SOUTH BANK DECENTRALISED ENERGY FEASIBILITY REPORT

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SBEG

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Appendices (Separate document)

Executive Summary

The South Bank Employers' Group (SBEG) and London South Bank University (LSBU) were supported by the London Development Agency (LDA) to assess the feasibility of installing Combined Heat & Power (CHP) across the SBEG area.

Simple building data was collected on the major buildings in and near to the SBEG area that could play a part in determining the success of CHP across the SBEG area. This included floor area, building type and location. In addition more detailed building data has been obtained from a number of SBEG members.

120 buildings of different types were identified as potential loads for CHP, including around 15 proposed new developments.

A master planning software tool was used to assess and place the indentified buildings into strategic clusters to allow further analysis of the overall energy demand patterns for each cluster.

Potential locations for the CHP plant/energy centres were also considered and heating/cooling and private wire distribution networks were investigated for each cluster using GIS mapping to estimate the infrastructure costs.

A rating system was used to identify the key existing buildings in each cluster based on heating demand, electricity demand and distance from CHP plant. This focused the analysis on 42 existing buildings and 11 new developments.

A CHP model was then used to assess the economic viability and CO_2 emissions of each of the clusters noted below:

- Blackfriars
- South Bank
- Waterloo
- London South Bank University

Each cluster was modelled using key existing buildings, then, in addition, key existing buildings 'and' new developments were modelled. The potential Waterloo Station redevelopment was assumed as a separate analysis due to its potential size.

Further analysis included the assessment of a strategic option linking Blackfriars, South Bank and Waterloo clusters to one single CHP Plant. Trigeneration (CCHP) was also considered.

Biomass heating as a stand-by and top-up to CHP was considered providing supply chain issues can be resolved. Including biomass renewable content could make the scheme much more attractive to developers in meeting the 20% requirement of the London Mayor. This is worthy of further investigation.

1. Introduction

There are a significant number of new high densities mixed use developments being planned in the South Bank area for delivery over the next five years. Such growth in building and energy density presents a rare opportunity to develop an integrated and area wide approach to energy supply and distribution, incorporating low carbon energy generation technologies with district heating and potentially cooling networks.

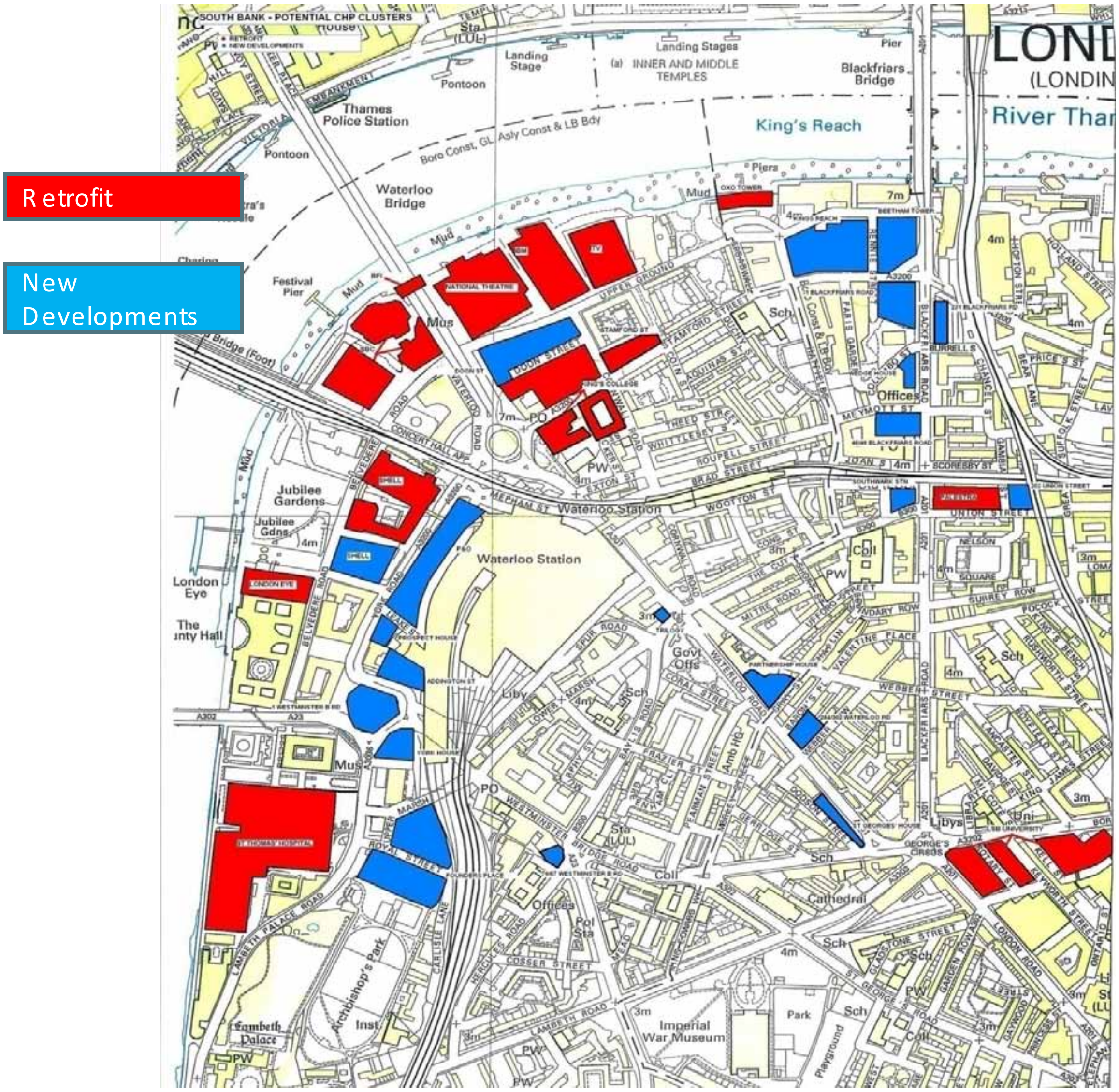

Figure 1.1 Large existing buildings and new developments in SBEG area

Such networks could potentially link together existing buildings on the South Bank, such as St Thomas' Hospital, Shell, the South Bank Arts Complex etc, with new the developments as these are delivered. The assessment and inclusion of existing buildings will help to catalyse the scheme initially, providing known & stable demand in the short term.

Such a scheme will present a significantly greater energy efficient solution to the supply of energy to these buildings and hence reduce their carbon footprint. This approach is entirely consistent with Mayoral policies and supplementary planning guidance in respect of energy efficiency and carbon reductions targets for buildings in London. In addition, the recently published Waterloo Opportunity Area Development Framework, also recognises the potential of area wide low carbon energy networks as a means of facilitating sustainable development, and proposes that this approach is explored further.

Opportunities for renewable forms of energy will also arise once the concept of a district heating network is introduced and there are likely to be other benefits, such as space saving within developments and lower operating costs for occupants

As a result of these opportunities, the South Bank Employers' Group (SBEG) and London South Bank University (LSBU) were commissioned by the London Development Agency (LDA) to assess the feasibility of installing Combined Heat & Power (CHP) across the SBEG area. This project aimed to quantify the building energy demands and analyse various energy supply options in order to estimate the likely costs, practicality, carbon savings and benefits that could delivered by adopting this approach, concluding with the identification of a recommended solution.

This report sets out:

- the work carried out
- building data collected
- an analysis of the data obtained
- key findings, conclusions and recommendations
- a brief commentary on the possible way forward

This report is based on the assumptions shown in section 4 and Appendix D that were current in mid 2008. The report summarises the work in phase 1 and 2 of the programme of work shown in Appendix F developed in early 2008.

The scope of the project extended slightly outside the SBEG area, shown in Figure 1.2, in order to ensure that large buildings and developments on the outer edge of the area that could contribute to CHP project were taken into account. The study was not restricted to SBEG members buildings but remains focused on the larger buildings in the area and is therefore dominated by SBEG members properties. A list of SBEG members is shown in Section 4. SBEG members comprise existing building operators and new build developers. The following is a list of SBEG Property Group members:

- St Thomas' Hospital
- Palestra
- Kings College
- London Eye
- British Film Institute
- Coin Street Community Builders
- IBM UK Ltd
- ITV
- London South Bank University
- National Theatre
- Shell
- South Bank Centre

Figure 1.2 The SBEG area

Key benefits for building owners, developers and property managers that could come from the introduction of CHP include:

- Lower energy running costs
- Reduced CO_2 emissions
- Reduced maintenance costs
- Less plant space required in buildings
- Helps meet the Mayor's energy planning policy

Whilst the LDA are focused on reducing emissions, building owners and property managers are motivated by increased efficiencies and reductions in operating costs. Developers are also focused on reduced CO_2 emissions in order to meet the London Mayor's energy planning policy.

2. Objectives

This reports aims to answer the following objectives:

- To estimate the annual heat, electricity and cooling energy consumption and peak demands of existing buildings and known future developments in the South Bank area, taking into account any existing district heating networks in the area and the timing of future developments;

- To identify a number of options for low-carbon energy supply and distribution to these developments and systems. Report on the technical viability of the options, including a determination of appropriate plant capacity, potential plant locations and principal infrastructure routes;

- To estimate the likely capital, operating and 25 year whole life cost of the options, when compared with a do-minimum scenario;

- To estimate the primary energy and resulting carbon savings which could be delivered by the different supply options;

- To provide recommendations on the way forward and present these to a workshop involving SBEG's members and other stakeholders.

3. Approach

The project began with an initial project meeting with SBEG, LDA to discuss the project plan, methodology and deliverables. This covered the practical issues involved in obtaining energy consumption & demand data for existing buildings, new developments and any existing district heating schemes. An introductory presentation was made to other key stakeholders at a SBEG Property Group meeting.

Simple building data was collected on the major existing buildings in and near to the SBEG area that might play a part in determining the success of CHP across the SBEG area. The data collected consisted mainly of floor area, building type and location. Initially, this was gathered by walking the area and identifying large buildings, estimating floor area and identifying the type of usage. Floor areas were then firmed up using GIS mapping to measure floor plates more accurately, leading to better estimates of total floor area.

Information about future developments was collected through SBEG which holds up to date outline information on all large schemes. Again, this consisted of mainly floor area, building type and location, alongside the likely date of construction.

Attempts were then made to gather more detailed data on each of these buildings using a questionnaire, shown in Appendix E. Information was also sought regarding the type of energy supply systems currently operated within existing buildings and developments e.g. size and capacity of principle plant, availability of space for additional plant, the distribution medium used, operating temperatures & pressures etc. Actual metered energy consumption and demand data for existing buildings was sought, but only very limited data was returned. LSBU have also attempted to identify any existing district heating/cooling schemes and proposed district heating/cooling schemes being planned in the area.

120 buildings of different types were identified as potential loads for CHP including around 15 proposed new developments. A specially developed masterplanning software tool was used to help establish clusters of buildings to allow an analysis of the overall energy demand patterns for each cluster. LSBU then developed a rating system to identify the key existing buildings in each cluster based on heating demand, electricity demand and distance from CHP plant. Potential locations for the CHP plant were then considered and the rating system was again used to concentrate the analysis on key 'focus' buildings within each cluster. Through an iterative process, the LSBU team focused the analysis around four clusters totalling forty two existing buildings and eleven new developments. Potential plant locations, heating/cooling and private wire distribution networks were then developed for each cluster. GIS mapping was then used to estimate the infrastructure costs.

Simple floor area data was used to generate energy load profiles based on standard energy benchmarks. These hourly energy demand profiles for all buildings (existing & proposed) have been integrated into an energy model which takes into account the growth in demand over time as new developments are built.

These energy supply options were then modelled against the building load patterns across a series of scenarios for each cluster. These scenarios were based on different plant configurations and operating regimes. A CHP model was then used to assess the economic viability and CO_2 emissions of each cluster CHP plant.

The project then identified possible energy supply options in terms of both technology, plant location and interconnections. Work focused on CHP supplying district heating and electricity but also considered trigeneration (CCHP) options, biomass and river water cooling. Electricity was modelled on the basis of using the distribution network as a supply route versus private wire electricity supply options. Each cluster was modelled across a combination of four different approaches, namely:

- Private wire
- Use of distribution network (DUOS)
- Heat Led control strategy
- Power Led control strategy

Each cluster was also modelled for key existing buildings only, then key existing buildings plus new developments. The potential Waterloo Station redevelopment was included in a separate analysis.

Further analysis included an assessment of a strategic option linking Blackfriars, South Bank and Waterloo clusters to one single CHP Plant. Trigeneration (CCHP) was then added as a further option to some of the leading options.

A brief analysis of the energy development/plant development/investment profile was then be carried out to provide an early view of phasing, levels of investment and investment timing. The CHP model was used in an iterative way to identify critical loads by running different scenarios and to develop different load scenarios for the piping network optimization. The modelling gradually became more detailed and the assumptions refined to identify the most deliverable, commercially viable and environmentally sustainable solution. The leading scenarios with the most economic overall approach and the greatest CO_2 reductions were then identified.

Work was then carried out to refine maps showing the distribution of the building clusters, proposed energy centre locations, the energy supply options, infrastructure routes, etc, and the system interconnections across the South Bank area. These maps show the proposed phasing of development over the next ten years.

An interim progress presentation has been made to the SBEG Property Group. A final presentation of the findings set out in this report is planned in the form of a workshop of key stakeholders, notably the SBEG property group, developers and their design consultants plus any organisations operating or planning district heating/cooling systems in the area.

4. Data collection

4.1 Building data collection process

External site visits were carried in almost the whole of the SBEG area to identify large buildings that might represent a significant energy demand in relation to CHP. Rough estimates of the floor area of the buildings were made by walking around the buildings, pacing distances, identifying building shape and counting the number of storeys etc. Pictures of all existing large buildings have been taken in order to record the location, number of storeys, building style etc. As data was obtained it was entered into spreadsheets and represented on a map. This mapping exercise clearly indicated four potential clusters of buildings with large loads, each with a good mix of new versus existing buildings.

A comprehensive building list was then developed in Microsoft Excel to log all known information about each building. This contained the following information of all the 120 large buildings identified in the SBEG area:

- Building name
- Building type
- Gross internal floor area of the building (m^2)
- Source of the information
- Corresponding cluster
- Post code
- Status of the building
- Cooling (i.e. portion of the building air-conditioned)
- SBEG member/Non member
- Address
- Website of the building
- Email address
- Phone number

Buildings known to have individual domestic boilers or room electric heating were discounted as being unsuitable for CHP. It was assumed that converting such buildings to a central system would be too expensive. In particular, this excluded a large student resident population at the universities in the area. Discussions were also held with Peabody Estates, the main social housing operator in the area, regarding their buildings but these also proved to be serviced by individual domestic boilers. It was not always possible to identify the method of heating for every building but the majority have been confirmed. Further investigation is necessary to identify the exact heating system in a small number of buildings but this should not have a major effect on the final results of the study.

In addition LSBU attempted to identify existing district heating/cooling schemes and proposed district heating/cooling schemes being planned. London Borough of Southwark provided data for seven community heating schemes they operate. London Borough ofLambeth also provided a list of community heating schemes they operate although none of these were directly relevant to the study. LSBU made every effort to identify other community energy and district heating schemes throughout the area but found none except large blocks of flats understood to have central boilers.

Google Earth software and GIS mapping was then used to refine the crude data of the remaining buildings in the spreadsheet. This provided a reasonably accurate estimate of gross internal building floor area. Where more detailed data was obtained from SBEG members this was used in the estimates.

A second, more detailed, four page questionnaire was then developed to gather further data from the SBEG member buildings, as shown in Appendix E. This questionnaire was sent by SBEG to members. This included requests for:

- Background building and contact information
- Annual energy consumption data
- Building occupancy levels and operational patterns
- Accommodation and equipment with significant influences on energy use
- Description of building services

Almost all SBEG members returned completed questionnaires. However, many of the returns were incomplete and lacked some of the detail required. Whilst these returns provided useful background material they did not provide a significant amount of detailed information and had no major influence on the studies findings. Sixteen questionnaires were returned (from twenty three sent) from:

- BFI
- Derwent London
- London Eye
- Beetham
- Delancey
- IBM
- ITV

- Guys & St Thomas'
- Kings' College London
- National Theatre
- P&O
- Park Plaza
- South bank Centre
- Scottish Widows
- Shell
- White House

As part of the above, a separate version of this questionnaire was developed to gather data on proposed new development as clearly energy data are not available pre-construction. In some cases, significant assumptions have been made regarding the completion date of future developments. The new developments are at different stages and there are more "unknowns" in buildings at planning stage than those in design. A small number of new developments are currently under construction and these have now been incorporated into the analysis as existing buildings since they are likely to be completed before CHP might be installed as a result of this work.

Later in the project a second supplementary questionnaire was sent to all the 'focus' buildings via SBEG, see Appendix E. This aimed to identify:

- Electrical supply, voltage, incomers, transformers etc
- Heat supply, boiler output, boiler room location etc.
- Cooling supply, chiller output, chiller room location etc.
- Future plans to install CHP
- Any existing connections to district heating/cooling schemes
- Current gas and electricity prices

Only five questionnaires were returned (from forty two sent) from:

- Delancey
- IBM
- ITV
- Shell
- White House

Few of these supplementary questionnaires were returned. As a consequence, some assumptions have had to be made about some buildings. Site visits were conducted at St Thomas' Hospital, three Kings College buildings and to three buildings in the South bank Centre. Potential plant locations have been visited including the undercrofts under Waterloo Bridge. Potential pipework routes have also been walked to identify any major practical constraints.

4.2 Overview of building data collected

The following provides an overview of the building data collected. Figures 4.1 and 4.2 show the total number of buildings identified by type and size. Initially, some 130 building were identified but around 120 were put forward into the ranking system for further analysis.

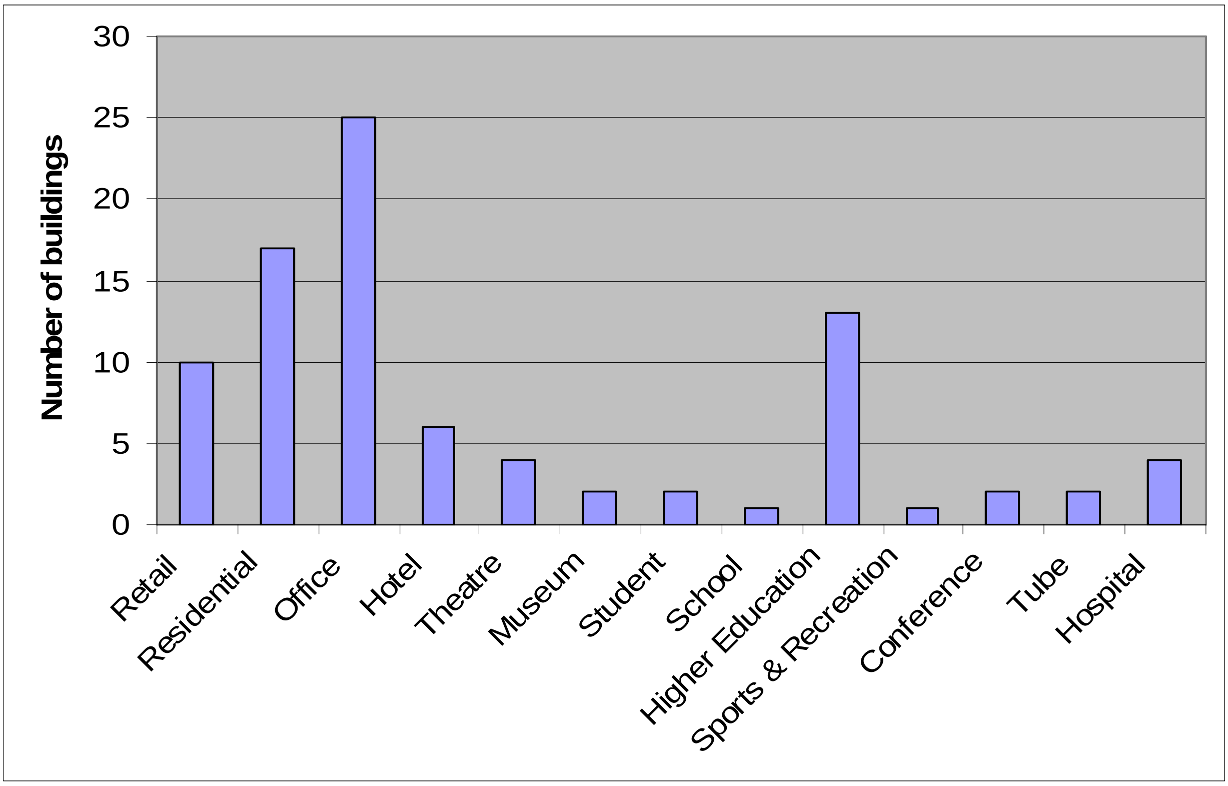

Figure 4.1 Total buildings by type

The overall number of buildings considered is dominated by offices and residential properties. Offices comprise around 47% of the floor area, residential 20% and hotels 12%. Table 4.1 shows the top 30 buildings by size. Buildings with mixed use were split into separate entries and each type of space was modelled separately.

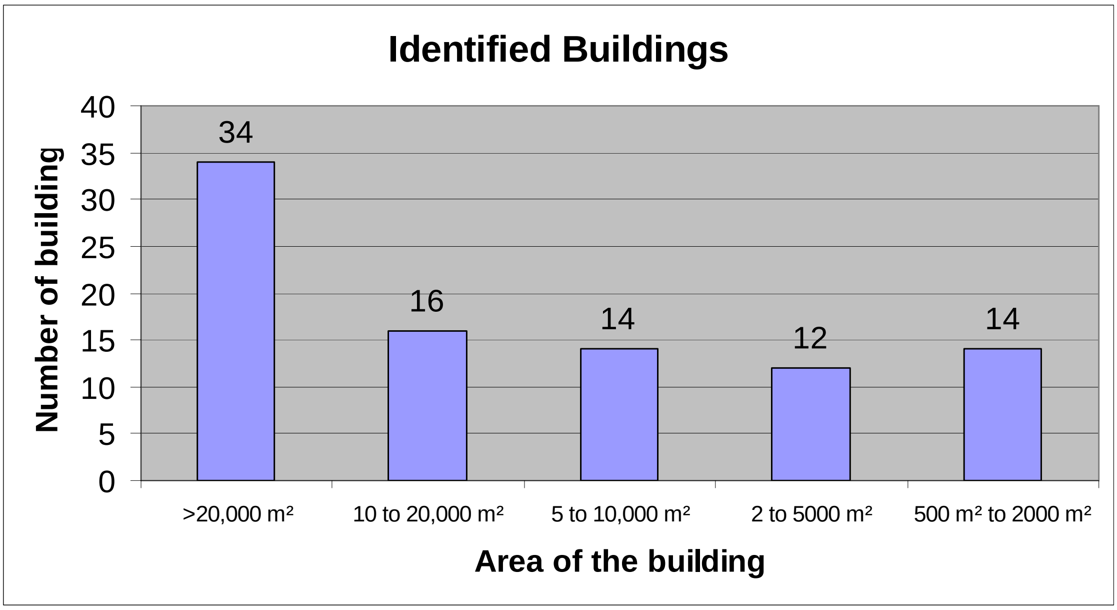

Figure 4.2 Total buildings by size

Building Name	Building Type	Area (m²)
Waterloo Station - Hotel	Hotel	120744
Elizabeth House - Office	Office	104477
Waterloo Station - Office	Office	95922
20 Blackfriars Road - Residential	Residential	83915
Shell Centre	Office	69765
King's Reach Tower - 2011 Development	Office	64286
St. Thomas' Hospital (North Wing)	Hospital	54014
Bank Side - 1	Office	46452
King's College (Franklin Wilkins Building)	Higher Education	44967
County Hall (All 4 Blocks)	Residential	44338
Sea Containers House	Office	43392
LSBU Eileen House - New - Offices	Office	43000
ITV	Office	40000
White House	Residential	36719
Beetham Tower - Hotel	Hotel	36267
Waterloo Station - Residential	Residential	36000
IBM UK Ltd - Sampson House	Office	35887
London County Hall - Hotel	Hotel	35508
York House - Office	Office	31825
Becket House, Ernst & Young - Office	Office	31562
St. Thomas' Hospital (South Wing)	Hospital	31338
St. Thomas' Hospital (Lambeth Wing)	Hospital	31201
National Theatre	Theatre	30483
LSBU Eileen House - New - Residential	Residential	27000
Skipton House	Office	26824
Beetham Tower - Residential	Residential	26808
Doon Street - Residential	Residential	26000
20 Blackfriars Road - Office	Office	25769
Kings Reach Tower - Existing	Office	25455

Table 4.1 Top 30 buildings by size

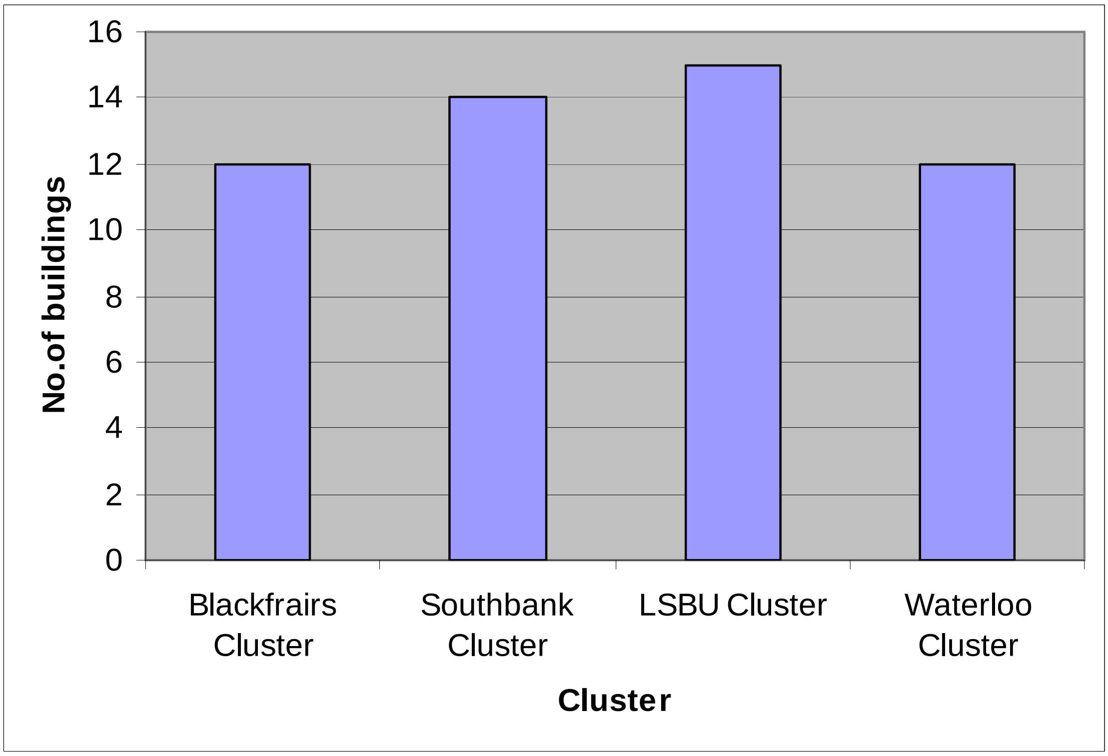

Figure 4.3 Focused buildings in each cluster

Following the ranking process and a number of iterations through the CHP model, fifty three 'focus' buildings were identified as shown in Figure 4.3. These went forward into a full economic analysis of each cluster.

5. Modelling

Analysis was based on an existing CHP model and a load profiling tool developed jointly by LSBU and Carbon Descent under a knowledge transfer programme. The load profiler was extended to include new types of buildings, cooling loads etc as part of this study.

A building data spreadsheet holds the data from all buildings considered. Excluded buildings were removed and a cut down data set of floor area, building type etc was used as the basic input file. This input data file was fed to a specially developed master planning tool which allowed LSBU to switch individual buildings in and out to form clusters. This iterative cluster analysis gave rise to the final four clusters.

The load profiler was then used to create heat, power and cooling demand energy load profiles for each cluster based on typical energy benchmarks. This iterative modelling process is shown in Figure 5.1.

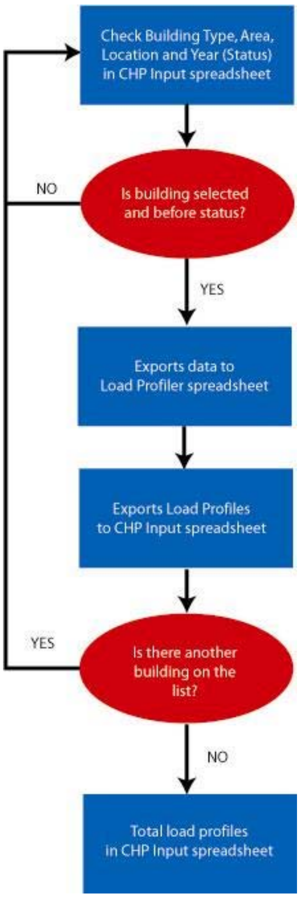

Figure 5. 1 Iterative modelling process

Using the load profiler masterplanning tools it was possible to develop load profiles for an entire area (cluster of buildings) to be supplied by a single CHP plant. Figure 5.2 shows an example of the CHP master planning software. These cluster energy profiles - a summation of the energy loads of between 15 to 30 buildings- were used as the input to the main CHP analysis model.

	Building Name	Building Type	Area	Source	Location	Post Code	Status	Cooling
✓	Waterloo Station	Office	185806	SBEG	B	SE1	2015	✓
	Waterloo Station	Residential	111483	SBEG	B	SE1	2015	
✓	Elizabeth House	Office	104477	SBEG	B	SE1 7NQ	2011	✓
✓	20 Blackfriars Road	Residential	83915	SBEG	A	SE1 8NY	2011	
	Waterloo Station	Retail	74322	SBEG	B	SE1	2015	✓
✓	Shell Center	Office	69766	uestionnare Recei	B	SE1 7NA	2007	
	King's Reach Tower	Office	64286	SBEG	A	SE1 9LS	2011	
✓	St. Thomas' Hospital (North Wing)	Hospital	54014	James Murphy	D	SE1 7EH	2007	✓
✓	Bank Side - 1	Office	46452	www.bankside123	A	SE1 0SU	2007	✓
✓	King's College(Franklin Wilkins Building	Higher Education	44967	uestionnare Recei	B	SE1 9LX	2007	
	London Development Agency	Office	44408	GIS Mapping	A	SE1 8AA	2007	
✓	County Hall (All 04 Block)	Hotel	44338	GIS Mapping	D	SE1	2007	
✓	Sea Containers House	Office	43392	GIS Mapping	A	SE1 9PF	2007	✓
✓	ITV	Office	40000	uestionnare Recei	B	SE1 9LT	2007	✓
✓	White House	Residential	36719	GIS Mapping	D	SE1 7NA	2007	✓
	Beetham Tower - Hotel	Hotel	36267	SBEG	A	SE1 9LW	2011	✓
✓	IBM UK Ltd - Sampson House	Office	35887	SBEG	A	SE1 9JH	2007	✓
✓	London Marriott County Hall	Hotel	35508	GIS Mapping	D	SE1 7PB	2007	✓
✓	London County Hall	Conference	35508	GIS Mapping	D	SE1	2007	✓

Figure 5.2 An example of the CHP master planning software

This main CHP model contains detailed information on costs and efficiencies for a wide range of CHP units from major UK manufacturers and suppliers. This model outputs technical information like "hours run", "engine inputs" and "outputs" etc. It also provides an economic analysis showing simple payback period, net present value (NPV) and internal rate of return (IRR). The model also provides an environmental assessment with outputs like CO_2 emissions, CO_2 per £ invested, CO_2 per NPV etc. The model analyses a ranges of CHP sizes and the CHP plant with the best IRR was selected as the optimum. An example of the output for the CHP analyser is shown in Figure 5.3.

Cash Flow Result		1	2	3	4	5	6	7	8	9
Unit Size	kWe	2,000	2,433	2,745	3,047	3,995	5,100	6,800	8,500	10,200
Control Strategy		Heat Led	Heat Led	Heat Led	Heat Led	Heat Led	Heat Led	Heat Led	Heat Led	Heat Led
Main Revenues										
Electricity	£k/a	782.2	946.4	1,055.6	1,134.5	1,455.7	1,695.8	1,806.2	1,556.6	1,396.7
Heat Sale	£k/a	366.7	397.6	473.4	512.0	496.6	617.0	919.6	929.6	1,018.6
CCL Fue	£k/a	23.3	25.3	30.1	32.6	31.6	39.2	58.5	59.1	64.8
CCL Elec	£k/a	60.4	73.0	81.4	87.5	112.3	130.8	139.4	120.1	107.8
Other Sa	£k/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Revenues										
Electricity	£k/a	0.6	2.9	4.6	7.5	25.2	51.0	115.0	255.3	413.0
Heat Exp	£k/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ROCs tra	£k/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CO2 Trad	£k/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other	£k/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Operating Costs										
CHP Fue	£k/a	-702.5	-779.6	-881.5	-952.8	-1,223.3	-1,399.5	-1,603.4	-1,657.8	-1,816.1
CHP Mai	£k/a	-62.3	-73.3	-80.9	-89.8	-106.0	-135.3	-160.3	-200.4	-240.5
Imported	£k/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Boiler Fu	£k/a	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Duos Cha	£k/a	-92.6	-112.1	-125.0	-134.4	-172.4	-200.9	-213.9	-184.4	-165.4
NET CASH	***£k/a***	***375.8***	***480.2***	***557.7***	***597.1***	***619.7***	***798.3***	***1,061.1***	***878.0***	***778.8***
Financial Results										
Estimated	£k	-4,672.0	-5,034.0	-5,294.8	-5,315.7	-6,036.2	-6,488.4	-7,651.2	-8,814.0	-9,976.8
Capital Gra	£k	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Loan	£k	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Simple Pay	years	12.4	10.5	9.5	8.9	9.7	8.1	7.2	10.0	12.8
Net Preser	£k/a	-659.6	112.9	695.4	1,124.4	527.4	2,047.1	3,691.5	197.6	-2,330.6
Internal Ra	%	8.3%	10.3%	11.5%	12.4%	11.0%	13.5%	15.3%	10.3%	7.1%

Figure 5. 3 Example output from CHP model

6. Inputs

6.1 Building Clusters

The SBEG area is shown in Figure 6.1 as the basis for developing the building clusters. Using a combination of pin board maps and the master planning tool, four main clusters were identified comprising the bulk of the main buildings identified by the building data collection process. The four clusters are shown in Figure 6.2. There was a noticeable lack of clusters of large suitable buildings between LSBU and South Bank area.

Figure 6.1 The SBEG area

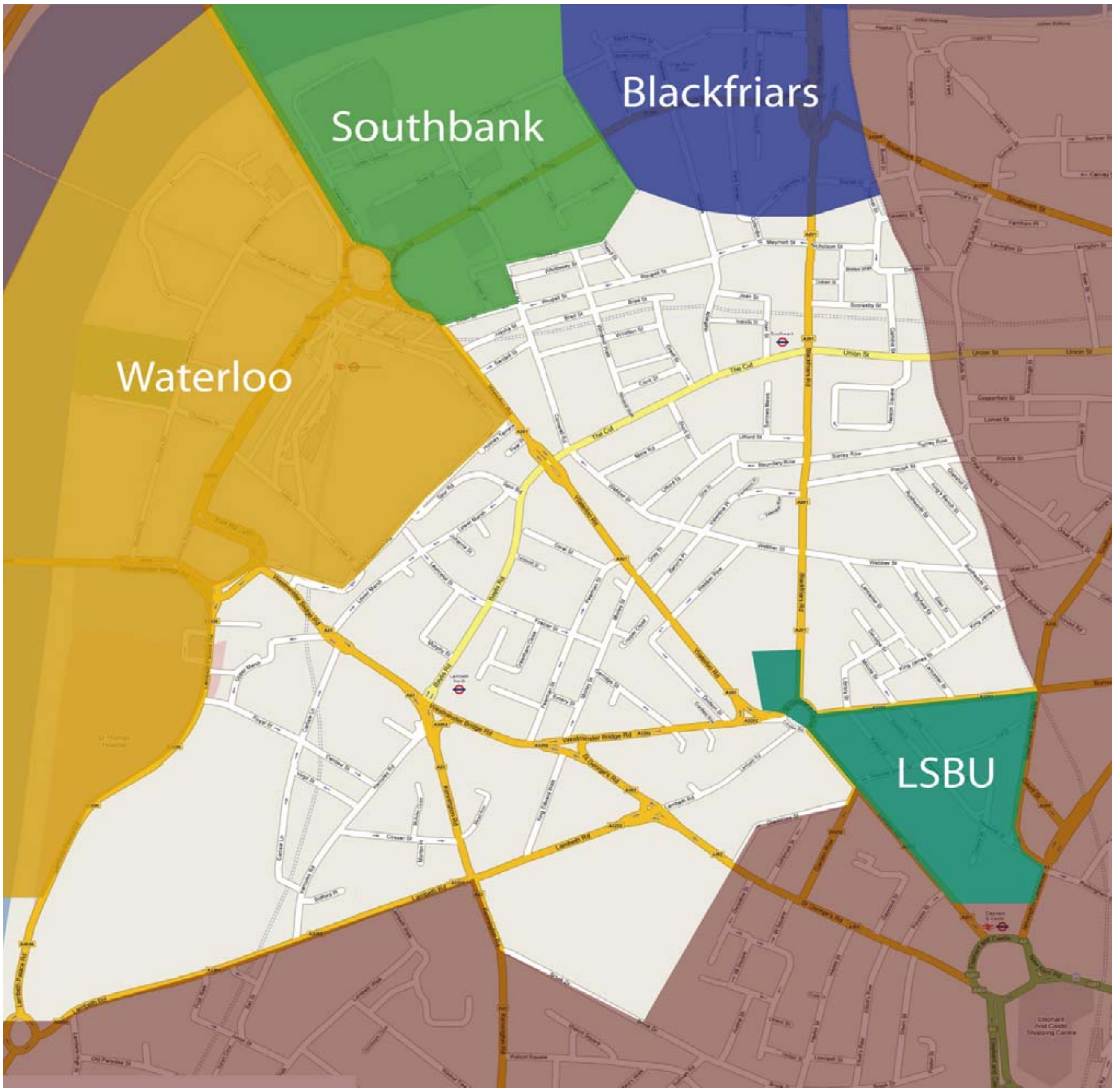

Figure 6.2 Four main building clusters

A series of potential CHP plant locations were identified within these clusters. Seven potential CHP central plant locations were then identified within these areas. They are:

- London South Bank University
- St. Thomas' Hospital
- Leake St. (near Waterloo)

- Southbank Centre
- Waterloo Road
- Shell Centre
- Blackfriars Bridge

Further investigation from site visits resulted in four particular locations then being identified as most suitable and these are shown in Figure 6.3. These were selected because they were reasonably central within the clusters and within the spread of large buildings already identified. They also had the following benefits:

Leake Street (Waterloo) – railway arches in a little-used street that are likely to present relatively easy to obtain space with low commercial value and low rental/purchase costs to the project. Close to Waterloo Station it presents a range of supply opportunities including supplying electricity to Network Rail for the tracks (not analysed) and to the massive proposed new development of the station. Although the arches themselves are relatively small, each arch could probably hold a 3MWe CHP plant to form a modular arrangement.

Waterloo undercroft (Southbank) – a series of under crofts underneath the southern end of Waterloo Bridge facing on to the Imax concourse. Owned by the South bank Centre, these spaces are currently used as storage and are likely to present relatively easy to obtain space with low commercial value and low rental/purchase costs to the project. However, it is understood that there are proposals to convert them into retail space but this has not been confirmed. Close to a 66kV EDF substation it presents easy connection to the local electrical distribution network. Although the undercrofts are unusual shapes, they are relatively large and could probably hold a series 3MWe CHP plant to form a very large modular arrangement.

Blackfriars Road (Blackfriars) – railway arches under the southern end of the old Blackfriars Bridge. Currently used as a car park for Ludgate House they are likely to present relatively easy to obtain space with low commercial value and low rental/purchase costs to the project. Close to the proposed Beetham Tower development it presents a central location in this cluster. The arches themselves are relatively large. Each arch could probably hold a 3MWe CHP plant to form a modular arrangement.

J Block LSBU (LSBU) – redevelopment and extension to J Block plant room on the LSBU campus. Currently this holds boiler plant with a small district heating network between buildings. LSBU have been keen to get CHP on site for some time for teaching, research and showcasing purposes as well as carbon reduction. This space should not present a great problem to obtain if the existing boilers are replaced and would have relatively low commercial value and low rental/purchase costs to the project. This plant room is at the heart of the campus and could be linked to the new Centre for Efficient and Renewable Energy in Buildings (CEREB) a teaching, research and showcasing space to be opened in early 2010. Although the plant room is relatively small, it is anticipated that the main CHP plant would sit outside this in a glass plant room to allow easy viewing. This space could probably hold a 3MWe CHP plant.

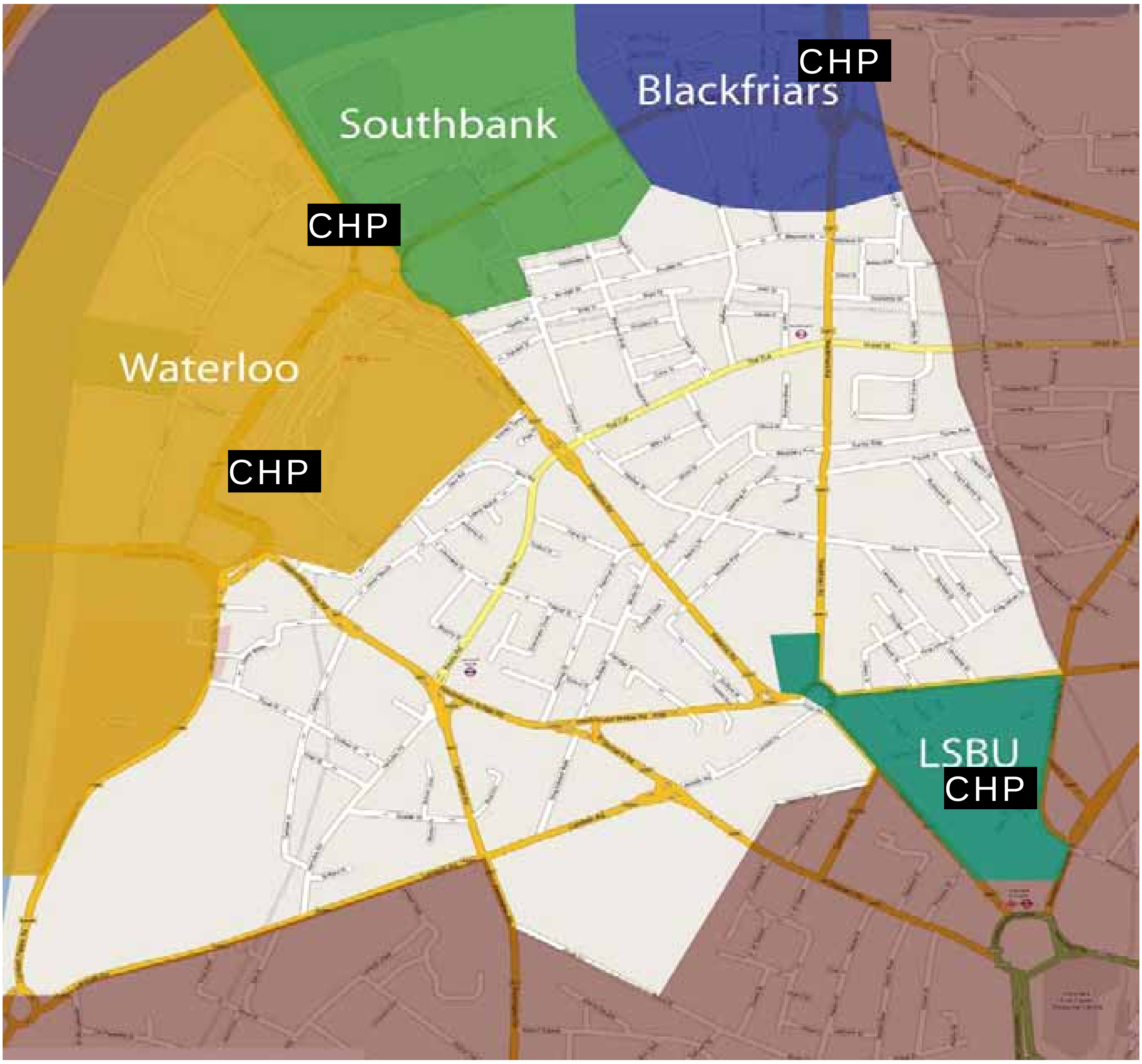

Figure 6.3 Four main CHP locations selected

6.2 Selection basis

Having identified the CHP locations shown above, it was then possible to rank the buildings based on their suitability to be connected to the plant. A building rating system was developed to assess the potential each building had in relation to a cluster around a selected CHP location. Buildings with individual domestic boilers were excluded and the remaining rating was based on annual heat load, annual electrical load and distance from the CHP, as shown below. Building ownership also contributed as it was thought to be easier to engage with public sector organisations, followed by SBEG members.

Community Boiler
- Yes: 1
- No: 0

Annual Heat Load (15%)
- >10,000 kWth: 15
- >5,000 kWth: 10
- >2,500 kWth: 6
- >1,000 kWth: 3
- >500 kWth: 1
- <500 kWth: 0

Annual Power Load (15%)
- >5,000 kWe: 15
- >2,500 kWe: 10
- >1,500 kWe: 6
- >1,000 kWe: 3
- >500 kWe: 1
- <500 kWe: 0

Building Ownership (10%)
- Public Building: 5
- Private Building & SBEG member: 3
- Private Building & non-SBEG member: 0

Pipework Distance (60%)
- <50m: 60
- <100m: 48
- <150m: 36
- <250m: 24
- <400m: 12
- >400m: 0

Table 6.1 Criteria for ranking buildings

The rating was calculated out of 100 as follows:

Rating = Community Boiler x (Peak Load + Building Ownership + Piping Distance)

The final rating list is shown in Appendix A. This is based on existing buildings only, as these were believed to be the main driver for initialising and initiating a CHP project started. Nearby new developments were then added in to each cluster to reach the 'focus' buildings shown in Table 6.2 This focused the analysis on forty two existing buildings and eleven new developments across four clusters: Waterloo, South Bank, Blackfriars and LSBU.

Alongside these buildings four other small outlying clusters of more distant, but high energy load, buildings were tested:

- Three large Bankside buildings (Blackfriars)
- Palestra and others (Blackfriars)
- Maclaren House and others (LSBU)
- Scovell Estate district heating and others (LSBU)

When run through the economic model, all four additional outlying clusters proved to be uneconomic due to the distance from the CHP plant and hence the additional pipework costs. These buildings were then discounted from the analysis leaving the focus buildings shown in Table 6.2

BLACKFRIARS	LSBU	SOUTHBANK	WATERLOO
IBM UK Ltd - Sampson House	LSBU Bourough Road Building	National Theatre	Park Plaza County Hall
Ludgate House	LSBU Keyworth House	South Bank Centre - Royal Festival Hall	Shell Centre
Falcon Point DH Scheme	LSBU Tower Block	White House	County Hall (All 4 Blocks)
Mad Hatter Hotel	LSBU E - Block	King's College (FWB Waterloo Bridge Wing)	St. Thomas' Hospital
Sea Containers House	LSBU J Block	Queen Elizabeth Hall Southbank Centre	London County Hall
Kings Reach Tower	LSBU M - Block	King's College (Franklin Wilkins Building)	Becket House, Ernst & Young
River Court	LSBU London Road	King's College (James Clerk Maxwell Building)	
Rennie Court	Borough Rd Residential - Mathieson Court	IBM UK Ltd	
OXO Wharf Tower	LSBU Technopark	IMAX British Film Institute	
	LSBU Perry Library	ITV	
	LSBU Faraday Wing	Coin Street Community Apartments	
	LSBU LRC	Southbank Centre -Art Gallary	
	Perronet House	BFI - MOMA Building	
	Skipton House		
Beetham Tower	Eileen House	Doon Street	Prospect House
20, Blackfriars Road			Founders Place
Kings Reach Tower			York House
			Elizabeth House
			Waterloo Station
			1 Westminster Road

(Yellow = existing buildings, blue = new developments)

Table 6.2 Focus buildings included in final analysis

6.3 Energy demand patterns

Simple floor area data and standard demand patterns were used to generate energy load profiles based on standard energy benchmarks. Figures 6.4 to 6.6 show an example energy demand profile for an existing 10,000m2 office block during a weekday.

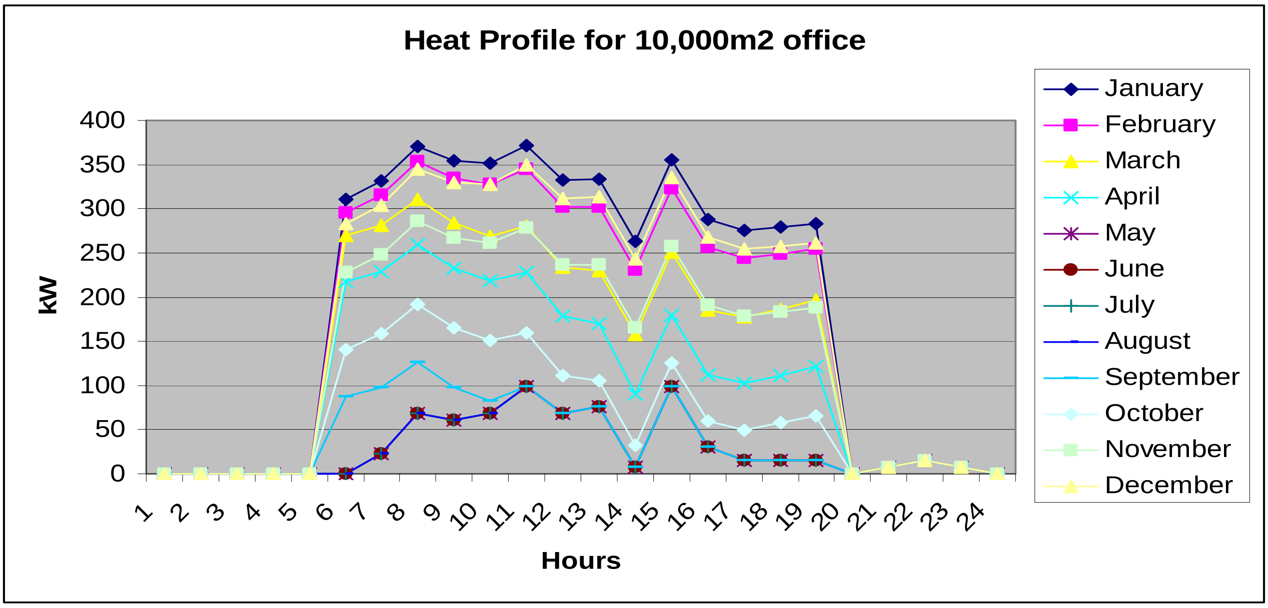

Figure 6.4 Typical heat load profiles for a large office

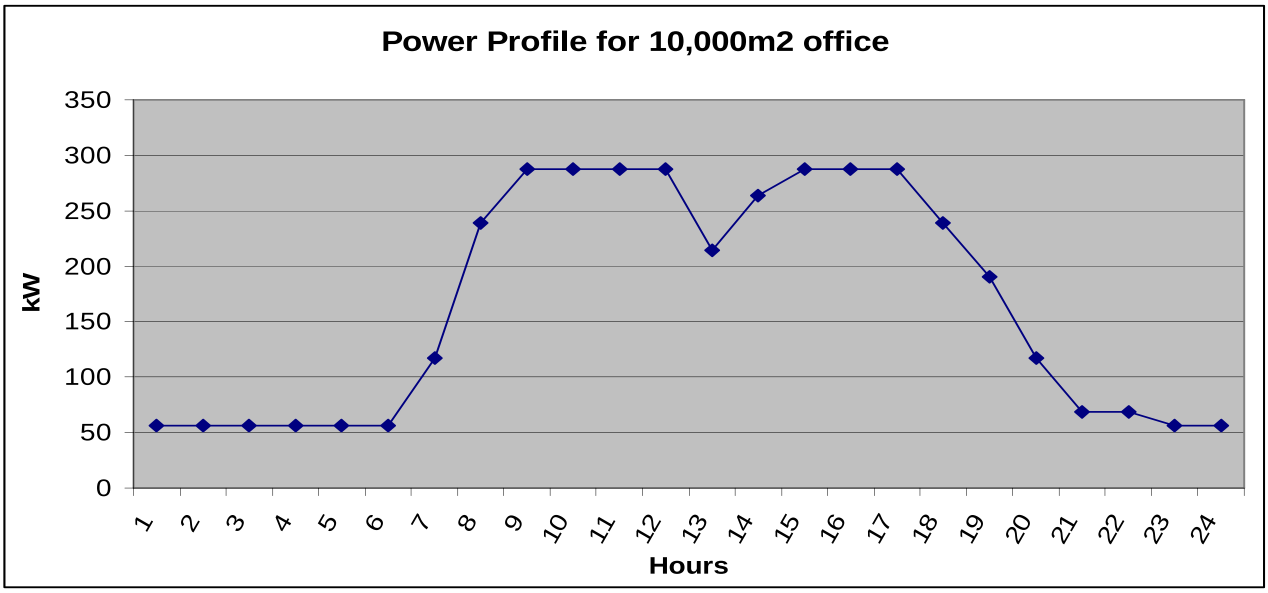

Figure 6.5 Typical power profile for a large office

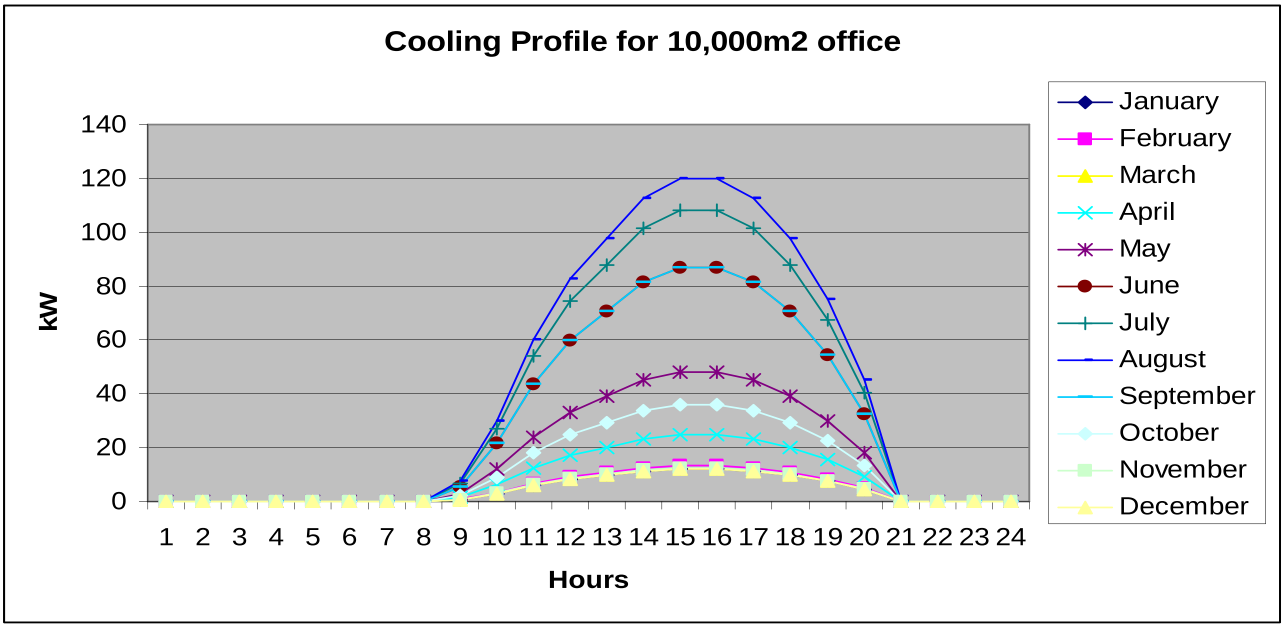

Figure 6.6 Typical cooling load profiles for a large office

Both existing and new buildings were modelled using CIBSE Guide F benchmarks good practice benchmarks, providing a conservative approach to the demands. New buildings are assumed to have a 20% space heating reduction over these benchmarks to reflect modern construction methods.

Once the clusters were established, the load profile and master planning tools were used to form demand patterns for each cluster of buildings as an input to the economic CHP model. The following example of a cluster consisting 12 existing buildings including office, residential and hotel building types.

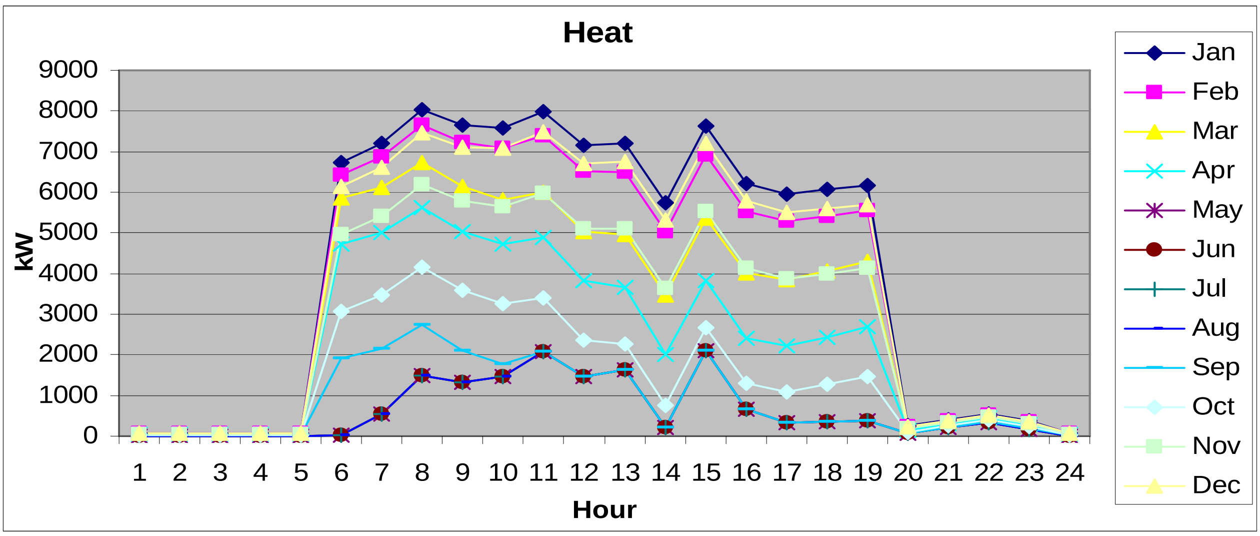

Figure 6.7 Heat demand profiles for an example cluster

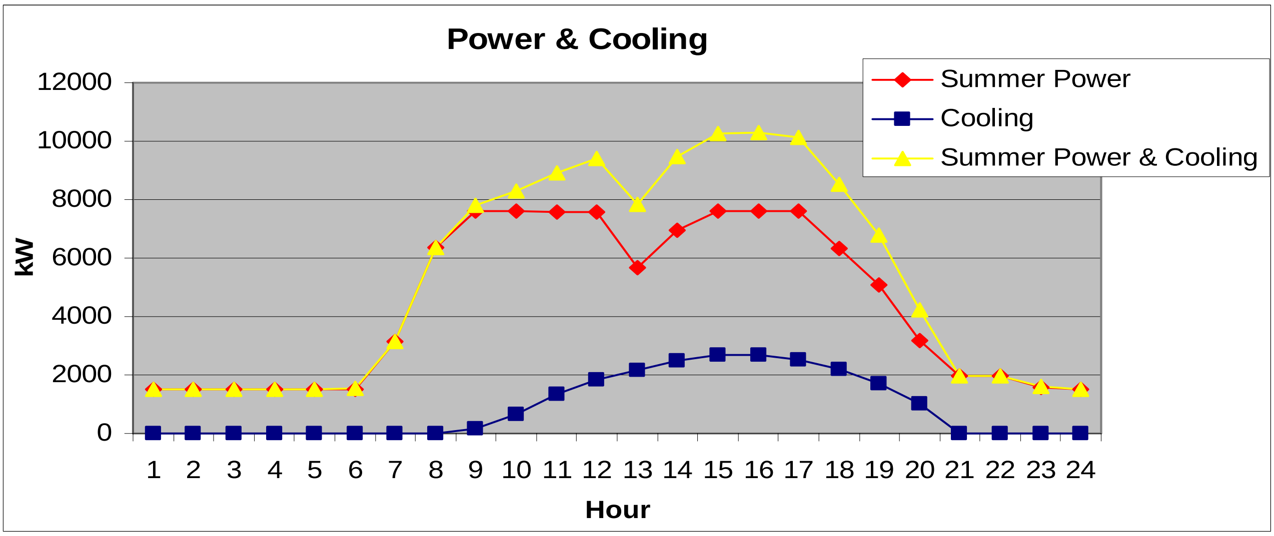

Figure 6.8 Power and cooling demand profiles for an example cluster

Actual demand profiles for the clusters containing the focus buildings are shown in Appendix B. The peak demands in each cluster are shown in Table 6.3. The proposed Waterloo Station redevelopment is so large that this cluster was analysed with and without the station development.

It became apparent from the cluster mapping and analysis that the three clusters along the river could be connected, providing a more strategic approach. Also, it was apparent that the LSBU cluster is too far away for it to be economic to connect to the other three. A strategic option was therefore developed to amalgamate the three riverside clusters, Blackfriars, South Bank and Waterloo with one large plant room at its centre. This is shown in more detail in Section 6.4

Scenario	Peak Heat Demand (MW)	Peak Power Demand (MW)
Blackfriars	32	26
South Bank	29	11
LSBU	11	8
Waterloo (ex Station development)	27	20
Waterloo (inc Station development)	39	28
Strategic (3 clusters)	100	63

Table 6.3 Approximate peak energy demands (including new developments)

Blackfriars cluster – a mix of office space and residential properties with three large office/residential developments including Beetham Tower.

South Bank cluster - comprises the major theatres and arts centres on the South bank, such as the National Theatre and the Royal Festival Hall which accounts for the heat and power loads in the late evenings. It also includes Large Kings College university buildings, ITN, IBM and some residential buildings.

LSBU cluster - comprises university offices, libraries, lecture halls although the university halls of residence are not included as they are too far away. Two other residential blocks and a large office are included.

Waterloo cluster – includes the Shell Centre and Ernst & Young offices, County Hall with a number of large residential blocks plus St. Thomas' Hospital. However St Thomas's hospital will have its own CHP by early 2009 and the demand profiles have been adjusted to account for this fact. The Waterloo cluster also includes a number of large new office and residential blocks.

It is clear from the cluster heat and power profiles that there is very little demand at night. The economic model has therefore assumed that the CHP will not run at night i.e. between midnight and 6am (usually uneconomic due to lower cost of grid electricity during the night).

6.4 Pipework networks

Having determined the building clusters, cluster energy demands and the most likely CHP plant locations, it was then possible to establish proposals for pipework routes and approximate sizing. By including approximate energy centre costs, private wire costs etc it was possible to estimate the overall capital costs of each scenario.

The pipework runs were then optimised to minimise length and likely disruption during installation. This resulted in the pipework networks shown in Figure 6.9 to 6.14 below. These figures were developed using GIS mapping software and this allowed accurate measurement of pipe lengths for each cluster and scenario. The green box indicates the CHP Energy Centre. The blue lines are heat pipe connections to new developments and the red lines are heat pipes to existing buildings.

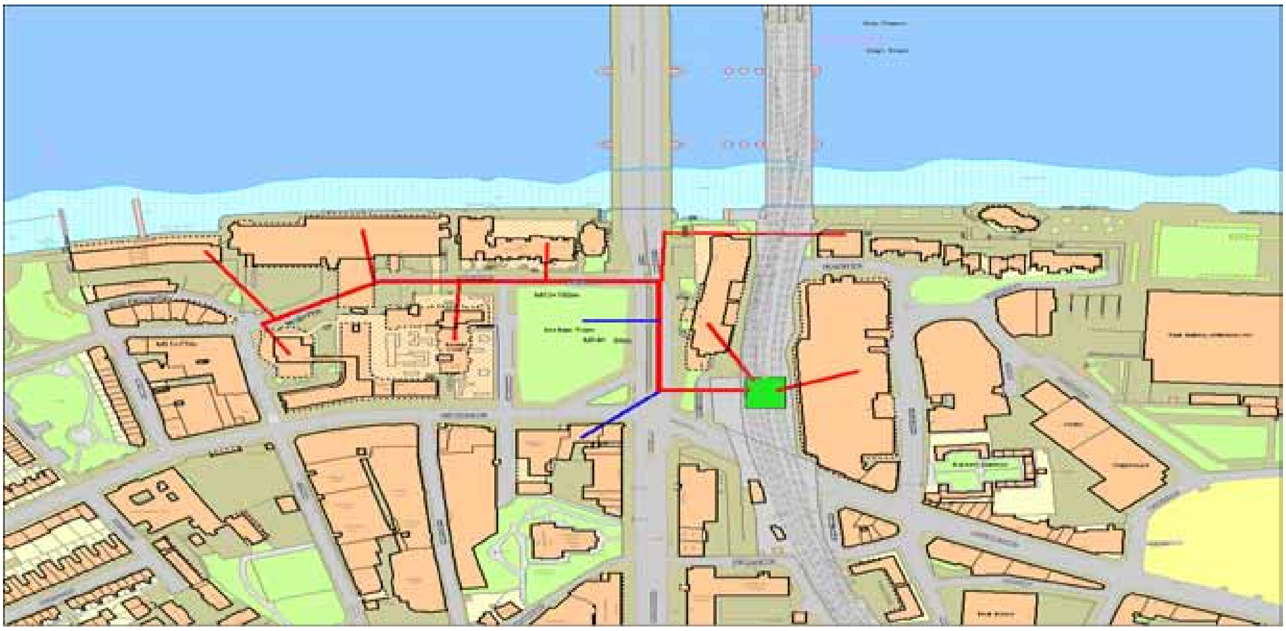

Figure 6.9 Blackfriars cluster pipework (Estimated pipework cost ~ £0.98m)

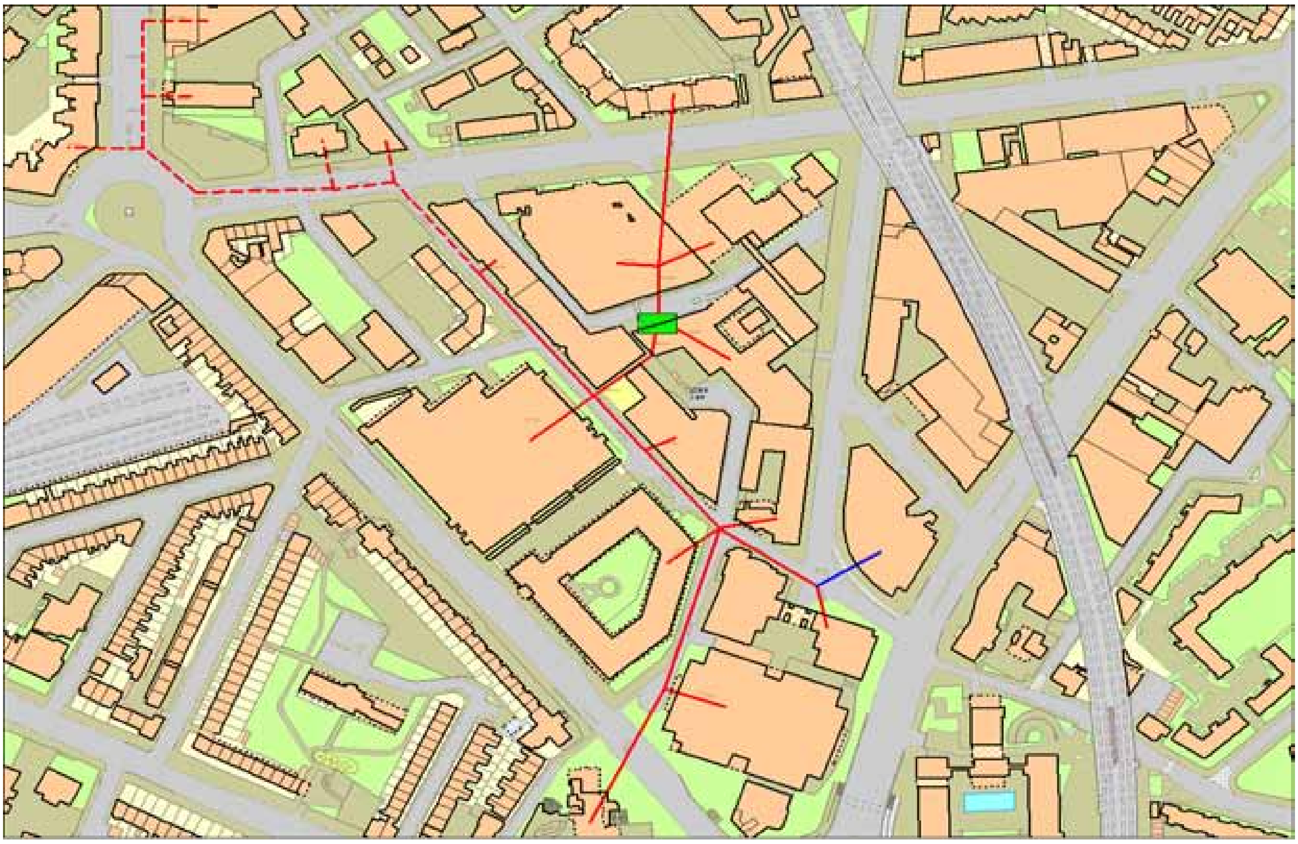

Figure 6.10 LSBU cluster pipework
(Estimated pipework cost - £0.7m exc dotted, Maclaren House test)

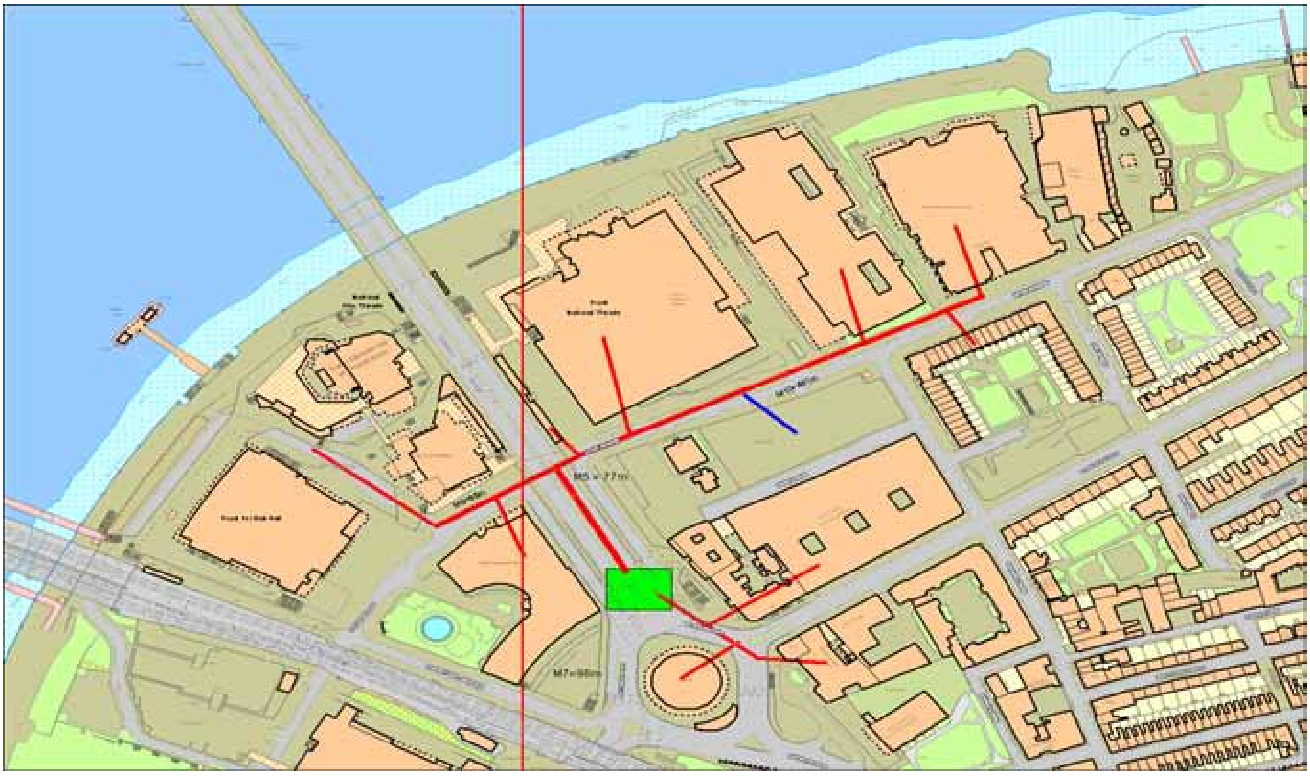

Figure 6.11 South Bank cluster pipework (Estimated pipework cost - £1m)

Figure 6.12 Waterloo cluster pipework (Estimated pipework cost - £2.0m)

Figure 6.13 shows how all four clusters relate to each other, clearly indicating the proximity of the three riverside clusters but the considerable distance to the more outlying LSBU cluster. Investigations showed that there are very few suitable large buildings with significant energy loads in between these two groups. Figure 6.14 shows some early thoughts on a ring between the four clusters but this approach was quickly dropped for the same reason and the excessive capital cost associated with this option.

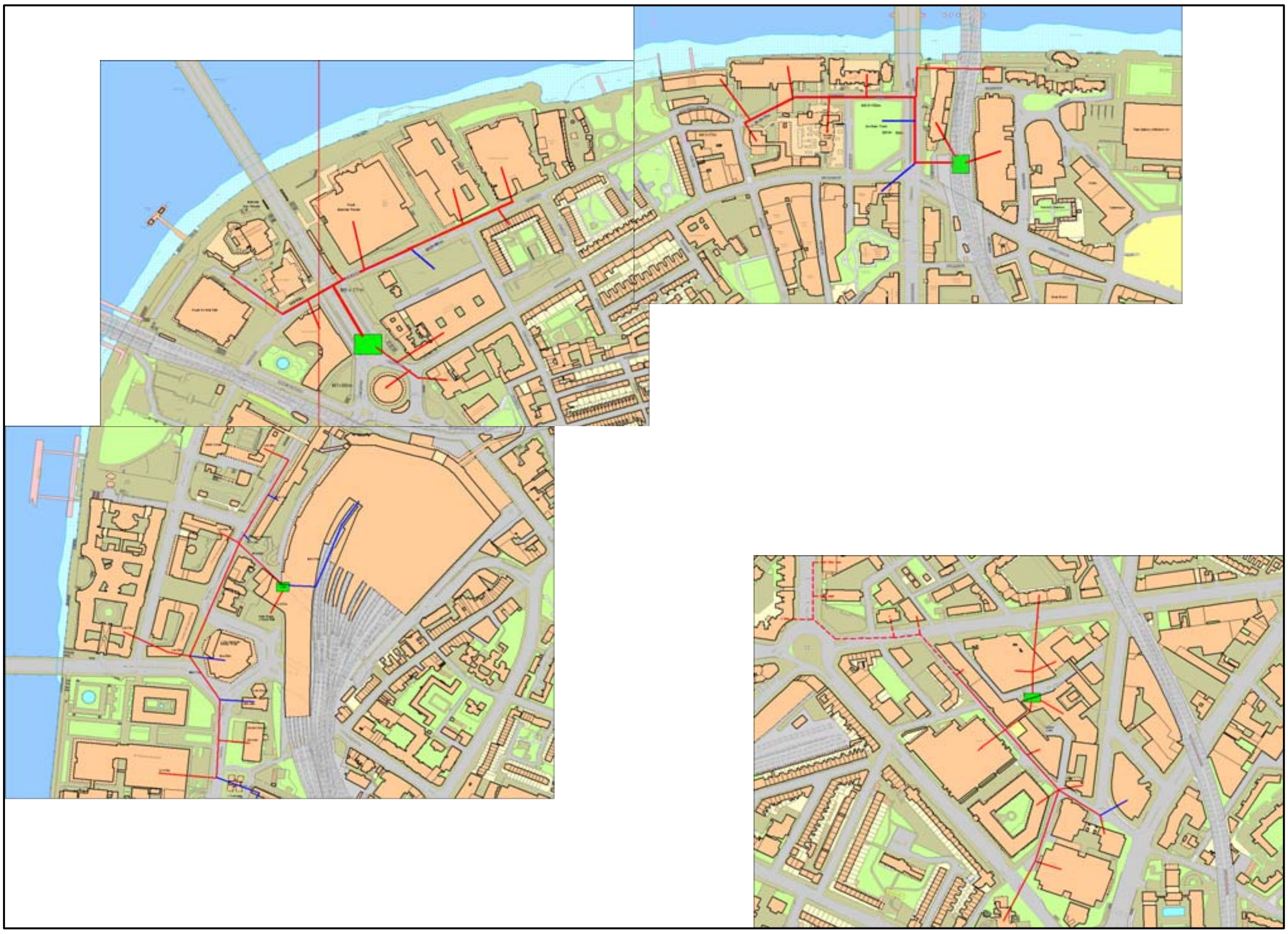

Figure 6.13 Four clusters shown together

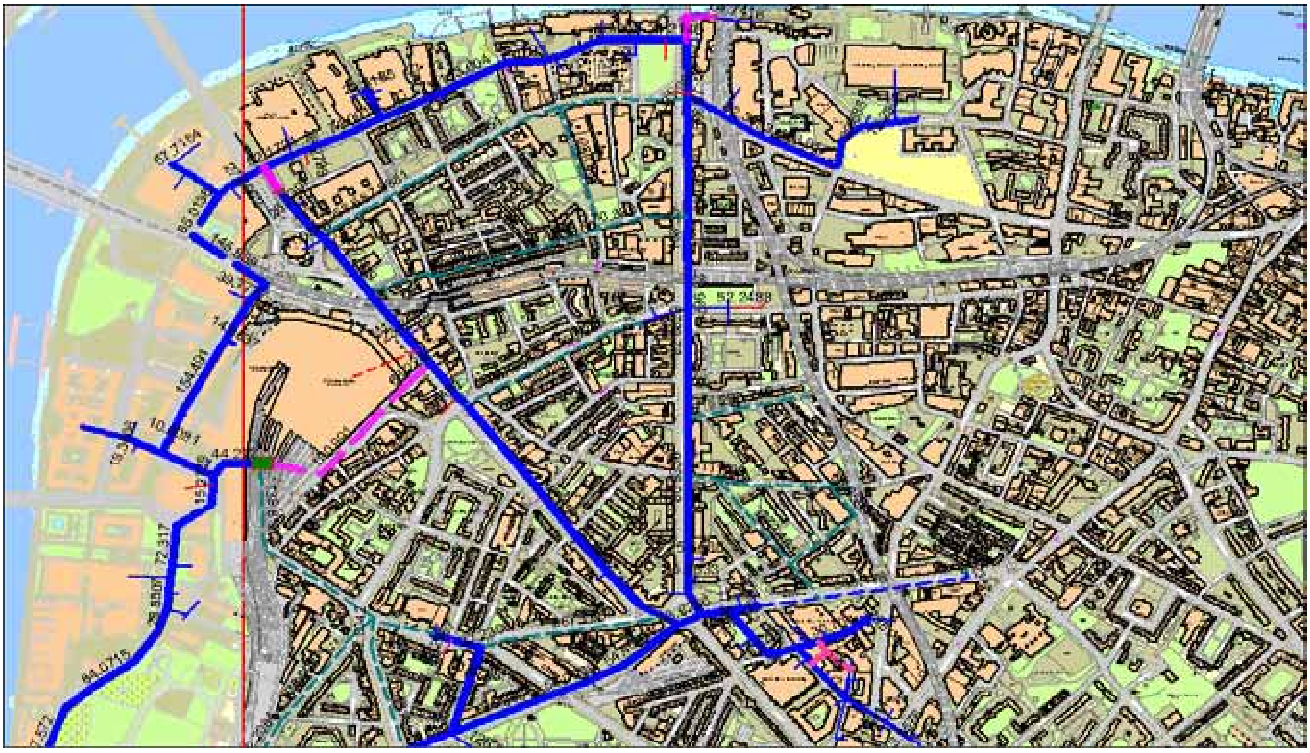

Figure 6.14 Early ideas for a pipework ring connecting all four clusters

It became apparent from the cluster mapping and analysis that the three clusters along the riverside could be connected, providing a more strategic approach. Also, it was apparent that the LSBU cluster is too far away for it to be economic to connect to the other three. A strategic option was therefore developed to amalgamate the three riverside clusters, Blackfriars, South Bank and Waterloo with one large plant room at its centre. The main pipework has been designed/sized to provide a system that can take on additional loads and be extended at either end which is not the case with the individual cluster pipe work. This is shown in Figure 6.15.

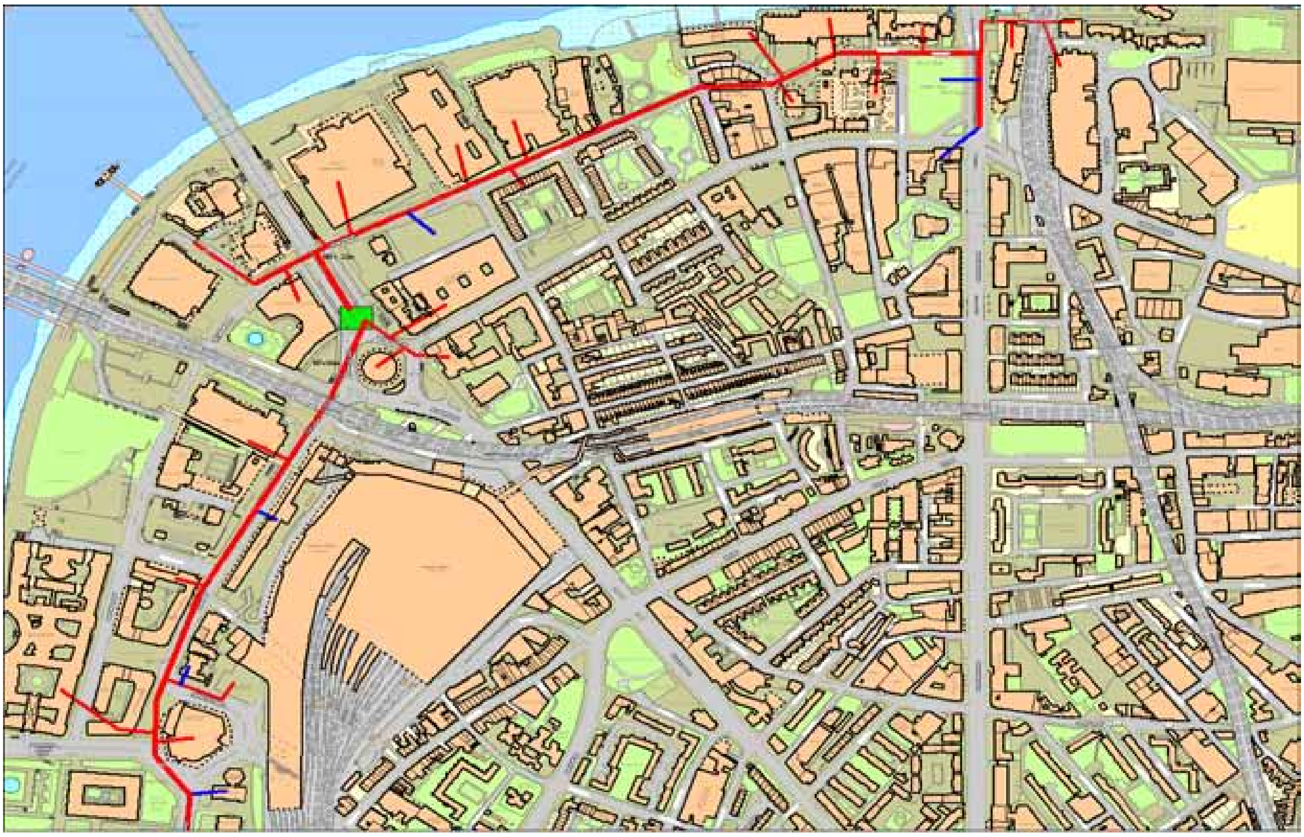

Figure 6.15 Strategic pipework connecting three clusters (Estimated pipework cost - £8.9m)

7. Renewable options

7.1 Biomass

An option for low carbon heating could comes from the use of biomass. The heat produced from biomass boilers could be used as a top-up to that provided by the CHP. The two typical fuels used in biomass processes are wood chip and wood pellet. Wood chip fuel is cheaper than pellets as chips are essentially unprocessed. However, wood pellets are much more dense, which results in reduced storage requirements and fewer fuel deliveries.

For the strategic scenario developed above (excluding trigeneration), the wood pellet quantities shown in Table 8.1 would be needed to meet the total heating demand for the energy network. All biomass wood pellet information has been taken from CIBSE KS10. Fuel cost taken as £180/tonne.

Proportion of heating met	5%	10%	20%
Total mass, tonnes	1,900	3,800	7,600
Deliveries per year	12	12	52
Delivery tonnage	158	317	146
Storage requirement, m3	233	465	215
Fuel cost, £ /year	340,000	680,000	1,360,000
Total CO2 emissions saved, tCO2/year	2,400	4,800	9,600
CO2 saving on heat	4.6%	9.1%	18.3%

Table 8.1 Biomass fuel requirement for strategic scenario

Fuel deliveries would be a major concern as the location of the development makes regular road transport undesirable. It can be seen in Table 8.1 that there is a large delivery and storage requirement to even meet 5% of the expected heat load of the strategic network. It is clear that there is a trade-off between frequency of delivery and possible storage volume available.

As the network is to be situated in central London, fuel storage will be of greatest concern as costs will be high for space. Assuming that 125m^3 (5m x 5m x 5m) of storage space can be allocated for wood pellets, if 10% of the heating is to be met, the deliveries would approximately occur every week.

As the road transport of biomass is both financially and environmentally costly, other means of delivery should be investigated. As some of the proposed CHP sites are near to the River Thames, deliveries from barge/boat could be feasible. This would result in much lower CO_2 emissions from transport and less disruption for the area when deliveries are being conducted.

The proximity of the CHP sites in Waterloo means that another alternative delivery method could be by train. To avoid major disruption, it is likely that deliveries would be conducted at night. Recent discussions with the Elephant & Castle MUSCO provider Dalkia indicate they are establishing up a railway supply of biomass and this is worth further investigation.

NOx emissions are of concern. A recent report by the AEA ("Review of the Potential Impact on Air Quality from Increased Wood Fuelled Biomass Use in London", 2008) outlined the potential problems associated with increased biomass use within London. A biomass system creating 20% of the heat requirement for the energy network could produce as much as seven tonnes of NOx, annually.

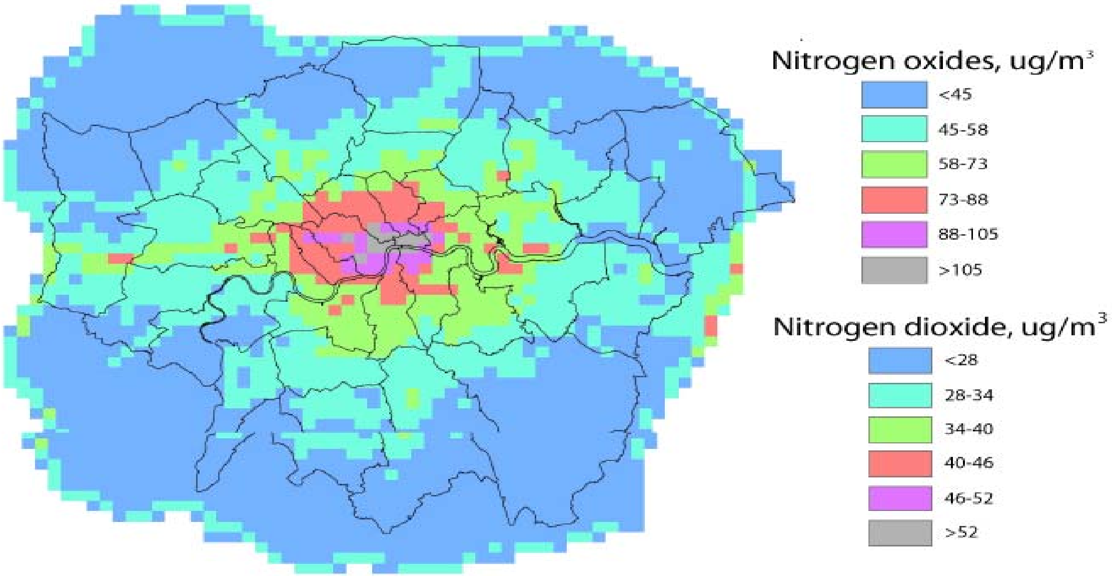

Figure 8.2 Modelled oxides of nitrogen and nitrogen dioxide in 2003 (AEA, "Review of the Potential Impact on Air Quality from Increased Wood Fuelled Biomass Use in London", 2008)

Wood pellet supply is a significant issue. Due to environmental considerations, it is recommended that, if possible, wood pellets are sourced from a local supplier (within 50 miles). Another important consideration is the security of supply and, due to the size of the energy network, it may be beneficial to create a supply chain dedicated to the supply of wood chips for the development.

7.2 River water cooling

A potential source of low carbon cooling situated adjacent to the SBEG area is the River Thames. Cold river water extracted from the Thames could be used to provide additional cooling for any developments that are linked to the decentralised energy system. Depending on the river extract temperature, the energy required to pump this water from the Thames would likely be much less than a vapour compression system's energy usage and would, therefore, provide a contribution to a proportion of the London Plan's 20% renewable obligation for new developments.

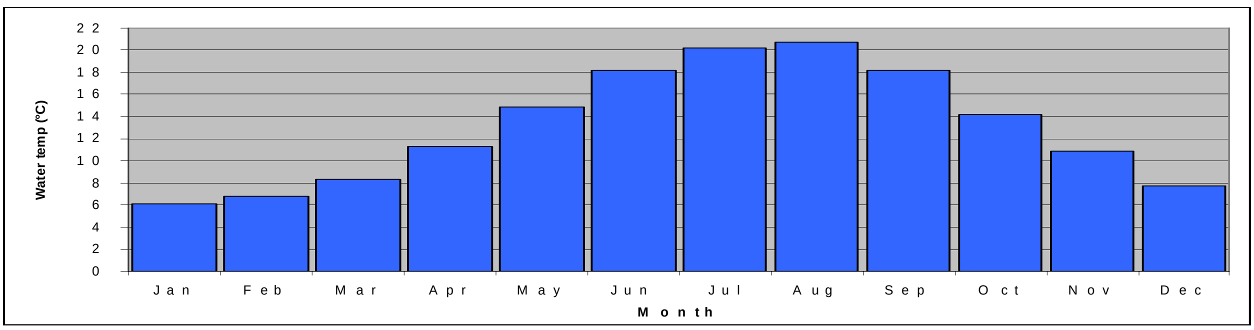

Figure 8.3 Average water temperatures of the River Thames between 1980-2006. Source: Environment Agency

It can be seen from figure 8.3 that the river temperature has a large seasonal variation from as low as 6°C to over 20°C during the summer. There is also a large year-on-year variation which may result in the need for alternative cooling systems during a hot period in the summer. In fact, the major limitation of this system is that during July and August, when cooling demand is at its greatest, the river water temperatures may be too great to provide beneficial cooling. However, there are many applications, such as data centres, that require a year round cooling supply that would receive the greatest benefit.

There are two main applications of river water cooling for this project. The first concerns the dissipation of excess heat into the river from the absorption chiller, removing the need for cooling towers. This river water heat rejection system would incorporate an additional heat exchanger that would transfer the excess heat in the absorption chiller to piped river water for the disposal of heat. This could potentially save both money (cooling towers) and energy (fans).

However, as there is a limit to the temperature that heat can be rejected into the Thames (~21°C), this could not be applied during the peak cooling months when the Thames water temperature is greater than approximately 16°C. This would mean that there would have to be an alternative heat rejection system during the majority of June to September, and therefore, a cooling tower would still be required, negating the benefits of reduced capital cost and size of equipment.

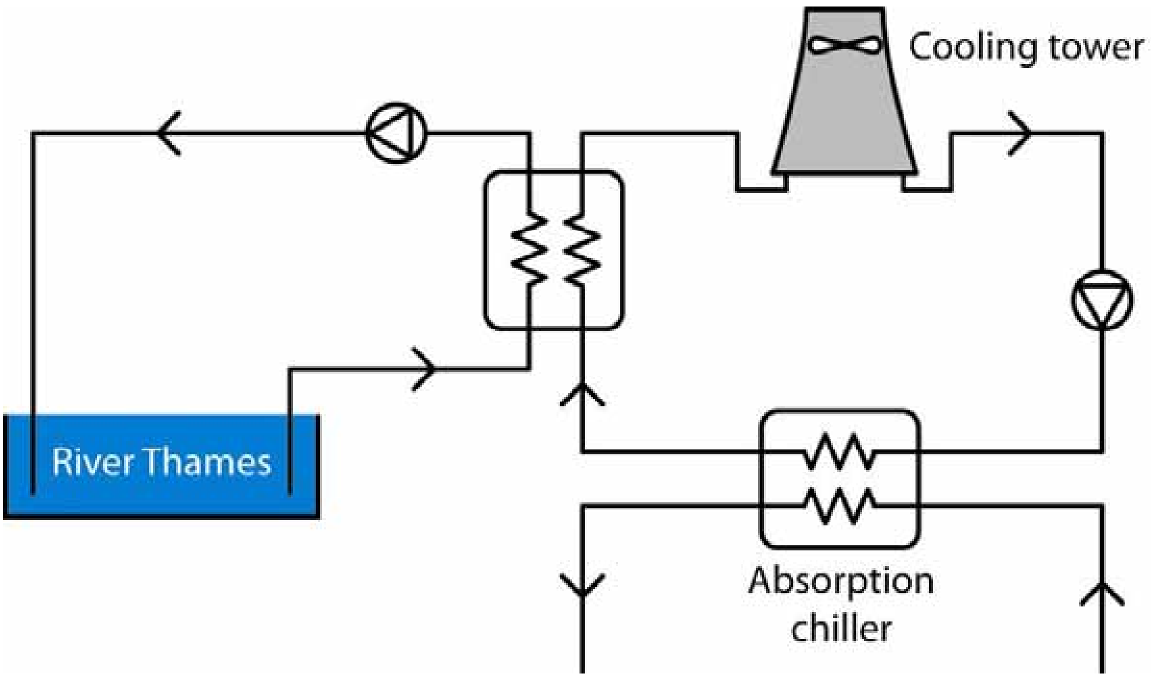

Figure 8.4 Schematic of proposed system

An alternative approach would be to utilise the river water to pre-cool the water in the cooling network as it enters the absorption chiller. After the cooling water has travelled around the cooling circuit, the temperature may have reached as high as 16°C and; therefore, where the river water is cooler than this, it can provide additional cooling to the water before entering the chiller. Once again, it is unlikely that the river would be able to provide this surplus cooling during the summer months due to high river temperatures but it would reduce the cooling load on the chiller for the majority of the year.

The advantages and disadvantages of both approaches are outlined in Table 8.1.

Advantages	Disadvantages
Smaller cooling towers/absorption chillers	Capital cost of additional river water cooling installation
Lower running costs and maintenance of cooling towers/absorption chillers	Running cost of additional pump
Low CO_2 cooling system enabling developments to achieve renewable targets more easily	Filtration maintenance

Table 8.1 Advantages/ Disadvantages of river water cooling

Thermal discharges to the River Thames have the potential to disrupt the ecology of the estuary. Due to this, extensive 3-D modelling will be needed to assess the impact of any proposed system.

The three main concerns for river water cooling systems are the deoxegenation due to temperature increases, the potential of entraining fish during abstraction and the possible affect a thermal barrier may have on migrating fish. Due to the migrating fish issue, the maximum temperature water can be discharged at is approximately 21°C.

It is likely that a river water cooling scheme would require the following licenses from the Environment Agency:

- Abstraction
- Discharge consent
- Land drainage consent

Further analysis would be required to investigate the full feasibility of this technology.

8. Conclusions

The South Bank Employers Group (SBEG) and London South Bank University (LSBU) were commissioned by the London Development Agency (LDA) to assess the feasibility of installing Combined Heat & Power (CHP) across the SBEG area.

Simple building data were collected on the major buildings in and near to the SBEG area that could play a part in determining the success of CHP across the SBEG area. This was mainly floor area, building type and location. More detailed data have been obtained for a small number of SBEG member buildings although this was limited.

About 120 buildings of different types were identified as potential loads for CHP some including around 15 proposed new developments.

A master planning software tool was used to form clusters of buildings to allow an analysis of the overall energy demand patterns for each cluster.

Potential locations for the CHP plant were then identified and heating/cooling and private wire distribution networks have been developed for each cluster using GIS mapping to estimate the infrastructure costs.

A rating system was used to identify the key existing buildings in each cluster based on heating demand, electricity demand and distance from CHP plant. This focussed the analysis on 42 existing buildings and 11 new developments.

A CHP model was then used to assess the economic viability and CO_2 emissions of each cluster CHP plant. These clusters were:

- Blackfriars
- South Bank
- Waterloo
- LSBU

Each cluster was also modelled for key existing buildings only, then key existing buildings plus new developments. The proposed Waterloo Station redevelopment is so large that this was included in a separate analysis.

Further analysis included an assessment of a strategic option linking Blackfriars, South Bank and Waterloo clusters to one single CHP Plant. Trigeneration (CCHP) was then added as an option to some of the leading options.

Southbank, Blackfriars and Waterloo all appear to be economically viable but LSBU appears to be somewhat marginal. All but two of the options involve both existing and new developments, although Waterloo also appears to be viable without any new building taking place. Three options include trigeneration with associated heat rejection plant and cooling pipework.

Based on this first pass analysis, decentralised CHP across the SBEG area appears to merit further investigation.

Biomass heating as a stand-by and top-up to the CHP may present an option provinding supply chain issues can be resolved. This is worthy of further investigation. Including this renewable content could make the scheme much more attractive to developers in meeting the 20% requiremnt of the London Mayor.

9. Key risks

This study is based on a range of assumptions. There are therefore some key risks associated with the project, as follows:

- Energy prices could reduce significantly, in particular the spark gap reduces, making CHP less viable
- Energy pricing regimes could change, making CHP less viable (e.g. availability charges, maximum demand charges, sell back tariffs, DUOS charges etc).
- Regulation changes that disadvantage CHP (e.g. additional OFGEM certification and licensing, changes to the building regulations or changes to the planning regulations in London).
- Inadequate gas supply to the selected plant room
- Difficulty or cost in connecting to the local electricity grid or to electrical supplies in individual buildings
- Plant room space is either unavailable, expensive, faces planning problems, or has unexpected practical difficulties (e.g. additional building costs, exhaust or ventilations problems, access problems).
- Pipework costs rise significantly or there are difficulties in achieving reasonable pipework routes due to practicalities or objections from the statutory authorities
- SBEG members may not buy-in to the project, perhaps due to poor pricing structures, poor contractual arrangements or building owners simply fail to see the benefits of the scheme.

10. Recommendations & next steps

As outlined in this report, the first phase of potential project evaluation -this Initial Feasibility Study- has looked at and indentified the following broad areas of information from key stakeholders across the South Bank area:

- Identification of potential consumers
- Estimated likely energy consumption
- Identified probable scale
- Suggested possible plant locations

Having undertaken this review the outline figures indentified based on a heat led network suggest that there is a good case for further work to move forward with the development of the project by undertaking a more detailed evaluation of the technical and economical considerations. In order to undertake this next phase we believe that there should be a phased approach adopted and that the South Bank and Waterloo clusters which are predominately based on existing buildings are considered the most appropriate clusters for this further detailed evaluation at this stage.

Buildings to be considered in the next phase of work

1. South Bank Centre
2. National Theatre
3. Kings College
4. Shell
5. ITV
6. IBM
7. BFI
8. County Hall
9. CSCB – Doon Street (Proposed development)
10. Park Plaza's (on site)
11. P&O (Proposed development)
12. St Thomas' Hospital (existing CHP)

It is proposed to undertake the further evaluations of the technical and economical considerations in partnership with the above stakeholders in order to fully investigate and identify the following areas of project development:

Phase 2 - Technical & Economic Development Work

- Identify and work with key parties to develop most viable cluster
- Use actual energy consumption and cost information
- Take account of existing building services and plant
- Determine most viable locations for plant and network routes and investigate any permissions/legal issues associated with the proposals.

Following successful completion of the phase 2 evaluation further decisions will then need to be taken on how the project is to continue toward ultimate delivery. These decisions will be completely dependent on the outcomes of phase 2 but will broadly need to address the following areas in terms of:

Phase 3 - Commercialisation

- Identify key parties & delivery options
- Option 1 – Fully outsourced DBFO with several consumers & common agreement
- Option 2 – Social enterprise with sub-contracts for DBFO (Design, Build, Fund and Operate)
- Develop heads of terms

Phase 4 - Procurement

SOUTH BANK DECENTRALISED ENERGY

APPENDICES

FEBRUARY 2009

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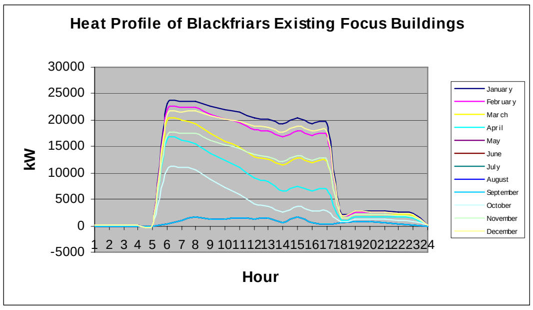
APPENDICES

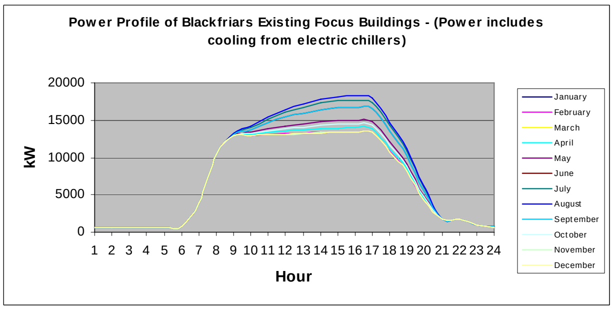
A. List of existing buildings showing building rating

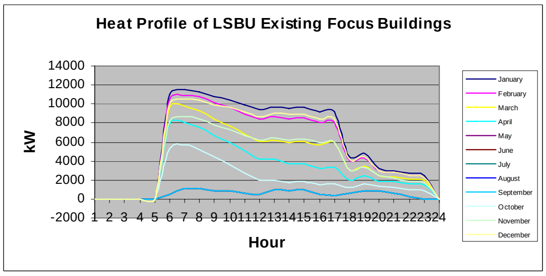
The right hand columns show the building rating out of 100 and if the building was included in the final analysis. A range of additional tests were carried out on outlying clusters of billings to see if these were economic to include in the focussed clusters. All these tests proved to be uneconomic due to the cost of additional pipework relative to the heat load involved.

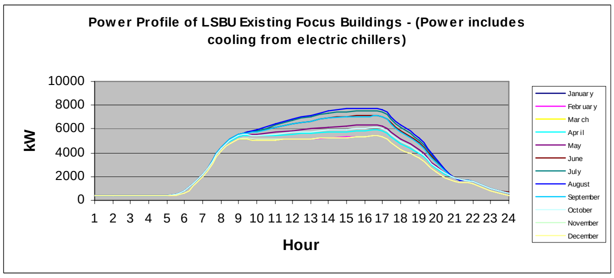
Building Name	Cluster	Central Boiler	Public Building	Peak Heat (kWth)	Peak Power (kWp)	Annual Heat (MWh)	Annual Power (MWh)	E/P Ratio	Pipwork Distance (m)	Rating (out of 100)	IN or OUT?
IBM UK Ltd - Sampson House	Blackfriars	Y	N	2665	674	4606	3050	1728	40	76	IN
Ludgate House	Blackfriars	Y	N	1199	303	2072	1372	1728	40	66	IN
Falcon Point DH Scheme	Blackfriars	Y	N	698	100	1788	326	2561	120	39	IN
Mad Hatter Hotel	Blackfriars	Y	N	172	43	629	241	3666	100	37	IN
Bank Side - 1	Blackfriars	Y	N	3450	872	5962	3948	1728	320	32	PHASE 2 BANKSIDE TEST
Sea Containers House	Blackfriars	Y	N	3223	815	5569	3688	1728	300	32	IN
London Development Agency	Blackfriars	Y	Y	3298	834	5700	3775	1728	430	30	PHASE 3 PALESTRA TEST
Kings Reach Tower	Blackfriars	Y	S	1891	478	3267	2164	1728	360	29	IN
River Court	Blackfriars	Y	N	806	116	2115	383	2561	170	27	IN
Bank Side - 2	Blackfriars	Y	N	1222	309	2461	1399	1728	360	18	PHASE 2 BANKSIDE TEST
230 Blackfriars Road	Blackfriars	Y	N	840	212	1452	961	1728	250	16	PHASE 3 PALESTRA TEST
Rennie Court	Blackfriars	Y	N	736	106	1930	350	2561	300	15	IN
Bank Side - 3	Blackfriars	Y	N	1616	409	2793	1849	1728	400	12	PHASE 2 BANKSIDE TEST
Southwark College	Blackfriars	Y	Y	256	156	546	800	2139	600	12	PHASE 3 PALESTRA TEST
Friars House	Blackfriars	Y	N	1396	353	2413	1598	1728	764	9	OUT
OXO Wharf Tower	Blackfriars	Y	S	758	109	1942	354	2561	440	8	IN (Subject to Sea Containers)
Styles House DH Scheme	Blackfriars	Y	N	355	51	910	166	2561	600	1	PHASE 3 PALESTRA TEST
Rowland Hill House	Blackfriars	N	N	662	95	1696	309	2561	560	0	PHASE 3 PALESTRA TEST
LSBU Bourough Road Building	LSBU	Y	Y	468	286	1001	1467	2139	40	76	IN
LSBU Keyworth House	LSBU	Y	Y	285	174	609	892	2139	40	72	IN
LSBU Tower Block	LSBU	Y	Y	559	141	965	639	1728	40	72	IN
LSBU E - Block	LSBU	Y	Y	176	108	377	551	2139	30	71	IN
LSBU J Block	LSBU	Y	Y	130	79	278	407	2139	30	70	IN
LSBU M - Block	LSBU	Y	Y	38	23	82	120	2139	30	70	IN
LSBU Pocock House	LSBU	Y	Y	98	60	210	308	2139	60	58	OUT
LSBU London Road	LSBU	Y	Y	1261	319	2179	1443	1728	120	52	IN
Borough Rd Residential-Mathieson Court	LSBU	Y	Y	544	78	1394	254	2563	120	49	IN
LSBU Technopark	LSBU	Y	Y	302	184	645	945	2139	140	48	IN
LSBU Perry Library	LSBU	Y	Y	208	127	446	653	2139	240	35	IN
LSBU Faraday Wing	LSBU	Y	Y	123	75	263	385	2139	160	34	IN
LSBU Rotary St	LSBU	Y	Y	39	10	68	45	1728	160	34	OUT
LSBU LRC	LSBU	Y	Y	111	68	238	349	2139	180	34	IN
LSBU Blackwells	LSBU	Y	Y	34	21	74	108	2139	240	34	OUT
LSBU Eileen House	LSBU	Y	Y	196	50	340	225	1728	220	34	OUT
Perronet House	LSBU	Y	Y	1496	305	3832	698	2561	340	29	IN
Skipton House	LSBU	Y	N	1992	504	3443	2280	1728	260	24	IN
Salvation Army Building	LSBU	Y	N	2011	509	3476	2302	1728	260	24	OUT
LSBU Erlang House	LSBU	Y	Y	182	111	389	569	2139	380	23	PHASE 2 MACLAREN HOUSE TEST
Imperial War Museum	LSBU	Y	Y	1348	314	2665	1545	1976	640	22	OUT
LSBU Caxton House	LSBU	Y	Y	44	27	95	138	2139	260	22	PHASE 2 MACLAREN HOUSE TEST
LSBU The Nursery	LSBU	Y	Y	52	4	78	21	1492	260	22	PHASE 2 MACLAREN HOUSE TEST
LSBU McLaren House	LSBU	Y	Y	1419	453	3633	1474	2561	400	19	PHASE 2 MACLAREN HOUSE TEST
Gaywood DH scheme	LSBU	Y	N	584	84	1495	272	2561	340	15	OUT
Scovell Road Estate DH Scheme	LSBU	Y	N	742	106	1901	346	2561	340	15	PHASE 3 SCOVELL TEST
ITF 49 Borough Rd	LSBU	Y	N	299	75	516	342	1726	260	13	PHASE 3 SCOVELL TEST
IPSOS MORI	LSBU	Y	N	180	46	310	171	1722	320	12	PHASE 3 SCOVELL TEST
Hill House	LSBU	Y	N	904	229	1562	1034	1728	500	6	PHASE 2 MACLAREN HOUSE TEST
Days Hotel Waterloo	LSBU	Y	N	586	147	2147	824	3666	880	4	OUT
Metro Central Heights	LSBU	N	N	1959	281	5017	914	2561	360	0	OUT
Lancaster/Tadworth House	LSBU	Y	N	171	25	439	80	2561	600	0	OUT
LSBU David Bomberg House	LSBU	N	Y	603	193	1544	627	2561	440	0	OUT
National Theatre	Southbank	Y	Y	7583	2127	16324	8230	2153	80	88	IN
South Bank Centre - Royal Festival Hall	Southbank	Y	Y	6191	1737	13326	6719	2153	140	76	IN
White House	Southbank	Y	N	2913	417	7459	1359	2561	40	73	IN
King's College (FWB Waterloo Bridge Wing)	Southbank	Y	Y	200	122	427	626	2139	40	71	IN
Queen Elizabeth Hall Southbank Centre	Southbank	Y	Y	2227	625	4796	2418	2153	120	58	IN
King's College (Franklin Wilkins Building)	Southbank	Y	Y	1752	1070	3746	5486	2139	160	55	IN
King's College (James Clerk Maxwell Building)	Southbank	Y	Y	912	291	2337	948	2561	100	50	IN
IBM UK Ltd	Southbank	Y	S	1860	470	3215	2129	1728	200	41	IN
IMAX British Film Institute	Southbank	Y	Y	758	88	1691	853	2231	200	38	IN
ITV	Southbank	Y	S	2971	751	5134	3400	1728	320	37	IN
Coin Street Community Apartments	Southbank	Y	S	180	26	461	84	2561	280	17	IN
Union Jack Club	Southbank	Y	N	1102	207	2518	895	2285	420	7	OUT
King's College (Stamford street apartments)	Southbank	N	Y	1074	343	2751	1116	2561	360	0	OUT
BFI -MOMA Building	Southbank	Y	Y	61	13	121	65	1984	80	58	IN
South Bank Centre - Art Gallary	Southbank	Y	Y	122	26	241	130	1975	110	46	IN
Park Plaza County Hall	Waterloo	Y	N	2293	574	8407	3225	3666	60	68	IN
Shell Centre	Waterloo	Y	S	5182	1310	8954	5930	1728	360	42	IN
County Hall (All 4 Blocks)	Waterloo	Y	N	3517	504	9007	1640	2561	220	40	IN
St. Thomas' Hospital	Waterloo	Y	Y	16213	1931	59384	9711	3663	420	40	IN
London County Hall	Waterloo	Y	N	5777	2003	17815	10654	3084	400	30	IN
Becket House, Ernst & Young	Waterloo	Y	N	2350	603	4063	2734	1729	280	28	IN
Plaza On The River	Waterloo	Y	N	2511	629	9205	3531	3666	1000	20	OUT
Morley College	Waterloo	Y	Y	379	231	810	1186	2139	620	14	OUT
100 Westminster Bridge Road	Waterloo	Y	N	2153	544	3721	2464	1728	520	12	OUT
Hotel Novotel London Waterloo	Waterloo	Y	N	1152	288	4223	1620	3666	1000	12	OUT

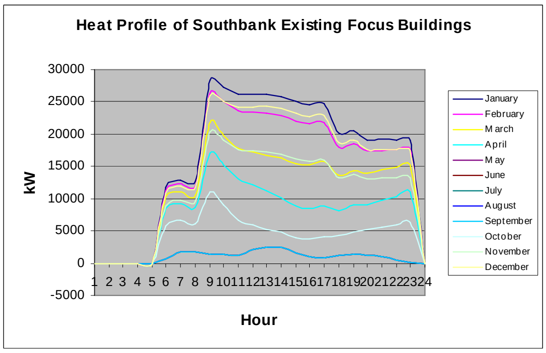
B. Cluster load profiles

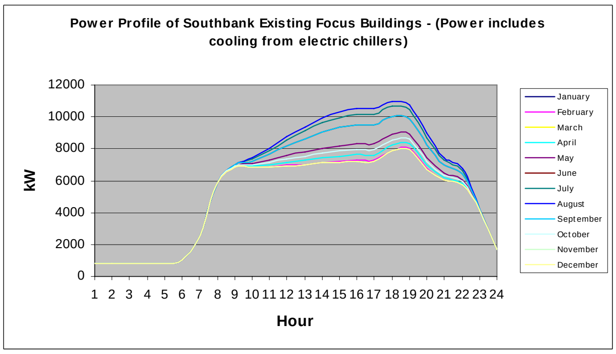


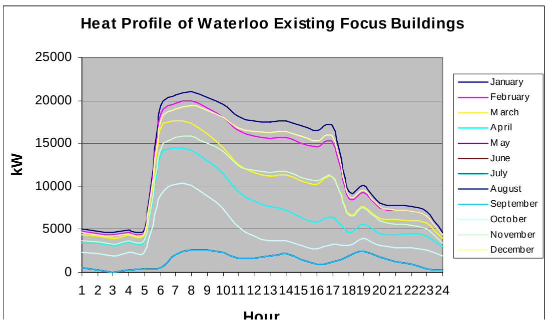


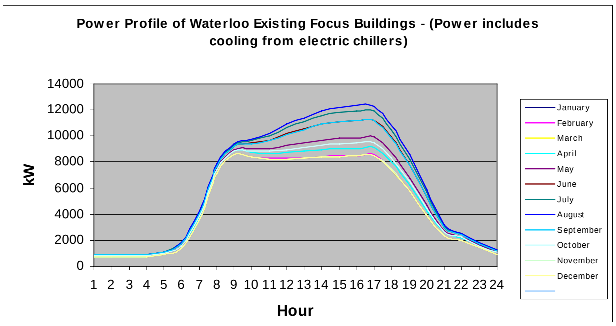


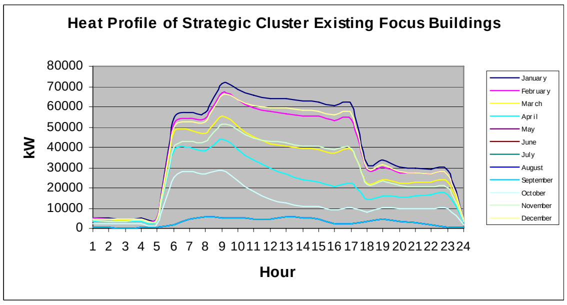











Heat Profile of Strategic Cluster Existing Focus Buildings
80000
70000
60000
50000
40000
30000
20000
10000
0
kW
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour
January
February
March
April
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September
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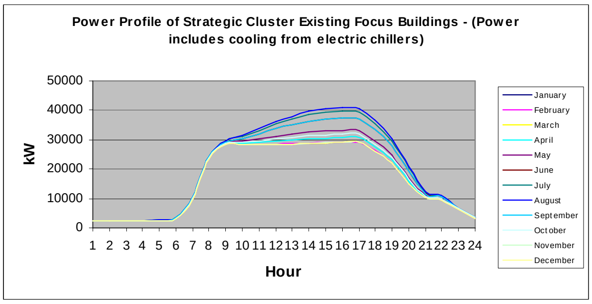
November
December


Power Profile of Strategic Cluster Existing Focus Buildings - (Power includes cooling from electric chillers)
50000
40000
30000
20000
10000
0
kW
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour
January
February
March
April
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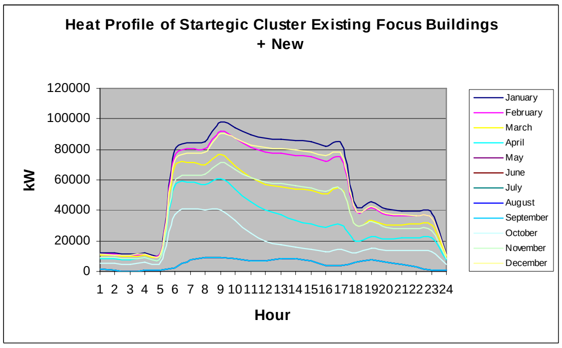
November
December


Heat Profile of Startegic Cluster Existing Focus Buildings + New
120000
100000
80000
60000
40000
20000
0
kW
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour
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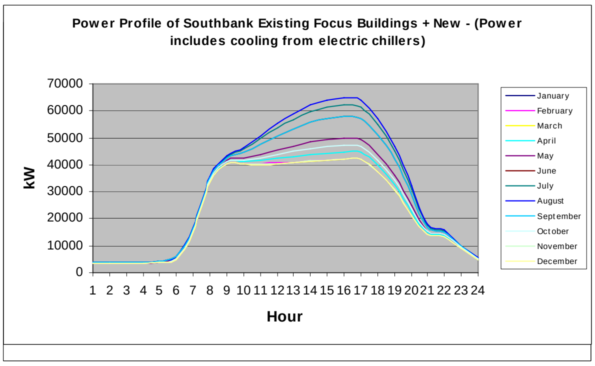
Power Profile of Southbank Existing Focus Buildings + New - (Power includes cooling from electric chillers)
70000
60000
50000
40000
30000
20000
10000
0
kW
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour
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February
March
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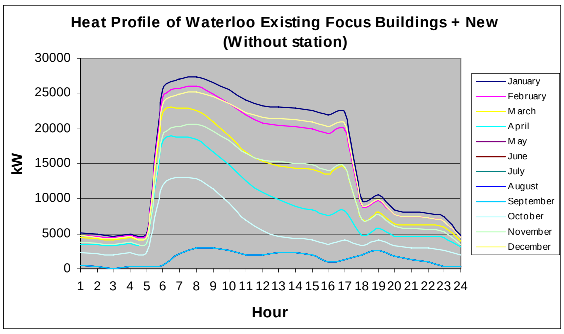
Heat Profile of Waterloo Existing Focus Buildings + New (Without station)
30000
25000
20000
15000
10000
5000
0
kW
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour
January
February
March
April
May
June
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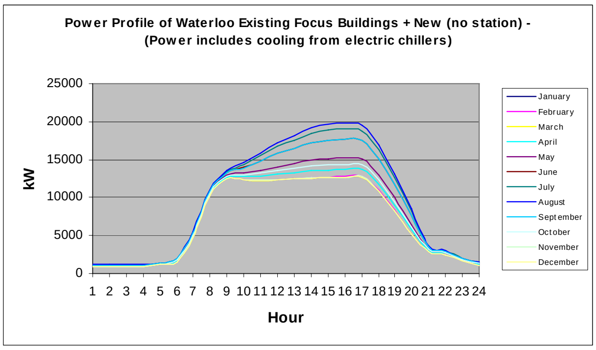
November
December


Power Profile of Waterloo Existing Focus Buildings + New (no station) - (Power includes cooling from electric chillers)
25000
20000
15000
10000
5000
0
kW
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour
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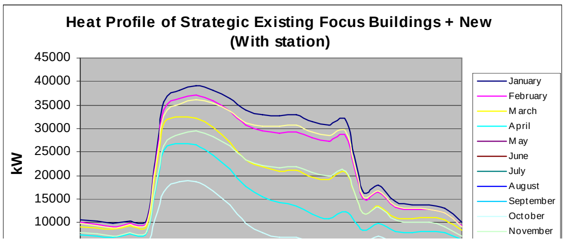
Heat Profile of Strategic Existing Focus Buildings + New (With station)
45000
40000
35000
30000
25000
20000
15000
10000
kW
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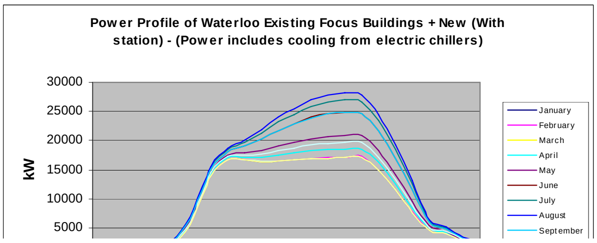
November


Power Profile of Waterloo Existing Focus Buildings + New (With station) - (Power includes cooling from electric chillers)
30000
25000
20000
15000
10000
5000
kW
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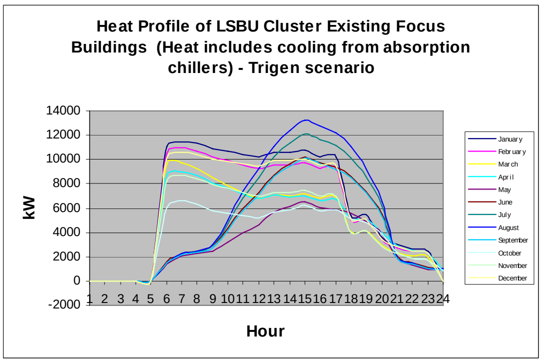
Heat Profile of LSBU Cluster Existing Focus Buildings (Heat includes cooling from absorption chillers) - Trigen scenario
kW
Hour
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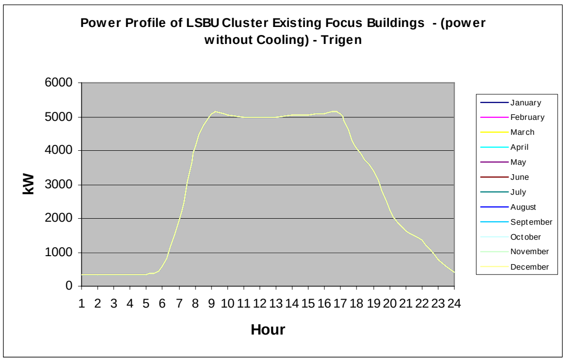
December


Power Profile of LSBU Cluster Existing Focus Buildings - (power without Cooling) - Trigen
kW
Hour
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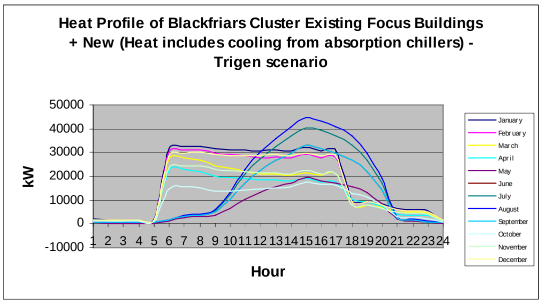
Heat Profile of Blackfriars Cluster Existing Focus Buildings + New (Heat includes cooling from absorption chillers) - Trigen scenario
kW
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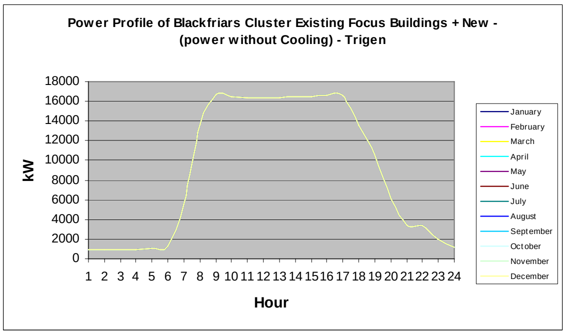
Power Profile of Blackfriars Cluster Existing Focus Buildings + New - (power without Cooling) - Trigen
kW
Hour
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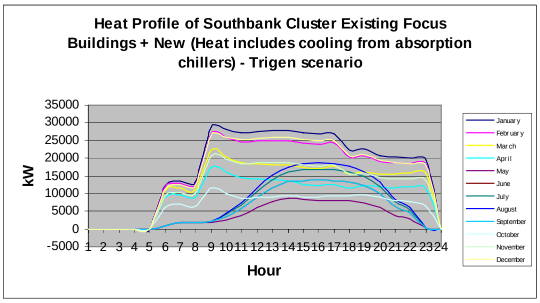
Heat Profile of Southbank Cluster Existing Focus Buildings + New (Heat includes cooling from absorption chillers) - Trigen scenario
kW
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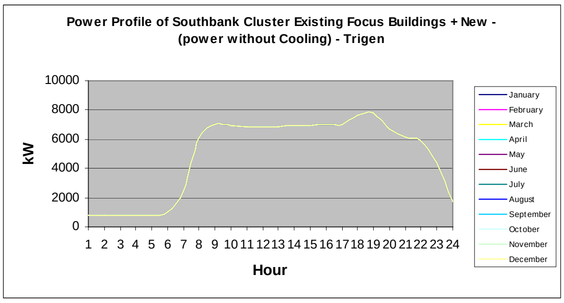
Power Profile of Southbank Cluster Existing Focus Buildings + New - (power without Cooling) - Trigen
kW
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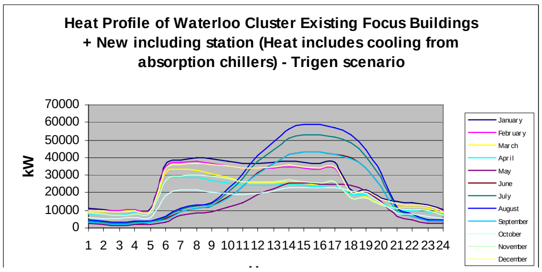
Heat Profile of Waterloo Cluster Existing Focus Buildings + New including station (Heat includes cooling from absorption chillers) - Trigen scenario
kW
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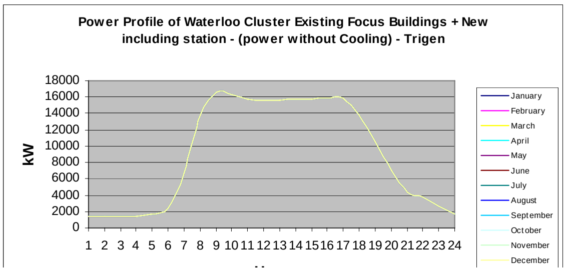
Power Profile of Waterloo Cluster Existing Focus Buildings + New including station - (power without Cooling) - Trigen
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C. Examples of pipe sizing/costing

Spread sheets were developed for each and every scenario for the piping cost calculations. The spread sheet below is the waterloo cluster's heat pipe cost sheet, which has been developed by using the following linear relation (Reference BP feasibility report, 2006), Pipe Cost (£) / m length = (5*pipe_diameter+500)

Southbank Cluster - Focus + New					**Pipe Work**			
	Length				Length			
Mains	m	Pipe Size	Pipe Cost	Branch Pipe	m	Building	Pipe Size	Pipe Cost
M1	27	225	£43,875	L1	32	White House	125	£36,000
M2	29	200	£43,500	L2	0	South Bank Centre - Royal Festival Hall	175	£0
M3	55	200	£82,500	L3	0	Queen Elizabeth Hall Southbank Centre	100	£0
M4	28	225	£45,500	L4	52	National Theatre	200	£78,000
M5	88	175	£121,000	L5	34	IBM UK Ltd	100	£34,000
M6	75	150	£93,750	L6	41	ITV	125	£46,125
M7	52	125	£58,500	L7	17	Coin Street Community Apartments	50	£12,750
M8	18	125	£20,250	L8	17	King's College (FWB Waterloo Bridge Wing)	50	£12,750
M9	76	125	£85,500	L9	38	King's College (Franklin Wilkins Building)	100	£38,000
M10	48	100	£48,000	L10	35	IMAX British Film Institute	75	£30,625
		Total	**£642,375**	L11	34	King's College (James Clerk Maxwell Building)	75	£29,750
					23	BFI MOMA Building	75	20125
					0	South Bank Centre - Art Gallary		0
Total	496			Total	300		**Total**	**£338,125**
				Total Pipe Length	796	**Approximate Pipe Cost**	**£980,500**	

New Buildings								
Mains	m	Pipe Size	Pipe Cost	Branch Pipe	m	Building	Pipe Size	Pipe Cost
			£0.00	N1	23	Doon Street	50.00	£17,250.00
		Total	**£0.00**				**Total**	**£17,250.00**
				Total Pipe Cost	=	**£997,750.00**		

Strategic pipework

Blackfriars Cluster					**Pipe Work**				
	Length				Length				
Mains	m	Pipe Size	Pipe Cost	Branch Pipe	m	Building	Pipe Size	Pipe Cost	Distance from CHP
M1	43	250.00	£75,250.00	L1	26	IBM Sampson House	100.00	£26,000.00	26
M2	15	225.00	£24,375.00	L2	120	Falcon Estates	65.00	£99,000.00	120
M3	39	200.00	£58,500.00	L3	20	Mad Hatter Hotel	50.00	£15,000.00	63
M4	37	200.00	£55,500.00	L4	28	Ludgate House	80.00	£25,200.00	125
M5	78	200.00	£117,000.00	L5	23	River Court	65.00	£18,975.00	235
M6	73	175.00	£100,375.00	L6	41	Rennie Court	65.00	£33,825.00	253
		Total	**£431,000.00**	L7	35	Sea Containers House	125.00	£39,375.00	320
				L8	69	Kings Reach Tower	175.00	£94,875.00	354
				L9+L10	112	Oxo Wharf Tower	65.00	£92,400.00	397
Total	285			Total	474		**Total**	**£444,650.00**	
Focus Existing Buildings						**Approximate Pipe Cost**	**£875,650**		

New Buildings									
Mains	m	Pipe Size	Pipe Cost	Branch Pipe	m	Building	Pipe Size	Pipe Cost	Distance from CHP
			£0.00	N1	40	Beetham Tower	100.00	£40,000.00	83
			£0.00	N2	64	20 Blackfriars Road	100.00	£64,000.00	107
			£0.00	N3	0	Kings Reach Tower	0.00	£0.00	
			£0.00						
		Total	**£0.00**				**Total**	**£104,000.00**	
Focus Existing+New						**Approximate Pipe Cost**	**£979,650**		

LSBU Cluster					**Pipe Work**			
	Length				Length			
Mains	m	Pipe Size	Pipe Cost	Branch Pipe	m	Building	Pipe Size	Pipe Cost
M1	48	100	£48,000	L1	15	LSBU Bourough Road Building	75	£13,125
M2	67	65	£55,275	L2	18	LSBU Tower Block	75	£15,750
M3	0	0	£0	L3	20	Borough Rd Residential-Mathieson Court	75	£17,500
M4	12	100	£12,000	L4	26	LSBU London Road	100	£26,000
M5	23	100	£23,000	L5	14	LSBU LRC	50	£10,500
M6	67	50	£50,250	L6	17	LSBU Keyworth House	50	£12,750
M7	30	150	£37,500	L7	17	LSBU E/J/M - Block	50	£12,750
M8	27	150	£33,750	L8	10	LSBU Faraday Wing	50	£7,500
M9	31	150	£38,750	L9	25	LSBU Technopark	50	£18,750
M10	73	150	£91,250	L10+L11	86	LSBU Perry Library	50	£64,500
				L12	12	Skipton House	100	£12,000
				L13	84	Perronet House	100	£84,000
				N1	20	Eileen House	90	£19,000
Total	378			Total	364			
LSBU Main Pipes Cost			£389,775			Branch Pipes Cost		£314,125
LSBU Total Pipe Network Cost				**£703,900**				

Blackfriars Cluster					Pipe Work				
	Length				Length				
Mains	m	Pipe Size	Pipe Cost	Branch Pipe	m	Building	Pipe Size	Pipe Cost	Distance from CHP
M1	43	250.00	£75,250.00	L1	26	IBM Sampson House	100.00	£26,000.00	26
M2	15	225.00	£24,375.00	L2	120	Falcon Estates	65.00	£99,000.00	120
M3	39	200.00	£58,500.00	L3	20	Mad Hatter Hotel	50.00	£15,000.00	63
M4	37	200.00	£55,500.00	L4	28	Ludgate House	80.00	£25,200.00	125
M5	78	200.00	£117,000.00	L5	23	River Court	65.00	£18,975.00	235
M6	73	175.00	£100,375.00	L6	41	Rennie Court	65.00	£33,825.00	253
		Total	**£431,000.00**	L7	35	Sea Containers House	125.00	£39,375.00	320
				L8	69	Kings Reach Tower	175.00	£94,875.00	354
				L9+L10	112	Oxo Wharf Tower	65.00	£92,400.00	397
Total	285			Total	474		**Total**	**£444,650.00**	
Focus Existing Buildings						**Approximate Pipe Cost**	**£875,650**		

New Buildings									
Mains	m	Pipe Size	Pipe Cost	Branch Pipe	m	Building	Pipe Size	Pipe Cost	Distance from CHP
			£0.00	N1	40	Beetham Tower	100.00	£40,000.00	83
			£0.00	N2	64	20 Blackfriars Road	100.00	£64,000.00	107
			£0.00	N3	0	Kings Reach Tower	0.00	£0.00	
			£0.00						
		Total	**£0.00**				**Total**	**£104,000.00**	
Focus Existing+New						**Approximate Pipe Cost**	**£979,650**		

Southbank Cluster					Pipe Work				
	Length				Length				
				Branch Pipe	m	Building	Pipe Size	Pipe Cost	Distance from CHP
				L1	32	White House	125	£36,000	
				L2	23	South Bank Centre - Royal Festiv	175	£31,625	
				L3	60	Queen Elizabeth Hall Southbank (	100	£60,000	
				L4	52	National Theatre	200	£78,000	
				L5	34	IBM UK Ltd	100	£34,000	
				L6	41	ITV	125	£46,125	
				L7	17	Coin Street Community Apartment	50	£12,750	
				L8	17	King's College (FWB Waterloo Br	50	£12,750	
				L9	38	King's College (Franklin Wilkins B	100	£38,000	
				L10	35	IMAX British Film Institute	75	£30,625	
		Total	**£0**	L11	34	King's College (James Clerk Maxv	75	£29,750	
					23	BFI MOMA Building	75	20125	
					0	South Bank Centre - Art Gallary			
Total	0			Total	383		**Total**	**£429,750**	
				Total Pipe Length	383	**Approximate Pipe Cost**	**£429,750**		

New Buildings									
Mains	m	Pipe Size	Pipe Cost	Branch Pipe	m	Building	Pipe Size	Pipe Cost	Distance from CHP
			£0.00	N1	23	Doon Street	50.00	£17,250.00	
		Total	**£0.00**				**Total**	**£17,250.00**	
				Total Pipe Cost	=	**£447,000.00**			

Waterloo Cluster					Pipe Work				
	Length				Length				
				Branch Pipe	m	Building	Pipe Size	Pipe Cost	Distance from CHP
				L1	37	Park Plaza County Hall	125	£41,625	
				L2+L4	63	County Hall (All 4 Blocks)	200	£94,500	
				L3	38	Shell Centre	200	£57,000	
				L5	70	London County Hall	200	£105,000	
				L6	44	Becket House, Ernst & Young	125	£49,500	
				L7	79	St. Thomas' Hospital	250	£138,250	
								£485,875	
			£0						
Total	0			Total	331				
Waterloo Existing Only				Total Pipe Length		Approximate Pipe Cost	**£485,875**		

New Developments

				N1	12	Prospect House	65	£9,900	
				N2	17	Elizabeth House	125	£19,125	
				N3	179	Waterloo Station	200	£268,500	
				N4	50	1 Westminster Bridge Road	50	£37,500	
				N5	48	York House	65	£39,600	
				N6+N7	103	Founders Place	50	£77,250	
				Total	409		**Total**	**£451,875**	

Total Pipe Length for existing and new						Approximate Pipe Cost		**£937,750**	
				Mains	M				
		3982525		total Length	1882		600	£6,587,000	
				Total				**£8,951,400.00**	

Waterloo Cluster					Pipe Work				
	Length				Length				
Mains	m	Pipe Size	Pipe Cost	Branch Pipe	m	Building	Pipe Size	Pipe Cost	Distance from CHP
M1	83	350	£186,750	L1	37	Park Plaza County Hall	125	£41,625	
M2	16	175	£22,000	L2+L4	63	County Hall (All 4 Blocks)	200	£94,500	
M3	67	175	£92,125	L3	38	Shell Centre	200	£57,000	
M4	59	150	£73,750	L5	70	London County Hall	200	£105,000	
M5	181	300	£362,000	L6	44	Becket House, Ernst & Young	125	£49,500	
M6	77	250	£134,750	L7	79	St. Thomas' Hospital	250	£138,250	
M7	60	250	£105,000						
M8	56	225	£91,000					**£485,875**	
			£1,067,375						
Total	599			Total	331				
Waterloo Existing Only				Total Pipe Length		Approximate Pipe Cost	**£1,553,250**		

New Developments

				N1	12	Prospect House	65	£53,625	
				N2	17	Elizabeth House	125	£140,625	
				N4	50	1 Westminster Bridge Road	50	£37,500	
				N5	48	York House	65	£53,625	
				N6+N7	103	Founders Place	50	£37,500	
				Total	230		**Total**	**£322,875**	

Total Pipe Length for existing and new			Approximate Pipe Cost		**£1,876,125**

Heat Pipe Diameter Calculation:

The following relation has been used for the calculation of the heat pipe's diameters.

$Q = mCp\ \Delta T$,

Where,

Q = Peak heat load (kW)

m= mass flow rate = Area x Velocity = AV = $(\Pi d^2 / 4) \times V$

Cp= Specific heat of water = 4.187

ΔT = Temperature difference

d = Heat pipe diameter

Heat pipe's calculation has been carried out by considering the peak heat loads of individual buildings. The peak heat loads of each individual building was taken from the heat profiles developed in the model.

In and Out temperatures were taken as 90/60 °C. So,

$\Delta T = 90 – 60°C = 30°C$

Velocity = V = 3m/s (Reference CIBSE Guide – C, Table 4.4)

Pressure losses / meters have been considered by using CIBSE Guide – tables. And diameters have been selected according to that.

Heat Pipe Cost

The following linear equation has been used for the heat pipe cost calculation based on the LSBU CHP feasibility study by BP, 2006. An inflation rate 0f 20% has been considered additional to the BP's costs. This also includes the labour cost, trench cost etc.

Pipe Cost (£) / m length = (5*pipe_diameter+500)

Cooling Pipe Diameter Calculation

Same equations have been used for the calculation of cooling pipe's diameter.

$\Delta T = 16 - 6°C = 10°C$

Velocity = V = 3m/s (Reference CIBSE Guide – C, Table 4.4)

$Q = mCp\ \Delta T$,

m. = AV = Area x Velocity = $\Pi d^2 / 4 \times V$

Pressure losses / meters have been considered by using CIBSE Guide C – tables. And diameters have been selected according to that.

Cooling Pipe Cost

It has been assumed as the half of the heating pipe cost. Pipe Cost (£) / m length = Heat Pipe Cost /2

D. Assumptions

Building Benchmarks

Building Type	Existing (Typical practice)		New Build (20% below good practice)			
	Fuel (kWh/m²/yr)	Power (kWh/m²/yr)	Fuel (kWh/m²/yr)	Power (kWh/m²/yr)	Cooling (kWh/m²/yr)	Thermal Base load
Conference[1]	151	85	63	43	28	10%
Higher Edu.[2]	98	122	78	98	16	20%
Hospital[3]	518	72	320	38	16	30%
Hotel[4]	410	135	216	68	28	30%
Museum[5]	142	70	77	46	5	10%
Office[6]	151	85	63	43	28	10%
Pool[7]	1336	237	458	122	0	80%
Residential[8]	239	37	60	40	5	30%
Retail[9]	248	294	155	190	16	10%
School[10]	144	33	86	20	0	10%
Sports[11]	598	152	211	77	16	50%
Student Acc.[12]	290	100	192	68	0	30%
Theatre[13]	630	270	336	144	28	10%

1. Offices data used
2. Data acquired from LSBU facilities used
3. Long-stay hospitals, CIBSE Guide F
4. Luxury Hotel, CIBSE Guide F
5. Museum, CIBSE Guide F
6. Equidistant between a typical type 3 (standard air-conditioned) and type 4 (prestige) office, CIBSE Guide F
7. 25m swimming pool centre, CIBSE Guide F
8. Existing buildings based on typical existing stock, AECB. New dwellings modelled on SAP 2005 for a generic building

9. Weighted benchmark based on selection of retail types as follows:

   - 10% banks

   - 10% book shops

   - 20% clothes shops

   - 30% department stores

   - 10% electronic retailers

   - 10% shoe shops

   - 10% small food

   All 100% electric with the exception of banks and department stores, CIBSE Guide F
10. Secondary school without swimming pool, CIBSE Guide F
11. Combined centre, CIBSE Guide F
12. Residential – Halls of residence, CIBSE Guide F
13. Theatre, CIBSE Guide F

As few, reliable cooling benchmarks are available for all of the required building types, three individual levels where created.

- Trace (5kWh/m^2/year)
- Low (16kWh/m^2/year) – equidistant between good practice and typical for banks/agencies, CIBSE Guide F
- High (28kWh/m2/year) – equidistant between a good practice type 3 and a typical type 4 office, CIBSE Guide F

Cooling

The following COPs were used in the calculation of cooling loads for CHP and Trigeneration:

Electric chiller COP = 3.00

Absorption chiller COP = 0.65

Costs

General

For sizing purposes, the Shell Office was selected as it was typical of a large load for the area.

	Peak (kWp)	Annual Load (MWh)
Heat	5,200	9,000
Power	1,300	6,000

Energy Prices

According to BERR Energy Trends – March 2008 (URN 08/79a ISSN number: 0308-1222), the aforementioned building is classified as follows:

Fuel	Size	Price (incl. CCL)	Date
Electricity	Moderately Large	6.57p/kWh	4th Qtr 2007
Gas	Medium	1.89p/kWh	4th Qtr 2007

Therefore, to provide incentives for possible future consumers a 10% reduction in the electricity price is assumed.

Electricity Community Sale Price = 5.91p/kWh

To calculate the community heat price, the typical gas price of 1.89p/kWh is used with an assumed existing boiler efficiency of 80% giving an initial price of 2.36p/kWh. However, an additional cost for boiler maintenance of 0.14p/kWh is added assuming that there is a £12,500 annual maintenance charge for the 9GWh annual heat demand.

Heat Community Sale Price = 2.50p/kWh

From Defra's Analysis of UK Potential for CHP – Oct 07, the predicted large-scale CHP export price will be approximately 2.56p/kWh in the near future (2010).

Electricity Export Price = 2.56p/kWh

CHP gas price is less than the gas price for a medium size consumer (1.89p/kWh) due to the larger supply and Climate Change Levy exemption.

CHP Gas Price = 1.512p/kWh

It has been assumed that any electricity over and above the output of the CHP unit will simply pass through the system with the bulk purchase price set the same as the sale price. i.e. no profit is made through the bulk purchase and re-sale of electricity. This ensures that the model identifies the savings from the CHP and that any possible bulk purchase and re-sale profits would simply enhance the economics of each scenario. Bulk purchase profits are very difficult to estimate and can often mask the viability of the CHP plant.

Administration costs have been calculated using the assumption that a typical annual electricity supply is 20,000MWh/year and that the annual running costs of the administration centre would be £50,000. Therefore:

Administration cost = 0.25p/kWh

An additional Duos charge would be payable on electricity that was to be distributed to customers through the existing local energy networks. This comprises of three parts:

- Metered tariffs
- Availability charge
- Power factor

Therefore, assuming that all of the buildings would be half-hourly metered and accepting a high-voltage supply (greater than 1kV).

Metered Tariff

Time	Duos Charge (p/kWh)	Proportion
Night	0.021	10%
Winter Evening	1.2	10%
Winter Day	0.36	55%
Summer Day/Evening	0.235	25%
TOTAL	0.3	100%

Availability Charge

An availability charge for each month for each kVA of available capacity:

(1,300 kVA x 102.6p/kVA)/6,000,000 = 0.22p

Power Factor

Assumed power factor minimum of 0.8, a conservative estimate would be a 1.08 power factor. This equates to 8% of the electricity charge of 0.59p/kWh.

5.91p/kWh x 0.08 = 0.48p/kWh

Therefore,

Duos charge = 0.3p/kWh + 0.22p/kWh + 0.48p/kWh = 1.00p/kWh

Project Information

		Comments
Project Life	25 years	New CHP engine at 13 years
Discount Rate	10%	-
Inflation	3%	-

Environmental Financial Information

Climate Change Levy - Electricity	0.456p/kWh
Climate Change Levy - Gas	0.159p/kWh
Carbon dioxide value	£0/ton

Capital Costs

The capital costs of some sections of the network were calculated as a % of the CHP unit cost. The costs were as follows:

	% of CHP unit cost
DH customer connections	25%
Project management & engineering	36%
Contingency and other soft costs	36%

Energy Centre Costs

Every CHP unit has an associated energy centre cost. The cost consists of a fixed and variable element to model the economies of scale for the energy centre.

Energy centre cost = (70 x CHP unit size in kW) + 300,000

District heating, private wire and cooling network costs

Each scenario had an individual piping network mapped. The sizes of the pipes were calculated and then the following cost calculation was used:

Hot water pipe cost = (5 x hot water pipe diameter in mm) + 500

Private wire costs are assumed to be £200/m which includes all building connection associated costs.

The cost of installation of a cooling network was assumed to be 50% of the hot water pipe cost.

Absorption Chiller Costs

It was assumed that the price for absorption cooling was £160/kW cooling output.

License Costs

From: Comparative Costs of Operating On-Site/Private Wire Distributed Energy Systems on a Licensed rather than Licence Exempt Basis - A report for the London Climate Change Agency

Establishment cost of a Licensed supplier: £71,626 - £151,226 (p5)

Therefore, the mean will be taken at: £110,000 (rounded from £111,426)