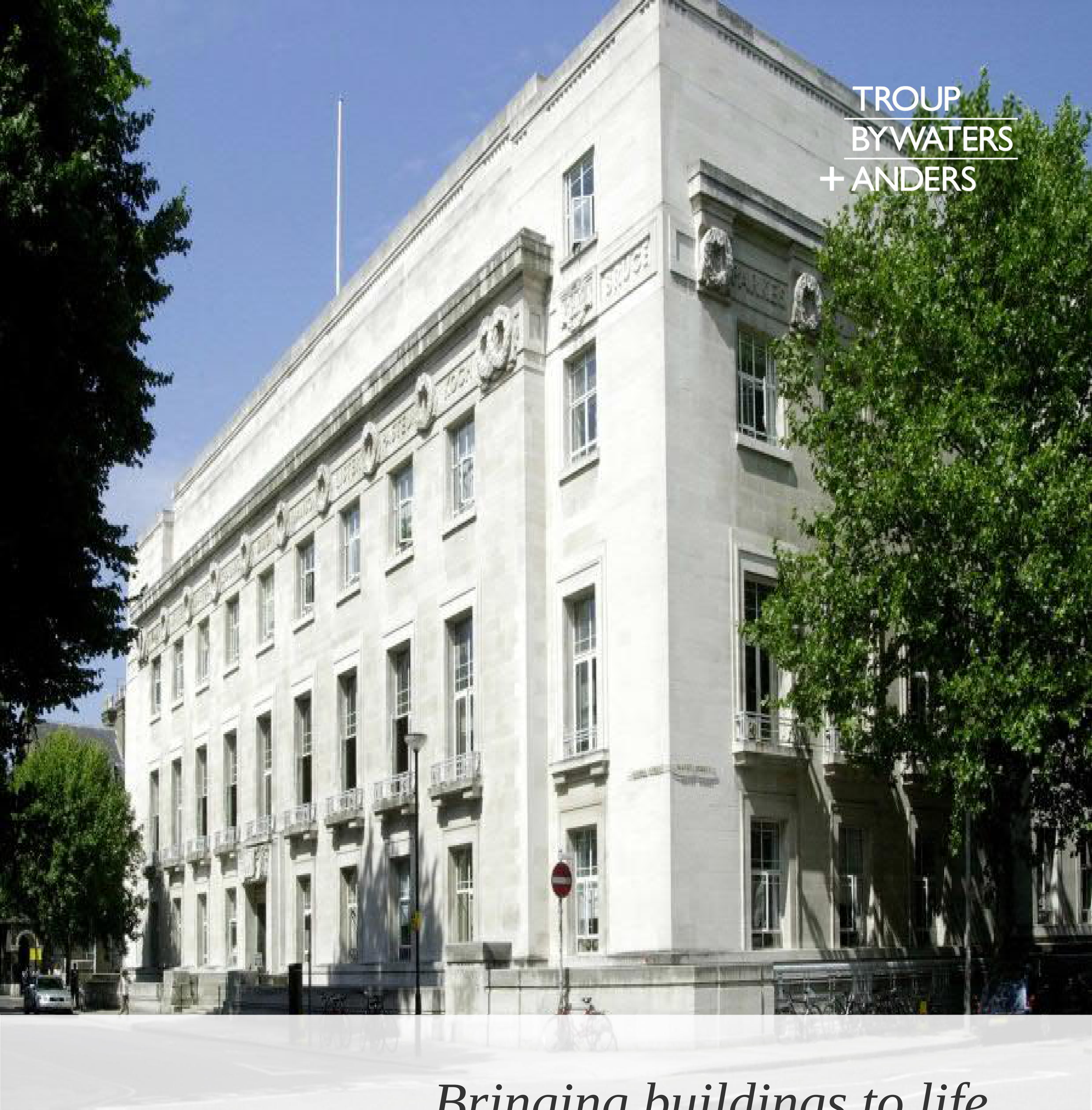

Bringing buildings to life

London School Hygiene & Tropical Medicine
Heat Decarbonisation Plan
LL0048_HDPRPT_A1

September 2021

TROUP BYWATERS + ANDERS

PROJECT
London School of Hygiene & Tropical Medicine

PROJECT REF
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Heat Decarbonisation Plan

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Allan Cross
Partner

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This report is hereby signed off as the brief by: -

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TROUP BYWATERS + ANDERS

Contents

Executive Summary

LSHTM is a prestigious research faculty having worldwide acclaim sited within the centre of London. The campus comprises largely of buildings constructed in the 1930's which have been progressively refurbished and modified to meet the needs of the school.

The Heat Decarbonisation Plan will fundamentally support LSHTM Carbon reduction programme and identify areas of inefficiency that require additional funding to be secured for the introduction of energy efficient heating solutions to reduce the campus prime heating carbon emissions.

It is apparent that a large proportion of the prime heat energy is currently provided from the local Bloomsbury DEN. District energy networks are usually considered to be more efficient than standalone boiler installations however this is not the case for LSHTM. The current DEN carbon intensity factor is very poor indeed resulting from natural gas and oil-fired central plant that has depreciated over time and whose condition has exacerbated system efficiency. So much so that the carbon factor is significantly higher than both the natural gas and National grid electricity factors [circa 2 and 1.5 times greater respectively].

Lucy Pemble of the Carbon Trust has confirmed in an email 28th July 2021 that that while they have received support from BEIS, GLA and LB Camden, the Bloomsbury DEN were unsuccessful in securing funding from the Heat Networks Investment Project [HNIP], as they could not meet the stringent criteria. They are apparently now trying to secure funds from the Green Heat Networks Fund [GHNF]. This lack of investment is stalling their energy efficiency improvement works and may impact upon future re-connection to the network.

Prior to considering any re-connection to a local DEN LSHTM will need to review the associated carbon factor as part of the negotiations. If it is greater than the national grid carbon factor, then the focus will be on de-fossilising the campus heating infrastructure through the introduction of new low carbon technologies. Conversely if the DEN carbon Intensity is lower than the electrical grid then it would make sense to utilise their prime energy feed for the campus, subject to any financial considerations, tariffs etc.

The Heat Decarbonisation Plan has highlighted that the primary focus of the London School Hygiene and Tropical Medicine campus must be Keppel Street as it contributes 94% of the estate's carbon dioxide heating emissions, 66% resulting from the space heating. Steam and domestic hot water are responsible for 30% of emissions and the resultant carbon heat emissions associated with cooking and preparation of meals is virtually negligible by comparison.

Tavistock Place 1 contributes 4% of the heating carbon emissions and Bedford Place 8 and 9 < 2% of heating emissions.

It is also apparent that the removal of 8 and 9 Bedford Square from the campus portfolio and the introduction of Tavistock Place 2 will not make significant change to the heating carbon emissions and gives a net reduction of 0.5% overall.

The master programme of planned measures to take place between 2021 and 2029 will progressively modernise and improve both the building services infrastructure and operations. These initiatives and remedial works to the fabric of the building, and the changes to how steam is produced [natural gas to electric] are all positive moves to improve the buildings however the associated heat carbon savings are relatively insignificant when viewed against the overall campus emissions.

LSHTM intend to stay ahead of the UK government's regulatory phase out of fossil fuels and the introduction of new low carbon technologies operating from the clean green national electrical grid is anticipated to gain momentum over the next decade. This will undoubtedly influence the key decisions to be taken by LSHTM stakeholders and HDP management and delivery teams.

Key HDP decisions going forward are;

+ 2024 Undertake low carbon technology feasibility study for Tavistock Place 1 to assess potential of heat pump technology and phase out of existing gas fired boiler plant.

+ 2027 LSHTM to review reconnection to a local low carbon DEN. This will ultimately be subject to the carbon intensity of both the DEN and the projected values of the national grid.
  Undertake Keppel Street feasibility on GSHP [potentially using existing 100m deep cold water boreholes, 2 extraction, and 2 reinjection, for low grade heating], ASHP's and review benefits of PV and other emerging technologies.

+ 2028 Undertake low carbon technology feasibility study for Tavistock Place 2 to assess potential of heat pump technology and phase out of existing gas fired boiler plant. The solution may be to provide 100% of the heating requirements or a considerable proportion with small top up by fossil fuels.

+ From 2029/30 to plan and execute new ASHP and GSHP technologies to provide low carbon solutions for Keppel Street to replace the existing Boiler plant, heating and hot water systems.

+ 2030 onwards - Hydrogen fuel cell technologies cannot be discounted as a future contributor to the heating and energy equation for LSHTM HDP. It is a new technology in wide spread use in countries like USA and Japan, but not as such in the United Kingdom or indeed London. Hydrogen will most likely require local production derived from natural gas and reformation of methane and there will be safety concerns to take into consideration due to the flammability of the hydrogen gas.

Within the next decade LSHTM HDP will achieve a 41% reduction in heat carbon emissions from the 2019 baseline of 1,480,479 to 870,217 $kgCO_2$ per year. The introduction of new low carbon technologies in subsequent years could further reduce the campus emissions to 280,934 $kgCO_2$ which is a commendable 81% below the current 2019 baseline heating emissions. This is reliant upon the UK national grid carbon factor continuing to decrease to < 0.1 $kgCO_2\ kWh^{-1}$ [This figure is a conservative value as BEIS projections suggest that the 2030 grid factor will be lower].

Fundamentally LSHTM will be responsible for implementing their masterplan, maintaining their plant for optimum efficiency and securing ongoing funding, management and support to ensure that the HDP plan is continually monitored, analysed and reviewed annually. This review will take into consideration changes in energy legislation, national grid carbon factors and the feasibility studies that need to be undertaken to ensure that the carbon emissions associated with the prime heating energy are reduced year on year.

1.0 Introduction

1.1 The Brief

The London School of Hygiene and Tropical Medicine [LSHTM] situated within the Bloomsbury conservation area has a world-class record for fundamental and clinical research, with particular expertise in microbial pathogens, antibiotic-resistant strains of bacteria and new and emerging viruses.

Troup Bywaters + Anders have been appointed by LSHTM to work collaboratively with their facilities and energy teams to deliver a Heat Decarbonisation Plan [HDP] to support their net zero carbon objectives.

Governance of the HDP falls under the remit of the London School of Hygiene and Tropical Medicine Director of Estates, Head of PMO, Head of Sustainability, Head of Maintenance and Stakeholder manager, their Sustainable Action Committee and the Capital Projects Steering Group.

1.2 Decarbonisation

Dramatic reductions of carbon dioxide [CO_2] and other greenhouse gas emissions are required to prevent damaging impacts of Climate Change. This requires an energy transition from high carbon intensity fuels to low or zero carbon energy systems.

Decarbonisation is the strategy employed to achieve a reduction in fossil fuels that have high carbon factors by increasing the use of low carbon energy sources and renewable energy technologies. The Decarbonisation heat model aims to provide a road map to inform the London School of Hygiene and Tropical Medicine decision making process and their investment planning programme in meeting their low carbon heat aspiration.

The road map to heat decarbonisation will include options for a phased replacement of the existing fossil fuel dependent systems with new technologies such as heat pumps, renewable energy systems and fuel cells.

The existing Bloomsbury DEN is currently less efficient in energy and carbon emissions than LSHTM's own local fossil fuel gas boiler heating system due to the onerous carbon factors, and is a fundamental consideration in any heat decarbonisation reduction plan, refer to section 4.1

Future collaboration with third party energy providers may be considered if it can be demonstrated that the carbon intensity of their local heating network is substantially better than the systems installed at the London School of Hygiene and Tropical Medicine.[1]

The HDP will also analyse the collaborative approach of combining both of the above options to deliver the optimum low carbon solution.

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[1] The carbon intensity would need to be < 0.1 $kgCO_2e$ /kWh

1.3 Context

1.3.1 UK / World response to Carbon Targets

Energy policy in the UK is the responsibility of the Department for Business, Energy and Industrial Strategy (BEIS). Although there are numerous regulators for specific parts of the energy sector, much of the energy market is regulated by OFGEM.

Historically, parts of energy generation, transportation, and supply were run by the public sector. Most of the market is now privatised; generation and supply are competitive, and transportation through networks is regulated as the operators are monopolies.

The Government and OFGEM continue to regulate the market for customers and deliver policy to meet the Government's aims on energy.

The energy policy of successive Governments has centred around three objectives of security, affordability, and decarbonisation. This year the Conference of Parties [CoP 26] will take place in the UK, where 196 countries plus representations from the European Union will discuss and support the United Nations Climate change convention[2]. Agreed actions may be subject to legally binding obligations, and the responsibility for carbon emission reductions need to be imposed in a fair and equitable manner without stifling the progress of emerging nations.

1.3.2 Climate Change Act

The Climate Change Act 2008 established long term statutory targets for the UK to achieve an 80% reduction in greenhouse gas emissions by 2050 against a 1990 baseline. In 2019, the target was changed to at least a 100% reduction of greenhouse gas emissions relative to 1990, otherwise known as a net zero target.

1.3.3 The 2050 NZC targets

The UK is set to vigorously pursue ambitious targets to reduce Greenhouse Gas Emissions (GHGs) to 'net-zero' by 2050, ending the UK's contribution to global warming within 30 years. To ensure parity Scotland will need to set a net-zero GHG target for 2045 and Wales will need to target a 95% reduction by 2050 relative to 1990 base levels.

A net-zero GHG target for 2050 will deliver on the commitment that the UK made by signing the Paris Climate Agreement. It is achievable with known technologies, alongside improvements in people's lives, and within the expected economic cost that Parliament accepted when it legislated the existing 2050 target for an 80% reduction from 1990. This is only possible if clear, stable and well-designed policies to reduce emissions further are introduced across the economy without delay, as current policy is insufficient for even the existing targets.

A net-zero GHG target for 2050 would respond to the latest climate science and fully meet the UK's obligations under the Paris Climate Agreement, and fundamentally goes beyond the reduction needed globally to hold the expected rise in global average temperature to well below 2°C and beyond the Paris Agreement's goal to achieve a balance between global sources and sinks of greenhouse gas emissions in the second half of the century.

The House of Commons in 2019 made a UK Declaration to the Climate emergency compelling the government to act. Subsequently April 2021 the UK set the world's most ambitious Climate Change target to cut emissions by 78% by 2035 compared to 1990 levels. This forms part of the 6th carbon

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[2] The prevention of dangerous anthropogenic [human induced] interference with the climate system

budget and incorporates the UK's share of international aviation and shipping emissions, bringing the UK more than 75% of the way to NZC by 2050.

With this in mind, there is an industry drive in all sectors to decarbonise by 2050.

1.3.4 Influence of the Green Grid

The ongoing decarbonisation of the electricity grid and the increase in renewable technologies is expected to lower the carbon factor of electricity to a value closer to that of Natural gas. The clean grid is seen as a pivotal factor in the cultural use of fossil and petroleum fuels as they are large contributors of nitrous oxide [N_2O] and other particulates. It is anticipated that dependency on these fuels will substantially reduce and that clean electricity will be used to provide heating through heat pump and fuel cell technologies.

The introduction of electric vehicles will increase the demand upon the electrical grid but will reduce air pollution and improve air quality within our towns and cities.

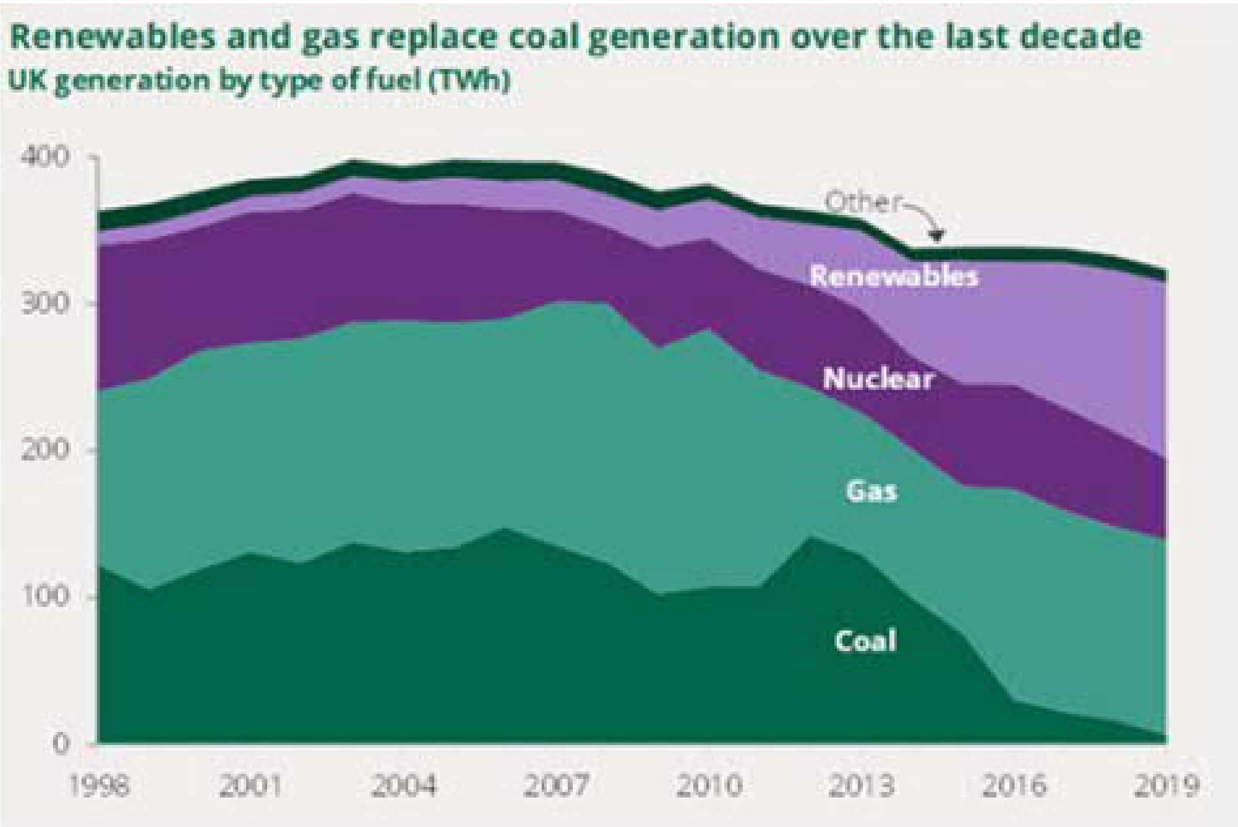


Fig 1.3.4.1 National Grid Fuel mix

1.4 LSHTM Policy

The London School of Tropical Medicine has initiated an Energy Management Strategy (see extract below detailing Hierarchy) and an ambitious Energy and Carbon Management Plan [ECMP] in 2020 to reduce carbon emissions to net zero across scopes 1,2 and 3 by 2030.

Scope 1 = Direct emissions from owned or controlled sources.

Scope 2 = Indirect emissions from purchased electricity, steam heating & cooling.

Scope 3 = All other indirect emissions from company value chain.

The ECMP suggests that LSHTM has an overall carbon footprint of 12,402 tonnes of CO_{2e} per annum. The carbon directly associated with heat production is circa 1,046,443 kWh $yr^{-1}$of Natural gas, which equates to circa 162 CO_{2e} tonnes per annum [Scope 1 and 2].

The Bloomsbury district heat network is responsible for circa 3,039,000 kWh $yr^{-1}$and 558 CO_{2e} tonnes per annum.

This gives a total emission from fossil fuels of 720 CO_{2e} tonnes per annum to be addressed under the HDP, approximately 6% of the overall carbon footprint.

The HDP will assist LSHTM to meet their net zero aspirations, however they will also need to substantially reduce the carbon impacts of both their business travel and supply chain partners to effectively reduce their carbon emissions.

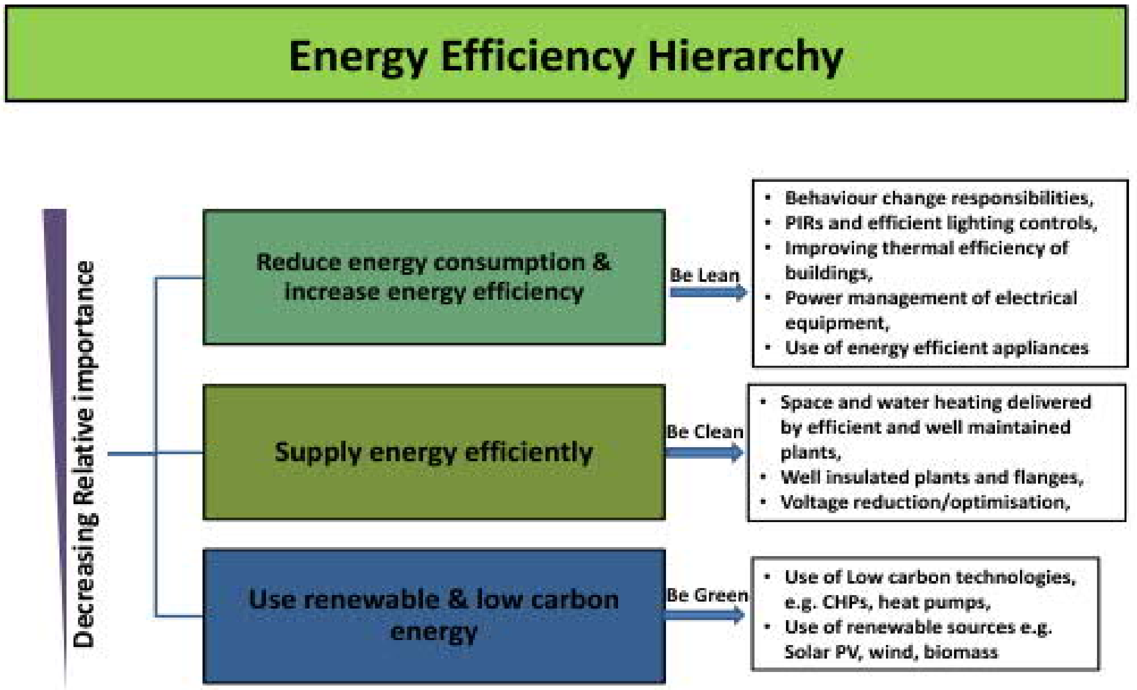


Fig 1.4.1 LSHTM Energy Efficiency Hierarchy

2.0 Information

2.1 Information Received

The list of information provided by LSHTM in developing this Heat Decarbonisation Plan is included in Appendix 1.

2.2 Abbreviations Used

AHU	Air handling unit
ASHP	Air Source Heat Pump
BEMS	Building Energy Management System
BMS	Building Management System
BSF	Biological Services Facility [Animal House]
BEIS	Department for Business, Energy & Industrial Strategy
CFL	Compact Fluorescence Lamp
CoP	Coefficient of Performance
DHW	Domestic Hot Water
ECMP	Energy and Carbon Management Plan
EDF	Electricite de France Utility company
EMS	Energy Management Strategy
FC	Fuel Cell
FCU	Fan coil unit
FORM 2	Wardrobe Cabinet type of MCC
FORM 4	Compartmented MCC
GHG	Green House Gases [Gases that contribute to Climate Change]
GLS	General Lamp Shade
GSHP	Ground Source Heat Pump
GRP	Glass reinforced plastic
KS	Keppel Street
HDP	Heat Decarbonisation Plan
HTF	Heat transfer Fluid
HWS	Hot Water System
LETI	London Energy Transformation Initiative
LSHTM	London School of Hygiene and Tropical Medicine
LTHW	Low temperature hot water heating
MCC	Motor Control Centre
MTHW	Medium temperature hot water

NG	Natural Gas
NCY	North Courtyard
OFGEM	Office of Gas and Electricity Markets
S&E	Supply and Extract
ST	Solar Thermal
SOAS	School of Oriental and African Studies
SCIF	Sustainable Climate Impact Fund
SCY	South Courtyard
TP1	Tavistock Place 1
TP2	Tavistock Place 2
TPN	Triple Pole and Neutral
PV	Photo voltaic
UK GBC	United Kingdom Green Building Council
UKPN	United Kingdom Power Networks
VAM	Ventilation air and moisture recovery exchanger
VRV	Variable Refrigerant Volume
XPS	Extruded Polystyrene Insulation

2.2 Scientific Notation

A	Ampere
kW	Kilowatt [10^3 Watts]
kW_p	Kilowatt peak
kVA	Kilovoltamperes
MW	Megawatt [10^6 Watts]
W_e	Watts electrical
W_{th}	Watts thermal
kWh	Kilowatt hours
$kgCO_2$	Kilograms of Carbon Dioxide
CO_{2e}	Carbon Dioxide equivalent [is a measure of how much gas contributes to global warming relative to carbon Dioxide, and may include methane, Nitrous oxide etc]
NOx	Nitrous Oxide
Yr^{-1}	Per annum
pa	per annum
L	Litre
M^3	Metres cubed
R410A	Hydrofluorocarbon refrigerant – replacement with R32 or R454B

2.3 Caveats

This Heat Decarbonisation report has been based upon the information kindly provided by London School of Hygiene and Tropical medicine Director of Estates and the respective facilities and sustainability teams.

The carbon factor associated with the Bloomsbury district energy network has been provided by Stephen McKinnell [SOAS] who manages the DEN.

The structure and format of the Heat Decarbonisation report follows the guidance within LSHTM Project brief to satisfy the SALIX requirements.

This report has been reviewed by LSHTM Estates, facilities and sustainability teams to ensure that the content does not include any sensitive material and is as accurate and up to date as possible.

3.0 Estate Description

The London School of Hygiene and Tropical Medicine estate has a current portfolio comprising of five principal buildings;

Keppel Street

Tavistock Place 1

Tavistock Place 2

8 and 9 Bedford Square.

A brief description of the buildings and their services is listed below.

3.1 Keppel Street [KS]

3.1.1 Building description

Keppel Street was constructed circa 1929 and comprises of a steel framed building with Portland stone facade. In the 1980's the building was granted a Grade II listing. The existing roof is uninsulated and is in a poor condition.

The double glazing on the Malet Street façade has been replaced as part of the SALIX funding.The double glazing on the other facades is of varying age and quality and will be subsequently replaced during Masterplan delivery.

It was originally designed in the shape of a capital A. The two large open courtyards were originally designed to give air and light to the surrounding rooms.

Although the façade of the building has remained unchanged since 1929, there have been several internal transformations and refurbishments. The Malet Street wing suffered bomb damage in 1941 and was not restored until 1951. New floors were subsequently added during the 1950's, 1960's and 1970's. The terrazzo main foyer was partially restored in the 1990's.

In February 2004 a new seven storey building extension to the North was introduced, including a glass atrium to provide new offices, research space / laboratories and meeting space for over 100 staff.

The South Courtyard development was opened in May 2009. This five-storey building accommodates state of the art lecture theatres, teaching and research space and social areas for staff and students.

3.1.2 Systems

Cold Water Systems

Incoming mains water connections enter the building at lower ground floor level at Malet Street and Gower Street respectively. The Gower Street connection was originally introduced as a fire main and serves the basement archive sprinkler system.

The incoming mains are both individually boosted by designated pumped booster sets and are combined within the building. The pumps work alternately to share the duty and provide system resilience. The combined cold water main rises through the building to serve the water tank room at level 6.

The tank room houses 2 No sectional mild steel tanks each 6m x 2m x 2m having an actual capacity of 19,740 Litres. The total storage being 39,480 L.

The tanks provide a gravity feed cold water down service for the building dropping via NE and NW toilet accommodation and in addition provides a cold feed to serve the HWS storage cylinders sited within the basement plantroom.

Current modifications to the system include; -

+ The existing Gower Street booster pump is to be replaced by a new break tank and inverter driven triple pump booster set to serve the new tanks at roof level and the Category 5 break tank at basement level.
+ A new copper thermally insulated and vapour sealed boosted cold water service will be run within the Gower Street riser main pipework services riser to serve the new tanks.
+ A new copper thermally insulated and vapour sealed cold water down service will be installed with valved and plugged branch connections at each floor level for future extension.
+ Local water softening is to be provided to essential equipment only as required.

Hot Water System

The existing domestic hot water is provided by two 2250 litre horizontal open vented storage vessels heated by the ENGIE MTHW Bloomsbury district heating system via plate heat exchangers. The existing 80 mm dia flow from the HWS vessels serves the majority of the building and toilet accommodation.

The HWS system will be modified to incorporate; -

+ New return water pipework runs will be introduced to alleviate any non-circulatory areas such as ‘dead legs’ to prevent potential environments for ‘legionella’
+ A new Category 2 domestic hot water service system will be introduced comprising of four vertical indirect domestic low temperature hot water calorifiers, each unit having a storage capacity of 2000 litres based on the building occupancy with a total useable storage of approximately 8000 litres. The units will be arranged for open vented operation. Units will be of copper lined galvanized sheet steel construction and have a recovery time of two hours and have capacity to heat the stored water from 10 to 60°C.
+ The calorifiers will be piped in a reverse return arrangement to ensure that each unit sees equal flow and usage, and will be provided with an anti-stratification pump controlled by the BEMS to run during the pasteurization period for sterilization purposes as part of the ‘legionella control’ regime.
+ A new single hot water service return pump will be installed within the basement plant room and arranged to serve the two new calorifiers. Space will be retained in the plant room for an additional future unit to be installed if the School occupancy increases.

Low Temperature Heating

The prime heating energy to Keppel Street is currently provided from the Bloomsbury District heating ENGIE network. This agreement has been terminated by LSHTM for both carbon and financial considerations and is to expire in September 2021. Planned remedial works are currently in progress to ensure that the prime energy is autonomous. These works include:

+ Decommissioning of the existing 2.4MW MTHW ENGIE boiler, pump sets, heat exchangers and associated pipework.
+ The new unvented boiler installation comprising of 4 No. 596 kW modular natural gas fired condensing boilers installed within the boiler room.
+ New heating pressurisation unit / expansion vessel installation.
+ Relining of the existing flue to suit condenser operation.

- Installation of a new primary heating circuit run to connect to the 'redundant' MTHW flow and return pipework
- New plate heat exchangers, inverter controlled run and standby pumps to serve South Courtyard supply AHU's and associated pipework.
- A new pair of dedicated duty standby plate heat exchangers will be provided to serve the North Courtyard heating system.
- A new pair of plate heat exchangers will be provided to serve future chilled beam heating coils and fan coil units.
- A new pair of plate heat exchangers will be provided to replace those currently serving the BSF heating system. One unit being replaced and connected to the new heating infrastructure leaving the BSF heating system being served by one existing plate heat exchanger and the steam back-up plate heat exchanger.

The BSF steam generators located in 4^{th} Floor McQuay plant room, are served by a dedicated metered gas supply. The generators operate as run and standby to provide steam to 7 No autoclaves and 1 No cage wash. If there is a heating failure in the BSF the building management system activates the lead steam generator to provide backup heating.

Chilled water

The chilled water is provided by 4 new high efficiency chillers each rated at 600kW, along with a new pressurisation unit and additional expansion vessels. The new installation incorporates the provision of three port valves and inverter driven secondary pump arrangements to enable the chilled water flow temperatures to be elevated to serve new Chilled beams within the new office and write up areas. The circuits serving fan coil units and AHU chilled water coils will continue to operate at flow and return temperature of 6^0C and 12^0C respectively.

Chilled water is also provided via 4 No 100m deep boreholes [2 being used for extraction and 2 for reinjection]. The quantity of ground water used to be subject to an Environmental Agency agreement. These boreholes may be an option for future GSHP installations and recovery of low grade heating.

New form four [motor control compartmented control panel] and new control hardware and software devices have been introduced as part of the remedial works.

Mechanical ventilation

Mechanical ventilation is provided to the North Courtyard zone, Central and South Courtyard areas.

The South Courtyard [SCY] has 4 No Air handling Units [AHU];

SCY AHU 1	-	Serves Manson, Lower Ground, Third and Fourth Floors
SCY AHU 2	-	John Snow
SCY AHU 3	-	Kitchen, Refectory and Common room [Fire Rated].
SCY AHU 4	-	Registry, Ground Floor and Atrium

The North Courtyard [NCY] mechanical ventilation is provided by a new Trox air handling unit installed in 2018. This system serves Wet labs Levels 1,2,3 and 4], teaching labs [levels 1 and 3] and crossover zones. They incorporate run around coils to recover heat between supply and extract systems as this arrangement avoids any cross contamination. A second AHU will be introduced in 2023 / 24 which will complete the lab and NCY ventilation infrastructure.

The existing South Courtyard AHU's will be sequentially replaced as the respective areas served are refurbished in line with the current remedial works phasing plan, with the SCY being addressed during 2023.

A new suite of AHU's will be introduced in 2025, to serve all office spaces within the main building.

Supply and extract mechanical ventilation systems exist at LGF to serve the IT suite and meeting rooms.

High efficiency Refrigeration plant

All new air handling unit coils, chilled beams, and fan coil units will incorporate two port control valves and differential pressure reducing valve arrangements installed at the heads of the existing risers and the connections to the existing south courtyard air handling unit branch.

Electrical Systems

HV Power Supply

The London School of Hygiene and Tropical Medicine is currently fed by 3 no. UK Power Networks (UKPN) substations which are sited within the building. SALIX funding has been provided to enable the electrical sub – stations to be modified and increased to enable greater use of decarbonised electrical supplies, this is described in greater detail under section 4.4.

The current network comprises of the following:-

UKPN Transformer No 24361 has an availability of 800 kVA and is located at Lower Ground Floor Level in Room LG64 and is supplied at High Voltage from Services in Keppel Street. This is the original supply to the building and serves other non LSHTM customers.

UKPN Transformer No 21329 has an availability of 1000 kVA is located at Lower Ground Floor Level in Room LG65 and is supplied at High Voltage from Services in Keppel Street.

UKPN Transformer No 24601 has an availability of 1000 kVA is located at Basement Level in Room B23 and is supplied at High Voltage from services in Gower Street.

Each of the 3 incoming supplies is statutory metered at low voltage via remote monitoring.

Substation LG64 serves the divided switch board in LG69 with 2 no supplies of 630A TPN incoming into each side. LG64 transformer can only deliver a maximum of 1154A per phase.

Substation B23 is connected to a switch panel rated at 1250A. The TPN supply located in LG56 serves mechanical plant and local lighting and power boards within the North Courtyard.

Substation LG65 has a 600A TPN Panel within the South Courtyard at lower ground level and serves the refrigeration plant, lighting and power within the South Courtyard and the lecture theatres. There is also a switch board [appears to be a changeover panel board] for essential services which has a main incomer from either LG64 or LG65 and the site generator.

LV Power

The existing small power installation generally comprises;

+ General 13 amp small power via ring main circuits
+ Small power to ancillary items i.e. Water Heaters, Hand driers
+ Office power
+ Laboratory Power (General and Specialist)
+ Power supplies to Mechanical Services / BMS Outstations

The low voltage supplies are provided via a combination of installed sockets, surface mounted trunking mounted outlets, individual outlets, underfloor busbar trunking and flush floor outlet boxes and surface mounted trunking mounted outlets in laboratories.

Final circuit wiring for the majority of the building is completed using PVC single core cables in metal trunking and conduit run at high level in ceiling voids or within floor voids in corridors.

Armoured cables are also used to feed, mechanical plant, further sub-distribution or additional connections and outlets. Where old distribution boards have been routinely replaced, the discrimination between circuit protective devices has been not been taken into consideration and discrimination issues result.

Photovoltaic Array
A small array of Photo voltaic panels is installed at Keppel Street Roof comprising of 91 panels having an area of 60m^2 and a design output of 8.19 kWp. The panels typically should generate circa 90 – 100 kWh m^{-2} however the yield is 2310 kWh yr^{-1}, about 39 kWh m^{-2}[43%]. The panels in some cases are in partial shadow due to the congested plant arrangements and are not all accessible and have an accumulation of dirt on the surface which will impair performance.

This array currently offsets circa 590 kg CO_2yr^{-1}.

3.2 Tavistock Place 1 [TP1]

3.2.1 Building Description

LSHTM's main accommodation (aka TP1) at 15-17 Tavistock Place was first constructed between 1896 and 1916. Since this time the front facing portion of the building has been extended upward by 1 floor. LSHTM acquired the building in 2009. The contemporary extensions were added by LSHTM to the inward facing elevations in 2010. The land comprising the dairy sheds to the rear was acquired at the same time as the main accommodation in 2009 (3500m2). The rear sheds and a part of the main accommodation to the rear was demolished in 2020 to make space for the construction of the new Tavistock Place 2 building (aka TP2) which is due to compete in 2022 and be occupied in 2023.

The site falls within the Bloomsbury Conservation area under the Kings Cross ward.

3.2.2 Systems

Cold water systems
Two number incoming mains water metred connections enter the building in the basement plantroom and store to serve showers and potable water outlets throughout the building.

The mains water is monitored via pulse meters and cold water storage is provided by 2 No GRP sectional pre-insulated tanks. Tank No 1 is 2150mm L x 1150mm W x 1000mm H [2000L nominal capacity], Tank No 2 is 1850mm L x 1150mm W x 1000mm H [1500L nominal capacity].

A cold water downservice is provided under gravity from the storage tanks to serve toilet accommodation throughout the building.

Hot water systems
Hot water is provided to the toilets, and water outlets from 3 No HWS cylinders with water stored at 65^{0}C. Two cylinders are heated by the LTHW heating primaries, and the third cylinder is heated by 8 No solar thermal HW collectors sited at roof level. The solar hot water connection also serves a

FCU sited in the basement which acts as a ‘heat dump,’ to dissipate any residual heat within the system.

Low Temperature Hot water heating

Heating to the building is provided from 4 No gas fired modular steel boilers. The high efficiency, low NOx boilers are served by a natural gas supply which enters the building at basement level.

The boilers operate at 80 / 60^{0}C flow and return temperatures and serve a primary heating circuit and 6 No secondary circuits. The primary heating provides hot water to serve the HWS cylinders, and the secondary zoned radiator circuits. All circuits have run and standby pumps with inverter driven motors. The heating system also incorporates pressurisation unit and expansion vessel, dosing pot assembly and automatic controls.

All perimeter radiators have local temperature control via Thermostatic radiator valves.

Incoming gas has been extended to serve the boilers and incorporates emergency solenoid safety shut off valve with battery backup, emergency push button.

Mechanical Ventilation

The basement boiler room has fan driven combustion air ducted to low level, and natural high level exhaust air ductwork.

Fresh air is provided by Daikin VAM units incorporating supply and extract fans, with heat recovery via a high efficiency paper heat exchanger. Direct expansion refrigerant coils heat or cool the air to meet seasonal demands.

Kitchen and Tea points are served by local extract fans to discharge vitiated air and odours from the space.

Comfort cooling is provided by a VRV [R410A] air conditioning system comprising of 4 way ceiling mounted cassette units on all floors, and inverter controlled scroll compressor / condenser units sited externally at roof level.

The Basement Data centre is served by 2 No direct expansion [resilience N+1] R407c downflow run and standby air conditioning units complete with electric heating / humidification, centrifugal plug fans with 7 speed settings.

Electrical

A 2000A TP&N ACB/MCCB transformer output switchboard has been installed within the new Substation on the Ground floor at the rear of the building. The switchboard incorporates two outgoing ways, one with a 400A TP&N MCCB to serve the existing main distribution panel within the building and a second with a 1600A TP&N MCCB to serve the future TP2 building at the rear of the site.

The electrical supplies serve the lighting and small power distribution boards throughout the building.

3.3 Tavistock Place 2 [TP2]

3.3.1 Building Description

Tavistock Place 2 is a new build extension to the rear of 15-17 Tavistock place, providing 3661m^2 (GIA) of dry research laboratories, open plan write up spaces and offices. The new construction being designed to Part L2A (2013) Building Regulations and 2016 amendments. The building design incorporates extensive solar shading to minimise overheating during peak summer solar gains.

3.3.2 Systems

The building services descriptions are similar to TP 1 and include; -

+ Highly efficient heating and cooling plant
+ Low NOx Boilers <40 mg/kWh
+ New Air handling Units with heat recovery via thermal wheels 70% efficiency
+ LTHW perimeter heating with radiators and heating via multi – serviced beams.
+ mixed mode ventilation to perimeter areas
+ VRV Comfort cooling
+ Low fan power
+ 100 per cent low energy lighting across all spaces;
+ Capped connection points to allow for future connection to a District Energy Network for heating
+ 100m^2 PV 15 kWp $_{array}$
+ Electrical Lighting and Small power

3.4 No 8 / 9 Bedford Square

3.4.1 Building description

The Bedford Square premises (No 8 and No 9) are both Grade 1 listed Georgian terraced houses built 1775. The houses are brick built with single glazed casement windows, with an arched portico entrance. There are 4 storeys above ground and a basement.

3.4.2 Systems

House No 8 has domestic LPHW heating from an old gas boiler and radiators, and hot water is provided from an electric immersion heated cylinder. Mains water provides drinking water to the kitchen and serves the cold water storage tank. The cold water downservice from this tank provides cold water services to the toilets and wash hand basins, and a cold feed to the HW immersion heater. The electrical services include lighting and small power only.

Natural ventilation is achieved via the single glazed openable windows.

House No 9 is very similar in terms of building services systems, except the LPHW heating is provided from a new domestic gas boiler which serves the radiators and supplies primary heating to the domestic hot water cylinder. Hot and Cold water services, Lighting and small power, natural ventilation is as described for No 8.

4.0 Decarbonisation Initiatives

4.1 Carbon Factors

The carbon footprint of the respective buildings within LSHTM campus has been attained using the Government conversion factors 2019 and 2020[3]. The factors being;

Carbon Factors	Kg CO_2 / kWh	
	2019	2020
Grid Electricity	**0.2556**	**0.2331**
Natural Gas	**0.1838**	**0.1838**
District Heating Network	**0.41**	**0.37**

The factors for the district heating network have been supplied by Bloomsbury District Heating Network.

The UK government continue to focus on the decarbonisation of the electrical grid with emphasis on renewable / low carbon technologies. This has been driven by; -

+ Reduction in coal use
+ Oil and Natural gas reserves have dwindled significantly
+ Limited opportunity for Fracking [extracting reserves of oil / gas from sedimentary rock] due to densely populated areas and risks of subsidence and landslides etc.
+ Climate change introduces extreme weather conditions resulting in high energy use.

In Fig 4.1.1 below it can be seen that coal use was circa 65 Million tonnes back in 1858 and peaked to around 221 Million tonnes in 1956, as post war Britain rebuilding programme reached full production. The cost of attaining coal and its impact on air quality resulted in coal being reduced to around 15 Mt in 2017 and this dropped to virtually zero use in terms of today's National grid contributions.

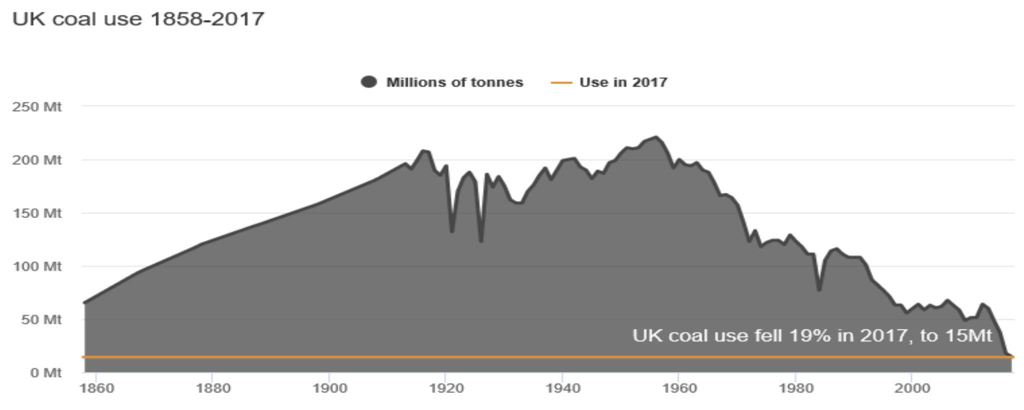


Fig 4.1.1 Coal Use 1858 - 2017

[3] Department for Business, Energy & Industrial Strategy [BEIS]

The subsequent impact of coal reduction and increased use of renewable energy [wind, solar and hydro-electricity generation] has decreased the electrical grid factor significantly and is now in parity with the Natural gas factor [see Fig 4.1.2] and this trend is expected to continue with the carbon factor approaching 0.1 $kgCO_2$ per kWh of electrical energy use by the end of this decade [2030].

These factors are fundamental in the UK Government strategy to reach Net zero Carbon by 2050 and will by default see a decrease in the use of fossil fuels and an increase in the use of technologies that can operate on electricity such as heat pumps.

	Year	Nat Gas	Electricity	Biomass	LPG	Oil
	2002	0.190	0.410	0.000	0.249	0.270
	2006	0.194	0.422	0.025	0.234	0.265
	2010	0.198	0.517	0.019	0.245	0.297
SAP 2012	2013_15	0.216	0.519	0.019	0.241	0.319
SAP 2013	2013_17	0.216	0.519	0.019	0.241	0.319
SAP 10	2019	0.210	0.233	0.028	0.241	0.298

Fig 4.1.2 Change in Carbon factors over the last 20 years

4.2 Carbon Factor Projections

The Department for Business and Industrial Strategy (BEIS) periodically produces an Energy and Emissions Projection (EEP), indicating the future grid carbon factor for the UK. THE EEP (2019), published in October 2020, indicates that by 2030, the national grid carbon factor for electricity will be as low as 0.1$kgCO_2$/kWh. This is a conservative estimate of the value taken from the latest EEP projections, shown in figure 4.2.1.

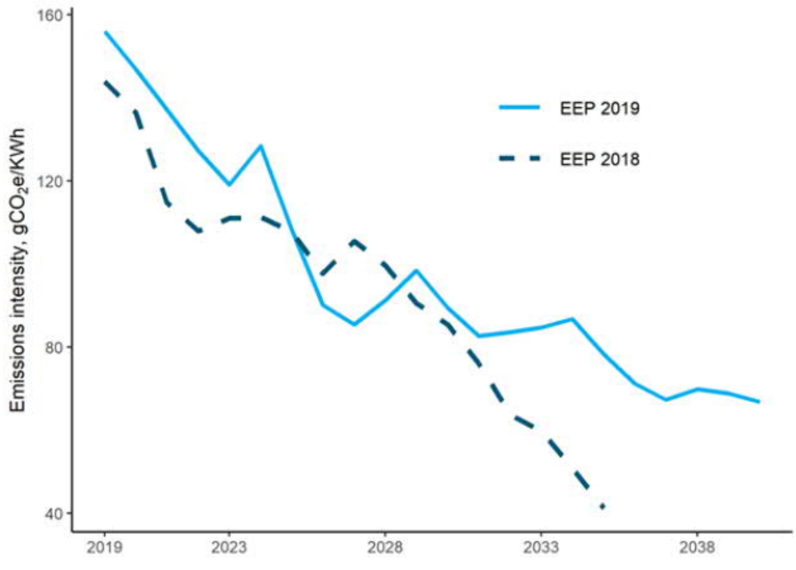


Figure 4.2.1 EEP 2019 Carbon Factor for Grid Electricity (BEIS)

It can be seen in Figure 4.2.1 that the national grid decarbonisation trend is not a linear decrease in carbon per unit energy, but is predicted to fluctuate year on year. However, for the purpose of this heat decarbonisation study, the decrease has been assessed as a linear projection to aid and demonstrate the effect of the decarbonisation measures being enacted.

It should also be noted that future EEP decarbonisation predictions will show different fluctuations and rates of decrease in grid carbon, supporting the use of a linear decrease for this study.

4.3 Current Energy Use

Following discussions with LSHTM it was agreed that the Base year for energy use and their associated carbon emissions would be 2019 pre – Covid 19 pandemic.

The base year site wide campus consumption is indicated in Table 4.3.1 and totals 10,866,137kWh. The heat contribution being 4,693,396 kWh yr^{-1}[1,626,796 kWh yr^{-1}associated with the LTHW gas fired boiler plant and 3,066,600 kWh $yr^{-1}$from the Bloomsbury DEN]. It should be noted that the Base year excludes Tavistock Place 2 as this building is not anticipated to make any significant contribution to the carbon footprint until the third quarter of 2023.

Period		Site consumption (kWh)											
		Keppel Street						Tavistock Place 1		8 Bedford		9 Bedford	
Year	**Month**	**Elec.**	**DH**	**DH Steam**	**Boiler Steam**	**Kitchen Gas**	**LTHW Gas**	**Elec.**	**Gas**	**Elec.**	**Gas**	**Elec.**	**Gas**
2019	Mar	457,537	316,600	0	97,118	1,802	0	67,523	43,071	4,357	9,397	3,009	6,906
2019	Apr	427,256	337,100	0	86,595	2,600	0	61,582	34,158	3,718	8,503	2,753	5,390
2019	May	451,654	264,000	0	95,906	2,714	0	64,304	25,127	3,838	3,183	2,731	2,904
2019	June	452,351	126,800	0	83,573	2,765	0	60,124	7,426	3,646	145	2,590	1,762
2019	July	498,436	124,100	0	93,159	2,842	0	69,829	6,133	3,768	157	2,922	1,764
2019	Aug	470,543	149,600	0	91,925	1,398	0	67,558	6,285	3,684	157	2,790	1,577
2019	Sept	437,805	165,600	0	102,844	2,963	0	65,663	7,435	3,479	358	2,638	1,856
2019	Oct	448,608	241,200	0	65,377	3,746	0	63,944	34,681	4,152	6,534	2,874	4,750
2019	Nov	423,144	308,400	0	91,899	6,542	0	63,911	39,831	4,271	13,262	3,159	7,009
2019	Dec	409,419	416,200	0	128,683	7,860	0	64,679	38,889	3,962	14,778	2,786	8,248
2020	Jan	420,111	254,000	0	81,464	8,592	0	68,397	38,748	4,288	15,517	3,103	8,559
2020	Feb	411,118	363,000	0	87,412	7,718	0	65,868	42,688	4,046	13,915	2,813	8,196
Total		**5,307,982**	**3,066,600**	**0**	**1,105,955**	**51,542**	**0**	**783,382**	**324,472**	**47,209**	**85,906**	**34,168**	**58,921**

Table 4.3.1 Base year 2019 – Site wide consumption kWh per annum

The Base year heating carbon dioxide emissions are indicated in Table 4.3.2.

Fuel Type	Consumption (kWh)	kgCO2				
		Kepp.Street	Tav Pl.	8 BP	9BP	Total
Electricity	6,172,741.03	1,338,051	197,217	11,879	8,600	1,555,748
Gas	1,626,796.00	212,810	59,656	15,794	10,833	299,093
District Heat	3,066,600.00	1,181,386	0	0	0	1,181,386
Total	10,866,137.03	2,732,246	256,873	27,674	19,433	3,036,226
	% of Total	89.99%	8.46%	0.91%	0.64%	

Table 4.3.2 Base year 2019 – Total Site wide Carbon Emissions kg CO_2 per annum

The illustration below demonstrates the percentage contribution of the current LSHTM building portfolio. Keppel Street represents circa 90% of carbon emissions and is the fundamental area of concern in terms of this Heat Decarbonisation Plan.

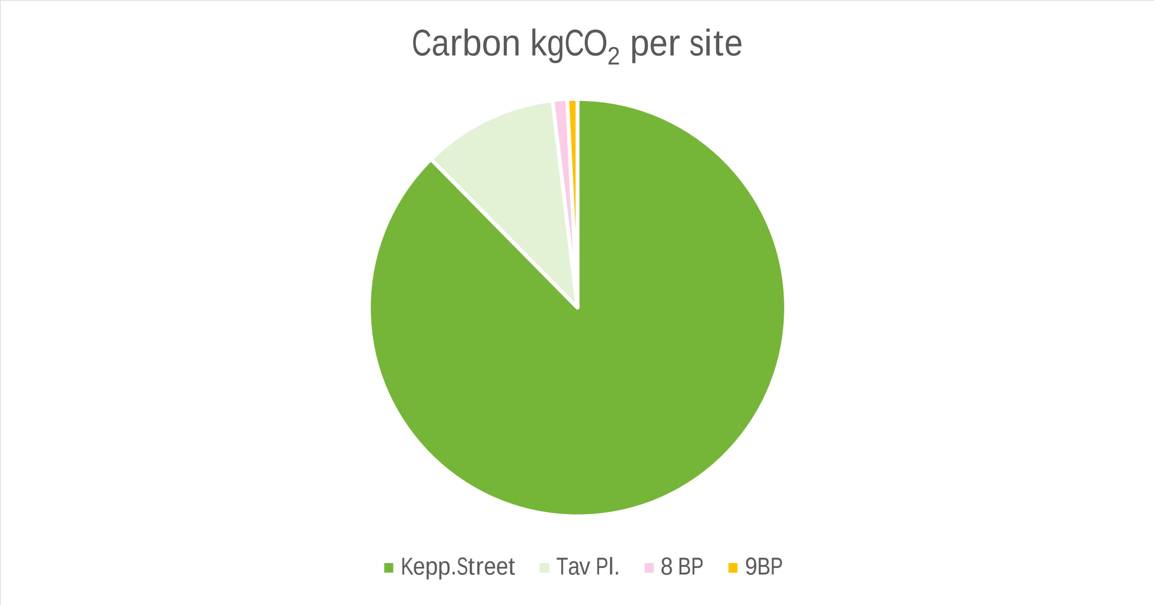


Fig 4.3.1 Base year 2019 – Illustration Building percentage contribution

4.4 Energy Saving Initiatives and Carbon reduction impacts

This section includes energy saving initiatives that are under consideration by LSHTM. Some of these initiatives will not directly impact upon the heat decarbonisation plan and are therefore excluded from the HDP road map, however they have been included for information as they demonstrate the commitment to reducing the LSHTM carbon footprint through other energy efficiency measures.

4.4.1 Keppel Street Initiatives

1.Fundamentally notwithstanding any financial benefits it is imperative that the current thermal energy provided by the Bloomsbury DEN is terminated as the carbon factor associated with this network is 2.23 times greater than the use of natural gas [fossil fuel]. The inefficiency of the DEN being related to the use of Oil combined heat and power generators. The disconnection will immediately give a saving of circa 40% in CO_2 heat emissions.

2.The introduction of new double glazing also forms part of the Masterplan works. The existing North Courtyard rooflights [2 No] have been replaced under Phase 1 improving the U value from 2.2 to 1.26 $Wm^{-2}K^{-1.}$ One rooflight at the South Courtyard will also be replaced to accommodate new ductwork penetrations. At level 2 West wing 3 existing single glazed units facing the South Courtyard will be replaced by new double glazed windows. The associated U values improving from 5.6 to 2.3 $Wm^{-2}K^{-1}$.

The Gower Street façade window replacement programme levels G – 4 is to be installed under Phase 6a with planned completion 2029. This improvement has however an insignificant carbon impact, giving a saving of 0.4% in carbon dioxide emissions. While it reduces solar gains to the internal space, and external noise pollution, the non-opening windows will influence the need for mechanical ventilation resulting in increased carbon emissions associated with pre-heating the air during the winter season.

3.Fabric improvements are to be introduced under each Phase of the master programme. The North Courtyard level 5 roof was improved under the Phase 1 workstream with the waterproof membrane being replaced and the insulation increased to 180mm XPS, with 50mm deep paving slabs. The thermal transmittance co-efficient [U value] improving from 0.21 to 0.16 $Wm^{-2}K^{-1}$. The 400mm strip of roof at the perimeter was replaced but had less insulation due to the existing parapet detail.

The roof around the new chillers will be upgraded in similar fashion circa October 2021, and Malet Street North roof replaced in 2026 [Ph 4b] and Malet Street South roof replaced in 2028 [Ph5] respectively. Gower Street and Keppel Street roofs are to be addressed in 2030 and 2031 under Phase 6a and b.

The Level 2 North West and West wings are existing 1929 walls comprising of solid masonry limestone blocks on the outer leaf and brick on the inner leaf with no cavity. There are circa 370mm thick and have a U value of circa 1.48 $Wm^{-2}K^{-1.}$ The Courtyard facing walls are also solid brick 205mm thick with 30mm plaster. The U value is approximately 1.86 $Wm^{-2}K^{-1}$. The introduction of thermal insulation to the internal walls and ceilings is possible however there are limitations to how successfully this could be introduced, and this is discussed under section 5.3.

4.The phased replacement of the existing building management control system will provide the tools for the facilities team to monitor and manage the energy use and to target annually reductions in the carbon footprint of the campus more effectively.

The introduction of Heat Metering of the heating systems will support the carbon reduction programme by providing live data for in depth analysis of the energy / carbon emissions to assess the positive impact of any operational changes introduced on the campus.

5. Control deadbands will be automatically incorporated into the system controls to avoid simultaneous heating and cooling. This is fundamental where two distinct systems are installed, such as perimeter radiator heating and VRF / direct expansion cooling. A 'dead band' needs to be set of approx. 4 - 5°C which ensures that neither the heating and cooling is operating between the given temperatures. The diagram below shows a dead band of 5°C from 19°C - 24°C, see illustration below.

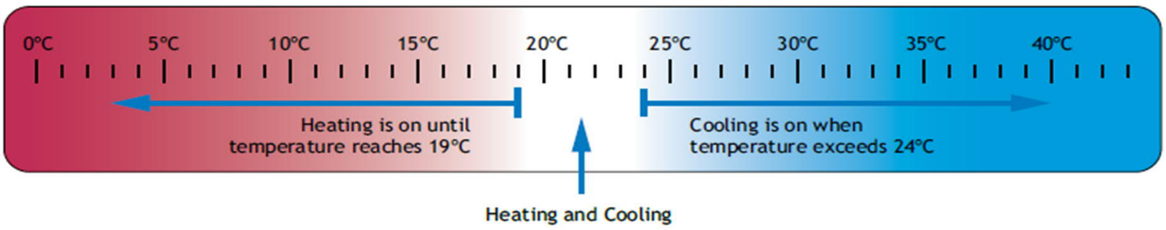


Diagram of 'dead band' control indicating recommended temperatures

6. Set points adjustment during hours of low occupancy at early morning, lunch times and evening periods could be introduced to save energy and emissions.

7.Low grade heating via Ground Source heat pumps has been discounted as it appears unlikely due to the location of the building and the logistics of introducing 100- 150m deep bore holes within the existing building structure.

8.At some point in the future circa 2027 it is possible that the campus may consider re-connection to a DEN if the associated carbon factor is favourable, less than 0.1 kg CO_2 kWh^{-1}

9. The introduction of active or passive chilled beams operating on elevated chilled water $12/15^0$ C rather than $6/12^0$ C will also save both prime energy use and carbon dioxide emissions.

10.The need to generate on site electricity will also become more prevalent and it is anticipated that the introduction of fuel cells (using green hydrogen) or other yet to be developed technologies will become the 'norm' rather than combined heat and power systems. Fuel cells can provide uninterrupted electricity and the associated waste heat can be used to heat the building. Improvements in battery technology will allow excess electricity to be stored and used off peak.

Of course, if the electricity grid continues to become cleaner as anticipated from renewables, atomic power, hydrogen generation etc the use of electrode boilers or standalone heaters may become the ‘norm’ and the existing heat network is likely to require a rational rethink. This however is unlikely to occur within the next decade.

Other efficiency measures in the pipe line

1.Steam humidification

The existing Steam plant serving the BSF facility (animal house) and Laboratory processes also provides heating redundancy via plate heat exchangers as described previously. LSHTM intend to undertake a design review during the phased programme of works (Phase 3B) to evaluate with the stakeholders the benefits of potentially introducing local electric humidification to serve the autoclaves and cage wash. This will be carried out circa late 2023 / early 24.

2.Reducing static pipe loss emissions

To facilitate new heating risers, the electrical services installed within the older mixed service risers at Malet Street and Gower Street are programmed to be stripped out and replaced by new thermally insulated heating flow and return pipework, installed from the basement plant room to high level fourth floor, thus reducing static heat loss and increasing system efficiency.

3.Thermal energy recovery

New stacked supply and extract AHU are to be introduced under the phased replacement works for the South zone area to provide heating and thermal energy recovery, and new AHU for the new office areas. The North zone AHU will also be upgraded. These works are scheduled for 2023,24 and 25.

4.Electrical Considerations

LSHTM have secured funding and been in dialogue with UKPN to put in place a robust strategy to ensure that there is sufficient electrical capacity to support future electric based technologies that may provide heating.

SALIX funding has been secured to allow a new substation to be built to increase electrical incoming capacity. The original scheme has been changed through discussion with UKPN, so that Transformer No 24361 described under section 3.1.2 will be decommissioned, and a new 3kVA sub will be installed on Gower street. This increases the electrical capacity from 2200kVA to 4400kVA, to support the decarbonisation journey. The peak demand prior to phase 2 was 1190kVA.

The upgrade will provide sufficient capacity for the current masterplan and resilience against any potential issues with the Keppel street substations which are shared and nearing the end of their life expectancy; and in addition provide the infrastructure to support the migration of the fossil fuel plant [providing heating and steam] over to electrode steam boilers and electric ASHP’s.

To reduce the electricity demand LSHTM have introduced progressive measures to replace all halogen, tungsten, metal halide, GLS, CFL, linear fluorescent luminaires to LED's on a phase by phase basis.

The manual lighting controls are also being replaced by smart lighting controls, daylight dimming, and lux level regulation on a phase by phase basis.

PFC [power factor correction] is being installed to every switchboard and replaced where equipment has failed or is considered obsolete.

All new motors and drives being installed are variable speed inverter type ensuring soft start and efficiency in operation.

Tapping of transformers is not an option for LSHTM as these are not private substations.

4.4.2 Tavistock Place 1 Initiatives

1. A new solar thermal hot water system comprising of 6 No 3.03m^2 vacuum solar plate collectors, integral pump and expansion vessel, interconnecting pipework and controls is to be installed September 2021. This will pre-heat the hot water storage vessels that provide hot water and offset circa 8113 kWh per annum of prime heating energy.
The carbon dioxide emissions saving is anticipated to be 1,488.74 kg CO_2yr^{-1}, circa 1.5 tonnes.

TP1 Funding has subsequently been allocated to recommission the Solar Thermal system to maximise the available annual thermal heat recovery yield, assessed at a nominal 8113 kWh/pa based on existing orientation and location.

The three existing Domestic Hot Water (DHW) Storage Cylinders (total capacity 2.4m^3) located within one of the basement plantrooms are to be reused following inspection and internal descaling. The existing DHW pre-heat Storage Cylinder is to be converted to a Thermal Store for the recommissioned Solar Thermal heat recovery system to pre the remaining two DHW Storage Cylinders as a priority heat supply source and independently of the existing NG Boiler(s).

The existing NG fired Boiler(s) shall be configured to supplement any remaining DHW thermal heat requirements and will not operate when the Solar Thermal heat recovery system is in operation and will only augment thermal heat demand at specific key operational times to maximise Solar Thermal heat transfer at all times.

In 2025-26, Tavistock Place 1 will undergo a planned refurbishment, providing opportunity to further decarbonise the site. The use of gas-fired heating will be reviewed, along with the ventilation strategy. Connection to potential DEN schemes will be considered, dependent on the CF of available and viable schemes.

4.4.3 Tavistock Place 2

Tavistock Place 2 is a newly constructed building at the rear of Tavistock Place 1 which was designed to 2013 [2016 amendments] Building regulations which ensures that it is thermally efficient with highly efficient heating and cooling systems. It has 100m^{2}15kW$_p$ photo voltaic array on the roof, and 100% LED lighting.

It is unlikely that the building will require immediate efficiency improvements however the low NO_x boilers [<40 mg/kWh] still use fossil fuels and at some point in the future will need to be replaced by either electrical powered heat pumps of hydrogen fuel cells [generating electricity and heat]. The heating system also incorporates capped connections for future extension to a local low efficiency DEN subject to the carbon factor being less than or equal to 0.1kg CO_2kWh^{-1}.

4.5 Third Party Heating networks and opportunities on site

This section examines the potential of utilising any local heat resource networks that may be available that could assist the transition to low carbon heat.

4.5.1 Decentralised Energy Networks

The London Plan outlines the Mayor's desire to generate a significant proportion of London's heat and power through localised and decentralised energy systems. Policy 5.6 recommends that Major Development proposals should select energy systems in accordance with the following hierarchy, in conjunction with the London Heat Map tool:

1. Connection to existing heating or cooling networks
2. Site wide CHP network
3. Communal heating and cooling

Many of London's existing heat networks have grown around combined heat and power (CHP) systems. However, the carbon savings from gas engine CHP are now declining as a result of national grid electricity decarbonising, and there is increasing evidence of adverse air quality impacts.

Heat networks are still considered to be an effective and low-carbon means of supplying heat in London, and offer opportunities to accelerate transition to zero-carbon heat sources faster than individual building approaches

The London Plan recommends that Developments should connect to existing heat networks wherever feasible. New and existing networks should incorporate good practice design and specification standards comparable to those set out in the CIBSE/ADE Code of Practice CP1 for the UK or equivalent.

Previous studies undertaken on behalf of LSHTM suggest that Combined Heat and Power (CHP) has limited benefits to LSHTM due to seasonal variations in the heat demand profile of the buildings.

The Keppel Street campus has maintained appropriate spatial allowance in the plant room for a plate heat exchanger to facilitate future connectivity to an external energy network should the opportunity arise.

LSHTM campus development is located within 1km of 5 district schemes:

+ Somers Town Decentralised Energy Network [Vital Energy]
+ Kings Cross [Vital Energy]
+ Bloomsbury Heat and Power Network
+ Euston Road [Argent]
+ Camden Town Hall

The Somers Town DEN is operated by Vital Energy and provides heating and electrical power to 339 homes [Monica Shaw Court, Oakshott Court, Clyde Court and Goldington Estate] and also serves the Francis Crick Institute adjacent St Pancras Station. This network is East of the site comprises of 3 No 1.3 MW_{th} boilers, 900 kW_{th} CHP and 3 No 11000L Thermal stores. With limited opportunity to increase supplies to neighbouring sites this DEN is discounted.

The Kings Cross DEN is also operated by Vital Energy and was designed specifically for the Kings Cross Station 67 acre site. The 4 No - 10 MW boilers and 2 No 2 MWe Combined Heat and Power generators and 2 No 74m^3 thermal stores provide heat, power and cooling to 25 new office buildings, 20 new streets, 10 new major public buildings, the restoration and refurbishment of 20 historic buildings and structures and 2,000 new homes. The potential to extend this network is under review.

The proposed Euston road DEN is under construction and may be appropriate for the Tavistock place campus. Connection to the Euston DEN will require further investigation and is a potential contingency energy provider if the CHP is omitted for fuel cells / heat pumps.

The existing Bloomsbury Heat and Power network is < 0.5 km and provides energy by two gas-fired CHP engines (725kWe each), two gas-fired boilers and back up oil-fired boilers and steam generators. This network currently serves LSHTM and is scheduled to be modified with modular boilers and new low carbon heat providing technology.

The existing heat production plant has a high carbon factor which reflects poorly on LSHTM carbon footprint and local air quality, so they have subsequently decided to terminate the current contract in the autumn 2021.

Bloomsbury DEN are looking to improve their network by introducing low carbon heating options through waste heat recovery from the underground sewer infrastructure and introduction of heat pumps.

Negotiations may continue from time to time to review potential reinstatement to the network in 2027/8 subject to the revised carbon impacts and financial implications being favourable to LSHTM. Plate heat exchanger infrastructure has been installed as a contingency within both Keppel Street and Tavistock Place 1 for any future connection to any Decentralised Energy Networks that may become available locally.

Previous studies on the Camden Town Hall scheme extension indicated the viability of small district network fed from a new CHP in the Town Hall would not be financially viable. A second study considered an extension project, with further expansion to include potential housing estates and a school, but this was not financially viable. Extension of the proposed network down Judd Street to Tavistock Place was considered but has not yet been constructed. Further investigation for connection would be required, if and when the network is constructed.

5.0 Decarbonisation Pathway

5.1 Carbon Calculations Summary

The carbon calculations within this HDP have been based upon data provided by LSHTM or their third party representatives. In some instances, it has been necessary to make assumptions or adjustments to simplify the carbon calculations, and these are identified and explained in the table below: -

Data	**Source**	**Description**	**Assumptions / Adjustments**
Electricity invoices for all sites	Smartest Energy	Sum of electrical energy consumed across LSHTM sites.	Base year's data agreed as being (March 2019 - February 2020)
Gas invoices for all sites	Total Gas	Sum of natural gas consumed across LSHTM sites.	Base year's data agreed as being (March 2019 - February 2020)
Previous master data on energy use across estate	LSHTM	Report on energy use from all sources to LSHTM sites	
DH Energy consumed	SOAS (Mr. S. McKinnell)	Sum of all energy drawn from the Bloomsbury DEN network for Keppel Street consumption	

Current DH carbon factor	SOAS (Mr. S. McKinnell)	The carbon factor of the Bloomsbury DEN network for the studied period	
Future projected carbon factor	SOAS (Mr. S. McKinnell)	The projected carbon factor of the Bloomsbury DEN network, shown in roadmap to zero carbon	It is assumed that the CF for the DEN should be no greater than 0.1 $kgCO_2/kWh$ by 2030 for meaningful discussions to occur. This is because grid electricity is predicted to be comparable to this figure by then and would therefore be more viable is the DEN CF does not decrease similarly.
National grid carbon factors	BEIS	Carbon factor ($kgCO_{2e}$) for electricity on the national grid (2019 and 2020)	
Natural gas carbon factor	BEIS	Carbon factor ($kgCO_{2e}$) for natural gas (2019 and 2020)	
National Grid future predicted electricity carbon factor	BEIS	Most recent prediction of future grid carbon factors	A continued decrease in the Electricity Grid CF is likely to occur in the next decade to circa 0.1 $kgCO_2$per kWh. For the purposes of the HDP the CF is modelled to decrease linearly from 2020 to represent the predicted change over the period, as the main aim of the study is to assess the LSHTM position at 2030.
Drawings of LSHTM sites	LSHTM	Plans and elevations of buildings to aid with calculations	
O&M manuals	LSHTM	Operation and Maintenance manuals for LSHTM sites, giving detail on past works taken out and current systems setups	
Keppel Street Asset list	LSHTM		
Keppel Street - New Boiler Spec	LSHTM	Datasheet of new boiler, including efficiency	
Roof Refurbishment drawings	LSHTM	Marked up drawing showing the areas to be refurbished	Used to calculate the total area of roof improved. Assumption made is that the roof perimeter is remaining untouched due to drainage design, and that no heating carbon is gained or lost from this area.
Occupancy levels - current and master plan	LSHTM		
Window refurbishment plan - 2 docs	LSHTM	Document showing windows intended for replacement on Malet Street elevation. Second document stating current estimated and future intended U-Values of windows.	Keppel Street Elevation used (in lieu of detailed Malet Street elevation) to assess window area for replacement. Images and site visit confirm that the windows in question are a good match in size and do not affect the calculation

Tavistock Place 2 BRUKL document	LSHTM	Final BRUKL doc for construction of T2. Used to estimate the annual energy consumption of the site once occupied.	Assumptions were made to scale the BRUKL output. A CIBSE case study for a typical office was taken, where actual annual energy use and BRUKL output are compared. The case study showed that heat consumption was generally very close to BRUKL values, suggesting that there are no major errors in terms of incorrect scaling.
Tavistock Place 1 Solar Thermal Upgrade document	LSHTM	Document detailing the calculations undertaken for recommissioning of the solar thermal system at T1. Document contains data on hot water usage.	Data used is for the period 2017-2019. Results are adapted on a pro--rata basis. Reduction in natural gas usage reported is from 10% to 27%. The average being used in the calculations. This document is also used to calculate the percentage Space / DHW heating split (91/9).
LSHTM Space Temperature Guidance	LSHTM		
AHU Replacement Strategy Keppel Street	LSHTM	Marked up drawings showing areas to be served mechanically after AHU replacement. Areas calculated to give values of additional heating carbon assigned to KS upon completion.	
Borehole and Extraction and Discharge Agreement Info	LSHTM	Permit detailing the allowed water discharge rate from the heat exchanger in the ground source cooling system.	Heat energy available is calculated on the basis of the allowed discharge rate, the allowed temperature change in extracted/discharged water, and the capacity of the current gas fired boiler.
General 1			Office buildings have a typical % split between space heating and DHW consumption (kWh) annually of 90/10% respectively. KS has a split of 80/20% due to other uses of heat and high number of occupants. T1 shows a typical split of 91/9 %from solar thermal doc
General 2			Roof replacement carbon savings span relevant phases. To assess the impact of these measures, the savings are assumed to occur at the same time and included in 2029 [to simplify matters] before the 2030 target, and prior to any 'future options' are undertaken.

Table 5.1.1 Basis of CO_2Calculations and assumptions / adjustments made

5.2 The Starting Point – Current Carbon Footprint

The current Campus carbon dioxide emissions associated with Heating total 1,480,479 kg CO_2 per annum based upon the base year of 2019 [Mar 2019 – Feb 2020] pre Covid 19 Pandemic.

The breakdown of Heating Carbon Emissions being: -

Building	**Kg CO_2**	**Contribution**
Keppel Street	1,394,156	94%
Tavistock Place 1	59,656	4.03%
No 8 Bedford Place	15,794	1%
No 9 Bedford Place	10,833	0.7%
Total	1,480,479	100%

Table 5.2.1 Campus Heating CO_2Emissions per building

The relative contribution of each building is illustrated in Fig 5.2.1 below,

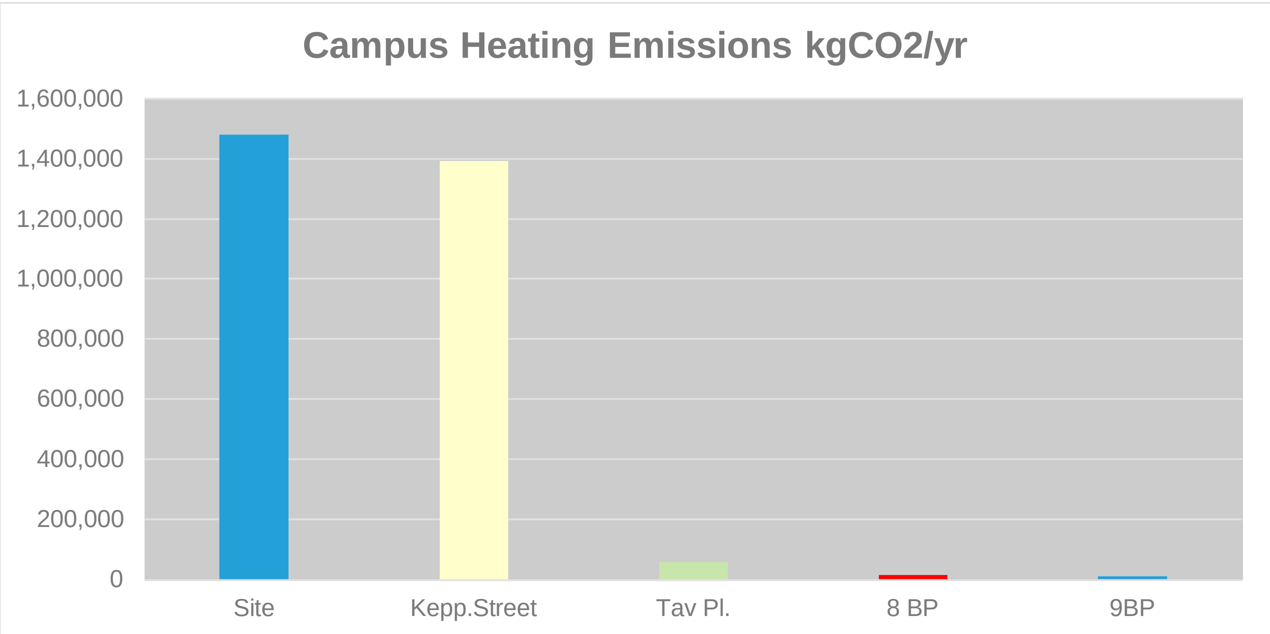


Fig 5.2.1 Site Wide Heat Carbon Emissions kgCO_2per annum 2019

5.3 The Pathway – LSHTM Carbon Reduction Programme

The following table indicates the year on year actions that are scheduled to be undertaken in line with the LSHTM Master Plan programme [see Appendix 2] and the net change in their Carbon dioxide emissions.

Year	Action	Reduction Kg CO2	Increase Kg CO2	Total Campus Emissions kg CO2 per yr.
2019	**Baseline**			**1,480,479**
2021	Bloomsbury DEN connection terminated	**589,152**		891,327
2022	KS - Window replacement at Malet Street façade has a very insignificant saving TP1 - Recommissioning of solar thermal cells	**14,520**		876,807
2023	TP2 – Completed and Occupied KS – Cooking facilities transform from NG to electric hobs / ovens		**26,197**	903,004
2024	No 8 and No 9 Bedford Place leases expire and are removed from the campus portfolio. Keppel Street Process Steam is generated by local electrode generator	**30,773**		872,231
2025				872,231
2026	KS - Completion of AHU replacement, adding to mechanically ventilated areas	**1,481**		870,750
2027				870,750
2028				870,750
2029	KS – Roof replacement programme continues	**533**		870,217

5.3.1 Table of progressive LSHTM Campus Carbon Emissions $kgCO_2$

The main changes having significant impact to the HDP site wide carbon emissions are as follows;

2020: Covid 19 Pandemic – People working from home energy use dramatically reduced. For the purpose of the HDP the energy use is assumed to be as year 2021.

2021: The Bloomsbury DEN is disconnected. This made a saving of 589,152 kg CO_2 reducing heating emissions by 39.795%.

2022: KS - Window replacement at Malet Street façade has a very insignificant saving of 1992 kg CO_2, about 0.135%.

2022: Recommissioning of solar thermal cells at Tavistock Place 1 achieves a further saving of 1492 kg CO_2, about 0.102%

2023: Tavistock Place 2 is completed and occupied. This results in an increase the heating carbon emissions by 13,764 kg CO_2.

2023: KS - Cooking facilities transform from Natural gas to electric hobs / ovens

2024: No 8 and No 9 Bedford Place – LSHTM made the decision leases to sell the properties and removing them from the campus portfolio. This gives a saving of 29,429 kg CO_2.

2024: Keppel Street Process Steam is generated by local electrode generator.

2025 – No change emissions as 2024.

2026 – Completion of AHU replacement, adding to mechanically ventilated areas for Keppel Street. This gives an increase in energy use but a small reduction in carbon emissions due to the estimated improvement in the grid carbon factor, see caveats.

2027 – 2028: No changes anticipated.

2029: Keppel Street Roof replacement strategy completed

The Carbon CO_2 emission reductions associated with the above actions are illustrated in the bar chart below, see Fig 5.3.1.

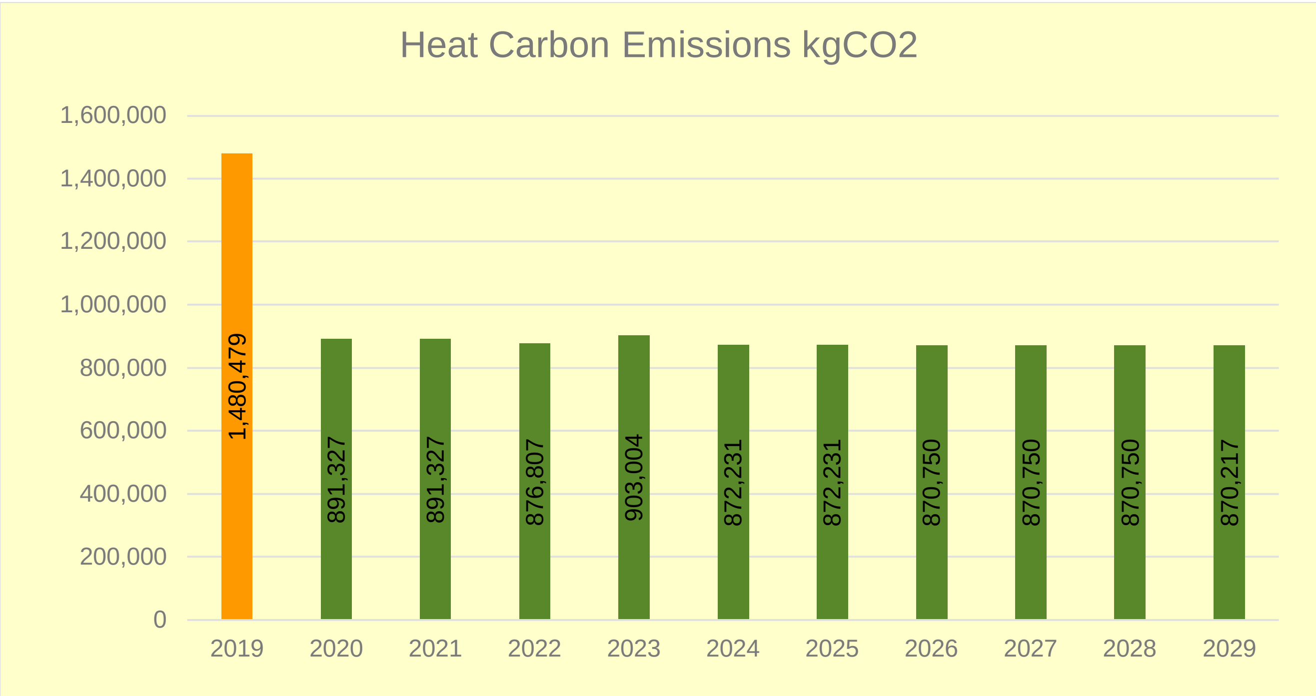


Fig 5.3.1 LSHTM Carbon Reduction Predictions

5.4 Further Opportunities

In addition to the proposed infrastructure works to the campus there are opportunities to further reduce energy and save carbon by introducing alternative systems and strategies.

Boiler plant using fossil fuels emits both CO_2 and NOx (nitrous oxide) pollutant gases that impact upon both Climate change and air quality. As the UK government continues to exercise the decarbonisation program for the national grid, the carbon factor for clean electricity is expected to achieve parity or better the carbon factor for natural gas. This will ultimately pave the way for fossil fuels to be phased out and replaced by cleaner / low carbon systems such as heat pumps and hydrogen driven plant (fuel cells). This is a consideration that LSHTM will need to include on any future prime plant replacement strategy.

As part of the HDP process, options for introducing Air source heat pumps and fuel cells have been assessed. Calculations were undertaken to assess the feasibility of converting the boreholes at Keppel Street from cooling mode to heating mode. There are 4 boreholes of 100m depth (2 extraction, 2 reinjection). These boreholes are currently in use to cool parts of the site.

According to the licence agreement between The Environment Agency and LSHTM, a maximum 558m^3 of water can be extracted/reinjected per day, with a maximum temperature change of 5˚C. The heat available is low grade heat and there would be some inherent system inefficiencies however, it has been established that approximately 50% of the annual space heating load of Keppel Street could be obtained using the borehole water in conjunction with a water to water heat pump with top up by gas boilers to elevate the water temperature to meet the design characteristics of the existing heat emitters. This option is proposed for future consideration, and will require the engagement of a system specialist who can undertake a detailed feasibility analysis of the site and estimation of savings.

To utilise the low grade heating water directly it would be necessary to make substantial alterations to the heating network radiators and heating coils as their heating surface areas would be inappropriate for the reduced mean water temperatures associated with conventional water – water heat pumps. This could be potentially overcome by the introduction of 'cascade heat pumps' which effectively are two heat pumps installed in series and which are reportedly able to elevate mean water temperatures to circa 75^0 C thereby enabling the existing infrastructure to be retained. Cascade heat pumps are however embryonic in development terms and it is anticipated that this technology will undergo several design iterations before they are introduced as future solutions.

The options considered were ASHP's for Keppel Street and Tavistock Place 1, GSHP for Keppel Street, and the introduction of a fuel cell to Keppel Street. The comparative Carbon impacts are illustrated below; -

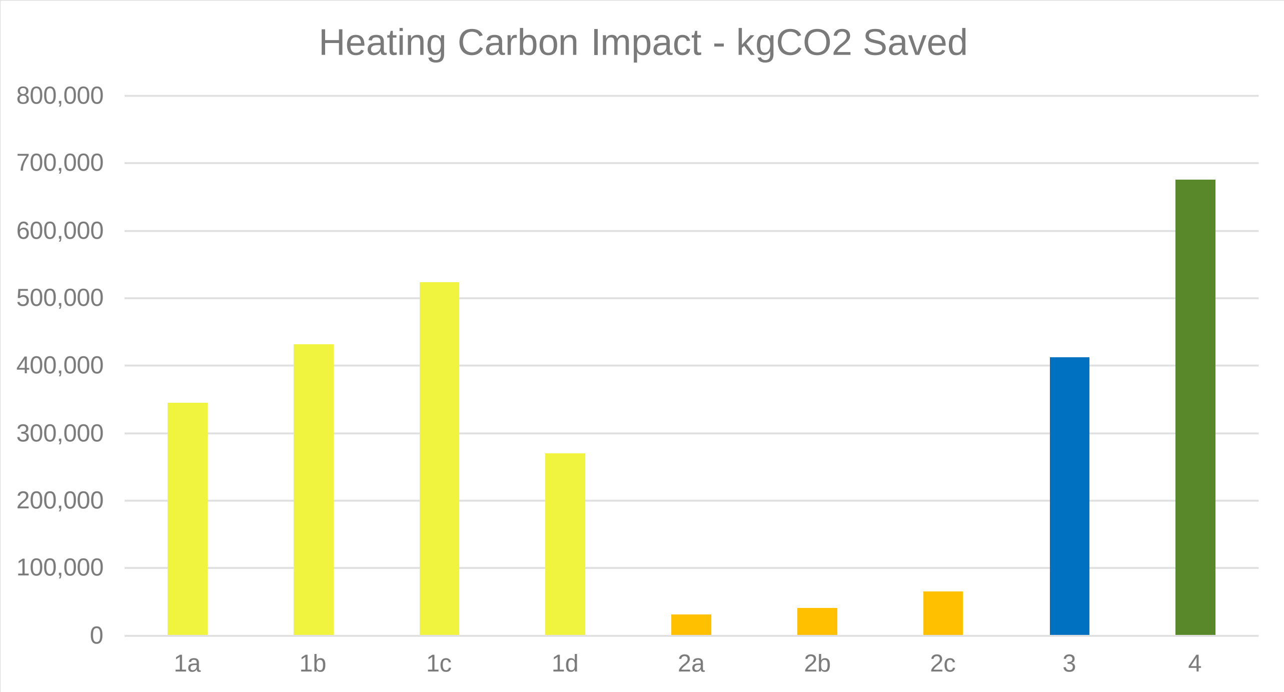


Fig 5.4.1 Comparative Carbon impact of individual measures. See Table 5.4.1 for index and options descriptions.

Measure Taken	Option Name	Description	Carbon Impact (kgCO2)
2029 Baseline	2029 Baseline	Baseline after all currently-planned works are undertaken	N/A
1a	2030 70 KS (3.5 SCOP)	2030 carbon factors. 70% of Keppel Street Space heating is supplied by ASHP with SCOP of 3.5. The remaining space heating is met by gas boilers.	345,503
1b	2030 100 KS (2.5 SCOP)	2030 carbon factors. 100% of Keppel Street Space heating is supplied by ASHP with SCOP of 2.5.	432,041
1c	2030 All KS LHW (2.5 SCOP)	2030 carbon factors. 100% of Keppel Street space heating and DHW is supplied by ASHP with SCOP of 2.5.	523,679
1d	2030 borehole GSHP, 50% of KS Space, SCOP 4	2030 carbon factors, with a borehole water-water GSHP providing 50% of KS heating, with a SCOP of 4. The remaining space heat is provided by gas boilers.	270,729

2a	2030 70 T1 Space (3.5 SCOP)	2030 carbon factors. 70% of Tavistock Place 1 Space heating is supplied by ASHP with SCOP of 3.5. The remaining space heating is met by gas boilers.	31,555
2b	2030 100 T1 Space (2.5 SCOP)	2030 carbon factors. 100% of Tavistock Place 1 Space heating is supplied by ASHP with SCOP of 2.5.	41,336
2c	2030 All T1 LTHW (2.5 SCOP)	2030 carbon factors. 100% of Tavistock Place 1 space heating and DHW is supplied by ASHP with SCOP of 2.5.	65,604
3	2030 60% DEN 40% ASHP KS	2030 carbon factors. 60% of Keppel Street space heating and 100% of Keppel Street DHW is met by the district heat network. The remaining 40% of space heating is met by ASHP with SCOP of 3.5.	413,011
4	2030 Fuel Cell	Hydrogen Fuel Cell technology is used with 'green' hydrogen (CF of 0). All space heating and DHW is supplied by the fuel cell. For every kWh of heat energy produced, 1kWh of electricity is also produced.	675,747

Table 5.4.1 - Description of all future options calculated. Here the individual impact of each measure can be seen, with a full description of the measures taken.

The introduction of the ASHP to handle 70% of the space heating for Keppel Street and Tavistock Place 1 (plant Coefficient of Performance 3.5, options 1a + 2a) with top up from the existing boiler plant results in a potential saving of 377,058 kg CO_2 and would take the annual campus emissions down to 493,159 kg CO_2.

If the ASHP [CoP 2.5] handled 100% of the heating load of KS and TP1 (option 1b + 2b) the campus emissions would reduce to 396,839 kg CO_2. The boilers provide the DHW but are not required for space heating.

If the ASHP's [Option 1c plus 2c] also included all LPHW space heating and the Hot Water load for both Keppel Street and Tavistock Place 1 the emissions would reduce to 280,934 kg CO_2.

If a GSHP [CoP of 4] is utilised in the Keppel Street site (via the existing boreholes) to provide 50% of space heating annually with top up from the existing boiler plant, the emissions would reduce to 599,488 kg CO_2.

Option 3, the heating being provided at Keppel Street by a new energy efficiency DEN and ASHP [60/40 split respectively], would give a reduction to 457,206 kg CO_2.

The introduction of a Fuel Cell option using green hydrogen at Keppel Street was also reviewed giving an annual campus CO_2 emissions of 194,470 kg CO_2.

Note: The reason for the difference in COP between gas aided heating and 100% ASHP heating is due to the achievable temperatures of the technology. The ASHPs can achieve lower temperatures at the higher COP of 3.5 but require a top up to reach the necessary temperature to heat the developments with their current heating apparatus.

At a lower COP, higher temperatures can be achieved, allowing the necessary space heating to occur without needing to replace radiators etc.

These options are depicted in the bar chart below; -

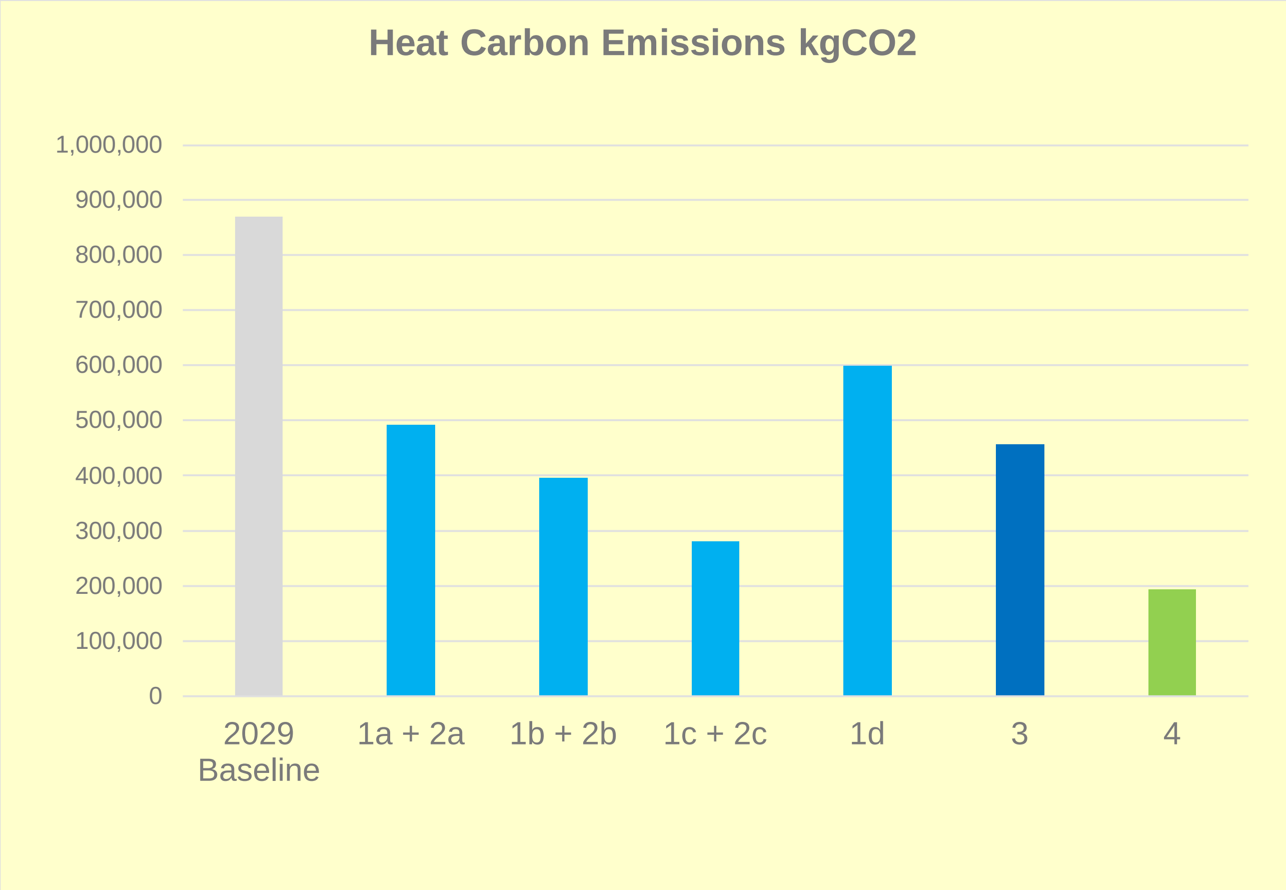


Fig 5.4.2 Further Options to save Carbon emissions. See Table 5.4.1 for index and options descriptions.

The fuel cell calculation is based on providing all space heating and DHW from the clean technology. A heat / power ratio of 1.0 is used [for every 1 kWh of heat provided, 1kWh of electricity is provided to the development], with any further electrical power being drawn from the grid.

The carbon factor for the Hydrogen-fueled heating is 0, as this calculation assumes that the 'Green Hydrogen' (produced by renewable means) is used, rather than 'Blue Hydrogen' (that derived from fossil fuels). While blue hydrogen can decrease CO_2 emissions (due to both power and heat being generated simultaneously), it is not a desirable fuel source as it is reliant on fossil fuels, meaning any CO_2 emitted contributes to global warming. The use of green hydrogen ensures CO_2 emissions are minimised.

In the summer months, any surplus heat energy can be utilised to cool the building, via an absorption chiller.

LSHTM is subjected to the London 'heat island' effects and associated poor air quality and noise pollution experienced within a congested city having high thermal mass and vehicle traffic. The option to relocate to a new bespoke low energy facility at a rural location such as Cambridge or

Oxford has been considered previously and discounted as the decarbonisation of the grid, electric vehicles and greater pedestrianisation is anticipated to improve the metropolis.

Their current net lettable area is circa 18353 m^2 [Keppel Street, Tavistock Place 1, and 8/9 Bedford Square]. The gross area being 27429 m^2.

The current baseline total combined electrical and fossil fuel carbon emissions for the campus is 3,036,226 $kgCO_2$per annum [2019] which gives a total benchmark energy use of 110.7 $kgCO_2\,m^{-2}$. This is considerably higher than the benchmark for Offices and University campus which are 75.1 and 89.6 $kgCO_2\,m^{-2}$ respectively. By 2029 the campus emissions will be circa 61,727 and 870,217 $kgCO_2\,yr^{-1}$ [electricity and heating] giving a benchmark of around 34 $kgCO_2\,m^{-2}$, based on the assumption that the national grid carbon factor attains a level of 0.1 $kgCO_2\,kWh^{-1}$.

The London Energy Transformation Initiative [LETI] suggest that **new** office and schools should be targeting operational energy levels of 55 – 65 kWh m^{-2} which if based on electrical energy as the prime fuel give a benchmark of 12.8 – 15.1 $kgCO_2\,m^{-2}$[using CF 0.233 $kgCO_2\,m^{-2}$ per kWh].

With the expectation that the electrical grid carbon factor will continue to fall the LETI benchmark energy use may attain figures < 9 $kgCO_2\,m^{-2}$ by the end of the decade.

Continuing investment in new low carbon technologies from 2030 onwards will further reduce heating emissions to circa 280,934 $kgCO_2\,yr^{-1}$. The total carbon emissions [heating and electricity] being circa 343,000 $kgCO_2\,m^{-2}$, which equates to a benchmark of 18.7 $kgCO_2\,m^{-2}$. If the UK Hydrogen economy develops over the next decade then there will be opportunities to further reduce heating carbon emissions to less than circa 200,000 $kgCO_2\,yr^{-1}$ and push the benchmark use below 18 $kgCO_2\,m^{-2}$.

This figure can be further improved by carbon emissions savings achieved through changes to the working environment brought about by mobile data, apps and the way individuals communicate with one another has presented greater flexibility to how teaching spaces can be used. Learning can be conducted ‘on the move’ and has resulted in agile working, flexible use of offices and teaching space, and lower power requirements. The dress code for internal spaces has become more liberal encouraging staff / students to dress appropriately for their environment. This provides an opportunity to relax comfort temperatures and elevate set points within internal spaces to 25^0 C dB in summer and to lower them to 18^0 C during winter.

The introduction of Demand control ventilation based upon carbon dioxide levels [occupant fresh air requirements] will also reduce the operational energy requirements.

Intelligent building controls where technology is used to deliver sustainable buildings that meet the users ever changing needs should be considered for LSHTM campus. Sophisticated artificial intelligence and monitoring tools can create environments that are capable of continual interaction with the occupants to save energy and operational costs, enhance security and reduce carbon footprints of the building, by using self-learning software that can analyse real time data for comparison to past experiences.

Monitoring of temperature, humidity and carbon dioxide can enable fresh air ventilation and heating and cooling strategies to optimise air quality and comfort conditions to suit variable occupancies.

The current Covid – 19 pandemic has influenced the way we work and use buildings and increased the need to flush buildings on a regular basis to remove bacteria and sterilise surfaces.

Power monitoring can also be introduced to minimise peak electrical loads. The engineering team will inevitably need to assess the building management systems capabilities to ensure that analytical software is in place and that sufficient data is collected to influence intelligent system control.

Priorities will need to be set, along with an action plan to achieve LSHTM vision of heat decarbonisation.

5.5 Limitations / Challenges

The LSHTM campus generally comprises of buildings constructed circa 1929. Tavistock Place 2 extension is under construction to current building regulations and is the exception. Keppel Street is a Grade II listed building and is the prime focus of improvement as it contributes 90% of the estate's carbon emissions.

Keppel Street roof scape may be described as very busy, refer to images 5.5.1, 2 and 3.

While phased replacement roof works have commenced large portions of the roof remain uninsulated and in a poor condition as it cannot be easily rectified due to the conglomeration of mechanical plant and access maintenance gantries that have progressively been introduced to serve the various medical functions and processes.

The complex stacking of plant restricts the introduction of renewable technologies such as solar hot water heating and photovoltaic arrays, and where these technologies have been incorporated they are small in magnitude due to the area available.

The introduction of air source heat pump technology may be introduced over time as air handling plants exceed their operating life expectancy, however this will involve considerable re-planning of the roof and access gantries and phased introduction to maintain 'live' operations.

The external envelope could be improved by insulating the internal walls and ceilings, however a meaning full contribution will require circa 100mm of thermal insulation [90mm Celotex or similar block plus 12.5mm plasterboard and skim finish] to meet current regulations. The net savings are relatively insignificant as the thermal mass of the building is substantial. Improving the fabric would also result in a considerable loss of net lettable area and prevent access to existing drainage and heating pipes that have been encased within the external fabric of the building.

There are existing defects to the North Courtyard that require attention. The North West and North East corners have holes at high level within the cladding where daylight can be physically seen. These are to be addressed under the Phased master plan works.

Keppel Street also has a legacy asbestos situation, and this has been identified and is being addressed pragmatically as part of the ongoing phased replacement works.

The existing perimeter heating systems are currently fossil fuel dependent. The old boiler plant has been replaced with new high efficiency condensing boilers and the existing boiler flue re-lined with twin wall lining to enable the heating system to operate under condensing mode allowing heat from the flue gases to be recovered during operation.

5.5.1 Image 1 Keppel Street Roof scape

5.5.2 Image 2 Keppel Street Roofscape

5.5.3 Image 3 Keppel Street Roofscape

5.6 Carbon Offsetting

Having exhausted all technical and financial constraints to reduce the carbon footprint of LSHTM portfolio there will inevitably be some residual carbon emissions that need to be addressed through the HDP process. It is envisaged that with continuing investment in new low carbon technologies that the residual heat carbon emissions will bottom out between 281,000 – 195,000 kg $CO_2 Yr^{-1}$ depending upon what technologies are introduced [ASHP's or HFC] refer to Conclusion Fig 6.1.

This may relate to a shortfall in the technology available at the time being able to reduce operational / energy in use or be associated with embodied energy of the construction process itself.

The residual carbon from energy in use may be offset by making what may be termed as a 'Climate contribution,' where organisations [businesses] can buy carbon credits through Brokers by offering financial support to projects that are seen as benefiting the earth's atmosphere thereby compensating for the carbon emissions that are yet to be eliminated.

These projects fall into two categories;

Reduction Schemes – where emissions are cut by improving processes by introduction of renewable energy such as wind farms, stoves that cook with solar energy, LED lighting etc.

Removal Projects – that absorb or eliminate GHG's through re-forestation, carbon capture and storage.

Fundamentally the projects need to be regularly audited and verified by government or certified by independent third parties.

While the projects may initiate better conditions for people living in deprived areas of the world, cynics may point out that these projects can be introduced relatively cheaply and that the ongoing success of many of the initiatives is questionable.

It is however a potential option for LSHTM to mitigate any residual carbon and further information relating to the schemes can be found @

How to Acquire Carbon Offset Credits - Carbon Offset Guide

The Third Party Certified Offset Carbon projects vary in cost depending upon the complexity of the initiative and its location. In addition the UKGBC published formal guidance on what is allowed and what is not, including a recommended carbon price aligned to the Paris Agreement (£70/tCO_2).

Embodied carbon is often cited particularly when considering net zero carbon targets. In terms of the LSHTM portfolio the majority of buildings are circa 1930's buildings and it may be argued that the energy used and carbon emitted in the past, sometimes referred to as' the sunk embodied energy and carbon' does not have any significance in achieving the set UK reduction targets for greenhouse gas emissions, or for mitigating the energy consumption and carbon emissions of today and the future.

This supports the sustainability view for retaining existing buildings as durable long lasting materials must reduce refurbishment cycles, therefore requiring less energy and carbon long-term. Yes, they will require upgrades to improve thermal efficiency which LSHTM have been doing, but the skeleton of the building is in place, no construction, no excavation works, or purchase of raw materials being required.

Tavistock 2 is a new build extension and many of the materials and products will be re-usable if and when disassembly is considered. This work is likely to be undertaken using renewable or low carbon intensity energy [including transportation which will be electric or hydrogen generation] therefore the associated embodied carbon emissions will be virtually zero carbon emissions.

The target would be to attain 0kg CO_2m^{-2}over the lifetime of the building and therefore offsets, or carbon capture would seem minimal.

LSHTM's SCIF Initiative

LSHTM have for some time been researching into the merits and potential drawbacks of carbon offsetting and has set up a subsidiary social enterprise called the Sustainable Climate Impact Fund (SCIF).

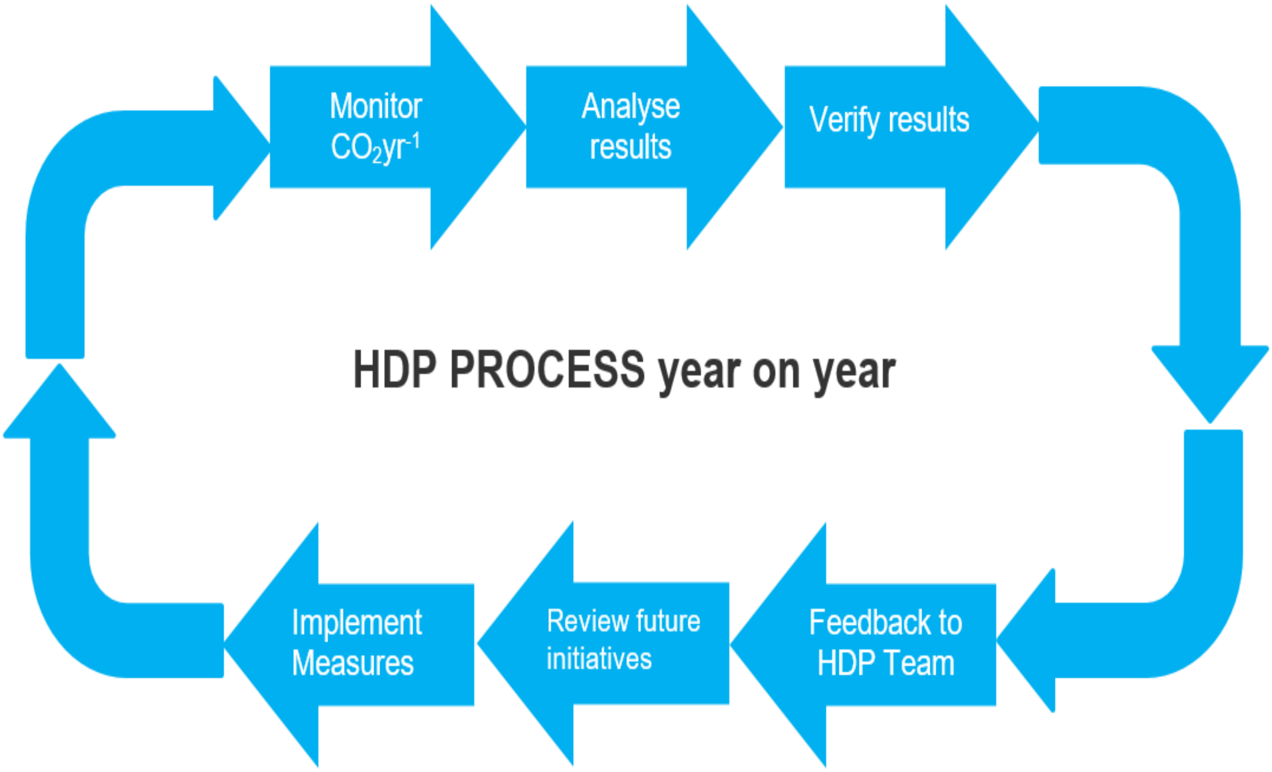
The aim of the SCIF is to run projects which provides socio-economic and health co-benefits to communities in developing countries where LSHTM already has a presence (for example Uganda and The Gambia). Invariably some of these projects will also have environmental benefits and will give the SCIF opportunities to offer carbon credits for offsetting – which will be priced in line with the World Bank recommendations and aligned to Paris climate accord. With the SCIF carbon credits will be used to offset unavoidable and residual emissions, ensuring that it is not used as a substitute to reduce emissions at source as the priority. Furthermore, the presence and long-term commitment in these countries ensures continued oversight of viability of implemented projects. Therefore, the SCIF approach negates some of the criticisms associated with offsetting while providing much needed social good.

5.7 Next steps

Having initiated a Heat Decarbonisation Plan it is fundamental that LSHTM have an ongoing process in place to measure the actions taken and assess their impact upon the decarbonisation strategy.

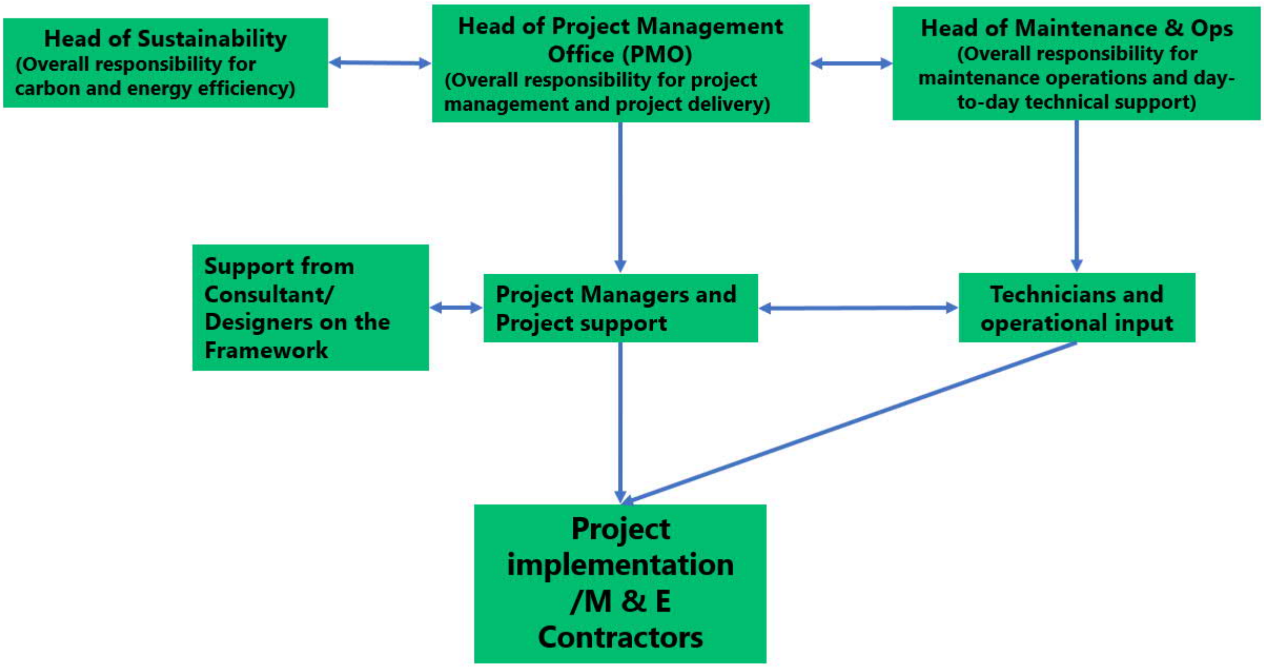
The facilities and energy team should collectively revisit the HDP year on year to;

+ Monitor the energy use and the associated carbon dioxide emissions both monthly and annually against the plan.
+ Analyse the results over the year to establish the monthly pattern of energy and carbon emissions. Are the results as anticipated, question any unusual trends and seek to understand the contributing factors for both high or low end use.
+ Seek independent verification of the results from an energy consultant and discuss progress to date.
+ Provide feedback to the HDP management team and discuss the ongoing projects and any potential opportunities for delivery of the Heat Decarbonisation Plan.
+ Review the initiatives in place for the year ahead to ensure that any operational changes are in place. Consider setting additional operational targets to reduce heating energy through operational change (adjusting set points out of hours and periods of low occupancy, introducing zoning controls, reviewing start / stop times etc). Undertaking an annual review of new technologies that are available in the market place.
+ Implement the agreed measures and repeat the process for each subsequent year.



5.8 Resources

LSHTM have a structured team in place dedicated to developing and deliver the Heat Decarbonisation Plan.



5.8.1 LSHTM Project Team Organogram

Head of Sustainability is responsible for managing energy consumption across the estates and PMO will oversee the delivery of the plan in coordination with Sustainability/Maintenance

The Project Management team are appropriately trained to manage and deliver large scale capital projects, ably supported by LSHTM designer framework which has design partners capable of taking the HDP aims and ensuring that they are transferred to the projects to maintain delivery of the HDP and the 2030 objective.

LSHTM acknowledge that the findings of the HDP and the scale of intervention required may identify gaps where supplementary training may be required.

LSHTM Project management Office head up the Salix projects and initiatives assisted by the Sustainability team to ensure that they align with the LSHTM capital masterplan, the Salix Heat decarbonisation plan, and the organisations aims for 2030.

The Estates masterplan features a series of large capital projects to improve the condition and functionality of the estate through implementation of infrastructure upgrades and alterations, to improve energy efficiency and carbon reduction as part of the HDP. While there is currently enough depth within the team LSHTM anticipate that larger projects may potentially require increase in staffing levels to fully execute and manage the HDP plan.

LSHTM has developed a designer and contractor framework to assist in the delivery of the Estates Masterplan. These companies will be intrinsic partners in the development and delivery of LSHTM sustainable goals, the delivery to heat decarbonisation. and the reduction in the overall energy / carbon footprint.

For LSHTM to fully benefit from the output of the current HDP a full feasibility will be required to further develop the avenues identified in the report including fees associated with the design process, plus funding for the capital interventions recommended in the report

Higher Education Institutions will inevitably have budgetary concerns and LSHTM will seek sources of funding to ensure capital and change programmes are delivered to meet the 2030 deadline.

6.0 Conclusions

This Heat Decarbonisation Plan has highlighted that the primary focus of the London School Hygiene and Tropical Medicine campus must be;

+ Keppel Street as it contributes to 94% of the estate's carbon dioxide emissions, of which 66% are from the space heating requirements. Steam and domestic hot water are responsible for 30% of emissions and those emissions associated with cooking and preparation of meals is negligible.
+ The current carbon factor of the Bloomsbury District Energy Network is significantly higher than both the natural gas and National grid electricity factors [circa 2 and 1.5 times greater respectively].
+ Tavistock Place 1 contributes 4% of the heating carbon emissions and Bedford Place 8 and 9 circa < 2% of heating emissions.
+ The removal of 8 and 9 Bedford Square from the campus portfolio and the introduction of Tavistock Place 2 will not make a significant change in heating carbon emissions, it gives a net reduction of 0.5%.

Between 2021 – 2029 there will be a planned sequence of measures introduced to progressively modernise and improve both building services infrastructure and operations. By far the most significant step change in the HDP will be the disconnection from the Bloomsbury DEN. While there will be a national push to phase out fossil fuels to accommodate new low carbon technologies operating from the clean national green electrical grid to provide heating prime energy, it is acknowledged that the instant change over to the new condensing natural gas [fossil fuel] fired boilers will provide a 40% reduction in CO_2 emissions due to the DEN having an extremely poor carbon factor.

The remedial works to the fabric of the building, and the changes to how steam is produced [natural gas to electric] are all positive moves to improve the buildings however the associated heat carbon savings while welcomed are relatively insignificant when viewed against the overall emissions.

The key decisions for the HDP going forward are;

1) From 2027 LSHTM to review reconnection to a local low carbon DEN. This will ultimately be subject to the carbon intensity of both the DEN and the projected values of the national grid. If the DEN carbon factor is greater than the national grid, then the focus will be on de-fossilising the campus heating infrastructure through new low carbon technologies. Conversely if the DEN carbon Intensity is lower than the electrical grid then it would make sense to utilise their prime energy feed for the campus, subject to any financial considerations, tariffs etc.

2) From 2029/30 to plan and execute new ASHP/GSHP technologies to provide low carbon solutions for the campus. The solution may be to provide 100% of the heating requirements or a considerable proportion with small top up by fossil fuels (refer to options Table 5.4.1). The final decision being dictated by how much change can be accommodated to the existing heating system infrastructure.

3) Climate change will continue to make headline news and there will be inevitably peer pressure from government, staff and students to reduce carbon emissions and carbon intensity fuels such as natural gas. This will influence decisions made by LSHTM stakeholders and HDP management and delivery teams.

4) 2030 onwards – The decisions by the UK government to produce 5 GW of low carbon Hydrogen production by 2030 suggests that fuel cell technology solutions cannot be discounted as a future contributor to the heating and energy equation for LSHTM HDP. It is a new technology in wide spread use in countries like USA and Japan, but not as such in the United Kingdom or indeed London. Hydrogen currently is reliant upon local production derived from natural gas and reformation of methane and there will be safety concerns to take into consideration due to the flammability of the hydrogen gas.
   Hydrogen production can be termed ‘blue or grey’ when derived from natural gas and methane subject to the mix. Green hydrogen has the lowest carbon impact as it is produced using renewable electrical energy streams such as wind, solar photovoltaic cells etc.
   The fuel cell option if implemented will reduce the residual carbon emissions to194,470 $KgCO_2Yr^{-1}$.

5) The option to relocate to a rural site has been considered previously and discounted.

It is likely that LSHTM can substantially reduce their current heat carbon emissions by 41% by the end of the decade from the current baseline of 2019 emissions to 870,217 $kgCO_2$ per annum.

With further investment and funding into known low carbon technologies, it is conceivable that their emissions could attain a level of 280,934 $kgCO_2$ per annum which is a commendable 81% below the current baseline heating emissions.

The UK commitment to a Hydrogen economy by 2030 suggests that hydrogen fuel cells will become more prevalent served from a central network and the potential exists to further reduce heating carbon emissions to circa 194,470 $kgCO_2$ per annum.

These residual emissions could be offset largely through the LSHTM SCIF Initiative as discussed in Section 5.6.

The Heat Decarbonisation Pathway and considerations to be taken are detailed in Fig 6.1 overleaf.

Year	HEAT DECARBONISATION PLAN [HDP]	CARBON REDUCTION Kg CO_2Yr^{-1}
2019	**BASELINE EMISSIONS**	**1,480,479**
2021	***Focus on Keppel Street*** ***Bloomsbury DEN connection terminated***	891,327
2022	***KS - Window replacement at Malet Street façade has a very insignificant saving*** ***TP1 - Recommissioning of solar thermal cells***	876,807
2023	***TP2 – Completed and Occupied*** ***KS – Cooking facilities transform from NG to electric hobs / ovens, Review Decentralising steam production.***	903,004
2024	***No 8 and No 9 Bedford Place leases expire and are removed from the campus portfolio. Keppel Street Process Steam is generated by local electrode generator*** ***Consider introduction of ASHP's, NG fired boilers to be retained for top up purposes.***	872,231
2025		872,231
2026	***KS - Completion of AHU replacement, adding to mechanically ventilated areas*** ***TP1 – review possibility of using local DEN for heating***	870,750
2027	***KS- Review benefits of ASHP's and other low carbon technologies Consider Heating modifications or migration to DEN subject to carbon factor being <0.1 $kgCO_2kWh^{-1}$***	870,750
2028	***TP2- Consider introducing new technologies to reduce carbon intensity***	870,750
2029	***KS –South Roof replacement programme completed***	870,217
2030	***KS – Gower Street Window replacement G-L4*** ***KS and TP2 – implement ASHP's or other new technologies for heating see options 1c, 2c and 1d*** ***UK Hydrogen Economy in full production***	280,934
2031	***KS – roof replacement works continue*** ***Undertake feasibility studies for Hydrogen Fuel cell and other future available technologies including utilisation of borehole water.*** ***Introduce Carbon offset programme for residual carbon emissions***	280,934
2032	***Introduce Hydrogen Fuel Cell technology***	194,470
2033		
2034	***KS – Roof replacement programme completed***	

Fig 6.1 LSHTM Heat Decarbonisation Plan

Appendices

Appendix 1

List of Information Provided by LSHTM

See Document Register attached.

Incoming document register

Project: **LSHTM_Decarbonisation Strategy**

Documents received from: **LSHTM**

Series: **<Enter here>**

Project No: **LL0048**

File Location: M:\LL0048_LSHTM_Decarbonisation_strategy\02_Document_Regs\[LL0048_LSHTM_Incoming Doc Register Rev 1 Aug 20173.xlsx]Incoming

		Day:	**14**	**15**	**19**	**20**	**24**	**26**	**28**	**04**	**05**	**24**	**25**	**26**	**04**	**30**	**07**	**21**	**17**	**06**
		Month:	04	04	04	04	04	04	04	05	05	05	05	05	06	06	07	07	08	**09**
		Year:	21	21	21	21	21	21	05	21	21	21	21	21	21	21	21	21	21	**21**
Title:	**Number:**	**Scale:**																		
F Gas Register		N/A	X																	
Sustainability Forum notes 26 Jan 21		N/A		X																
Sustainability Initial thoughts		N/A		X																
Salix Heat decarbonisation Plan **[Fundamental points for report]**		N/A		X																
ECMP plan		N/A		X																
LSHTM Temperature Heating & Cooling guidance		N/A		X																
LSHTM Masterplan		N/A																		
Utility Electricty Consumption figures		N/A			x															
District Heat Consumption Figures		N/A					x													
LSTHM Data MASTER 2015-16 to 2019-20' and District Heat Data		N/A						x												
Utility Gas Consumption figures		N/A							x											
DECs for Keppel Street and Tavistock 1		N/A								x										
9 Bedford Square Gas data 2018 to 2019		N/A								x										
RFI-8 LSHTM Energy Management Strategy		N/A									x									
RFI-17 new Keppel Street boiler spec		N/A									x									
MGP Phase 2C - RIBA Stage 3 Report		N/A									x									
RFI-21 occupancy numbers (current and projected)		N/A									x									
RFI-22 12193 Cond Survey roof KS		N/A									x									
T1 Solar Thermal Upgrade		N/A									x									
O&M Manuals		N/A									x									
RFI-22 windows refurbishment		N/A									x									
RFI-22-23 current and new Malet street windows spec		N/A									x									
Estate Gas Invoices		N/A									x									
RFI-7: Existing Keppel Plant Replacement Strategy		N/A										x								
DH Network Current Carbon Factor Information		N/A											x							
DH Network Future Carbon Factor Information		N/A												x						
DH feed in energy (Keppel)		N/A													x					
PV Maintenance Inspection Report- - LSOHTM - 2021		N/A														x				
LSHTM _SteamPlantUpdatedAppraisal (Rev 2 AECOM 04-08-15)		N/A														x				
Masterplan phases and associated infrastructure 07-07-2021		N/A															x			
RFI-7- Current and future AHUs replacement and room ventilation		N/A															x			
739-IRAL-FN-230-01 Building Fabric Information		N/A																x		
Borehole and Extraction Agreement Info		N/A																	x	
Aude Decarbonising Heat networks in University Estates	Sep-21	N/A																		x
Keppel Street Plans																				

GA_Basement Level	06-0108	1:100				3A																																
GA_LGF	06-0107	1:100				3A																																
GA_Ground Floor	06_0100	1:100				3A																																
GA_Level 01	06_0101	1:100				3A																																
GA_Level 02	06_0102	1:100				3A																																
GA_Level 03	06_0103	1:100				3A																																
GA_Level 04	06_0104	1:100				3A																																
GA_Level 05	06_0105	1:100				3A																																
GA_Level 06	06_0106	1:100				3A																																
Part roof Plan		1:100				3A																																
Gower Street Façade	06_0201	1:100				3A																																
North Courtyard West	06_0204	1:100				3A																																

Appendix 2

LSHTM Master Plan

Year	Keppel Street	Tavistock Place 1	Tavistock Place 2	8 & 9 Bedford Place
2019	***Baseline set March 2019 – February 2020***			
2020				
2021	***Disconnection from DH***	***Potential DH connection*** ***New Solar Thermal HW system 8113 kWh/yr installed Sept 2021***		
2022	***Window replacement at one elevation***	***Recommissioning of existing Solar Thermal***		
2023	***Electric induction hobs to replace gas*** ***New AHU for Kitchen / Refectory*** ***3 New AHU's L6 Roof*** ***Existing Chillers replaced*** ***Decentralise steam production and review steam backup for heating***		***Extension completed Q4***	***Removed from Portfolio Q4 2023***
2024	***Decommission gas fired steam production. Review potential for local electric steam generation.*** ***New AHU serving NCY***	***LSHTM need to consider introduction of ASHP and/or GSHP, NG fired boilers to be retained for top up purposes.***	***Occupation Q1***	
2025	***New AHU SCY offices***			

2026	***June Malet Street North Roof replaced*** ***Additional Mechanical Ventilation***	***Is a migration to local DEN possible***		
2027	***Review benefits of PV against ASHP's.*** ***Consider Malet Street Roof availability for ASHP's – what is CO_2 saving?*** ***Consider Heating modifications or migration to DEN.***			
2028	***May Malet Street South Roof replaced***		***Consider introducing new technologies to reduce carbon intensity***	
2029	***Gower Street South Roof replacement***			
2030	***Gower Street Windows replaced G -L4***		***Action heating via new technologies.***	
2031	***Keppel Street elevation Window Replacement L1-4*** ***Keppel Street Roof replacement***			
2032				
2033				
2034	***Complete window replacement programme***			

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