DESIGN NOTE 08

PROJECT: BELGROVE HOUSE
TITLE: WASTE HEAT OPTIONS FROM TFL

DN08

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1.0 Introduction

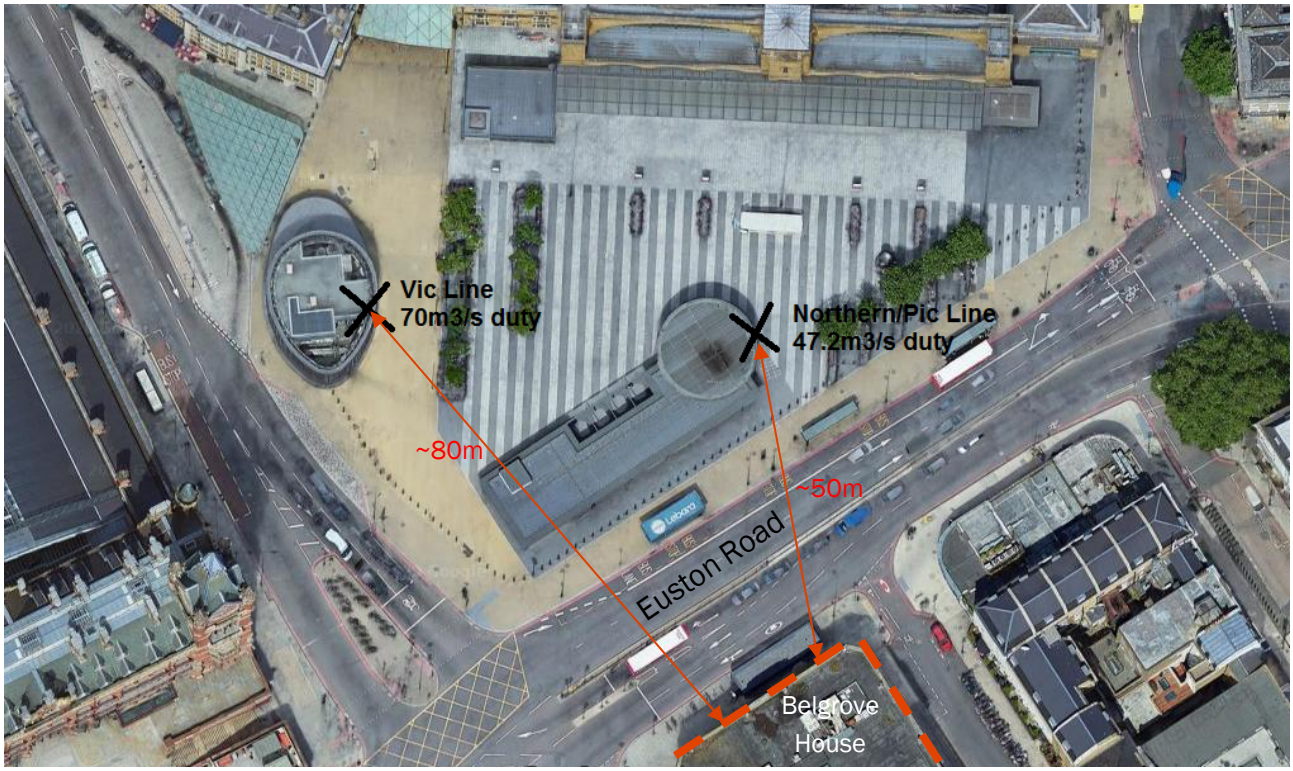
The design team met with representatives from Transport for London on 17th December 2020 to explore opportunities for utilising waste heat from Kings Cross underground station to supply the proposed Belgrove House commercial office development. This design note summarises the possibilities and presents a technical commentary.

2.0 Potential sources of waste heat

TfL advise there are two ventilation shafts near to the site where heat from London Underground is exhausted to atmosphere. These are as follows:

- King's Cross Victoria Line shaft - advised heat pump output of 773kW. Average temperature for 2019 was 26.4°C
- King's Cross Northern/Piccadilly Line shaft - advised heat pump output of 521kW. Average temperature for 2019 was 24.5°C

The location of both these shafts relative to Belgrove House is shown on the plan below:



Both shafts are located to the north of Euston Road. Each shaft contains a mechanical fan which operates continuously, 24 hours per day, 7 days per week. TfL advise that for the majority of the time the fans run in exhaust mode, drawing unwanted heat from the tunnels below and expelling this to atmosphere. In this mode, it is understood the temperature of the air being drawn from the platforms is relatively consistent, with an average temperature in the mid-20's.

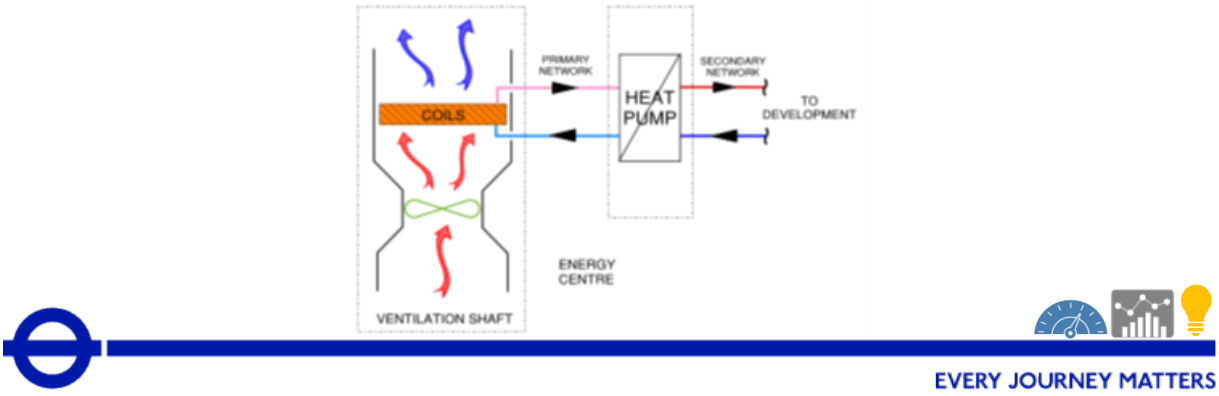
However, the fans are also capable of being reversed, enabling outside air to be drawn in and supplied to the tunnels. In this mode, the temperature of the air moving through the fan would be at outside air temperature.

In order to extract heat from the shaft vent airstream, a heat exchanger in the form of a coil would need to be installed within the shaft. This would enable water to be passed through the coil absorbing low grade heat from the air stream. Water is then pumped back to an electric heat pump which would elevate the temperature to facilitate use for the building's space heating or hot water systems.

A schematic diagram of this arrangement provided by TfL is shown below:

Heat recovery process

- Air from the running tunnels extracted over coils transferring heat to the primary water circuit that flows within.
- The primary water circuit pumps the heat to the energy centre via buried plastic pipework.
- A heat pump located in the energy centre further raises the temperature of the primary water circuit after which it is distributed to homes in the development through the secondary water circuit.



Neither vent shaft qualified for a site visit or further assessment under TfL's previous feasibility study. The main challenges for each shaft are listed in the appendix to this document.

3.0 Initial assessment

3.1 Energy

TfL have provided some figures with regards to the heat available from each of the vent shafts. A comparison of these energy sources with the estimated energy demand of the Belgrove House site is tabulated below:

ANNUAL ASSESSMENT	Victoria Line Ventilation Shaft	Northern/Piccadilly Line Ventilation Shaft
Air flow rate	70 m^3/s	47.2 m^3/s
Heat available (advised by TfL)	773 kW continuously	521 kW continuously
Annual heat available	6,771 MWh/year	4,564 MWh/year
Belgrove House annual heat energy demand after energy efficiency measures applied	467 MWh/year	467 MWh/year
Equivalent percentage of available heat	6.9 %	10.2 %

It is clear the quantity of waste heat available from either vent shaft far exceeds the requirements of the Belgrove House site. Even assuming all of the heat energy demand of Belgrove House were sourced from one of the TfL vents, the site would be extracting 10% or less of the available waste heat energy.

The instantaneous peak heating demand for both space heating and domestic hot water for Belgrove House is approximately 1300kW, higher than the capacity of either shaft. Note this heating demand is not continuous and only occurs during peak winter conditions. In order to utilise the maximum amount of heat from the shafts, a thermal store would need to be introduced into the scheme to enable the system to meet the peak demand without supplementary system. A thermal store would have to be located within the building, where space is at a premium.

A detailed energy modelling exercise would need to be undertaken to estimate the most appropriate size of water source heat pump, however this is likely to be in the range of 50 – 400kW heating capacity.

3.2 Carbon

As described in the Energy and Sustainability Statement submitted for Planning, it is proposed to utilise air source heat pumps on the roof of Belgrove House to generate both heating and cooling for the building. These electrically powered machines enable the recovery of heating and cooling energy which would otherwise be lost to atmosphere, helping to reduce the development's carbon emissions by 25% after energy efficiency measures have been applied.

Considering the relatively consistent air temperatures from the vent shafts, these do provide a low-grade heat source which would enable a water source heat pump to operate with a higher Coefficient of Performance in heating mode compared with an air source heat pump in peak winter conditions. However, by meeting the heating demands with the waste heat from the vent shafts, there would be no opportunity to recover heat from the building's own cooling system. The air source heat pumps would effectively operate as air cooled chillers, with all their heat rejected to atmosphere. As a result, the efficiency of the cooling system would be reduced to the point where any meaningful difference in carbon emissions would be eroded.

At part load during the mid-seasons, the air source heat pumps would operate more efficiently than a water source heating only heat pump. This would likely result in greater carbon emission savings being realised.

Furthermore, should a connection be made to the vent shafts for waste heat recovery, there would be no further benefit to be gained from providing a connection to a future district heating system.

3.3 Infrastructure works

The following is a provisional non-definitive list of works required to install a waste heat recovery system to either vent shaft.

- Construction works below ground in vent shafts to enlarge the ducts and reduce air speed to facilitate efficient heat exchange with the new coils
- Installation of two nominal 150mm diameter flow and return pipes across Euston Road to connect Belgrove House to one of the vent shafts. Road closure required.
- Provide additional plant space in the basement of Belgrove House, approximately 10m x 8m.
- Installation of two water source heat pumps, associated pumps, pressurisation vessels and thermal store.

In undertaking such works, the embodied carbon associated with the equipment and modifications to existing structures should also be taken into account.

3.4 Financial considerations

In terms of annual electricity costs, these are likely to be comparable between the air source and water source solutions. Any difference between the two is likely to be small, in the order of less than £5,000 per annum at today's prices. Detailed energy modelling would need to be undertaken to refine this estimate.

In additional to the utility charges, if it could be demonstrated the waste heat recovery system provides lower emissions than the air source heat pumps, the calculated carbon offset payment for the development would need to be reduced accordingly.

It is understood TfL have no plans to charge for the heat being extracted from the vent shafts, on the basis the capital cost of the infrastructure works is expected to be borne by the developer.

It is not possible to estimate the cost of the necessary infrastructure works, however given the disruption to Euston Road and the below ground works in front of Kings Cross station, these are likely to be significant. It is unlikely the payback period for the upfront investment in the waste heat recovery system will pay for itself in energy saving costs over the life of the building.

3.5 Tenant considerations and reliability

Belgrove House has secured a long-term pre-let with MSD, a pharmaceutical company who will occupy the whole building. The site will include a significant portion of lab space, as well as more conventional office accommodation.

Given the business-critical functions of the laboratory floors, MSD have expressed a need for resilient services systems to be provided by the base build. Although TfL have advised the fans in the shafts run continuously 24/7, they have also advised that these fans can be reversed depending on the prevailing needs of the underground platforms, put into bypass around the coils or even turned off at their discretion for maintenance. This level of uncertainty will not be acceptable to the tenant, who would likely still require stand-alone building specific plant to be installed to provide the level of resilience they require.

The current base build plant provision would therefore be retained; there would be no reduction in plant space or capacity should the waste heat option be incorporated.

3.6 Programme

The development is due to achieve practical completion in 2024. In order to achieve this, design and procurement needs to be complete by mid-2021.

Initial conversations with TfL suggest a detailed feasibility study would need to be undertaken to further assess the viability of the waste heat recovery scheme. Such an exercise could not be undertaken and concluded without significant detrimental effect on the base build design and construction programme.

4.0 Conclusion

The potential for utilising waste heat from the Kings Cross London Underground has been considered. The following points are noted:

- The proportion of heat required by Belgrove House compared to the quantum of heat available is comparatively small, less than 10%. The systems are ill matched.
- There is marginal difference in primary energy efficiency and associated carbon emissions between the base scheme utilising air source heat pumps and the water source heat pumps needed for the waste heat alternative.
- The vent shafts are on the other side of Euston Road. To install pipework to the shafts, a road closure will be required of the A501, a major road in London directly in front of one of the busiest transport hubs in Europe.
- Significant infrastructure works would be required below ground on Kings Cross square. Access to these locations is challenging for construction vehicles, increasing logistic complexity.
- Additional building services plant equipment in the form of water source heat pumps would be required within Belgrove House, where space is at a premium.
- Reliability – the availability of heat from the Underground is not guaranteed and would be controlled by TfL. This is likely to be unacceptable to any tenant; consequently, there would be no reduction in base build plant provision.
- Programme – the design, procurement and construction periods for utilising waste heat from the tunnels do not align with the base build programme.
- Financially, any savings in primary energy costs will not offset the upfront capital investment needed for the construction works within a reasonable time frame.

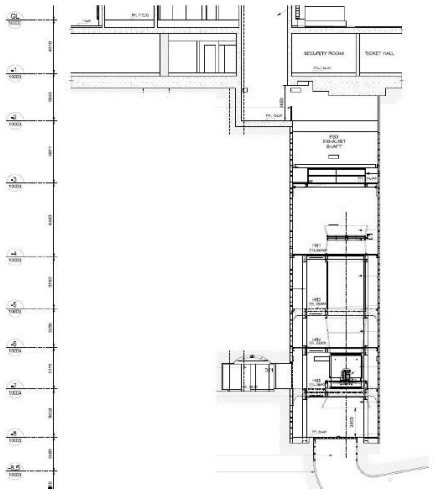
Based on the above, it is not recommended to explore this opportunity any further.

Appendices

The following diagrams were presented by Transport for London during the meeting on 17th December.

King's Cross Vic Line Shaft

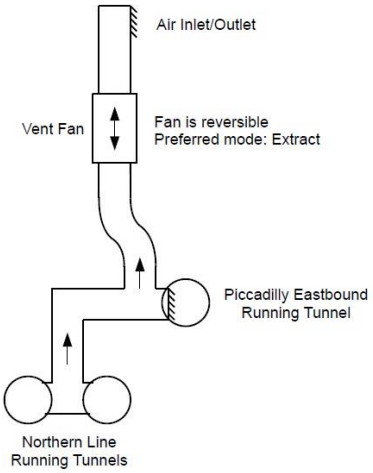
- Finished 25th in waste heat feasibility study of 55 sites
- Did not qualify for site visits/further assessment
- Approx heat pump output of 773kW
- Challenges:
  - No access for construction vehicles to site
  - Discharge point 20m above ground level
  - Coil locations would have to be in tunnel
  - Assumed development supply temp high
  - LA limited history of district heating
  - LA no specific carbon reduction target



EVERY JOURNEY MATTERS

King's Cross Northern/Piccadilly Line Shaft

- Finished 33rd in waste heat feasibility study of 55 sites
- Did not qualify for site visits/further assessment
- Approx heat pump output of 521kW
- Challenges:
  - Proximity of nearest building
  - Coil locations would have to be in tunnel
  - Assumed development supply temp high
  - Asset condition (B w/ existing non compliances)
  - LA limited history of district heating
  - LA no specific carbon reduction target



EVERY JOURNEY MATTERS

The following graph indicates the heating load profile for Belgrove House compared with the heat available from the TfL shafts.