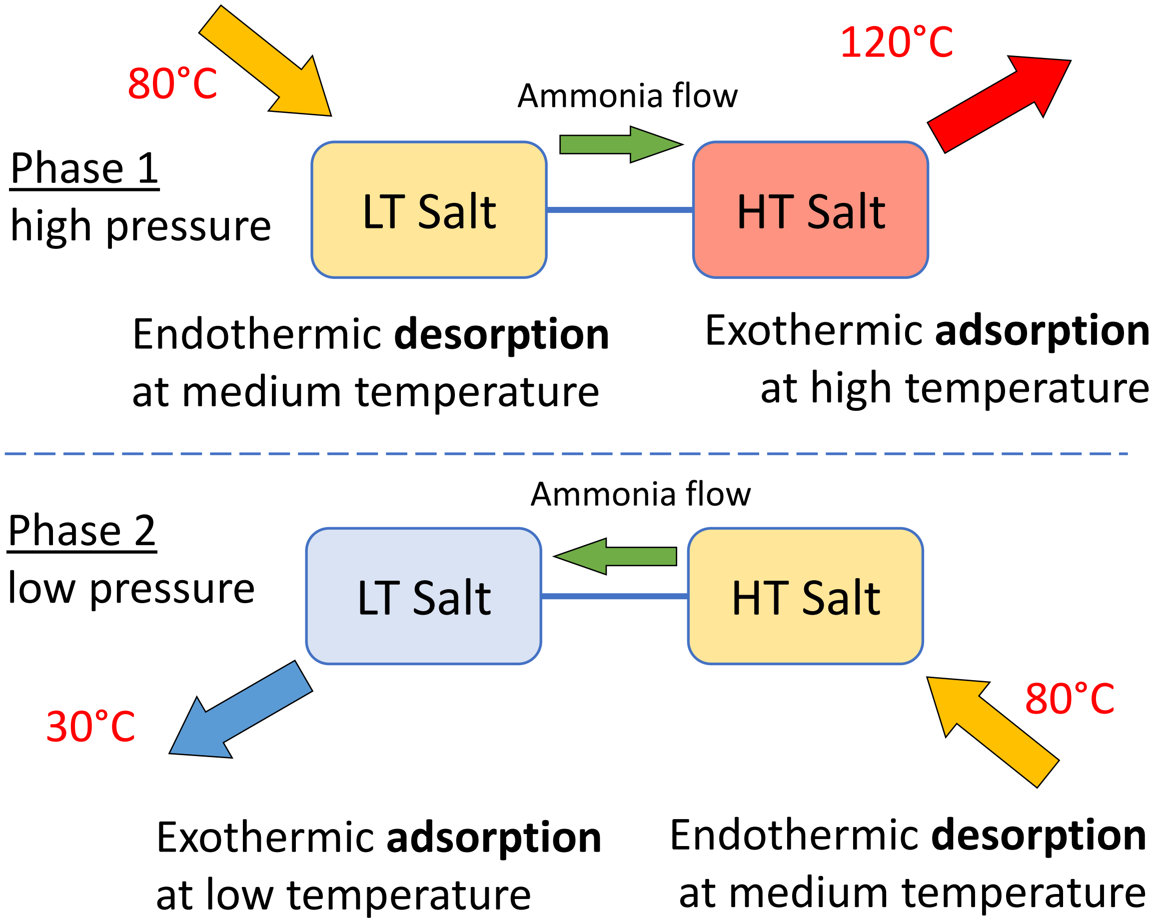
A few systems available commercially and characteristics known – no research needed prior to application.

Work Package 3.6 –Sorption heat pump from HT waste to network

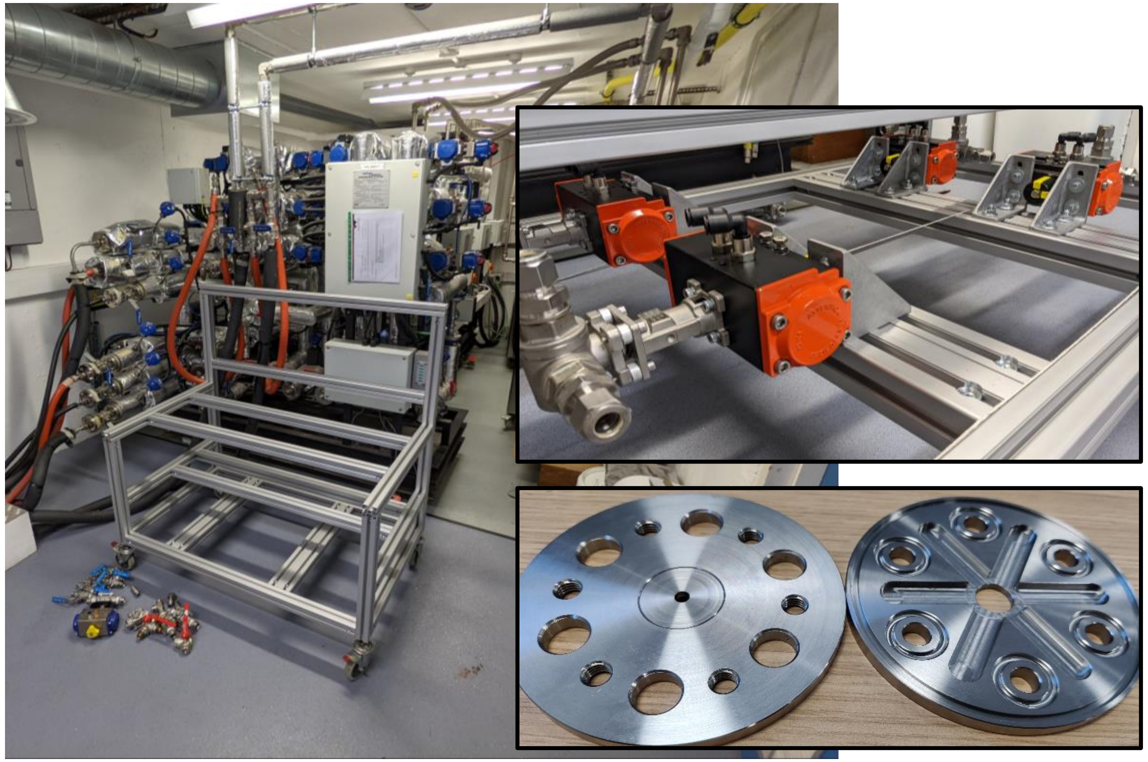
Similar technology to domestic gas heat pump research already underway at Warwick (BEIS and MI) and can receive results from those projects.

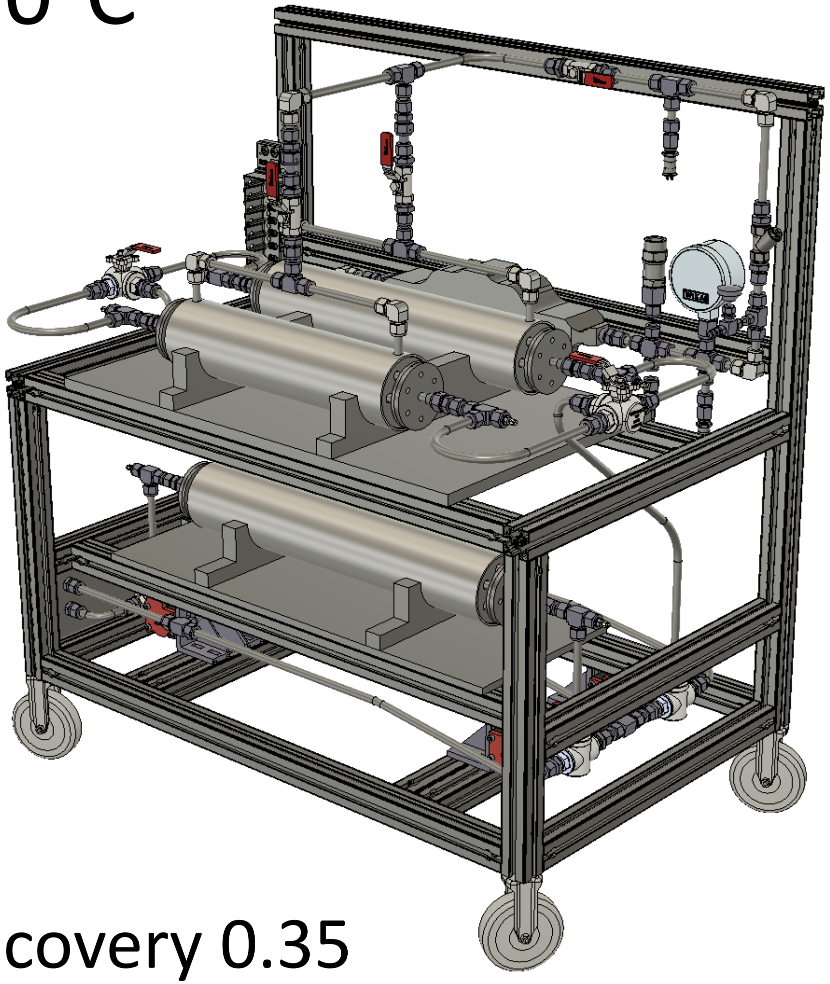
Work Package 3.7 – Heat transformer from waste to process heat and output to network

- A 2-stage process adsorbing/desorbing ammonia into salts impregnated into ENG
- Typically $MnCl_2$ and $CaCl_2$
- Potentially very simple construction
- 'LTJ tests' on small samples have been characterised and a model validated. This is a major step forward compared to past research.
- Final power densities of up to 1kW/litre are feasible.



Work Package 3.7 – 2.5 kW prototype under construction – commissioning May 2022 85/135/30°C





COP in rig 0.3 / COP with heat recovery 0.35

WP1-3 Summary and plans for future work

Broadly, all the technologies (WP2 and 3) must be characterised such that they can be modelled and put as technical options in the modelling environment being developed. Tasks may be summarised as follows:

WP 1: Extend modelling capability to new technologies and to other (case study) areas [LU]

WP2.1: Continued research on PC and TC storage technology [LU]. Suggested absorption storage research coming out of WP2.2[UW].

WP2.2: Laboratory proof of concept of TC heat distribution [UW]

WP2.3: [LSBU]

- Identify the costs associated with capturing the waste heat sources
- Decide how to connect them to a low-temperature energy network
- Map the size, scale and location

WP1-3 Summary and plans for future work

WP3.1: Adapting test facility to push COP to 9
WP3.2: Completion of tests on R410a replacements, then watching brief
WP3.3: Aligning with WP 3.1 for higher temperature applications
WP3.4: Starting building programme for laboratory reversible heat pump/ORC
WP3.5: Watching brief only
WP3.6: Watching brief only
WP3.7: Build and test thermal transformer at kW scale, then test larger (10 kW?) version with heat recovery system as a demonstrator for possible manufacture…

WP1-3 Summary and plans for future work

WPs 1-3 will feed into the Case Studies and continue to inform and update them for the duration of the project.

A detailed Work Programme for all WP’s including the possibility of a one year no-extra-cost extension is underway and will be included in the revised Mid-Term report.

Work Package 4 – Determination of successful proposition features for end users and business

- WP 4.1: Understanding household priorities [Loughborough Design Year 2-3, now 3-4]
- WP 4.2: From user requirements into technology design [Loughborough Design Year 3-4]
- WP 4.3: Consumer engagement with low carbon heating and cooling [Loughborough Design Year 4-5]
- WP 4.4: Energy transitions and competing for investment [WBS Year 1, 4]
- WP 4.5: Low temperature heat networks in Smart Local Energy Systems [WBS Year 2-4, now 2-5]

Work Package 4.1 – Understanding household priorities

- In-depth interviews with 26 households to explore attitudes to waste heat recovery
- All waste heat sources, to some degree, were viewed as being an acceptable as alternative heating and cooling source
- Mental images of waste heat sources were a significant barrier preventing some sources from being viewed as acceptable for residential use
- UK householders' knowledge of heat transfer is severely lacking, lending to false assumptions of heat being taken as truths e.g., catching COVID-19 from waste heat from hospitals
- Terminology is taken at face value when presented to UK householders
- Stakeholder characteristics and archetypes do impact UK household is perceptions when discussing the adoption of a new heating system

Research information and questionnaire booklet

Work Package 4.2 – From user requirements into technology design – implications from WP4.1

- Waste heat sources were perceived as being ‘acceptable’ by householders, with a preference for ‘clean heat’ – data centres provide a good option for domestic acceptance
- Improved knowledge of how heat is transferred from waste heat sources to the home is essential for wider adoption. Failure to do so will leave UK householders to continue to believe false assumptions and inaccurate statements about heat
- The term ‘waste heat’ is often misinterpreted. Use of the terms ‘waste heat’ or ‘low-grade heat’ with the public will have negative effects. We suggest the term ‘recovered heat’ is more appropriate
- Preconceived notions of stakeholders can alter the attitudes of UK householders. If these unengaging or untrusted stakeholders promote ‘waste heat recovery’, adoption is likely to be impacted. Messaging via trusted stakeholders will provide confidence in the technology and is more likely to lead to positive adoption of district heat networks

Work Package 4.3 – Consumer engagement with low carbon heating and cooling

- Not yet started, will explore engagement through one or more of the case studies – collaboration with 'Replicating GreenScies' in Part 2

Work Package 4.4 – Energy transitions and competing for investment

- Activity resumes in Year 5

Work Package 4.5 – Low temperature heat networks in Smart Local Energy Systems

Will be covered in Part 2 ‘Case Studies’ discussion

8. Progress and Plans (WP1, WP2)

Task	Progress and plans
WP 1.1: Heat Mapping and Analysis	Methodology developed and applied.
WP 1.2: Model Development	Model developed and applied, development of Digital Twin ongoing
WP 1.3: Application to Case Study	Applied to Loughborough case study area
WP 1.4: Generic (national) application	Ongoing
WP 2.1: Distribution medium	Theoretical research published. Will be evaluated for economic viability in New River case study. Lab scale hardware to be tested, plus possible storage application.
WP 2.2: Storage	Good progress made, ongoing
WP 2.3: Heat capture	Ongoing

8. Progress and Plans (WP3)

Task	Progress and plans
WP 3.1: Low temperature lift, high COP VC heat pump	Models completed, and practical equipment being developed that covers the required temperature range in both elements with a watching brief on alternative working fluids
WP 3.2: VC Heat pump for demand side management	Completed and being implemented in sister MI project CCB
WP 3.3: High temp. VC heat pumps from network to process heat.	As per 3.1.
WP 3.4: Heat pump/ORC for heat to electricity or reverse.	Under development from modelling to practical
WP 3.5: Sorption chillers for commercial cooling from network	Watching brief, no research needed. Information available to feed into Phase 2 models.
WP 3.6: Sorption heat pump from HT waste to network.	Watching brief, no research needed. Information available to feed into Phase 2 models.
WP 3.7: Heat transformer from waste heat to process heat and output to network	2.5 kW prototype under construction – commissioning May 2022 85/135/30°C. Move towards 10 kW prototype with heat recovery for commercial exploitation.

8. Progress and Plans (WP4)

Task	Progress and plans
WP 4.1: Understanding household priorities	Almost complete
WP 4.2: From user requirements into technology design	Almost complete
WP 4.3: Consumer engagement with low carbon heating and cooling	Starting
WP 4.4: Energy transitions and competing for investment	Initial work in Y1, Resume Y5
WP 4.5: Low temperature heat networks in Smart Local Energy Systems	Ongoing within Case Study

Discussion, then
Case Study Plans