Achieving resource demand reduction for existing occupied buildings: the use of underground thermal energy storage as part of a carbon masterplan for London's museum district

The architectural and cultural heritage of most cities is significantly enhanced by existing historic buildings. The preservation and evolution of such existing buildings, whilst retaining their architectural character, can be intrinsic to the success and identity of the city and hence forms a vital component of achieving sustainability in the urban environment.

Demand reduction and energy efficiency in existing buildings is essential to addressing preservation of resources and mitigation of climate change. It is predicted that by 2050, 60% of the building stock in the UK will still be comprised of buildings which exist today; with two-thirds of these predating the introduction of energy related Building Regulations in 1985.

In the UK the thermal demands of buildings in a given area of a city often comprise simultaneous cooling and heating demands, owing to the presence of newer highly insulated, airtight, buildings with high internal heat loads alongside older buildings with little insulation and high air infiltration rates. The UK climate also experiences significant seasonal variation and this is reflected in the varying thermal energy loads of buildings across the year. These basic phenomena give rise to potential for the transfer of heating and cooling loads between buildings and between seasons, with the introduction of urban thermal networks and inter-seasonal thermal storage.

Underground Thermal Energy Storage (UTES) uses reversible heat pumps to store excess energy from summer below ground for use in winter heating applications. Similarly cooling potential (or 'coolth') from winter can be stored in order to provide free low-carbon cooling in summer. Many cities demonstrate simultaneous heat demand from some buildings and heat excess in others. By introducing UTES, simultaneous heat sharing opportunities can be substantially increased by attempting to achieve a thermal energy balance over the course of a year. Aquifer Thermal Energy Storage (ATES) is a form of UTES that utilises slow-moving below ground aquifers as the storage medium; storing the thermal energy in water significantly increases the efficiency of the system.

This paper provides insight into research undertaken as part of the development and implementation of a 'carbon masterplan' for London's South Kensington Cultural and Academic Estate (SKCAE). It provides an analysis of the issues faced in implementing energy efficiency and carbon reduction measures for historic existing buildings with significant architectural and cultural value, that need to remain operational throughout the process.

In particular, the paper focuses on recent studies into the use of ATES and its potential when used with Combined Heat and Power (CHP) generation, using the underground energy store as a thermal accumulator for excess heat from the CHP plant in summer to achieve significant carbon emissions savings.

The first stage project findings, based on model load profiles, show that there are opportunities for substantial benefits in terms of creation of a low carbon infrastructure that deals with both new and existing buildings in a mixed urban or campus environment; and that ATES and CHP used in combination may give rise to around 5 times greater carbon savings than CHP alone.

Project Background

The South Kensington Cultural and Academic Estate (SKCAE) is principally comprised of the Natural History Museum, The Science Museum, The Victoria and Albert Museum, The Royal Albert Hall and The Imperial College. The buildings from which these partners operate range from imposing Victorian structures to very modern teaching and laboratory facilities. The Estate of 87 acres is united under one Landlord, The Royal Commission for the Exhibition of 1851, established to oversee the process of development of the world's largest integrated cultural and academic estate, following the financial and academic success of the Great Exhibition, to further the interest of science and art in the UK. Each SKCAE establishment has unique heating, cooling and power demand profiles which, combined, total some 200,000 MWh per annum, produce around 55,500 tonnes of carbon dioxide and generate fuel bills in the order of £8-9 million.

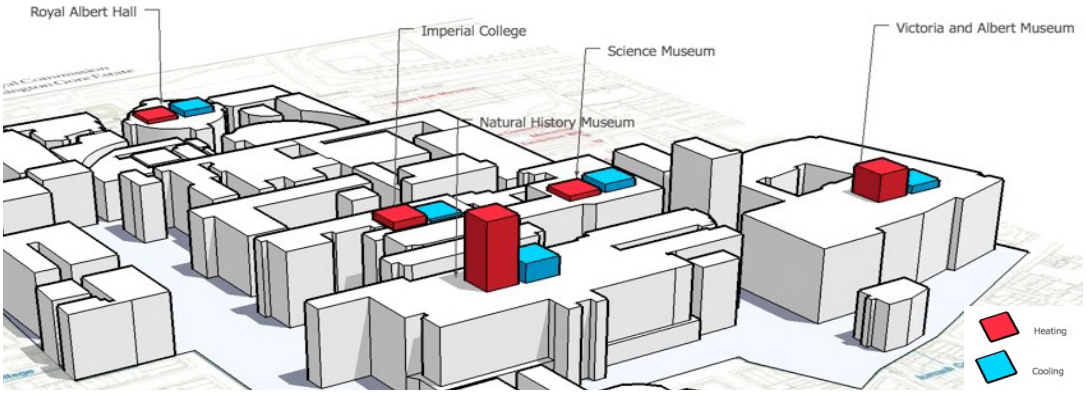

Figure 1. *Heating and cooling demand of the five principal SKCAE buildings.*

A number of key events were acknowledged to have stimulated the need to understand the energy consumption profiles of the SKCAE partners in far greater depth than ever before, including: The advent of the Emissions Trading Scheme; rising utility prices; the UK Government's Strategy for Combined Heat and Power (CHP) to 2010; the Kyoto Protocol; and the UK Government's target to substantially reduce carbon dioxide emissions.

SKCAE's response to these events was an innovative proposal to produce a groundbreaking and holistic 'Carbon Masterplan' as the first phase of moving to a 'zero carbon' operation. This involves investment in technology and expertise to fully understand energy profiles and flows so that opportunities for energy and carbon emission reductions can be identified. The project involves highly innovative application of tried and tested technologies. Through the high public profile and educational nature of the buildings involved, the project also has significant potential to help educate the public on climate change, carbon footprinting and the need for energy conservation and emissions reductions.

There are five main elements of the Carbon Masterplan:

1. Enhanced metering facilities for primary energy usage data;
2. Use of monitoring, targeting, data assimilation and visualisation software;
3. The introduction of a SKCAE climate and emissions controller team to interpret and act on the results of monitoring on a day-to-day basis and help effect behaviour change of building users;
4. A research programme to investigate technological solutions to reducing energy use and CO_2 emissions;
5. Introduction of a staff awareness and training programme for energy efficiency and carbon management;

This paper, written by those involved in this ambitious grant funded project, focuses on the potential benefits of the innovative technological solutions investigated and their applicability to other areas of the UK public estate, and dense urban environments worldwide.