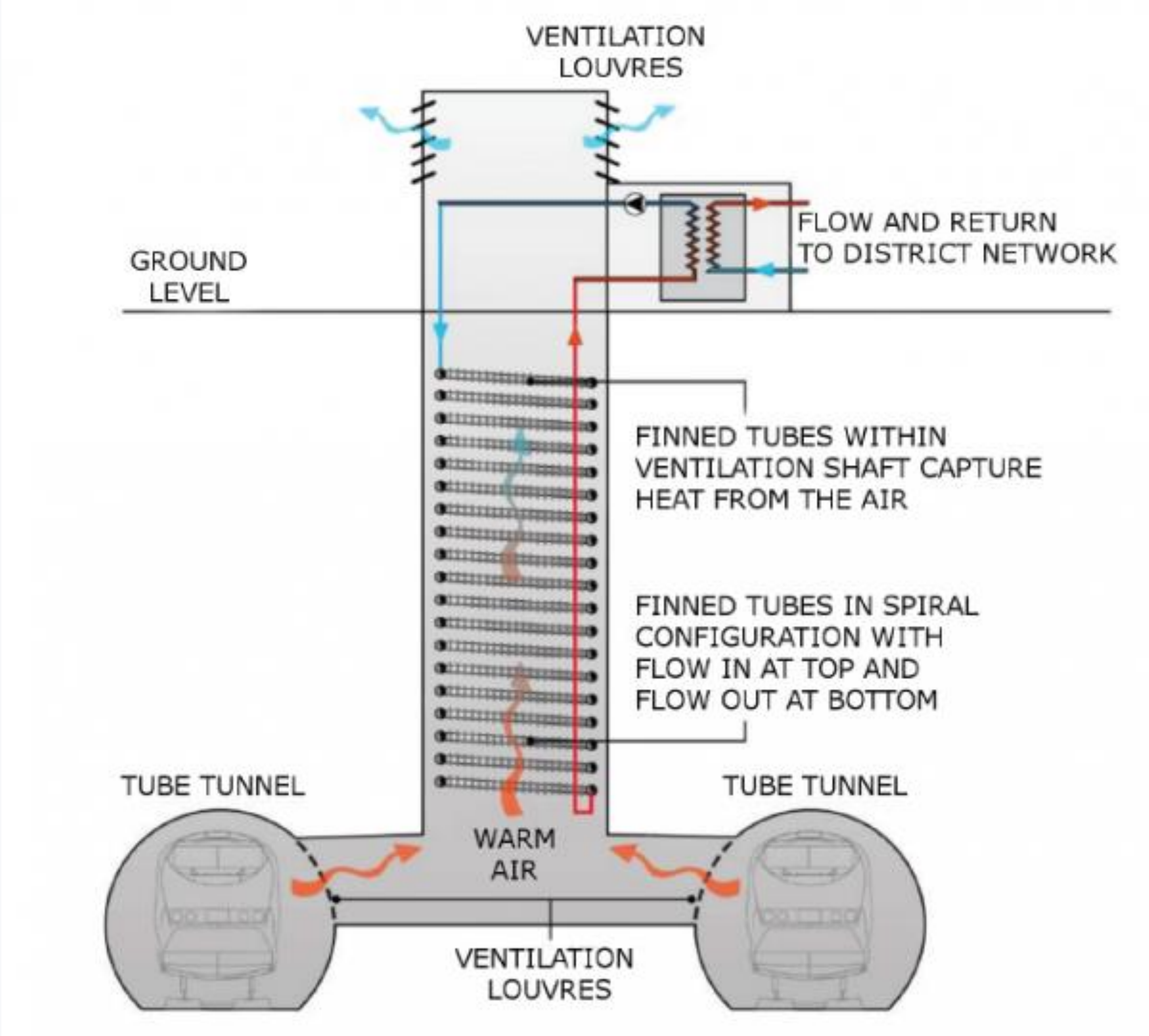
Capture of waste heat and extension of the seed network in Islington

Facts about this case

Installed heat capacity: 1 MW heat pump and 2 x 237 kW CHP gas engines.
Heat source: Excess heat from London Underground ventilation system (22-28 °C)
Potential: 10 % of heat losses from the London Underground is from ventilation.

Support: FP7-supported CELSIUS-project
Organization: Islington Council
District heating network: +1000 units
Link to web page: http://celsiuscity.eu/

Contact information:
CELSIUS-project



Source: Greater London Authority

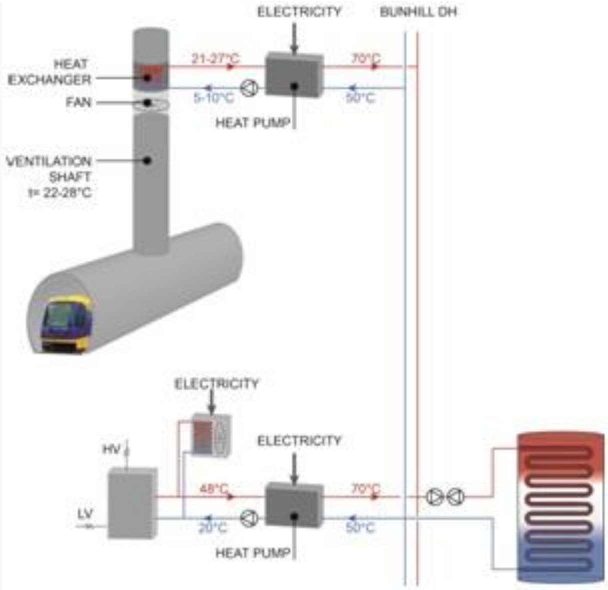
LO2 and LO3 are two of London's demonstrators. The demonstrated technologies are related to:

- **The capture of waste heat from electrical transformers and tube ventilation shafts and the integration of a thermal store.** Removing heating from the tunnel system in winter, when it is mostly needed above ground, can help cool surrounding walls and hereby lower overall temperatures during summer. Heat extraction during winter enables more absorption capacity for the tunnel walls during summer.

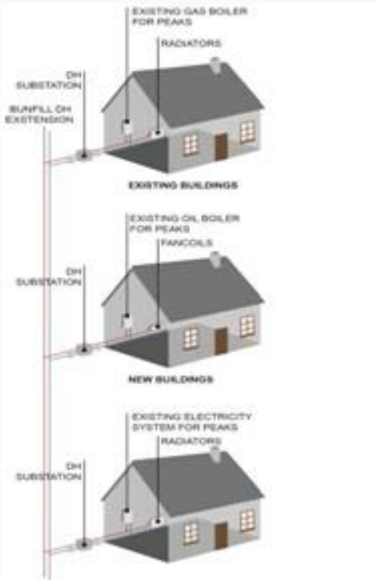
- **The extension of the Bunhill seed network.** The Bunhill Energy Centre already through a previously project in 2012 created a local district heating system to warm two leisure centres, three communally heated council houses and one private housing development, covering 805 units in total. The existing system consist of a 1.9MW CHP gas engine and 115m3 thermal storage with 1.5km of district heating pipework. The CELSIUS-project aims to expand this network with 454 homes and include excess energy from London Underground, potentially further supplying 1000 homes.

Asset

Idea and layout



New heat sources



Extended district heating system

The concept of the demonstrator foresaw the capture of heat from both:

- The **transformers of the electricity substation**, by means of an oil-to-water heat pump:

- Heat is generated from electrical transformers during their normal activity as a result of losses incurred during voltage conversion. At the demonstrator's site, the transformers are cooled using an oil system and the heat is currently lost to the environment. The feasibility study indicated that the expected available heat of the three transformers is approximately 160kW per transformer at full load, at oil temperatures assumed to be at least 48°C. Technical issues related to the age of the electrical transformers affected the feasibility of the project, and at present it will not be developed further.

- The **tube ventilation shaft**, by means of an air-to-water heat pump (integrating thermal storage)
  - The ventilation shaft expels exhaust air at a rate of 30 m³/s at a temperature of 22°C in winter and 28°C in summer. The feasibility study lead to the conclusion that the heat output for the mid-tunnel ventilation shaft would be around 0.4MW. In order to maximize the demonstrator's impact, it was decided to upgrade the extraction fan in the tube ventilation shaft, with the new fan expelling air at 70m³/s and increasing the heat output to around 1MW.

This will result in extending an existing district heating network using the heat coming from the identified sources of waste heat. In addition, to maximise the impact it is planned to install a new CHP plant at the London Underground vent site.

Impact

The overall demonstrator's performance is summarized in the following table according to 5 evaluation criterions. It can be noticed that the assignment of all the scores is directly linked to the values calculated for the Key Performance Indicators, except for socio-economic benefits where a qualitative assessment is carried out based on this cluster's indicators and on separate interviews.

Overall Impact	**Fair/Medium**				
Size [MWh/y]	1-100	100-1000	1000-5000	5000-10000	>10000
Primary Energy Savings	0-10%	10-20%	20-40%	40-60%	>60%
GHG Emissions Reduction	0-10%	10-30%	30-60%	60-90%	>90%
Pollutant Emissions Reduction	0-10%	10-30%	30-60%	60-90%	>90%
Socio-Economic Benefits	Low	Fair	Medium	High	Extrem

Replicability

Replication Potential

Replicability	**Low**	**Medium**	**High**

Authorizative easiness		X	
Adaptability to different climate conditions			X
Easy-to-implement (No needs of specific technical requirements)		X	
Easy-to-operate (No needs of specific technical requirements)			X
Opportunity of integrating waste energy sources			X
CAPEX needed for the deployment of the solution		X	

Technical requirements

Possible requirements for replicability for the demonstrator, related to heat extraction from the underground are:

- Presence of a ventilation shaft or a water source from the underground system and sufficient adjacent space to install the necessary equipment.
- Set-up of clear lines of responsibility between infrastructure and district heating.
- High temperatures in the waste heat source (minimum 20-30°C).
- Availability of a failsafe system to allow normal operation in case of district heating breakdown.

Possible requirements for the replicability of the demonstrator related to heat extraction from the electrical substation are:

- Presence of oil-cooled transformers with an oil-to-water heat exchanger in addition to normal cooling systems.
- Sufficient load on the transformer to require cooling systems.
- Availability of sufficient space for the equipment to be installed.
- Set-up of clear lines of responsibility between infrastructure and district heating.
- Presence of a failsafe system to allow normal operation in the event of district heating breakdown.

Stakeholders

Stakeholders	Organization Name	Organization Type	Organization Domain	Benefits from demo
District heating network operator	Islington Council	Local authority	Local government	Expanded district heating system and cheaper heat source

Ventilation shaft operator	London Underground	Public transit authority	Transport in London	Increased ventilation capacity, potential for cooling in summer
Islington residents	N/A	N/A	N/A	Reduced energy bills

Islington has a standard template contract which is used for the supply of heat. This forms this basis of discussions which take place and it aims to ensure that the council has the following guarantee's - A guaranteed bulk heat price which provides revenue certainty to both parties. - A maximum return temperature from connected buildings back into the network. This is required to ensure that the primary network operates as efficiently as possible and also to minimize thermal losses in the system. - A minimum heat takes for connected loads to the network. This effectively ensures that the connected development must operate their respective secondary systems with the primary district heating network as the lead.

The heat supply agreement/contract also has a clause which requires a review of the minimum take every 12 months.

Negotiations for the supply of heat can be broken into two sub-categories 1) Planning application stage. As operators of our network we are required to work closely with planning colleagues to mandate major developments within the vicinity of the network to connect in. Islington has strong policy support from the 'London plan' regional planning document and also the local planning guidance both these documents allow us to have planning conditions and section 106 conditions which lead the developer to connecting. This is a two-way relationship as developers who connect into district energy networks are able to meet there mandatory CO_2 targets for emissions reductions.

There are a number of ownership models which can be used for district heating networks. Most are either wholly public or wholly private, the Islington scheme is wholly public and is owned and operate by Islington council as a municipal scheme, other networks such as Citigen are wholly private and are typically owned by energy companies or energy service company providers (ESCO's).

Finance

Full procurement and preliminary stage is now completed for the project and we have appointed Colloide engineering systems as principal contractor. Details of the capital costs for the project are available from the project team.

A large number of public decentralized energy projects are developed as 'spend to save' with public bodies such as councils or NHS Trusts looking to recover their capital investment through reduced energy revenue savings.

Challenges & Risks

There are a number of risks to the project which could be categorized into financial, technical, reputational.

The key technical risks stem from the level of innovation in this project and the fact that heat recovery from an underground railway has never been done on a commercial scale before. The main technical risk is around the coil (Air to water heat exchanger) located in the ventilation shaft and the level of fouling as a result of dirty and contaminated air being extracted from the railway. To mitigate the risk we are designing a coil with wider than average spacing between the heat exchanger fins to reduce the ability of the coil to trap particulates, and we also developing a washer system which will automatically was the coil. The project team have worked closely with London Underground on undertake trials of heat exchanger coils within the Underground network.

In order to achieve flow temperatures in excess of 50c from the heat pump we have specified the use of an ammonia heat pump. This is a non-standard refrigerant and a full risk assessment was required along with a risk mitigation plan for the energy center.

The other major technical risk is around return temperatures in the network.

There are also a number of commercial and financial risks to the project. A number of these would be generic and applicable to most building and engineering projects of this scale, however there are still some specific risks that would be applicable to the Islington demonstrator are.

1) Drop in wholesale energy prices. Our network is reliant on power sales so any drops in electricity prices will affect the savings that we can offer to heat customers. 2) Lack of commercial connections. We going to be exporting heat to commercial developments within the Old street area, the majority of these are office buildings which have a more diverse and different load profile to council residential buildings, without these loads it will be harder to operate the plat at optimum conditions for as long. 3) Government support for renewable heat. The utilisation of the heat pump is classed as a renewable heat source and is therefore eligible for government subsidy in the form of the RHI (Renewable heat incentive). The government has recently slashed the subsidy available to renewable power generators so there remains a level of uncertainty with renewable heat.

Challenges

The complexity of the project coupled with the relatively small amount of space available the energy center has produced a number of specific challenges which the project team is working to overcome.

Collaboration with London underground railway authority (LUL). LUL are undertaking the works to demolish the existing building at the site and also to replace the existing ventilation shaft fan and other auxiliary mechanical plant. The level of detailed required in planning and coordinating the works and respective contractors has been substantial and to ensure that a program has been produced which is suitable for both parties then a series of programming meetings have taken place along.

Obtaining expertise. Decentralised energy is relatively small field and there is a lack of expertise within the field which has impacted on the delivery of projects in the past. To ensure that the project is successful the council undertook a full public procurement exercise to appoint a specialist client engineer to develop specifications, manage the design process, act of clerk of works and generally provide technical guidance and expertise to the client. As the client we also appointed a highly qualified project team to oversee the project for the council

Obtaining support. The overall aim of the project is to provide cheaper and greener heat to the residents of Islington and to obtain full support for the investment the project team had to demonstrate with certainty that a minimum saving would be generated by the project. To do this we used a complex energy modeling program to replicate the operating conditions and variability in energy markets to produce outputs in the form of heat prices and values for connected buildings.

Lessons learnt

Demonstrator development

An important lesson learnt is related to the optimization of the realization process: by twin tracking the procurement processes with the planning/authorization process it has been possible to move the project forward as efficiently as possible preventing possible delays.

Demonstrator performance monitoring

Following the monitoring methodology set up for monitoring the CELSIUS demonstrators, relevant key performance indicators are identified for this technology to quantify and measure its impact with respect to the specific baseline situation referred to the common mix of heating systems used in London, consisting of natural gas fired boilers, oil fired boilers, electric heaters and electric heat pumps.

Technical KPIs
Yearly amount of electric energy used by the installed heat pump system at ventilation shaft and thermal storage- *MWhe/year*
Seasonal COP of the heating pump system at ventilation shaft and transformer
Yearly amount of thermal energy recovered/provided by ventilation shaft and thermal storage- *MWht/year*
Thermal energy delivered to the buildings connected to the district heating system in the expansion of the network- *MWht/yea*

Environmental KPIs
Variation of emissions with reference to baseline situation- *kg/year of PM10, PM2.5, TSP, NOx, SOx, CO, CO2 and % of variation*
Yearly GHG variation- *% of variation and kg/year of CO2e*

Economic KPIs
Yearly cost for electric energy consumption at ventilation shaft and thermal storage(C)- *€/year*
Maintenance costs at ventilation shaft and thermal storage- *€/year*
Yearly savings for the end-user-*€/year per end*-*user*

Social KPIs
Additional buildings connected to the district heating system
Internal surface served by the new system- *m2*

Number of residents benefitting of the new system
Number of workplaces benefitting of the new system

This section will be updated as soon as the demonstrator will be fully operated and monitored, enabling the quantification of technology's impact in terms of performance indicators.

CELSIUS contacts

CELSIUS partners contributing to this article: Islington Council

For further engagement on this subject you are welcome to turn to your CELSIUS city contact person or use the contact form for guidance to relevant workshops, site visits or the expert team.

1. Jump up↑ Greater London Authority
2. Jump up↑ Handbook - 25 cases of urban waste heat recovery