GREATER**LONDON**AUTHORITY

Decentralised energy capacity study

Phase 1: Technical Assessment

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Greater London Authority

City Hall

The Queen's Walk

More London

London SE1 2AA

www.london.gov.uk

enquiries 020 7983 4100

minicom 020 7983 4458

Project team

The Greater London Authority

Michael Doust

Peter Daw

Peter North

Robert Tudway

Buro Happold Ltd

Alasdair Young

Camco

Duncan Price

This report has been led by the Greater London Authority working in collaboration with a consultant team from Buro Happold Ltd and Camco.

Contents

Table of figures

Table of tables

Glossary

AQMA	Air Quality Management Area
ASHP	Air source heat pump/s
BRE	Building Research Establishment
C&D	Construction and demolition
C&I	Commercial and industrial
CCGT	Combined cycle gas turbine
CCHP	Combined cooling, heat and power
CHP	Combined heat and power
COP	Coefficient of performance
CO_2	Carbon dioxide
DE	Decentralised energy
DECC	Department for Energy and Climate Change
Defra	Department for the Environment, Food and Rural Affairs
DEMaP	Decentralised energy and master planning
EA	Environment Agency
EER	Energy Efficiency Rating
EfW	Energy from waste
EGS	Engineered geothermal system
FIT	Feed-in tariff
GIS	Geographic information system
GLA	Greater London Authority
GSHP	Ground source heat pump/s
GWh	Gigawatt hour

IEA	International Energy Agency
hh	Household
LA	Local authority
LCBP	Low Carbon Buildings Programme
LCCA	Life cycle cost analysis
LCPD	Large Combustion Plant Directive
LEGGI	London Energy and Greenhouse Gas Inventory
LSOA	Lower layer super output area
MBT	Mechanical biological treatment
MSOA	Middle layer super output area
MSW	Municipal solid waste
MW	Megawatt
MWe	Megawatt electric
MWth	Megawatt thermal
MWh	Megawatt hour
NOABL	Numerical objective analysis of boundary layer
NO_x	Generic term for the mono-nitrogen oxides NO and NO_2 (nitric oxide and nitrogen dioxide)
ONS	Office for National Statistics
OS	Ordnance Survey
PV	Photovoltaic
RE	Renewable energy
RHI	Renewable Heat Incentive
RSPB	Royal Society for the Protection of Birds
SAC	Special Areas of Conservation

SHLAA	Strategic Housing Land Availability Assessments
SPA	Special Protection Areas
SRF	Solid recovered fuel
SSSI	Sites of Special Scientific Interest
SWH	Solar water heating
TSP	Total suspended particulates
WID	Waste Incineration Directive

Executive summary

This report forms part of a regional assessment of the potential for renewable and low carbon energy in Greater London and has been conducted by the Greater London Authority (GLA) with funding from the Department for Energy and Climate Change (DECC). It sets out the methodology and results of an assessment of the technical potential for renewable energy (RE) and decentralised energy (DE) up to 2031, which comprises Phase 1 of the regional assessment. Phase 2 of the study looks at economic viability and deployment constraints.

For the purposes of the study, RE has been defined as renewable energy sources arising within London (unless otherwise stated). DE has been defined as using heat networks to transfer heat from generation sources to areas of demand. For Phase 1 an estimation of the available supply of biomass has been included in the RE assessment, whilst the potential for using biomass within a district heating system has been examined in the DE section. Biomass includes the organic fraction of municipal and commercial and industrial (C&I) waste as well as wood and agricultural arisings.

Two approaches have been adopted:

- A standardised methodology developed by DECC (referred to as the 'DECC methodology') and a tailored version – developed by the project team to take into account the highly urbanised nature of Greater London – were used to determine the opportunities for RE;
- A separate methodology was developed by the project team for DE based on a range of technical and practical considerations.

Key findings from Phase 1 using the tailored methodology for RE are highlighted below. The results are for 2010 and all energy use and carbon dioxide (CO_2) emissions comparisons are relative to 2008.

Renewable energy

- Up to 34% and 49% of London's consumption of electricity and heating respectively can technically be met by RE sources from within Greater London, delivering annual CO_2 emission reductions of 5.4 million tonnes (see Table ii).
- PV and heat pumps (air source and ground source) have the greatest technical potential of any individual RE technology, providing 19% of electricity consumption and 44% of heat consumption respectively (see Table ii).
- Ground source heat pumps (GSHP) and air source heat pumps (ASHP) can respectively contribute 4,889MW and 18,981MW of undiversified peak heating capacity (see Table ii). However, total electricity consumption in London will increase by 32% (see Section 7.4).
- No consideration is made of the detailed performance of PV and heat pump technologies or their impact on the electrical distribution network. Modifying the electrical network to deal with large amounts of embedded generation from PV and higher peak demand levels from heat pumps is likely to represent a significant constraint to deployment. Further work is required to understand this issue.

- Biomass has the potential to meet around 4% of London's heat and electricity demand in 2010. The potential increases to over 5% by including wood fuel from the Greater South East (see Table ii). These resources are assumed to be used in combined heat and power (CHP) plants, requiring extensive heat networks.
- Under the DECC methodology, up to 12% and 57% of London's consumption of electricity and heating respectively can technically be met by RE sources from within Greater London, delivering annual CO_2 emissions reductions of 2.5 million tonnes (see Table i).
- The tailored methodology gives significantly greater estimates of the technical potential for certain types of RE than the DECC methodology. For example, the estimated potential for commercial-scale wind using the DECC methodology is 735MW rising to 2,197MW using the tailored methodology. The DECC methodology predicts 2,108MW of PV capacity whilst the tailored methodology estimates this at 9,247MW. This is due to the different assumptions about siting of wind turbines and the size of PV arrays on individual buildings (see Tables i and ii).

Technology	Installed capacity (MW)	Energy generation (GWh p.a.)		Carbon savings ($MtCO_2$ p.a.)	% of London's energy demand, 2008	
		Electricity	Heat		Electricity	Heat
Photovoltaics	2,108	1,744	-	0.7	4.4%	-
Solar water heating	796	-	512	0.1	-	0.8%
Heat pumps	28,687	-	34,654	0.03	-	52.5%
Wind (commercial)	735	1,529	-	0.6	3.8%	-
Wind (small-scale)	11.4	14.2	-	0.006	0.04%	-
Biomass (London)	-	1,401	2,524	1.1	3.5%	3.8%
Hydro	3.0	23.9	-	0.009	0.1%	-
Total	**32,341**	**4,712**	**37,689**	**2.5**	**11.8%**	**57.1%**

Table i: Summary of renewable energy technical potential using the DECC methodology, 2010

Technology	Installed Capacity (MW)	Energy generation (GWh p.a.)		Carbon savings ($MtCO_2$ p.a.)	% of London's energy demand, 2008	
		Electricity	Heat		Electricity	Heat
Photovoltaics	9,247	7,647	-	3.0	19.2%	-
Solar water heating	-	-	930	0.2	-	1.4%
Air source heat pumps	18,981	-	22,928	-0.7	-	34.7%
Grd source heat pumps	4,889	-	5,906	0.005	-	8.9%
Wind (commercial)	2,197	4,099	-	1.6	10.3%	-
Wind (small-scale)	11.4	14.2	-	0.006	0.04%	-
Biomass (London)	-	1,401	2,524	1.1	3.5%	3.8%
Tidal	120	300	-	0.1	0.8%	-
Hydro	3.0	23.9	-	0.009	0.1%	-
Geothermal	-	-	-	-	-	-
Sub-total	**35,447**	**13,485**	**32,288**	**5.4**	**33.8%**	**48.9%**
Biomass (Greater SE)	-	583	972	0.4	1.5%	1.5%
Total	**35,447**	**14,069**	**33,260**	**5.9**	**35.3%**	**50.4%**

Table ii: Summary of renewable energy technical potential using the tailored methodology, 2010

Decentralised energy

- The technical potential of DE using large-scale heat networks is 20% of London's energy supply, or 2,042MWth and 1,887MWe of thermal and electrical output respectively (see Table iii). The majority of this is from gas-fired CHP plants and waste heat from existing power stations.
- The technical potential of DE using local-scale heat networks (where large-scale heat networks are deemed not to be viable) is 3% of London's energy supply, or 525MWth and 210MWe of CHP thermal and electrical output respectively (see Table iii). This capacity is made up of gas engine CHP and biomass heat-only boilers.
- The overall technical potential of DE, based on the above mix of generation sources, gives CO_2 emissions savings of 0.8 million tonnes per year (see Table iii). A different mix of generation sources can yield significantly higher emissions reductions. The potential for DE using all of the available biomass resource is presented in Table iv.
- It is estimated that around 450MW of waste heat capacity is available from existing power stations and energy from waste (EfW) plants in the London area (see Table 13.3). This capacity can represent a stepping stone to future low, and zero, carbon heat generation sources if used to help establish extensive heat networks.
- An assessment of alternative heat generation sources suggests that, by 2031, an additional 45,580GWh p.a. of heat can be available, representing 66% of London's heat demand in 2031 (see Table 13.8). At present, however, this potential is zero. Sources include waste heat from

power stations outside of Greater London, sewage treatment plants and building cooling systems. Heat networks will be required to exploit these resources.

Heat network	Installed Capacity (MW)	Energy generation (GWh p.a.)		Carbon savings ($MtCO_2$ p.a.)	% of London's energy demand, 2008	
		Electricity	Heat		Electricity	Heat
Large-scale	1,887	10,939	11,836	0.7	27.4%	17.9%
Local-scale using anchor heat loads	210	1,214	2,132	0.1	3.0%	3.2%
Total	**2,097**	**12,153**	**13,968**	**0.8**	**30.5%**	**21.2%**

Table iii: Summary of decentralised energy technical potential, 2010

Combined technical potential

- The combined technical potential for RE and DE is up to 53% and 44% of London's consumption of electricity and heating respectively. This delivers combined CO_2 savings of 6.3 million tonnes per year (see Table iv). To calculate the combined potential, biomass is prioritised as a fuel source and assumed to be used solely in conjunction with heat networks. The technical potential is adjusted for heat network losses.
- The compatibility of RE and DE is considered by assuming that, in areas where it is considered viable, DE supply displaces 80% of the thermal microgeneration RE sources. This is based on the assumption that policies which strongly favour DE over other energy sources are required to reach high levels of heat network deployment.

Technology	Installed Capacity (MW)	Energy generation (GWh p.a.)		Carbon savings ($MtCO_2$ p.a.)	% of London's energy demand, 2008	
		Electricity	Heat		Electricity	Heat
Renewable energy potential excluding biomass	35,812	12,385	16,703	4.7	31.1%	25.3%
Biomass potential adjusted for heat network losses (including biomass in Greater South East)	n/a	1,511	3,031	1.1	3.8%	4.6%
Decentralised energy potential excluding biomass component	1,872	7,288	9,079	0.6	18.3%	13.8%
Total combined technical potential of renewable and decentralised energy	**37,685**	**21,184**	**28,812**	**6.3**	**53.1%**	**43.7%**

Table iv: Summary of combined technical potential, 2010

1 Introduction

This report forms part of a regional assessment of the potential for renewable and low carbon energy in Greater London and has been conducted by the Greater London Authority (GLA) with funding from the Department for Energy and Climate Change (DECC). It sets out the methodology and results of an assessment of the technical potential for renewable energy (RE) and decentralised energy (DE) up to 2031, which comprises Phase 1 of the regional assessment. Phase 2 of the study looks at economic viability and deployment constraints.

For the purposes of the study RE has been defined as renewable energy sources arising within London (unless otherwise stated). DE has been defined as using heat networks to transfer heat from generation sources to areas of demand. For Phase 1 an estimation of the available supply of biomass has been included in the RE assessment, whilst the potential for using biomass within a district heating system has been examined in the DE section. Biomass includes the organic fraction of municipal and commercial and industrial (C&I) waste as well as wood and agricultural arisings.

Two approaches have been adopted:

- a standardised methodology developed by DECC (referred to as the 'DECC methodology') and a tailored version – developed by the project team to take into account the highly urbanised nature of Greater London – were used to determine the opportunities for RE;
- a separate methodology was developed by the project team for DE based on a range of technical and practical considerations.

The report is accompanied by datasheets which contain the full calculations. Where numbers do not add up in tables, this is due to rounding. Full versions of these tables can also be found in the accompanying datasheets. Assumptions regarding baselines and methodologies are consistent throughout the report.

1.1 Section A: Renewable energy

Section A of the report sets out the methodology, assumptions and results of the work to establish the technical potential for RE in London:

1. Methodology
2. Wind potential – large-, medium- and small-scale wind potential in London
3. Biomass potential – assessment of the available biomass fuel
4. Solar photovoltaic (PV) potential
5. Solar water heating (SWH) potential
6. Heat pumps potential – ground source and air source
7. Hydropower potential
8. Tidal potential
9. Geothermal potential

10. Summary of technical potential

1.2 Section B: Decentralised energy

Section B of the report sets out the methodology, assumptions and results of the work to establish the technical potential for DE in London:

11. Methodology
12. Heat generation – review of possible low carbon heat sources in London
13. Heat distribution – review of heat distribution network potential in London
14. Summary of technical potential

1.3 Energy consumption and carbon emissions in London

The annual energy consumption and carbon dioxide (CO_2) emissions of London's built environment, broken down by non-residential and residential use for 2008, are illustrated in Figure 1-1 and Figure 1-2 respectively. Throughout this report, energy consumption and CO_2 emissions figures are taken from the London Energy and Greenhouse Gas Inventory (LEGGI) for 2008.

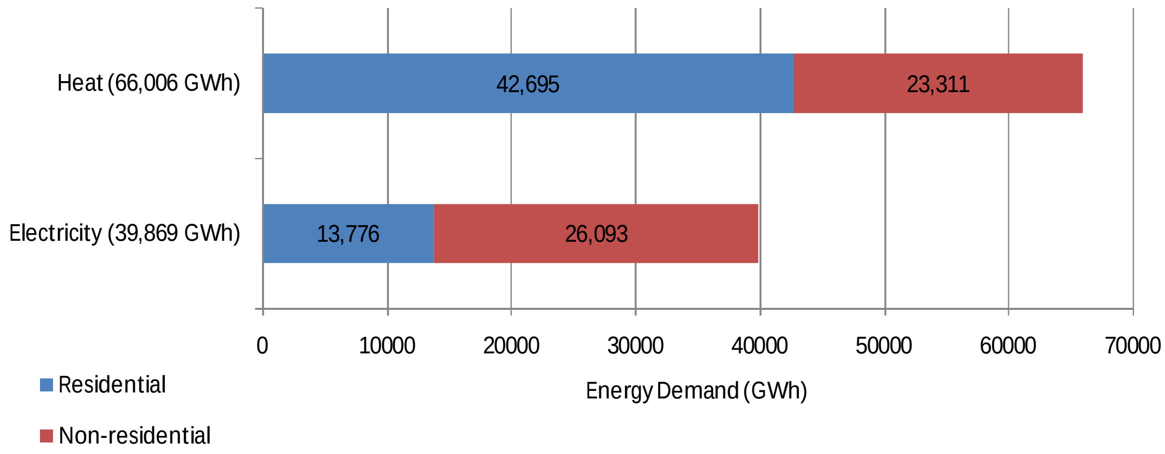

Figure 1-1: London energy demand, 2008 (Source: LEGGI 2008[1])

[1] GLA (2010) London Energy and Greenhouse Gas Inventory 2008: http://data.london.gov.uk/datastore/package/leggi-2008-database, assuming 85% boiler efficiency

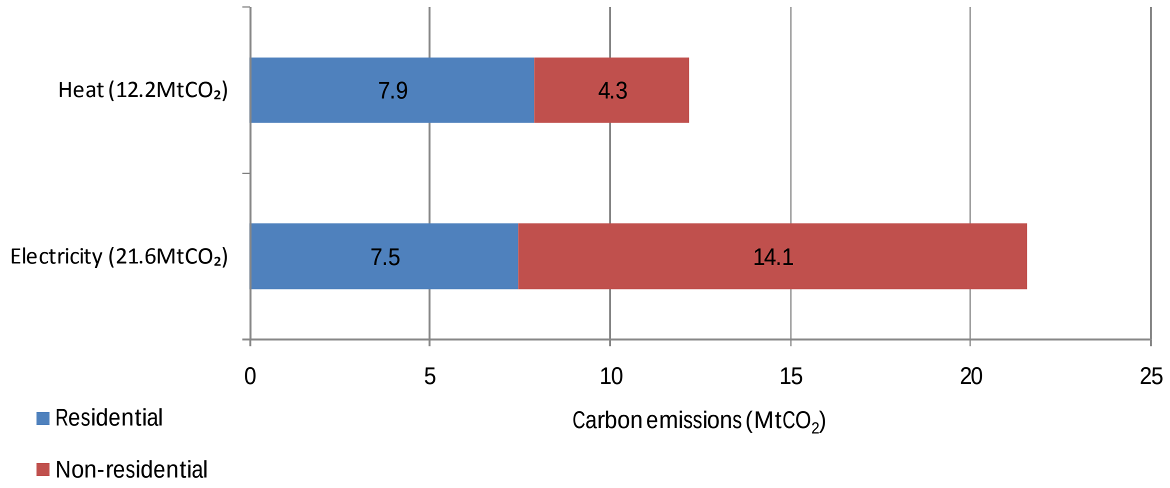

Figure 1-2: London CO_2 emissions, 2008 (Source: LEGGI 2008)

CO_2 emissions will be influenced by changes in the carbon intensity of electricity in the UK as more renewable and low carbon sources of generation are developed. The carbon factors used in this report are shown in Table 1-1.These factors vary with the scenario modelling developed for Phase 2 but are constant in the Phase 1 work.

Input	Values	Reference
Natural gas carbon factor	0.185 $kgCO_2$/kWh	DECC/Defra, 2010[2]
2010-2025 marginal grid electricity carbon factor	0.394 $kgCO_2$/kWh	DECC, 2010[3]
2008 five-year rolling average grid electricity carbon factor (used for the electricity consumption of heat pumps)	0.542 $kgCO_2$/kWh	DECC/Defra, 2010[2]

Table 1-1: Carbon factors used for Phase 1

[2] DECC/DEFRA (2010) GHG conversion factors for company reporting, Table 3C: http://archive.defra.gov.uk/environment/business/reporting/pdf/101006-guidelines-ghg-conversion-factors.pdf

[3] DECC (2010) Valuation of energy use and greenhouse gas emissions for appraisal and evaluation, Box2.B, Table 1, 2011, Marginal emissions factor: http://www.decc.gov.uk/assets/decc/statistics/analysis_group/122-valuationenergyuseggemissions.pdf

The projected future energy consumption of London's built environment in 2031 is shown in

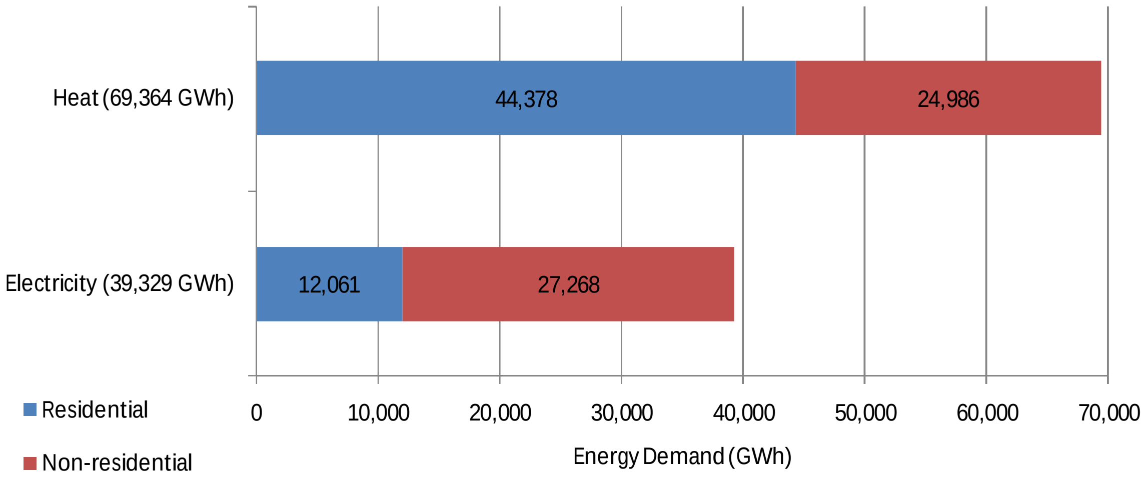

Figure *1-3*. It has been determined by applying the percentage change in energy consumption between 2008 and 2030 in the DECC 2050 Pathway Alpha[4] to London's 2008 energy consumption (as in Figure 1-1). This pathway assumes a significant energy efficiency programme. The Strategic Housing Land Availability Assessment for London (SHLAA)[5] has been taken alongside projections for employment land[6] which outlines the estimated growth for domestic and non-domestic buildings up to 2031 as shown in Table 1-2. The impact of new development on RE resources has also been modelled using this data.

Number of buildings	2010	2031
Domestic (SHLAA)	3,279,601	3,783,104
Non-domestic (London employment sites database)	434,749	456,779

Table 1-2: Number of buildings in London in 2010 and 2031

[4] DECC (2010) 2050 Pathways Analysis: http://www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/2050/2050.aspx

[5] GLA (2009) The London Strategic Housing Land Availability Assessment and Housing Capacity Study 2009: http://www.london.gov.uk/shaping-london/london-plan/docs/strategic-housing-land-study-09.pdf

[6] GLA (2009) London employment sites database, 2009: www.london.gov.uk/shaping-london/london-plan/docs/strategic-housing-land-study-09-appendix1.rtf

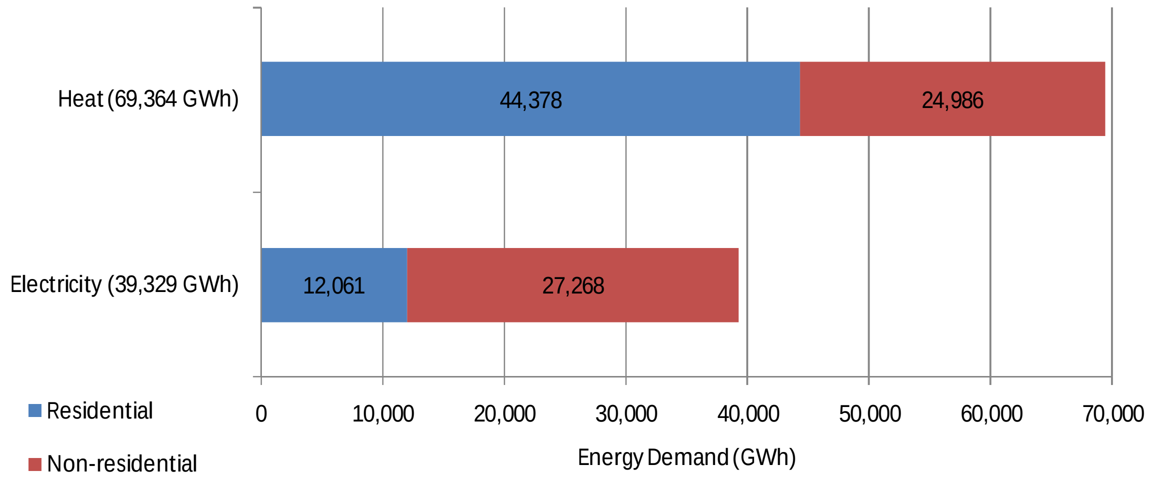

Figure 1-3: Projected London energy demand, 2031 (Source: LEGGI, 2008 and DECC 2050 Pathways Analysis)

SECTION A – RENEWABLE ENERGY POTENTIAL

2 Methodology

2.1 Overview of approach

Two separate assessments of the technical potential for RE have been undertaken, one using a standard methodology provided by DECC and a second assessment using a tailored methodology developed by the project team. Full technical details and assumptions are given as appendices to the main report.

2.2 The DECC methodology for renewable energy assessments

Figure 2-1 summarises the key stages of DECC's 'Renewable and Low-Carbon Energy Capacity Methodology for the English Regions', referred to as 'the DECC methodology' in this report[7]. The methodology intends to standardise regional assessments of the potential for RE. In line with the DECC methodology, the approach taken to assess London's renewable and low carbon energy potential has involved applying progressive layers of analysis to London's theoretical potential, in order to establish a more realistically achievable potential.

This Phase 1 report outlines the results for stages 1 to 4 of the assessment which provide an estimate of the *technical* potential of renewable and low carbon energy in London. Although the diagram illustrates all 7 recommended stages of the assessment, the DECC methodology does not provide any guidance or criteria to address economic and supply chain constraints (stages 5 to 7), which are evaluated in Phase 2 of this study.

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[7] SQW Energy (2010) Renewable and Low-carbon Energy Capacity Methodology: http://www.decc.gov.uk/assets/decc/What%20we%20do/UK%20energy%20supply/Energy%20mix/Renewable%20energy/ORED/1_20100305105045_e_@@_MethodologyfortheEnglishregions.pdf

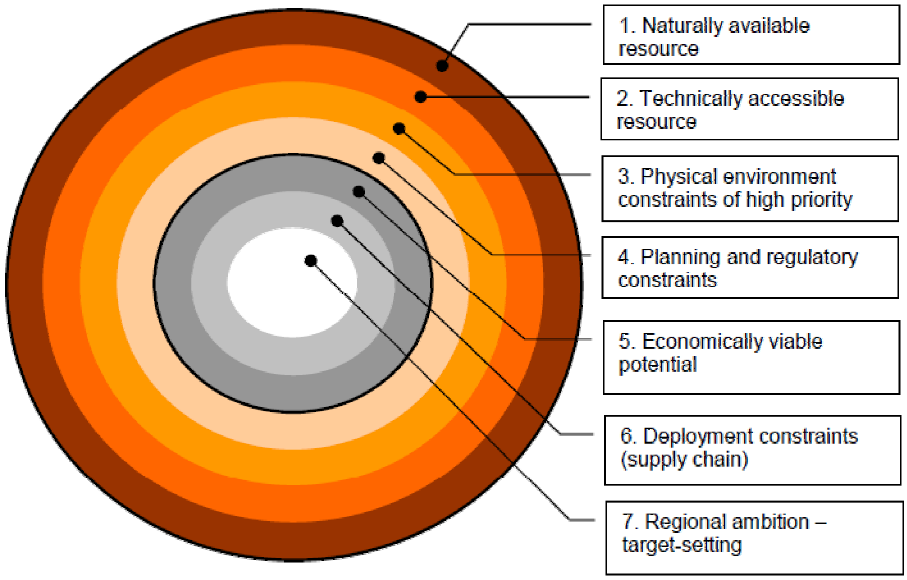

Figure 2-1: The DECC methodology for estimating renewable and low carbon energy capacity (Source: SQW Energy[7])

2.3 Tailored methodology for London renewable energy assessment

The DECC methodology aims to provide a standardised approach that can be applied across all the English Regions. However, London's heavily urbanised environment challenges some of its criteria and parameters, which could lead to an under or over estimation of the technical potential within London. In order to address this risk, a London specific methodology for stages 1-4 was developed, referred to as 'the tailored methodology' in this report.

2.4 Assessing renewable energy potential within both the existing built environment and new development up to 2031

As outlined above, stages 1 to 4 of the assessment provide an estimate of the RE technical potential. This is the total resource that could be exploited if all opportunities were taken advantage of, without taking into account economic or deployment considerations. The four stages are:

- Stages 1 and 2: Naturally available resource and technically accessible resource – this is the *opportunity* analysis of what currently available technology can capture and convert into useful energy;
- Stages 3 and 4: High priority physical environment constraints and planning and regulatory constraints – this is the *constraints* analysis of the restrictions that the physical environment and planning restrictions or other legislation places on the deployment of the technology.

The stage 1 to 4 assessments cover both the existing and the future built environment of London as it includes the RE potential associated with the planned new build for London between now and 2031. No allowance has been made for future improvements in technology.

2.5 Installed renewable energy capacity in London

In order to establish a baseline, information relating to the installed RE capacity in London has been gathered from five key sources: successful planning applications made in London for renewable technologies; installations under London Plan and local borough policies; an estimate of 60%[8] renewable component of waste incineration plants in London; and schemes installed under the Feed-in Tariff (FIT) since it was introduced. Consideration has also been made of renewable technologies supported under previous grant schemes.

2.5.1 Commercial installations in London

The Planning Database Project published on the DECC website[9] records RE projects with a capacity over 0.01MW and is updated on a monthly basis. Information is based on the installed capacity, not the operational performance as this is often commercially sensitive information which is not made available publicly.

The commercial applications covered are large individual installations, whereas the other data sources cover smaller applications aiming to provide a portion of energy demand of a development or individual property. Ground source heat pumps (GSHP), SWH installations and smaller PV systems are often permitted development and hence do not appear in this database.

Capacity (MW)	Biomass – Dedicated	Landfill Gas	Photo-voltaics	Wind	Total
Operational capacity	0	20.8	0.1	3.6	**24.5**
Under construction	3.0	0	0	2.0	**5.0**
Awaiting construction	0	0	0.3	11.1	**11.3**
Total	**3.0**	**20.8**	**0.4**	**16.7**	**40.8**

Table 2-1: Commercial renewable energy installations across London, 2010

The 20.8MW capacity from landfill gas consists of two projects at Rainham, Havering; these have both been operational since 2002. There is 3.6MW of capacity of large scale-wind situated at the Ford Dagenham plant (consisting of two 1.8MW turbines)[10] and planning permission for an additional 2MW large-scale wind turbine has been approved on this estate[11]. Planning permission has also been granted for an 11.1MW wind farm on the Willow Lane Industrial estate, Merton, however construction had not yet commenced at the time of publication[12].

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[8] GLA (2010) Breakdown of MSW content taken from Draft Municipal Waste Strategy: http://www.london.gov.uk/publication/draft-waste-strategy (the strategy states that 60% of MSW comes from components of the waste stream which can be classified as renewable)

[9] DECC (2010) Planning Database Project: https://restats.decc.gov.uk/cms/planning-database

[10] Ecotricity (2010) Wind Parks Gallery: http://www.ecotricity.co.uk/wind-parks/dagenham-london

[11] Ecotricity (2010) Dagenham II Wind Park: http://www.ecotricity.co.uk/our-green-energy/our-green-electricity/from-the-wind/wind-parks-gallery/dagenham-ii-london

[12] RESTATS (2011) Planning database extract, reference number N00311W: https://restats.decc.gov.uk/app/reporting/decc/monthlyextract/start/1621/showperpage/30

2.5.2 Installations driven by London Plan policies

Additional RE capacity in new developments in London has been driven through the GLA's London Plan energy policies. An analysis of this was completed by London South Bank University which reviewed data from energy statements submitted with planning applications for strategic developments referred to the Mayor between November 2006 and June 2009[13].

2.5.3 Schemes registered under the Feed-In Tariff

FITs were introduced on the 1st April, 2010 and cover all renewable electricity schemes under 5MW which were installed after July 2009. Schemes generating thermal energy will be covered by the Renewable Heat Incentive (RHI) which is expected to be introduced in 2011. Ofgem provides information on FIT installations by local authority[14].

2.5.4 Installations funded by Low Carbon Buildings Programme

The Low Carbon Buildings Programme (LCBP), which has been closed to applications since May 2010, had a significant role in increasing the uptake of renewable technologies. It provided around 20,000 grants, 11,000 of which were for thermal technologies. Data has been obtained for installations in London under Phase 1 (Stream 1, householders) and Phase 2 of the Programme[15].

2.5.5 PV Installations funded by Major PV Demonstration Programme

Between 2002 and 2007, the Major PV Demonstration Programme invested £26 million to secure long-term and sustained growth of the PV market. This represents around 1,800 installations with a total capacity of 8.7MWp.[16] London's share on a population basis is around 1MWp of PV capacity.

2.5.6 Summary of installed renewable energy capacity in London

The data sources above suggest that by the end of 2010 there was approximately 173MW of installed capacity, or around 858GWh of energy generation, within London, or awaiting construction as shown in Table 2-2. Although this may not be a complete picture of the total installed RE capacity in London, it nonetheless demonstrates that the installed RE resource is very small compared to the city's overall annual energy consumption of 105,000GWh.

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[13] London South Bank University (2009) Monitoring the London Plan Energy Policies Phase 3 - Part 1 report FINAL, December 2009: http://www.london.gov.uk/sites/default/files/lon-plan-energy-policies-monitoring-1.pdf

[14] Ofgem (2010) FIT Installation Statistical Report: https://www.renewablesandchp.ofgem.gov.uk/Public/ReportViewer.aspx?ReportPath=%2fFit%2fFIT+Installations+Statistical+Report_ExtPriv&ReportVisibility=1&ReportCategory=9_

[15] DECC (2010) Low Carbon Buildings Programme: http://www.lowcarbonbuildings.org.uk/

[16] IEA (2010) Major PV Demonstration Programme: http://www.iea.org/textbase/pm/?mode=weo&action=detail&id=1021

Capacity (MW)	Bio-mass	Landfill gas	Photo-voltaics	Solar water heating	Wind	Heat pumps	Micro CHP	Total
Commercial renewable energy installations[17]	3.0	20.8	0.1	0	5.6	0	0	**56.6**
London Plan policies	50.3	0	3.0	3.5	2.6	14.7	1.5	**75.6**
Schemes registered under the Feed-in Tariff	0	0	1.7	0	0.008	0	0.001	**1.7**
Low Carbon Buildings Programme	0	0	0.1	0.08	0	0.1	0	**0.3**
Major PV Demonstration Programme	0	0	1.0	0	0	0	0	**1.0**
SELCHP and Edmonton EfW (biomass element)	37.8	0	0	0	0	0	0	**37.8**
Total (MW)	**91.1**	**20.8**	**5.9**	**3.6**	**8.2**	**14.8**	**1.5**	**173**
Total (GWh)	**638**	**173**	**4.3**	**2.3**	**14.4**	**17.9**	**7.5**	**858**

Table 2-2: Estimate of renewable energy installed capacity in London, 2010

The data sources have been checked to ensure no overlap. The three microgeneration support programmes (Major PV Demonstration Programme, LCBP and FIT) have run sequentially and have not therefore supported the same installations. The biomass capacity stated in the Planning Database Project consists of a large facility in the west of the Olympic Park whereas the biomass capacity under the London Plan policies consists of 41 smaller installations. In addition, the biomass capacity stated in the Planning Database Project does not include the biomass component of SELCHP and Edmonton.

[17] Only installations which are operational or under construction have been reported

3 Wind potential

This section is split into two parts covering commercial-scale and small-scale wind turbines.

3.1 Commercial-scale wind turbines

3.1.1 Overview of approach

An assessment of the potential for commercial-scale wind was undertaken using both the DECC methodology and a tailored methodology. The DECC methodology considers the potential for large-scale wind turbines whereas the tailored potential considers the potential for both large- and medium-scale wind turbines. Large-scale wind turbines are typically favoured commercially due to their considerably greater power output and much lower capital costs per kW installed. However, medium-scale turbines can be an alternative in heavily urbanised areas like London where the deployment of large turbines is constrained by competing land uses. Turbine scales are given in Table 3-1. Further technical details are given in Appendix 1.

Scale	Capacity	Hub height	Rotor diameter
Large	~ 2.5MW	85m	100m
Medium	~ 250kW	31m	27m

Table 3-1: Scale of wind turbines assessed

Spatial analysis using Geographic information systems (GIS) was conducted to identify sites technically suitable for commercial-scale wind development as outlined in Figure 3-1. Subsequently, the maximum number of turbines that could be installed at each site has been estimated based on the minimum distance required between turbines. In line with the DECC methodology this has been assumed to be equivalent to five rotor diameters. This separation allows for adequate spacing between turbine blades to prevent air stream interference.

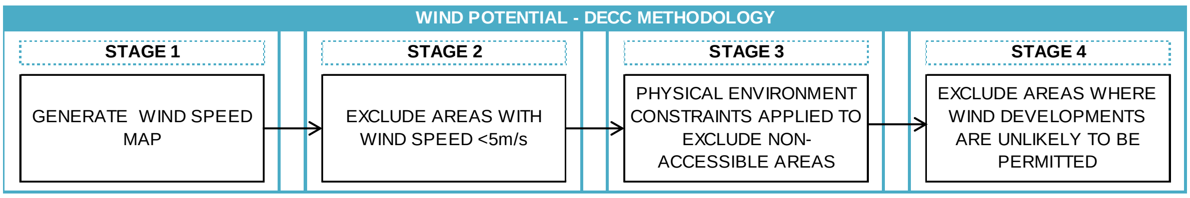

Figure 3-1: Overview of the DECC methodology for assessing commercial wind potential

A load factor[18] was used to calculate the electricity generation that can be expected from a wind turbine. The UK average annual load factor for all large-scale wind energy projects in 2009 was

[18] Load factor (or capacity factor) – the annual generation as a percentage of a turbine's theoretical maximum output

27.4%[19]; however a more conservative view of 25% has been assumed to account for the lower wind speeds in London. A load factor of 20% has been assumed for medium-scale wind turbines. In addition to the load factor, it is assumed that any wind turbine will be taken off line for maintenance for 5% of the time.

3.1.2 Overview of the DECC methodology for assessing commercial-scale wind turbine potential

The DECC methodology provides parameters to conduct the constraints analysis and calculate the technical potential for large-scale wind turbines only. These are summarised in Table 3-2.

[19] DECC (2010) Digest of UK Energy Statistics, Table 7.4: http://www.decc.gov.uk/assets/decc/Statistics/publications/dukes/313-dukes-2010-ch7.pdf

Assessment stage	GIS Layers/parameter – Large-scale turbines (~ 2.5MW)		
	Layer	Buffer	Source
Stage 1: Naturally available resource	Wind speed at 45m above ground level	-	NOABL database (Source: DTI, 2001[20])
Stage 2: Technically accessible resource	Exclude areas where average wind speed at 45m above ground level < 5m/s and apply benchmark of 10MW/km^2 to calculate maximum installed capacity[21]	-	Derived from NOABL database
Stage 3: Non accessible areas due to physical environment constraints	Roads (A, B, and motorways)[22]	-	OS Strategi® data (Source OS, 2010[23])
	Railways	-	OS Strategi® data
	Inland waters	-	OS Strategi® data
	Built-up areas (settlement polygons)	-	OS Strategi® data
	Airports and airfields	-	OS Strategi® data
Stage 4: Areas where wind developments are unlikely to be permitted	Ancient woodland	-	Natural England, 2010[24]
	Roads (A, B, Motorways) and railways	150m	Derived from OS Strategi®
	Built-up areas (settlement polygons)	600m	Derived from OS Strategi®
	Civil airports and airfields	5km	Derived from OS Strategi®
	Sites of historic interest	-	English Heritage, 2010[25] GLA, 2007[26]

Table 3-2: Parameters and constraints for commercial-scale wind development – DECC methodology

[20] DTI (2001) NOABL Windspeed Database: http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/explained/wind/windsp_databas/windsp_databas.aspx

[21] In order to calculate maximum installed capacity in a unit of area, the DECC methodology prescribes a distance of 5 rotor diameters between turbines, or a benchmark of 9MW/km^2, whichever results in the greater capacity. Based on a rotor diameter of 100m the maximum installed capacity is equivalent to 10 MW/km^2

[22] The constraints at this stage represent the physical road and rail infrastructure itself whereas the constraints in stage 4 represent buffer areas around this transport infrastructure

[23] Ordnance Survey (2010) OS Strategi ® [Shapefile geospatial data], Scale: 1:250,000, Coverage: Great Britain: https://www.ordnancesurvey.co.uk/opendatadownload/products.html

[24] Natural England (2010) GIS Digital Boundary Datasets v2.7 [Shapefile geospatial data] Scale: 1:10,000, Coverage: England: http://www.gis.naturalengland.org.uk/pubs/gis/GIS_register.asp

[25] English Heritage (2010) Designated datasets: Scheduled Ancient Monuments, Listed Buildings, Registered Historic Battlefields and Registered Parks and Gardens, World Heritage Sites [Shapefile geospatial data], Scale: 1:10,000, Coverage: England, English Heritage NMR Data Download Area: http://services.english-heritage.org.uk/NMRDataDownload/Default.aspx

[26] GLA (2007) Conservation Areas [Shapefile geospatial data], Geoinformation Group

The DECC methodology recognises the sensitivity of internationally and nationally designated areas for landscape and nature conservation, listed in Table 3-3. However, it states that these designations should not be automatically considered as absolute constraints to wind development. The DECC methodology recommends that, in the absence of more detailed local studies, high level assessment should be carried out to identify the type and level of RE infrastructure that could be accommodated within areas protected under these designations. However, in view of their sensitivity, these designations have not been included in the overall assessment of technical potential using either methodology. Appendix A contains an assessment of the technical potential in these designations.

Category	Designation
International and National Landscape designations	Areas of Outstanding Natural Beauty
	National Parks
	Heritage Coast
International and National Designations for Nature Conservation	Sites of Special Scientific Interest
	Special Areas of Conservation
	Special Protection Areas
	National Nature reserve
	Ramsar Sites

Table 3-3: International and national designations

3.1.3 Overview of the tailored methodology for assessing commercial-scale wind turbine potential

The key differences between the tailored methodology and the DECC methodology are:

The DECC methodology only covers potential from deployment of large-scale wind turbines. The tailored methodology covers large- and medium-scale wind turbines

The DECC methodology suggests that potential impact on residential amenity should be evaluated based on proximity to "built-up areas" (settlement polygons as defined by OS Strategi®) rather than to individual buildings. The tailored methodology evaluates this constraint based on the location of individual buildings and their use i.e. residential or commercial

The DECC methodology does not account for restrictions to commercial-scale wind posed by future developments. The tailored methodology considers SHLAA sites as constrained areas; however, no buffer has been created around these sites.

Applying buffers "around built-up areas" rather than around individual buildings can overestimate the constraint and underestimate the potential for carefully planned turbines on specific sites in or near large conurbations such as London. Conversely, this approach can overestimate the potential in the more open land around Outer London, where scattered residential properties are not identified as settlement polygons in OS Strategi® maps.

Under the tailored methodology, the location and footprint of all the buildings within London have been extracted from OS MasterMap[27], and the Geoinformation Group Land Use map[28] has been used to differentiate between residential and commercial buildings. For large-scale turbines, the buffers have been set at 50m and 350m around commercial and residential properties respectively (see Table 3-4). These buffers are consistent with the recommendations in the Companion Guide to PPS22[29].

Sites within the international and national landscape and nature conservation designations that were identified as technically viable by the initial constraints analysis have been excluded from the final estimate of technical potential (see Appendix 1).

Table 3-4 summarises the parameters and constraints used to assess the technical potential of large- and medium-scale wind turbines under the tailored methodology. The parameters used in this study to assess the potential for medium-scale turbines were agreed by the project team and are consistent with the guidance set out in PPS22. Data sources are similar to those set out in Table 3-2. Full references for this table can be found in the 'Phase 1_Wind energy' datasheet which accompanies this report.

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27 http://www.ordnancesurvey.co.uk/oswebsite/products/os-mastermap/

28 http://www.geoinformationgroup.co.uk/products/land-use

29 ODPM (2004) Planning for Renewable Energy: A Companion Guide to PPS22: http://www.communities.gov.uk/documents/planningandbuilding/pdf/147447.pdf

Assessment stage	Large-scale turbines (~ 2.5MW)		Medium-scale turbines (~0.25MW)	
	Layer	Buffer	Layer	Buffer
Stage 1: Naturally available resource	Wind speed at 45 m above ground level	-	Wind speed at 25 m above ground level	-
Stage 2: Technically accessible resource	Exclude areas with wind speed at 45m above ground level < 5m/s	-	Exclude areas with wind speed at 25m above ground level < 5m/s	-
Stage 3: Non accessible areas due to physical environment constraints	Roads (A, B, and motorways)	-	Roads (A, B, and motorways)	-
	Railways	-	Railways	-
	Inland waters	-	Inland waters	-
	Residential properties	-	Residential properties	-
	Commercial buildings	-	Commercial buildings	-
	SHLAA sites boundaries	-	SHLAA sites boundaries	-
	Airports and airfields	-	Airports and airfields	-
	MoD training sites	-	MoD training sites	-
Stage 4: Areas where wind developments are unlikely to be permitted	Ancient woodland	-	Ancient woodland	-
	Roads (A, B, and motorways) and Railways	150m	Roads (A, B, and motorways) and Railways	150m
	Residential properties	350m	Residential properties	150m
	Commercial buildings	50m	Commercial buildings	50m
	Civil airports and airfields	5km	Civil airports and airfields	3km
	MoD airbases	5km	MoD airbases	3km
	Sites of historic interest	-	Sites of historic interest	-
	International and National Designations for Nature Conservation	-	International and National Designations for Nature Conservation	-
	International and National Landscape designations	-	International and National Landscape designations	-

Table 3-4: Parameters and constraints to commercial-scale wind development – tailored methodology[30]

3.1.4 Technical potential of commercial-scale wind turbines

The analysis suggests that there is considerable technical potential for commercial-scale wind energy development in London under both the DECC methodology and the tailored methodology, as shown in Table 3-5 below.

30 Full references for this table can be found in the 'Phase 1_Wind energy' datasheet which accompanies this report, but they are very similar to those set out in Table 3-2

Commercial-scale wind	Methodology			
	DECC	Tailored		
	Large	Large	Medium	Combined
Land area (ha)	5,903	4,043	13,299	13,299
Number of sites	153	368	1,570	1,482
Number of turbines	294	426	6,406	4,953
Installed capacity (MW)	735	1,065	1,602	2,197
Electricity generation (GWh)	1,529	2,216	2,666	4,099
Carbon savings ($MtCO_2$)	0.6	0.9	1.0	1.6
% of London's electricity demand, 2008	3.9%	5.6%	6.8%	10.4%

Table 3-5: Technical potential of commercial-scale wind, 2010

The DECC methodology identifies a greater area for locating large-scale turbines but provides a lower energy generation estimate than the tailored methodology. This is because the DECC methodology divides the total area by the maximum number of turbines that can be installed per unit of area[31] whereas the tailored methodology sums up the number of turbines that can be individually located at each specific site.

The figure for "combined" potential takes account of the overlap of large- and medium-scale turbine opportunities, assuming that the large-scale turbines are installed in preference to medium-scale turbines. Figure 3-2 and Figure 3-3 illustrate the distribution of the technical potential identified under both methodologies, showing that the majority of the potential is concentrated around the periphery of London.

[31] The DECC Methodology aggregates all potential sites into one gross figure and applies assumptions for minimum separation distance between turbines, whereas the tailored assessment calculates generation potential at each individual site. Under the DECC Methodology a single site of 100ha (1km^2) could accommodate up to 4 large scale turbines; however, under the tailored assessment 10 sites of 10ha each could accommodate 1 turbine each i.e. a total of 10 turbines – which gives a much larger potential

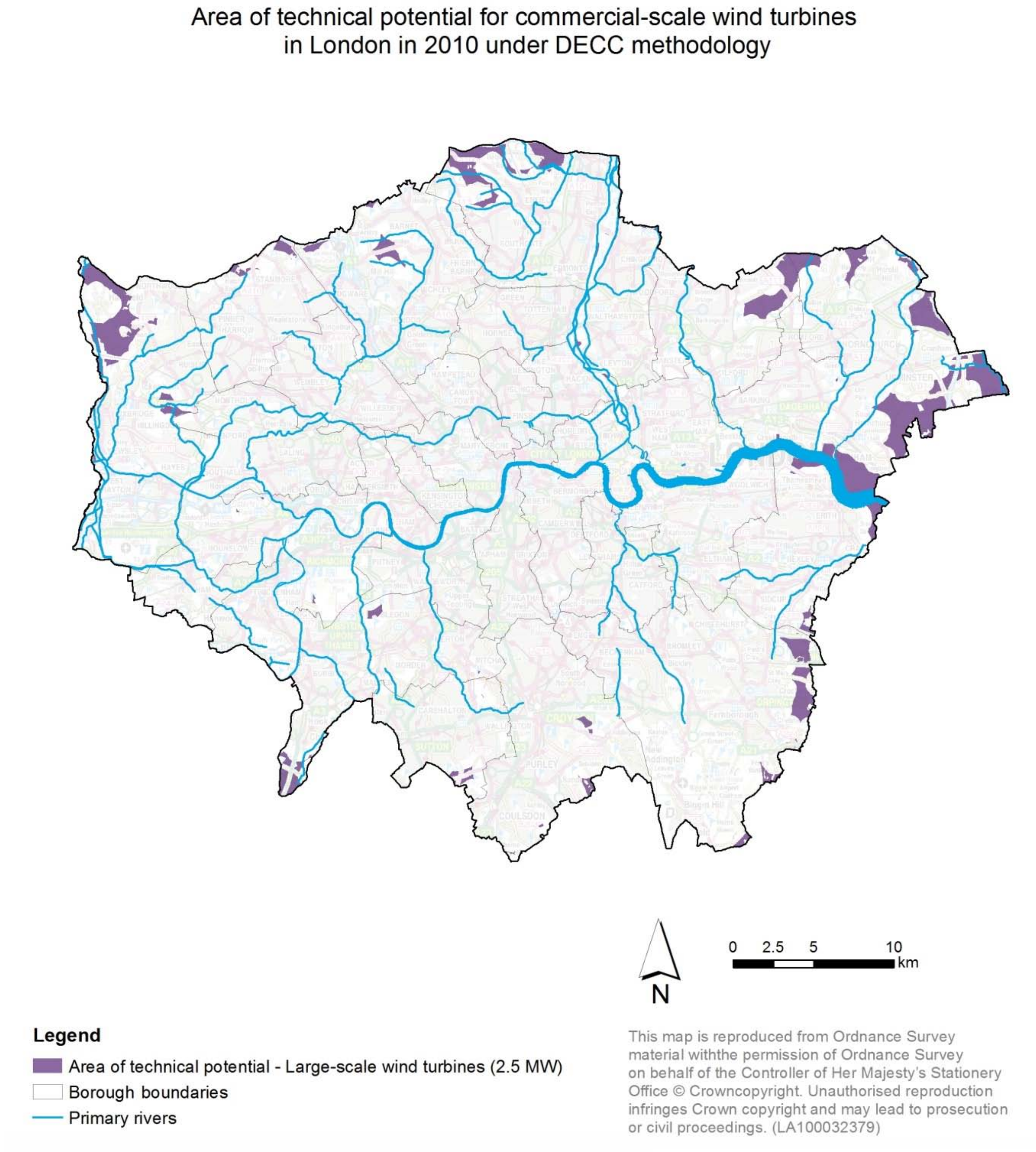

Figure 3-2: Technical potential of commercial-scale wind turbines under the DECC methodology, 2010

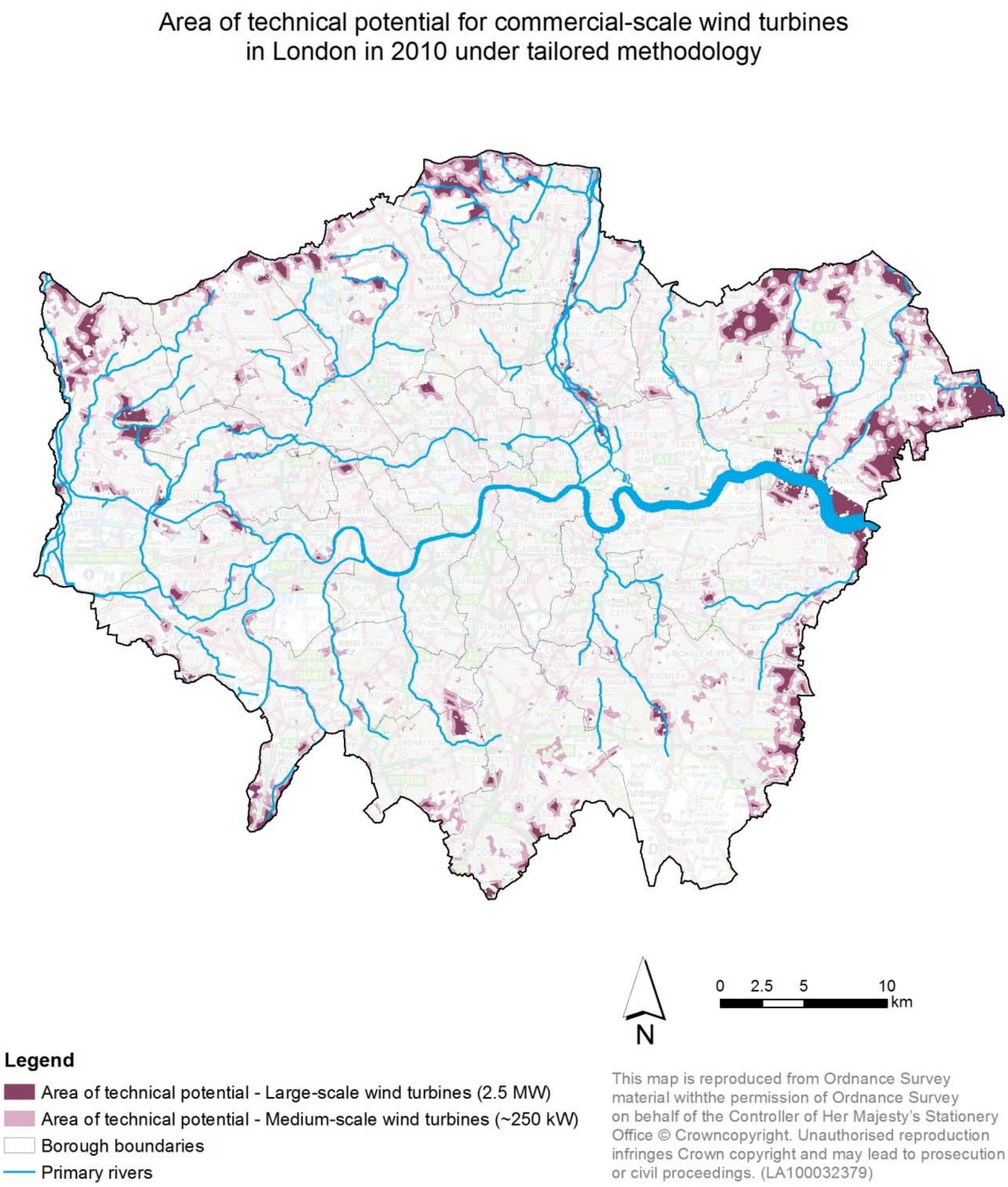

Figure 3-3: Technical potential of commercial-scale wind turbines under the tailored methodology, 2010

3.2 Small-scale wind turbines

3.2.1 Overview of approach

The assessment of small-scale wind turbines has been undertaken using the DECC methodology only (see Figure 3-4). The small-scale turbines considered in the DECC methodology are approximately 6kW turbines with hub heights of about 15m above ground level. They are technically viable at wind speeds of 4.5m/s at 10m above ground level. These turbines are typically located on or next to buildings in order to supply electricity for use on-site, with excess generation fed into the grid.

Correction factors have been applied to the wind speed at 10m above ground level provided by the NOABL wind speed database depending on whether the location is classified as urban, suburban or rural[20]. The Defra Rural-Definition dataset at Lower Layer Super Output Area (LSOA)[32] level has been used to categorise these areas as rural, urban or suburban and a mean wind-speed map superimposed onto this[33]. The scaling factors applied are consistent with the microgeneration installation standard MIS 3003[34].

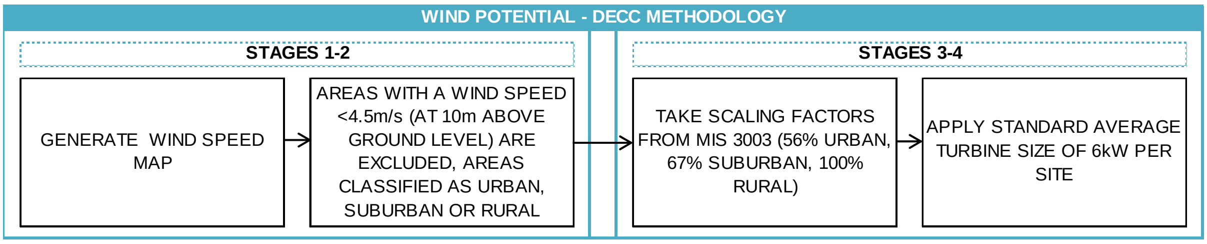

Figure 3-4: Overview of the DECC methodology for assessing small-scale wind potential

For small-scale wind turbines a load factor of 15%[35] and an availability factor of 95% were used.

3.2.2 Technical potential of small-scale wind turbines

Figure 3-5 shows that when scaling factors are applied, only certain areas in Bromley and Hillingdon present wind speeds at 10m above ground level of 4.5 m/s or higher, yielding a technical potential of 11.4 MW.

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[32] The Office of National Statistics (ONS) uses a hierarchy of geographical areas for data dissemination. Output areas are the lowest level, equivalent to a population of around 300; LSOAs represent a population of around 1,500.

[33] RERC (2005) Rural and Urban Area Classification 2004: http://www.ons.gov.uk/about-statistics/geography/products/area-classifications/rural-urban-definition-and-la-classification/rural-urban-definition/index.html

[34] DECC (2008) Microgeneration Installation Standard: MIS 3003: http://www.greenbooklive.com/filelibrary/MIS_3003_Issue_2.0_Micro_Wind_2010.08.26.pdf

[35] Based on Proven WT600 specifications: http://www.provenenergy.co.uk/

Small-scale wind	
Number of turbines	1,893
Installed capacity (MW)	11.4
Electricity generation (GWh)	14.2
Carbon savings ($MtCO_2$)	0.006
% of London's electricity demand, 2008	0.04%

Table 3-6: Technical potential of small-scale wind, 2010

Clearly, small-scale wind turbines will sometimes be installed in other areas of London but will underperform when compared with the DECC threshold of technical viability. This may include roof mounted turbines on blocks of flats or on C&I buildings, including 'micro-scale' turbines (less than 2kW). The Warwick Wind Trials report[36] provides evidence of the generally poor performance of micro-scale building-mounted wind turbines in areas with low wind speeds. On this basis only turbines of the 6kW size have been assessed, as per the DECC methodology, and micro-scale turbines have been excluded.

[36] Encraft (2009) Warwick Wind Trials Project, Final report: http://www.warwickwindtrials.org.uk/resources/Warwick+Wind+Trials+Final+Report+.pdf

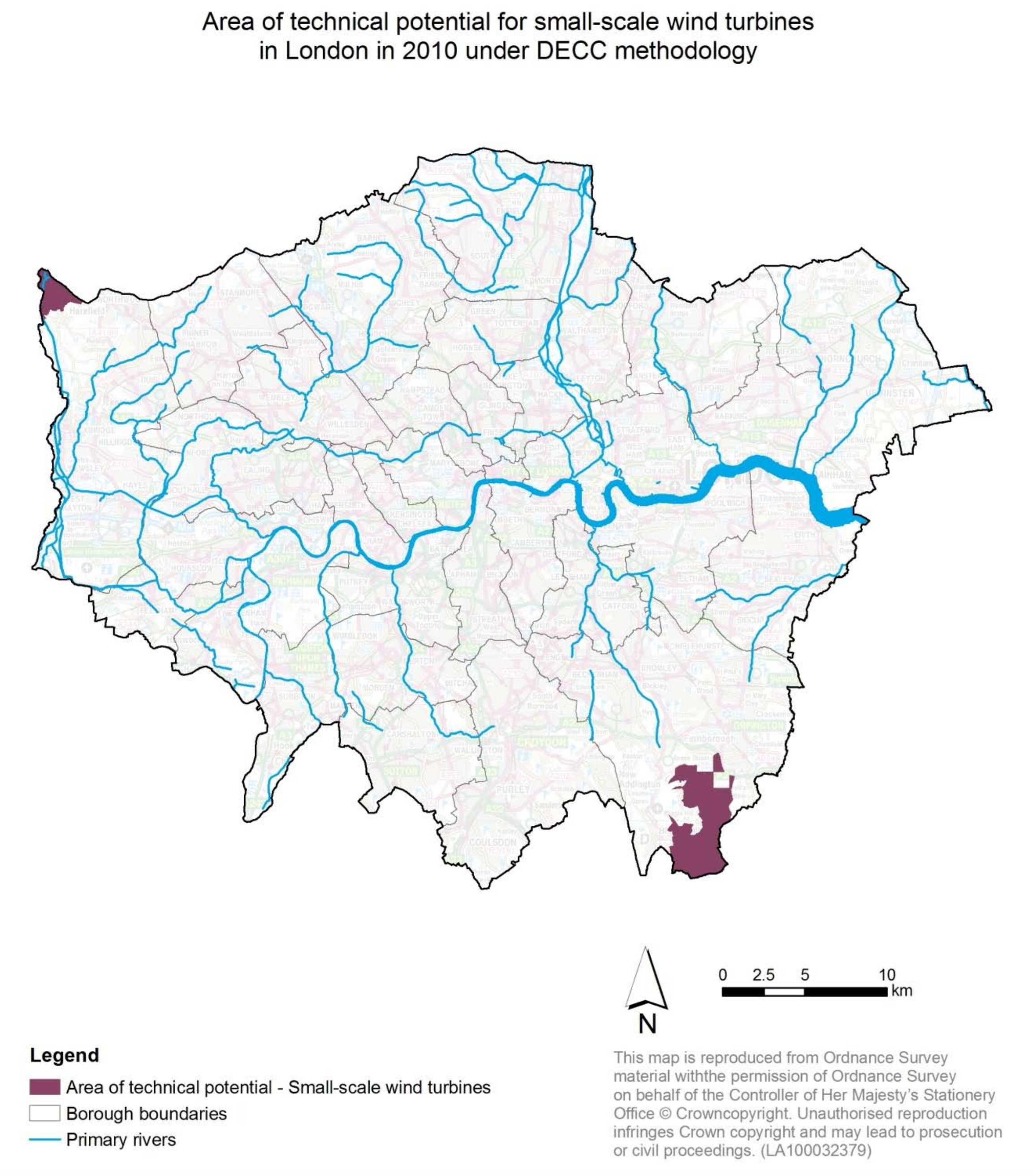

Figure 3-5: Technical potential of small-scale wind turbines under the DECC methodology, 2010[37]

[37] The square area in Bromley not included in the area of technical potential is because the NOABL wind speed data is in 1km squares and this square is below the threshold minimum wind speed

4 Biomass potential

4.1 Overview of approach

In the context of this study, the biomass technical potential refers to the energy that could be generated if all the available resource was used in combined heat and power (CHP) plants. This includes biomass plants using wood fuel, as well as various waste fuelled plants. Figure 4-1 outlines the general approach taken to assess the biomass technical potential. Due to gaps in the DECC methodology for biomass, two separate assessments have not been undertaken. Rather a single assessment using a tailored methodology has been applied. Further technical details and assumptions are given in Appendix 2.

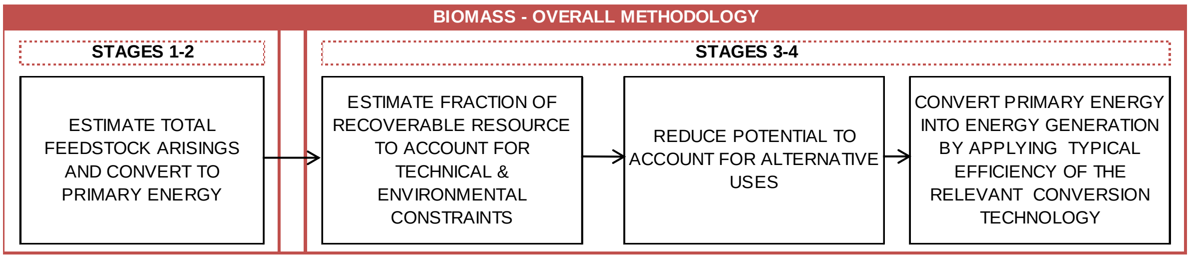

Figure 4-1: Overview of the tailored methodology for assessing biomass potential

4.2 Overview of the tailored methodology for assessing biomass potential

The total quantity of feedstock generated within London (i.e. naturally available resource) has been quantified based on information provided by the GLA and data collected from a number of different sources, including Waste Data Flow[38], GLA's Municipal and Business Waste Management Strategies[39], Forestry Commission's National Inventory of Woodlands and Trees[40] and Defra's Survey of Agriculture and Horticulture[41].

The resource has been reduced to take account of absolute technical and environmental constraints e.g. maximum quantity of straw that can be extracted from the field using technology currently available and without compromising soil properties. Sustainability principles that will prioritise alternative uses above energy recovery for certain fractions of some biomass streams have also been considered and the resource reduced further accordingly, for instance:

For paper and card, only the non-recyclable fraction of paper is available for energy recovery

For industrial food waste, reuse and recycling are prioritised

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38 Chartered Institute of Waste Management (2010): http://www.wastedataflow.org

39 GLA (2010) Draft Municipal Waste Management Strategy: http://www.london.gov.uk/consultation/waste-strategy

40 Forestry Commission (2002) National Inventory of Woodlands and Trees, Regional Report for London: http://www.forestry.gov.uk/pdf/nilondon.pdf/$FILE/nilondon.pdf

41 Defra (2010) Survey of Agriculture and Horticulture, June 2009: http://www.defra.gov.uk/evidence/statistics/foodfarm/landuselivestock/junesurvey/results.htm

For crop residues, feed and bedding needs are supplied first

For energy crops, arable land required for food production is excluded.

Resource limitations driven by market conditions have not been considered when assessing the technical potential. These and other barriers that will restrict further the access to the resource will be accounted for in Phase 2.

The approach used in this study is broadly in line with the DECC methodology. However, there are a number of areas where the DECC methodology presents gaps and/or requires interpretation and additions. For example, the section on Municipal Solid Waste (MSW) only provides guidance to obtain a high level estimate of the potential energy recovery from incineration of MSW as a whole. It recommends calculating the potential by applying a benchmark of 10,000 tonnes of MSW required per annum for 1MW installed capacity. Therefore, this estimate would include generation from both renewable and non-renewable sources such as plastics and other non-organic waste components.

In addition, the DECC methodology does not indicate how to take account of current, and target, recycling rates and misses the fact that a significant fraction of food and green waste in MSW is already being diverted and therefore could be used as feedstock for anaerobic digestion plants rather than incineration plants. The assessment considers the different organic components of MSW individually and calculates separately the potential from direct combustion of paper/card and waste wood and from anaerobic digestion of kitchen/food waste and green waste. Data has also been collated relating to the tonnage of each material currently diverted[42].

4.2.1 Coverage of different bioenergy feedstocks

The term "biomass" covers a range of materials of biological origin, some of which may also be regarded as wastes. Various definitions of biomass can be found in European and UK legislation and policy. In the context of the planning process, Planning Policy Statement 22[43] defines biomass as follows:

"Biomass is the biodegradable fraction of products, waste and residues from agriculture (including plant and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste."

The scope of the biomass assessment in this study is consistent with this definition and matches the scope proposed by the DECC methodology and the scope used in the UK Biomass Strategy44. Table 4-1 summarises the biomass feedstocks (general term for all the different types of material that contribute to the biomass energy resource) and sources covered by this study. Varying fractions of these materials will be treated in mechanical biological treatment (MBT) facilities as mixed waste and therefore contribute to energy generation as a component of the solid recovered fuel (SRF)

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[42] This data can be found in the 'Phase 1_Biomass' datasheet which accompanies this report.

[43] DCLG (2004) Planning Policy Statement 22: Renewable Energy: http://www.communities.gov.uk/documents/planningandbuilding/pdf/147444.pdf

[44] DECC (2007) UK Biomass Strategy: http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/explained/bioenergy/policy_strat/policy_strat.aspx

produced in these plants. Since SRF as a whole is considered as a low-carbon fuel, the contribution to energy generation from materials of fossil origins, such as plastics, making up the remaining fraction of the SRF is also reported in this study for completeness.

4.2.2 Biomass feedstocks in the Greater South East

In addition to the technical potential associated with the biomass resource originating strictly within London's boundary, this study presents an estimate of the additional clean wood resource within the Greater South East (made up of London, the South East and the East of England) which could potentially be transported into London as a fuel source. Other potential feedstocks originating within the Greater South East (green and food waste, animal manures, crop residues) have not been considered since the transportation of these materials in significant amounts into London is unlikely due to their low energy density and special handling requirements.

The assessment has been carried out using the Forestry Commission Woodfuel Research Tool[45]. The figures provided by this tool are estimates of the fraction of the annual sustainable production that can be made available for energy generation taking account of technical and environmental constraints. The assessment only covers untreated woody biomass: residues from forestry operations, short rotation coppice, arboriculture arisings and primary processing co-products.

[45] Forestry Commission (2010) Woodfuel Research Tool: http://www.eforestry.gov.uk/woodfuel/pages/home.jsp

Feedstock	Sources
Energy crops	Short rotation coppice or Miscanthus crops established in arable land out of production
Forestry residues	Woody residues from forestry operations (felling and thinning)
Coppice materials	Materials from traditional coppice of oak, hazel, etc
Crop residues – straw	Residues from harvest of cereal and rapeseed oil crops
Waste wood	This category includes a mixture of treated and untreated wood from various sources, including: • Packaging waste from municipal and C&I streams • Construction and demolition (C&D) waste • Secondary wood processing industry waste e.g. off cuts from furniture manufacturing, joinery, wood shavings, sawdust • Other municipal/household waste including furniture and waste brought to civic amenity sites
Paper and card waste	Paper and card waste in municipal and C&I waste
Food waste	Food/kitchen waste from household sources, retail, hospitality, and C&I mixed waste in general, as well as residues from the food processing industry
Green waste	This category includes plant waste such as grass cuttings, hedge trimmings, leaves, etc, arising from gardens, parks and street sweepings
SRF – fossil fraction	SRF is the dry residue produced in MBT. The composition of SRF includes materials of both biogenic and fossil origins
Wet animal manures	This category consists of wet organic waste and includes manure and slurry waste from livestock
Poultry litter	This category consists of dry organic waste from broilers and available resource is based on broiler bird numbers
Arboricultural arisings	These are the products of fellings, thinnings and prunings of trees
Primary processing co-products	These are the bark, chips, and sawdust waste products from sawmills and other wood processing facilities, which are unlikely to occur in London

Table 4-1: Sources of biomass feedstock covered by the study

4.3 Technical potential of biomass

The local biomass resource that can be made available for energy generation was estimated to be equivalent to 5,384GWh of primary energy[46]. If the full resource is used in CHP plants, it can supply approximately 3.9% of London's 2008 energy demand, generating approximately 1,427GWh of electricity and 2,566GWh of heat. Table 4-2 show the potential contribution from each feedstock to this total. Table 4-3 presents the estimated technical potential in 2031. The fluctuation over time of potential from different sources is due to projected increases in waste arisings and increasing fractions of certain materials being recycled or reused.

Over 98% of the biomass resource available originates from the municipal and C&I waste streams. Energy recovery of paper and card waste alone can deliver 505GWh of electricity and 1,136GWh of heat, equivalent to 41% of the total potential generation from biomass sources and 1.5% of

[46] Primary energy refers to the energy content of the fuel before the efficiencies of the respective conversion technologies are taken into account

London's total energy demand. The total paper and card waste in London amounts to over 2.4 million tonnes, of which just over 0.8 million tonnes has been estimated to be technically available for energy generation. This tonnage represents the fraction of paper and card waste that is currently not recycled because it is landfilled or already diverted for energy recovery (through direct incineration or as SRF).

Anaerobic digestion of all the food and green wastes currently available from MSW and C&I waste streams can produce enough biogas to power just under $60MW_e$ of CHP installed capacity, which in turn can generate around 447GWh of electricity and 638GWh of heat. This is equivalent to 1% of London's total energy demand.

The remaining potential from the MSW and C&I waste streams is associated with waste wood. It has been estimated that a total of just over 200,000 tonnes of waste wood from these sources can be used for energy generation, with the potential to generate 286GWh of electricity and 476GWh of heat. The C&D waste stream increases the total potential generation from waste wood to 450GWh of electricity and 749GWh of heat.

Varying fractions of the materials will be treated in MBT facilities as mixed waste and therefore contribute to energy generation as a component of SRF produced in these plants. The contribution to energy generation from the fossil fraction of SRF is reported separately as it is not strictly from renewable sources.

Feedstock	Technical potential – 2010					
	Resource		Generation			
	Oven dry tonnes	Primary energy (GWh)	Electricity	Heat	Total	
			GWh	GWh	GWh	% GWh
Agriculture and Forestry						
Energy crops	15,029	54.3	16.3	27.1	43.4	1.1%
Forestry residues	2,806	13.0	3.9	6.5	10.4	0.3%
Coppiced material	463	2.4	0.7	1.2	2.0	0.05%
Crop residues – straw	2,709	12.8	3.8	6.4	10.3	0.3%
Wet animal manures	1,241	1.7	0.6	0.9	1.5	0.04%
Poultry litter	95.3	0.4	0.08	0.2	0.3	0.01%
Municipal and C&I waste						
C&I – paper and card waste	483,436	1,477	295	665	960	24.0%
MSW – paper and card waste	342,658	1,047	209	471	681	17.0%
C&I – waste wood	61,885	289	86.6	144	231	5.8%
C&D – waste wood	117,161	547	164	273	437	11.0%
MSW – waste wood	142,090	663	199	332	530	13.3%
MSW – green waste	149,195	333	117	167	283	7.1%
MSW – food waste	114,738	558	195	279	474	11.9%
C&I – food waste	79,291	386	135	193	328	8.2%
Total biomass feedstocks	**1,512,798**	**5,384**	**1,427**	**2,566**	**3,993**	**100%**
Biomass feedstocks	1,512,798	5,384	1,427	2,566	3,993	95.3%
Fossil fraction of SRF	51,850	245	73.5	122	196	4.7%
Total biomass + low carbon fuels	**1,564,648**	**5,629**	**1,500**	**2,688**	**4,189**	**100%**

Table 4-2: Potential electrical and thermal generation from biomass resources, 2010

Feedstock	Technical potential - 2031					
	Resource		Generation			
	Oven dry tonnes	Primary energy (GWh)	Electricity	Heat	Total	
			GWh	GWh	GWh	% GWh
Agriculture and Forestry						
Energy crops	15,029	54.3	16.3	27.1	43.4	1.0%
Forestry residues	2,806	13.0	3.9	6.5	10.4	0.2%
Coppiced material	463	2.4	0.7	1.2	2.0	0.05%
Crop residues – straw	2,709	12.8	3.8	6.4	10.3	0.2%
Wet animal manures	1,241	1.7	0.6	0.9	1.5	0.03%
Poultry litter	95.3	0.4	0.08	0.2	0.3	0.01%
Municipal and C&I waste						
C&I – paper and card waste	491,663	1,502	300	676	976	22.7%
MSW – paper and card waste	311,138	951	190	428	618	14.4%
C&I – waste wood	56,554	293	88.0	147	235	5.5%
C&D – waste wood	133,258	622	187	311	497	11.6%
MSW – waste wood	183,888	858	257	429	687	16.0%
MSW – green waste	173,774	388	136	194	330	7.7%
MSW – food waste	133,641	650	228	325	553	12.9%
C&I – food waste	80,512	392	137	196	333	7.7%
Total biomass feedstocks	**1,586,772**	**5,741**	**1,548**	**2,748**	**4,296**	**100%**
Biomass feedstocks	1,586,772	5,741	1,548	2,748	4,296	77.8%
Fossil fraction of solid recovered fuel	324,550	1,533	460	766	1,226	22.2%
Total biomass + low carbon fuels	**1,911,322**	**7,273**	**2,008**	**3,514**	**5,522**	**100%**

Table 4-3: Potential electrical and thermal generation from biomass resources, 2031

4.3.1 Technical potential of woodfuel resource in the Greater South East

Table 4-4 shows the technical potential from wood fuel resource arising in the Greater South East. The technical potential estimate for 2031 for the woodfuel resource in the Greater South East area is assumed to be the same as the current resource as no predictions for significant change in this market were identified[47]. No assessment has been made for the potential to import biomass sources from beyond the Greater South East. In practice this will be dictated by economic factors and will be assessed in Phase 2.

[47] Forestry Commission (2000) Production Forecast 'Great Britain: New Forecast of Softwood Availability': http://www.forestry.gov.uk/pdf/publishedforecast2000.pdf/$FILE/publishedforecast2000.pdf

Source	Resource		Energy generation			
	Oven dry tonnes	Primary energy (GWh)	Electricity	Heat	Total	
			GWh	GWh	GWh	% GWh
Forestry residues	111,537	548	164	274	438	28.2%
Short rotation coppice	1,672	8.8	2.6	4.4	7.1	0.5%
Arboricultural arisings	215,980	1,140	342	570	912	58.7%
Primary processing co-products	46,768	247	74.1	123	198	12.7%
Total	**375,957**	**1,944**	**583**	**972**	**1,555**	**100%**

Table 4-4: Potential electrical and thermal generation from woodfuel resources in the Greater South East

4.3.2 Summary of biomass technical potential in London and the Greater South East

A summary of the technical potential of biomass across Greater London and the Greater South East is given in Table 4-5. This excludes the contribution made from Agriculture and Forestry arisings (<2%) as the data for these sources is not available at a borough level. This total is carried forward in the rest of the analysis. By 2031, biomass sources in London could supply 3.9% of London's electricity and heat demand. When the additional woodfuel resource potential from the Greater South East is also considered, it is estimated that 5.3% of London's electricity and heat demand can be met.

Biomass	Year	London	Greater South East	Total
Oven dry tonnes	2010	1,512,798	375,957	1,888,755
	2031	1,586,772	375,957	1,962,729
Primary energy (GWh)	2010	5,384	1,944	7,329
	2031	5,741	1,944	7,685
Electricity generation (GWh)	2010	1,401	583	1,985
	2031	1,523	583	2,106
Heat generation (GWh)	2010	2,524	972	3,496
	2031	2,705	972	3,677
Carbon savings (Mt CO_2)	2010	1.1	0.4	1.5
	2031	1.2	0.4	1.6
% of London's electricity demand	2008	3.5%	1.5%	5.0%
	2031	3.9%	1.5%	5.4%
% of London's heat demand	2008	3.8%	1.5%	5.3%
	2031	3.9%	1.4%	5.3%

Table 4-5: Technical potential of biomass in London and additional woodfuel in the Greater South East

5 Solar photovoltaic potential

5.1 Overview of approach

Both the DECC methodology and the tailored methodology were used to estimate the solar PV technical potential. The DECC methodology assumes a set percentage of buildings can accommodate individual PV installations of a fixed rated capacity. The tailored methodology calculates the actual roof area that could accommodate PV panels and calculates a rated capacity from this. A detailed flow chart and information on technical assumptions is given in Appendix 3. NB. The DECC methodology does not separate solar potential into PV and SWH.

5.2 Overview of the DECC methodology for assessing PV potential

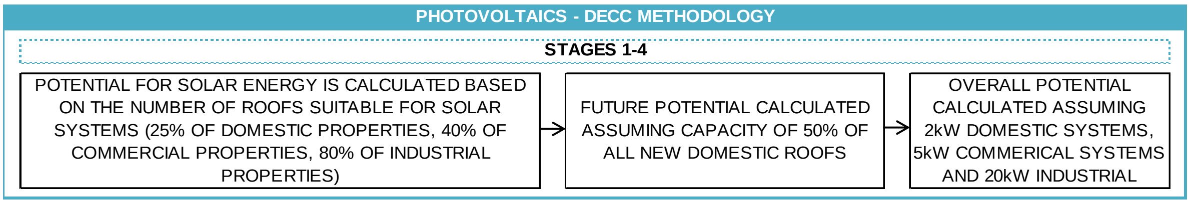

Figure 5-1: Overview of the DECC methodology for assessing solar energy potential

The DECC methodology assumes a fixed proportion of different property types are suitable for PV installations as well as a fixed rated capacity of PV for each installation type. It does not account for available roof area, orientation or other constraints. London's solar resource was calculated at LSOA level.

5.3 Overview of the tailored methodology for assessing PV potential

This assessment is split into existing development and future development to 2031.

5.3.1 PV potential in existing buildings

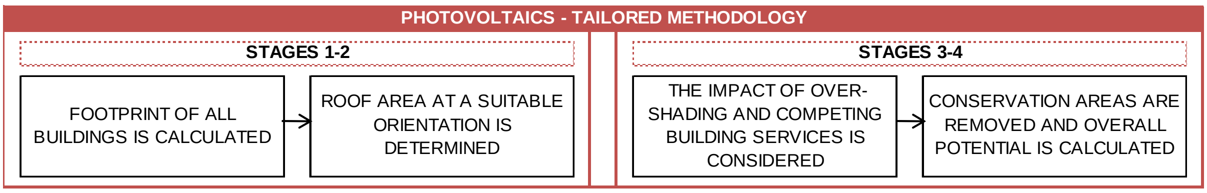

Figure 5-2: Overview of the tailored methodology for assessing PV potential

For the tailored methodology the actual roof space of the buildings was used and then buildings with the required orientation were selected. Finally the impact of over-shading and other competing uses of roof space in higher density areas was taken into account.

Roof area was determined from building footprint area. The orientation and pitch of roofs was accounted for by only considering flat and south-facing pitched roofs (between south-east and south-west). The DECC methodology does not differentiate between flat roofs and pitched roofs whereas the tailored methodology differentiates between the two and within pitched roofs it only allows technical potential for south facing parts of an individual roof.

The impact on PV potential of over-shading and competing roof space uses in high and medium density areas was incorporated by applying constraint factors. Constraints on the installation of PV on roofs in conservation areas meant that these were removed from calculating the overall potential.

5.3.2 PV potential in new development from 2010 to 2031

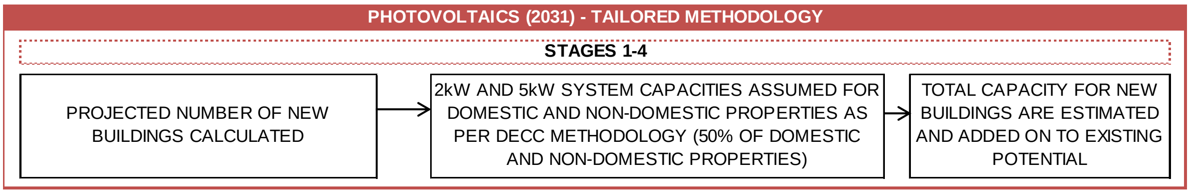

Figure 5-3: Overview of the tailored methodology for assessing PV potential for 2031

Additional roof space, created by an increase in the number of buildings between now and 2031 due to new development, is considered by taking data from the SHLAA and projections for changes to employment land. Whilst the DECC methodology considers only new build domestic buildings suitable for solar energy, the tailored methodology includes both domestic and non-domestic building. Assumptions regarding the proportion of demolition are included within the growth numbers.

Under the tailored methodology, the potential in new buildings is estimated as per the DECC methodology, where 50% of all new buildings are assumed to be suitable for PV. System capacities of 2kW and 5kW for domestic and non-domestic properties respectively are assumed. No account is made for any increase in the efficiency of the technology itself.

5.4 Technical potential of PV

5.4.1 Overall results for the DECC and tailored methodologies

Photovoltaics	Year	Methodology	
		DECC	Tailored
Installed capacity (MW)	2010	3,163	11,784
	2031	3,688	12,397
Electricity generation (GWh)	2010	2,616	8,576
	2031	3,050	9,083
Carbon savings (Mt CO_2)	2010	1.0	3.4
	2031	1.2	3.6
% of London's electricity demand	2010	6.6%	21.5%
	2031	7.8%	23.1%

Table 5-1: Technical potential of PV

Table 5-1 shows the technical potential for PV in London under both methodologies. The distribution of these potentials is shown in Figure 5-4 and Figure 5-5 and is described in Sections 5.4.2 and 5.4.3 respectively. The PV potential under the DECC methodology is significantly lower than the tailored methodology, which identifies 12,397MW of potential by 2031.

The analysis suggests that the DECC methodology's assumption of only 25% of homes being suitable for PV, with PV arrays of a fixed 2kW peak rated capacity per home, substantially underestimates the housing roof area that could in fact be available for PV installations. The analysis also suggests that the DECC methodology underestimates the available roof area of non-domestic buildings in London by limiting array size.

5.4.2 Distribution of potential under the DECC methodology

The DECC methodology shows the greatest potential for PV clustered in the centre of London with a peak around the City of London of over 330MWh/ha. Other areas with a high potential capacity include Islington, Hackney, Hammersmith and Tower Hamlets – all areas with a high density of buildings. The DECC methodology calculates the potential based on the number of properties within each LSOA and hence areas with a high proportion of flats (e.g. Hackney) show a high potential whereas sites with a lower density of properties show a lower potential.

The DECC methodology does not specifically account for conservation areas and parks in the Greater London area. However, due to the low density of housing in the LSOAs which include parks, the potential in these areas still appears relatively low.

5.4.3 Distribution of potential under tailored methodology

The tailored methodology shows a more scattered distribution than the DECC methodology. This difference is due to the consideration of the actual roof area in the tailored methodology. Areas such as Camden, Islington and Hackney which have a large number of tower blocks (and hence low roof area to dwelling ratio) show a comparatively lower potential.

In addition, the tailored methodology considers over-shading in higher density areas which would render a significant portion of the roof space unsuitable for PV. In the more sparsely populated areas towards the outskirts of London, it is assumed that there would be little or no over-shading and hence a higher proportion of the roof space would be suitable for PV installations.

Figure 5-4: Technical potential of PV installations under the DECC methodology, 2010

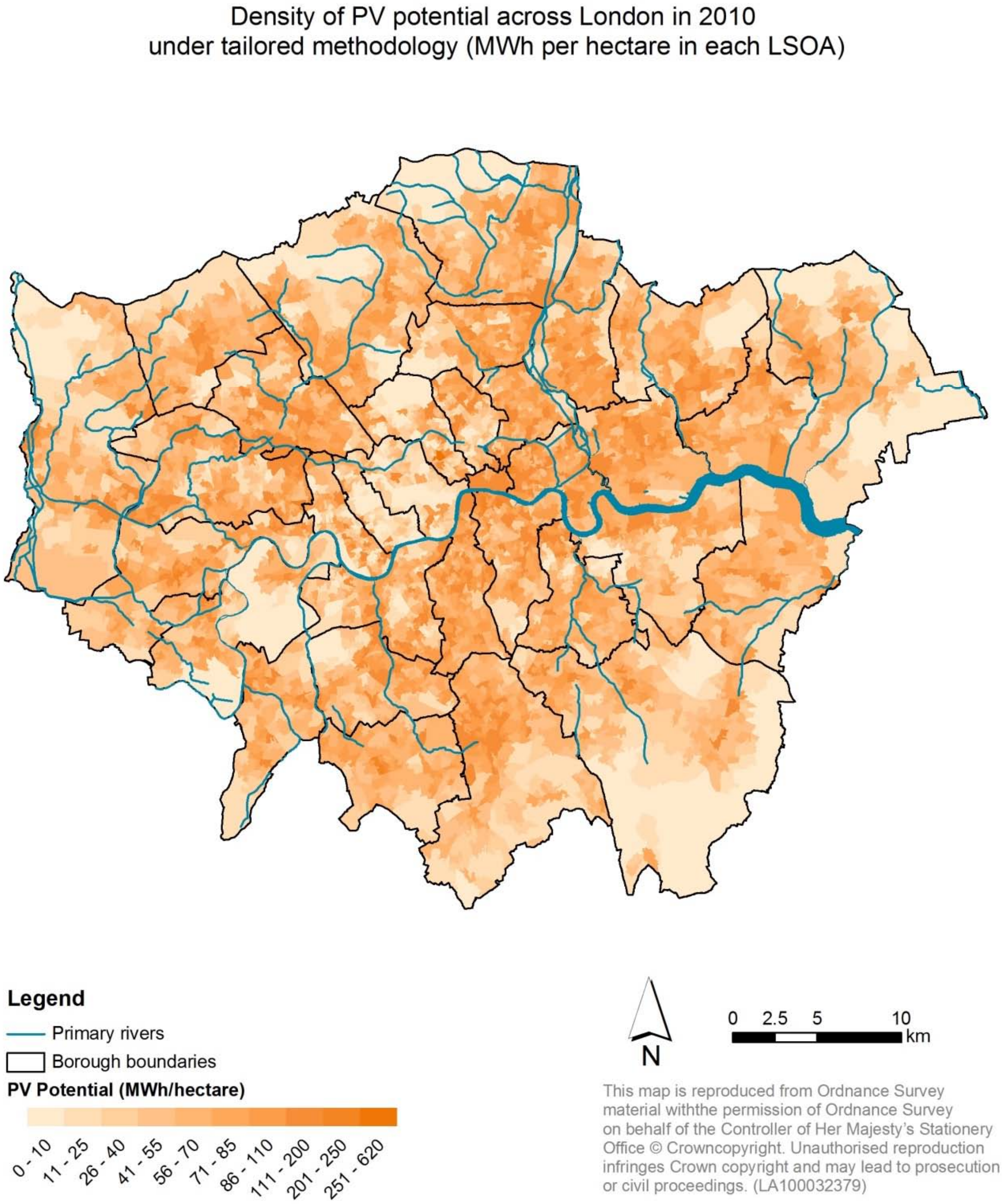

Figure 5-5: Technical potential of PV installations under the tailored methodology, 2010

6 Solar water heating potential

6.1 Overview of approach

The DECC methodology estimates the potential from solar energy as a whole, with no separate methodology for PV and SWH. It assumes that the total capacity of the systems will not vary significantly: a building might have one or both of the technologies installed either with a large system of one technology or one of each technology. The tailored methodology assumes a fixed capacity SWH system for domestic properties, and bases non-domestic systems on estimated hot water consumption by floor area.

It is important to note that the totals for PV and SWH have been generated independently for both methodologies in order to highlight the full potential for each technology. However, in reality, these technologies compete for roof space. Therefore assumptions have been made in order to avoid double counting when combining the potentials from these two technologies under the DECC and tailored methodologies. Under the DECC methodology 2/3 of the PV and 1/3 of the SWH technical potential were used when calculating the combined solar energy potential[48]. For the tailored methodology, the SWH potential was deducted from the PV potential. Full technical details are given in Appendix 4.

6.2 Overview of the DECC methodology for assessing SWH potential

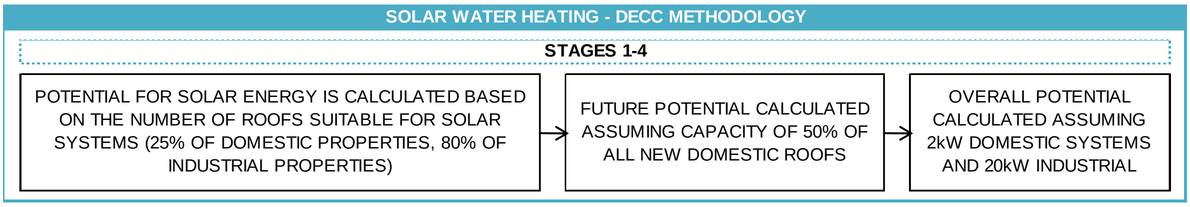

Figure 6-1: Overview of the DECC methodology for assessing solar water heating potential

The DECC methodology focuses on the residential building stock and industrial properties. Commercial properties are not considered suitable for SWH, and therefore the results are slightly lower than for PV under the DECC methodology, despite the overall methodology being otherwise identical.

6.3 Overview of the tailored methodology for assessing SWH potential

The tailored methodology looks at the potential for domestic and non-domestic SWH separately as shown in Figure 6-2 and Figure 6-3 respectively. The impact of roof orientation, over-shading, competition for roof space and conservation areas is also considered as for PV. Similarly the potential for SWH in new development has been calculated. These steps are, however, not shown below.

[48] These numbers were agreed by the project team.

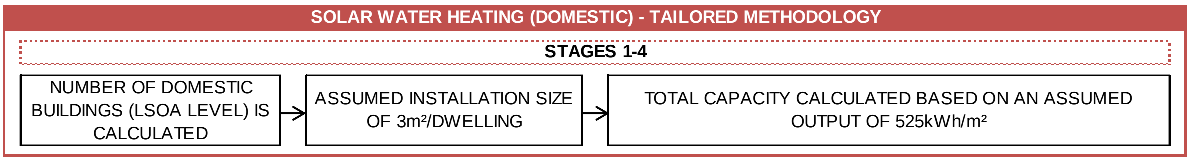

Figure 6-2: Overview of the tailored methodology for assessing solar water heating potential (domestic)

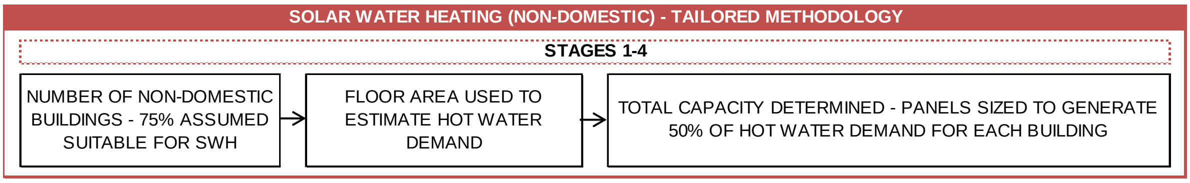

Figure 6-3: Overview of the tailored methodology for assessing solar water heating potential (non-domestic)

For the domestic stock, a system size of $3m^2$ per dwelling is assumed. For non-domestic buildings, it is assumed that 75% of the properties are be suitable. This is based on an assumption that they do not have a high hot water demand and therefore a SWH system will not require significant amounts of roof space. The non-domestic SWH systems are sized to produce 50% of the predicted hot water demand. This hot water demand is estimated based on published benchmarks[49].

6.4 Technical potential of SWH

6.4.1 Overall results for the DECC and tailored methodologies

Solar water heating	Year	Methodology	
		DECC	Tailored
Heat generation (GWh)	2010	1,535	930
	2031	1,872	1,293
Carbon savings ($MtCO_2$)	2010	0.3	0.2
	2031	0.4	0.3
% of London's heat demand	2010	2.3%	1.4%
	2031	2.7%	1.9%

Table 6-1: Technical potential of SWH

The overall potential for SWH is presented in Table 6-1. Figure 6-4 and Figure 6-5 show how this is distributed across London.

[49] CIBSE (2007) CIBSE Guide F: Energy efficiency in buildings Section 20, Second Edition.

6.4.2 Distribution of potential using the DECC methodology

As discussed in Section 6.1 the DECC methodology does not separate the potential of PV and SWH technologies. The distribution under the DECC methodology for solar energy has been described in Section 5.4.2; the only difference is the lower potential due to the exclusion of commercial properties.

6.4.3 Distribution of potential using tailored methodology

Results from the analysis of the potential for SWH in London again show a marked difference between the two methodologies. SWH potential under the tailored methodology shows a more even distribution in comparison with the DECC methodology where potential is focussed in the centre. However, many of the boroughs in central London include conservation areas, where SWH potential is constrained by heritage considerations. This is particularly apparent when comparing the difference in potential for the Royal Borough of Kensington and Chelsea. This borough has the largest proportion of protected building areas in London (approximately 70% of the total building footprint) and this is not accounted for under the DECC methodology. In contrast in the Borough of Barking and Dagenham only 0.23% of the building footprint is identified as protected and shows an almost identical distribution of SWH between the two methodologies.

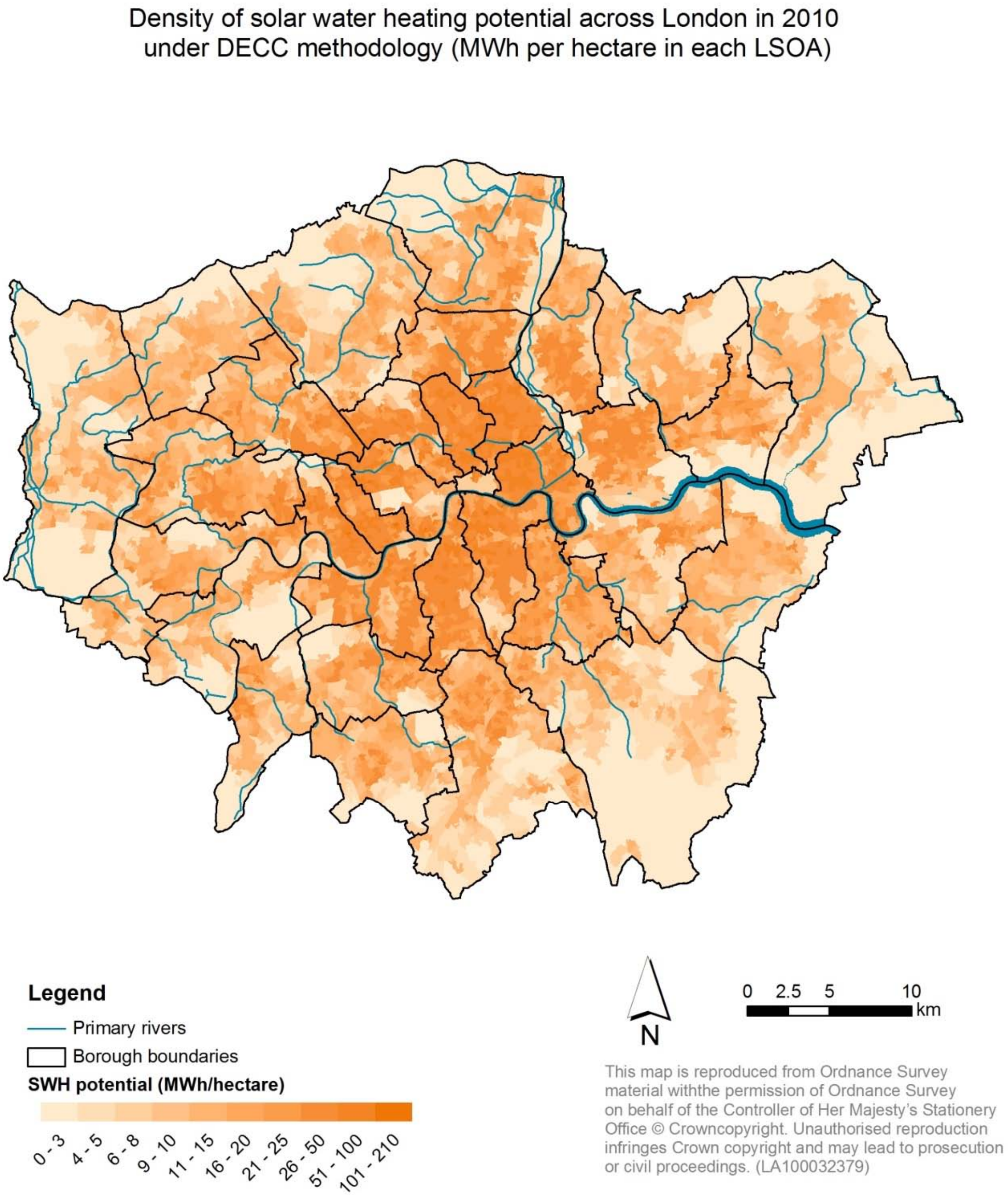

Figure 6-4: Technical potential of solar water heating under the DECC methodology, 2010

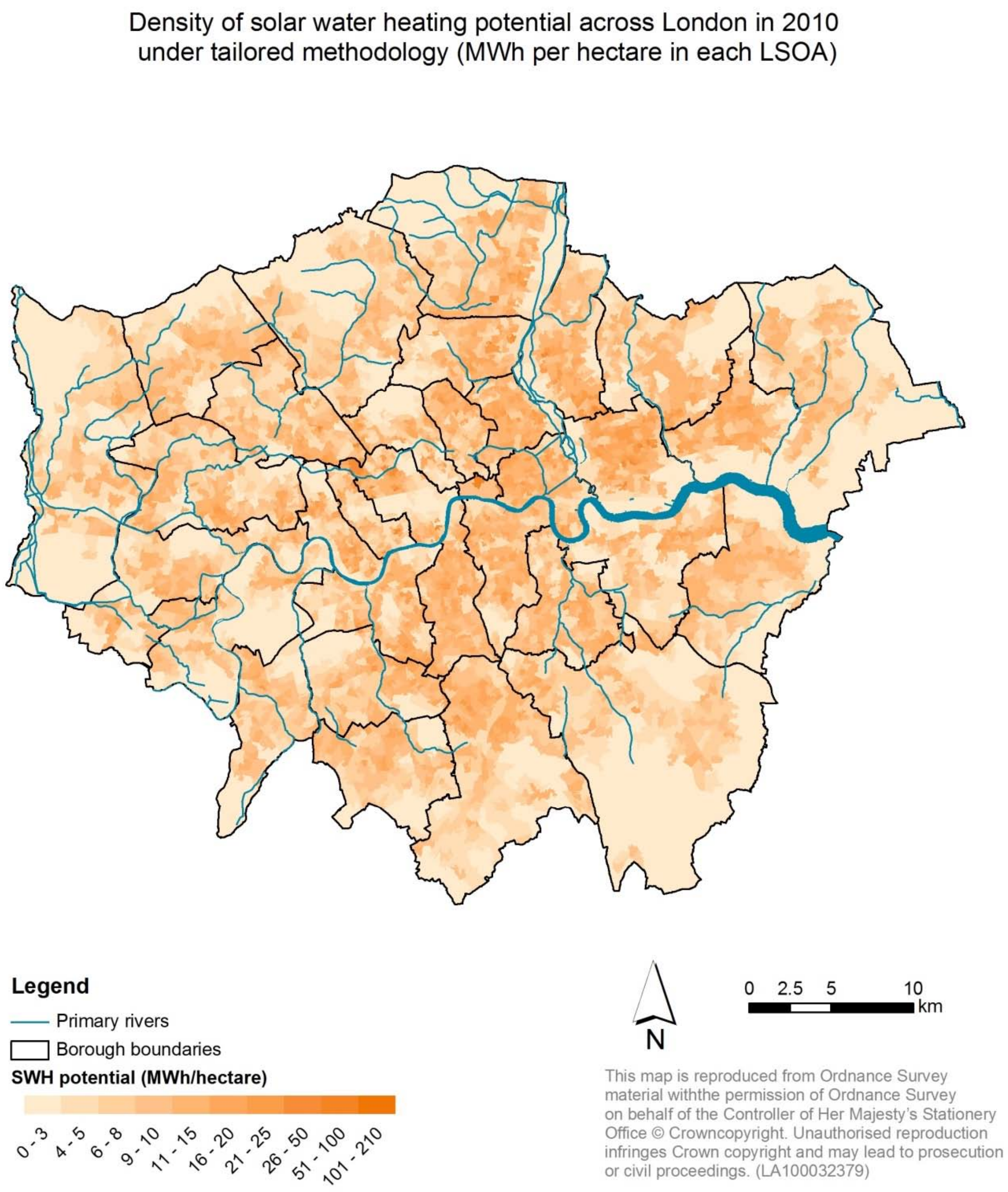

Figure 6-5: Technical potential of solar water heating under the tailored methodology, 2010

7 Heat pumps potential

7.1 Overview of approach

An assessment of the technical potential for heat pumps was made using the DECC methodology and a tailored methodology. The latter differentiates between ground source heat pumps (GSHP) and air source heat pumps (ASHP). The DECC methodology for assessing the technical potential of heat pumps is based on a set percentage of different types of properties that are assumed to be suitable for heat pumps. The tailored methodology also considers the energy efficiency of buildings which can limit the suitability of heat pumps[50]. It was therefore assumed that thermally inefficient properties do not contribute to the total heat pump technical potential. Additionally, no assessment of the significantly increased peak electrical demand has been made, nor the capacity of the electrical distribution infrastructure to meet this load. Full technical details are given in Appendix 5.

7.2 Overview of the DECC methodology for assessing heat pump potential

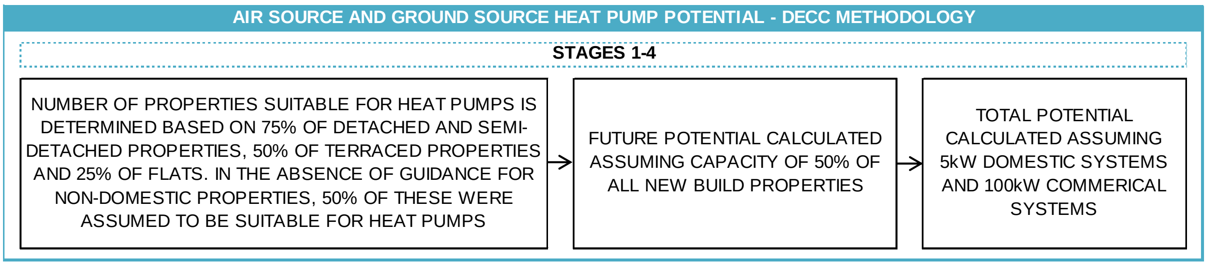

Figure 7-1: Overview of the DECC methodology for assessing heat pump potential

Figure 7-1 illustrates the DECC methodology for assessing heat pump potential. This methodology does not differentiate between GSHP and ASHP. It predicts the total technical potential for heat pumps on the premise that buildings will be suitable for the deployment of either GSHP or ASHP. A fixed proportion of buildings by building type are considered suitable, with a fixed capacity assumed for each building, by building type. Increases in potential to 2031 are based on applying the same methodology to projections of new development.

7.3 Overview of tailored methodology for assessing heat pump potential

The tailored methodology is split into two sections covering GSHP, including a sub-section on open loop systems, and ASHP. Each section is further split into the technical potential in existing development and future technical potential to 2031. Anticipated improvements to the energy efficiency of the existing building stock by 2031 results in significant differences in the technical potential between 2010 and 2031.

[50] Properties that are thermally inefficient require heating systems with larger capacities. More significantly the low temperature heat outputs that heat pumps can provide, either through under floor heating or radiators, may not be adequate to meet the peak heating loads in thermally inefficient properties.

7.3.1 GSHP potential in existing buildings

Separate methodologies for domestic and non-domestic GSHP are shown in Figure 7-2 and Figure 7-3.

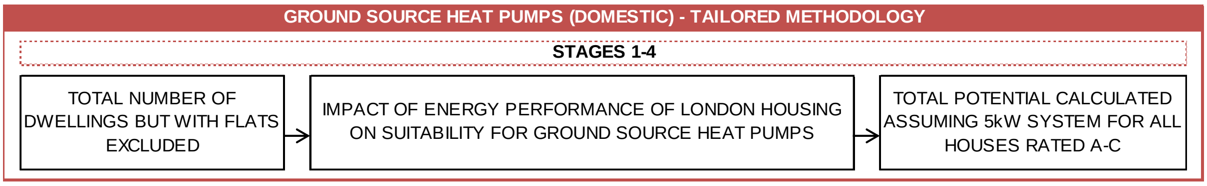

Figure 7-2: Overview of the tailored methodology for assessing domestic GSHP potential

Due to the high density nature of London and scarcity of garden area, it is assumed that flats are not suitable for GSHP. Within the remaining housing stock, only houses with an Energy Efficiency Rating (EER) of C or higher, corresponding to 13% of the stock[51], are assumed to be technically suitable for GSHP.

A fixed capacity of GSHP was assumed for each domestic property. GSHP potential in a given building is limited by the land area available for horizontal or borehole ground heat exchanger loops. However, data on garden areas was not used in the analysis as this was not available at an LSOA level, and the data which was available only covered mean garden area. Additionally using available ground area can overestimate capacity from large gardens, as individual building capacity is also constrained by the maximum capacity required to heat the building.

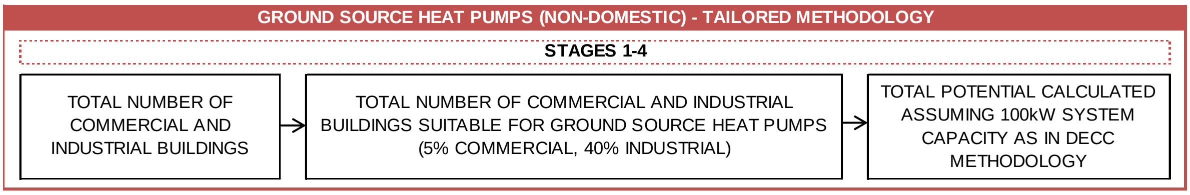

Figure 7-3: Overview of the tailored methodology for assessing non-domestic GSHP potential

The tailored methodology for non-domestic buildings was similar to the DECC methodology, however, further constraints were applied to account for the higher density characteristics of London. It is assumed that only 5% of existing commercial properties are suitable for ground source heat pumps. For industrial properties, the suitable proportion of the stock is assumed to be 40%.

7.3.2 GSHP potential in new development from 2010 to 2031

The potential for ground source heat pumps in new development is based on applying the same methodology to projected new domestic and non-domestic development. In addition, it is assumed that 75% of the existing domestic building stock that currently have an EER of less than C will be

[51] DCLG (2007) English House Condition Survey, Summary Statistics Table 7.2: http://www.communities.gov.uk/housing/housingresearch/housingsurveys/englishhousecondition/ehcsdatasupporting/ehcsstandardtables/summarystatistics/

upgraded to at least a C rating by 2031. This assumption is based on the target set by Mayor of London's RE:NEW programme which aims to improve the energy efficiency of all homes by 2030. It is reduced by 25% to account for hard to treat homes and lower than anticipated levels of uptake[52].

7.3.3 Open loop ground source heating and cooling

For the purposes of this study, it has been assumed that the potential capacity for open-loop ground source heating and cooling is included within the overall demand-driven GSHP capacity as it has not been possible to quantify the total capacity for open loop GSHP in London, partly due to limited information relating to the aquifer, the site specific nature of their performance and uncertainties about thermal interference between schemes which is difficult to predict.

Open-loop ground heat exchangers use groundwater stored in aquifers. The major aquifer in the London Basin is the chalk aquifer, which is regulated by the Environment Agency (EA). The use of open loop GSHP in London has been driven by a combination of the availability of the aquifer, London Plan policies and the potential cost, reduced space use and performance benefits versus closed loop systems. However, the aquifer can only accommodate a finite number of systems[53] and applications for new systems are considered on a case-by-case basis. Applications could potentially be refused on the grounds that they affect existing installations, groundwater flow or temperature or result in cumulative environmental impacts[54].

7.3.4 ASHP potential in existing buildings

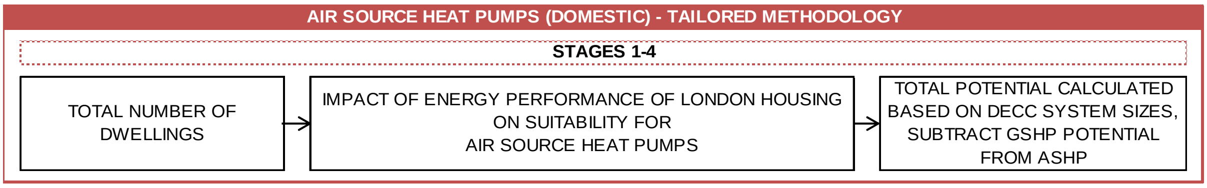

Figure 7-4: Overview of the tailored methodology for assessing domestic ASHP potential

The tailored methodology for ASHP is similar to GSHP. However, because this technology does not require a ground heat exchanger it has wider applicability within London. Hence, flats are also included in the total technical potential. Properties with an EER banding of C or less are excluded from the assessment, as they are deemed not to be technically suitable due to the low temperature heat output from ASHP (see Section 7.1).

The calculated GSHP potential is subtracted from the ASHP potential in order to avoid double-counting as these technologies are mutually exclusive. It is assumed that GSHP is the preferred

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[52] GLA (2011) Delivering London's energy future: The Mayor's Climate Change Mitigation and Energy Strategy: http://www.london.gov.uk

[53] EA (2009) Ground source heating and cooling pumps – state of play and future trends: http://publications.environment-agency.gov.uk/pdf/SCHO1109BRGS-e-e.pdf

[54] London Borough of Enfield (2010) Renewable energy and low carbon development study: http://www.londonheatmap.org.uk/Content/uploaded/documents/Enfield%20Renewable%20Energy%20and%20Low%20Carbon%20Study.pdf

technology due to their higher coefficient of performance (COP). For non-domestic buildings, 50% of buildings are assumed to be suitable for ASHP.

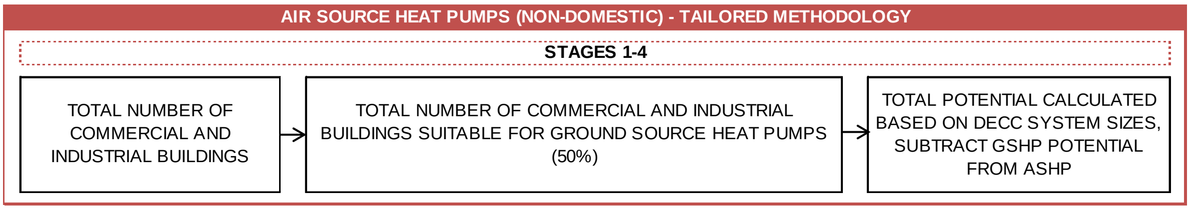

Figure 7-5: Overview of the tailored methodology for assessing non-domestic ASHP potential

7.3.5 ASHP potential in new development from 2010 to 2031

As for GSHP, It is assumed that 75% of the existing domestic building stock that currently have an EER of less than C will be upgraded to at least a C rating by 2031. All new development is assumed to be suitable for ASHP on the basis of the high levels of thermal efficiency required under building regulations.

7.4 Technical potential of heat pumps

Heat pumps	Year	Methodology			
		DECC	Tailored		
		Heat pumps	GSHP	ASHP	Combined
Installed capacity (MW)	2010	28,687	4,889	18,981	23,869
	2031	30,001	11,624	26,564	38,188
Heat generation (GWh)	2010	34,654	5,906	22,928	28,834
	2031	36,241	14,042	32,089	46,131
Electricity consumption (GWh)	2010	13,862	2,362	10,422	12,784
	2031	14,496	5,617	14,586	20,203
Carbon savings ($MtCO_2$)	2010	0.03	0.005	-0.7	-0.7
	2031	0.03	0.01	-0.9	-0.9
% of London's heat demand	2010	52.5%	8.9%	34.7%	43.7%
	2031	52.2%	20.2%	46.3%	66.5%
% increase in London's electricity demand	2010	34.8%	5.9%	26.1%	32.1%
	2031	36.9%	14.3%	37.1%	51.4%

Table 7-1: Technical potential of heat pumps

The technical potential of heat pumps is very large under both the DECC and tailored methodologies, with the potential to meet 53% and 44% of London's heat demand in 2010 respectively. The electricity consumption associated with this scale of heat pump use is very large, corresponding to a 35% and 32% increase in London's electricity consumption in 2010 respectively. The installed capacities quoted do not account for diversity of heat demand. However, even once diversity is accounted for, providing electrical power for this capacity of heat pumps is likely to require significant upgrades to London's electrical networks.

The assumptions made about the limitations of heat pumps in thermally inefficient existing domestic buildings significantly reduces the technical potential under the tailored methodology. The tailored assessment assumes that energy efficiency programmes over the next 20 years will improve the performance of housing so that a greater proportion is suitable for heat pumps. The corresponding 2031 heat pump potential under the tailored methodology is therefore much larger, with the potential to generate almost two-thirds of London's heat requirement.

Heat pumps do not deliver carbon savings when both the current electricity grid carbon factor and the low system efficiencies observed in field trials[55] are taken into account. However, heat pumps can deliver significant carbon savings in the future if the electricity grid decarbonises as forecast and system efficiencies improve.

7.4.1 Distribution of potential using the DECC and tailored methodologies

The relative distribution of heat pump potential (both GSHP and ASHP) is very similar under both methodologies. The main difference in the distribution between the methodologies arises from the assumption in the tailored methodology that only 5% of commercial buildings and 40% of industrial buildings are suitable for GSHP. This reduces the potential in central areas compared to the results using the DECC methodology. Only the distribution of the GSHP tailored methodology is shown in this report (see Figure 7-6) as the resolution of the maps does not show any differences between them. However, the different constraints applied to ASHP and GSHP results in different magnitudes of potential for each technology.

[55] EST (2010) Getting warmer: a field trial of heat pumps: http://www.energysavingtrust.org.uk/Media/node_1422/Getting-warmer-a-field-trial-of-heat-pumps-PDF

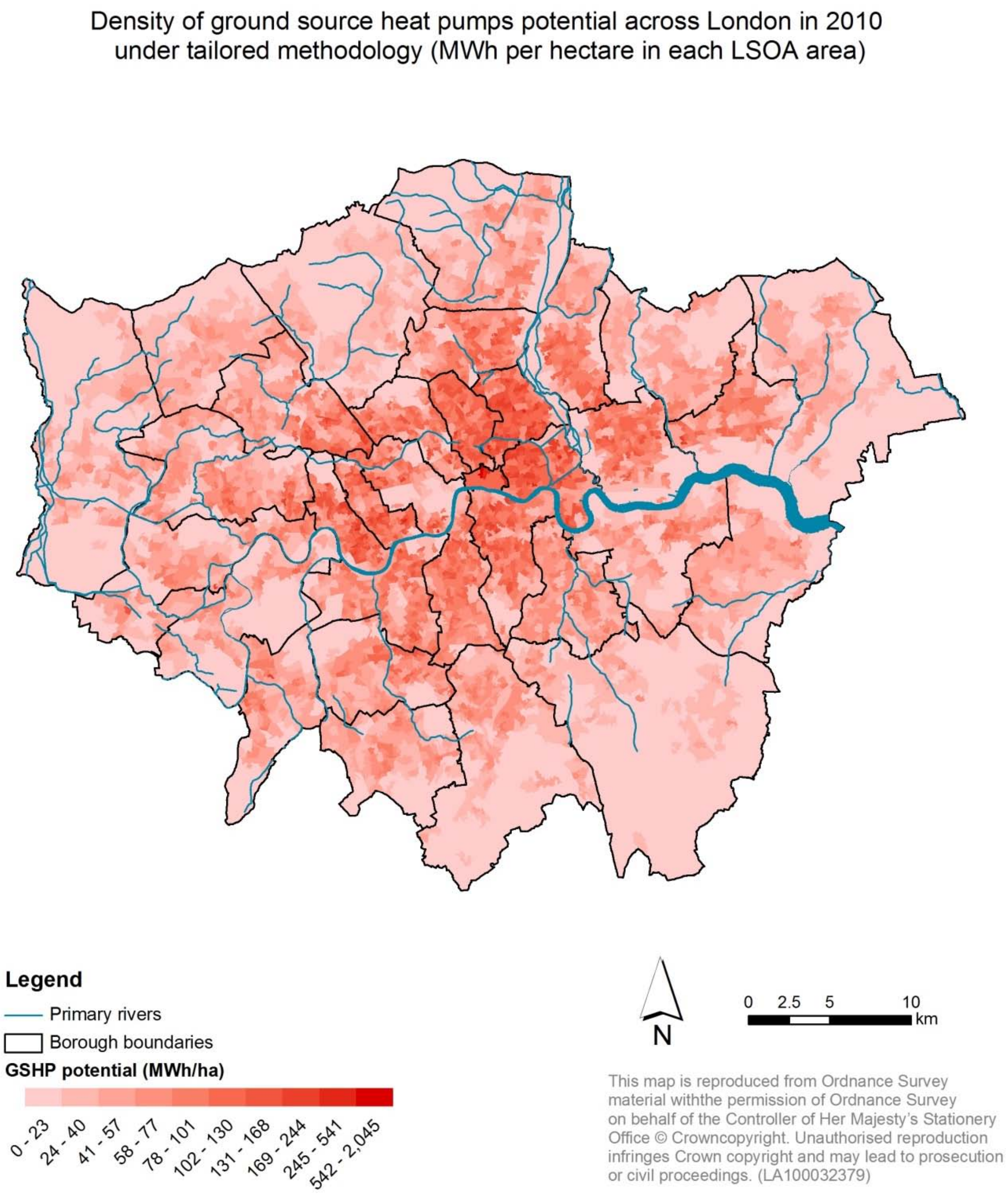

Figure 7-6: Technical potential of ground source heat pumps under the tailored methodology, 2010

8 Hydropower potential

8.1 Overview of approach

The assessment of hydropower potential has been undertaken using the DECC methodology only. It recommends that the results of the EA report 'Mapping Hydropower Opportunities in England and Wales' should be used to identify the total resource available and the proportion that is accessible and viable for development in each region[56].

The EA study identified 378 sites within rivers in Greater London where small-scale hydropower schemes could theoretically be implemented (Figure 8-1). If all these sites are used for hydropower, the total theoretical potential adds up to 9.2MW of installed capacity. Assuming an availability factor of 90%, these sites can generate approximately 72.9GWh/year. In reality, only some of these sites can be exploited due to environmental sensitivities, particularly the impact on migratory fish populations as well as practical constraints including access for construction and connection to the electricity network.

8.2 Overview of the DECC methodology for assessing hydropower potential

The EA study categorised the sites identified in accordance with the estimated potential generating capacity of the turbine that can theoretically be installed as a function of the turbine discharge flow and available head.

Where data was available, the sites were also classified with regard to their environmental sensitivity (see Figure 8-2). Opportunities were graded as low, medium or high sensitivity based on the fish species likely to be present, and whether the site is in a designated area. This is an indicative assessment only and does not consider the full suite of environmental impacts.

[56] EA (2009) Mapping hydropower opportunities in England and Wales: http://www.environment-agency.gov.uk/shell/hydropowerswf.html

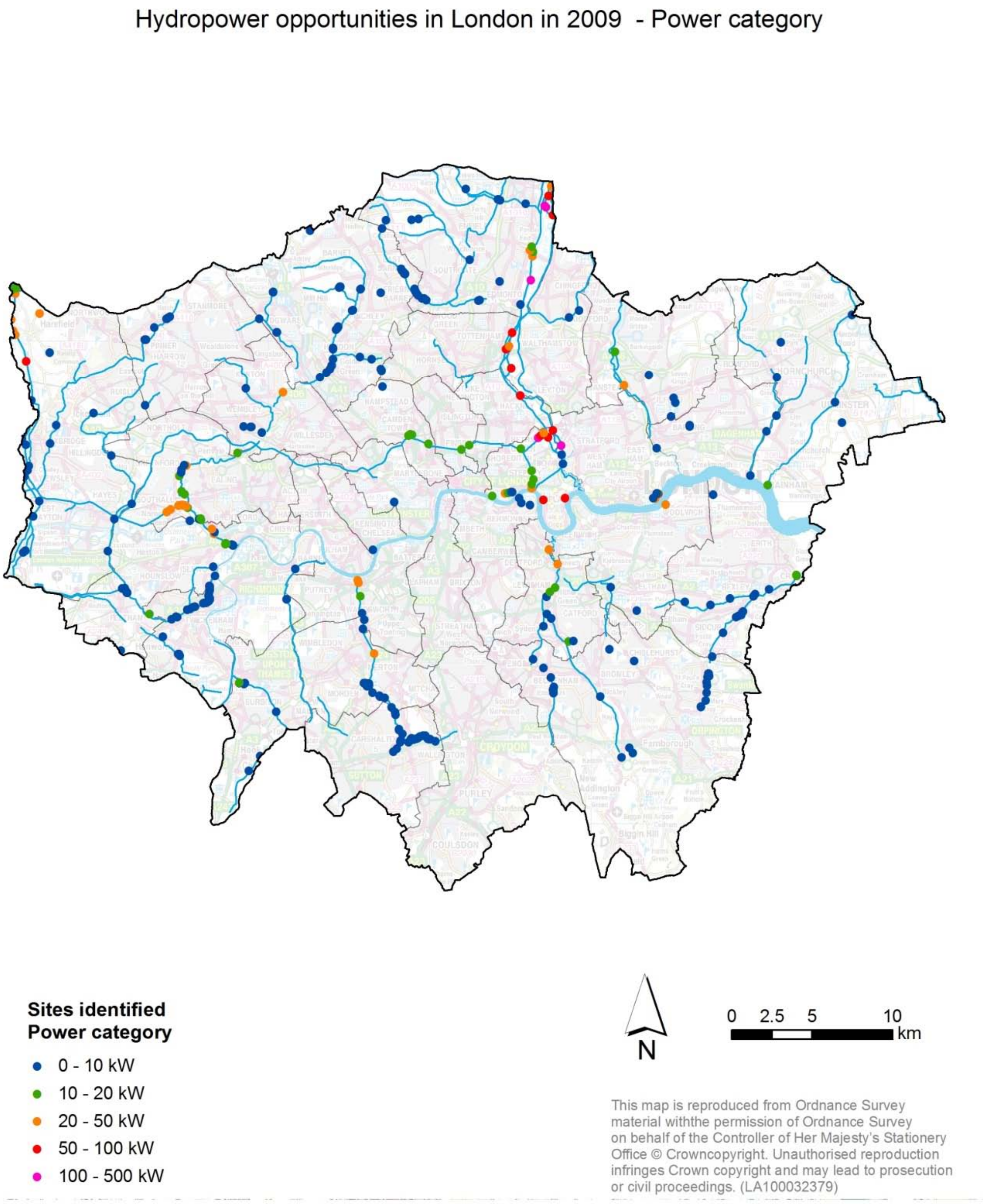

Figure 8-1: Hydropower opportunities defined by their power capacity, 2009

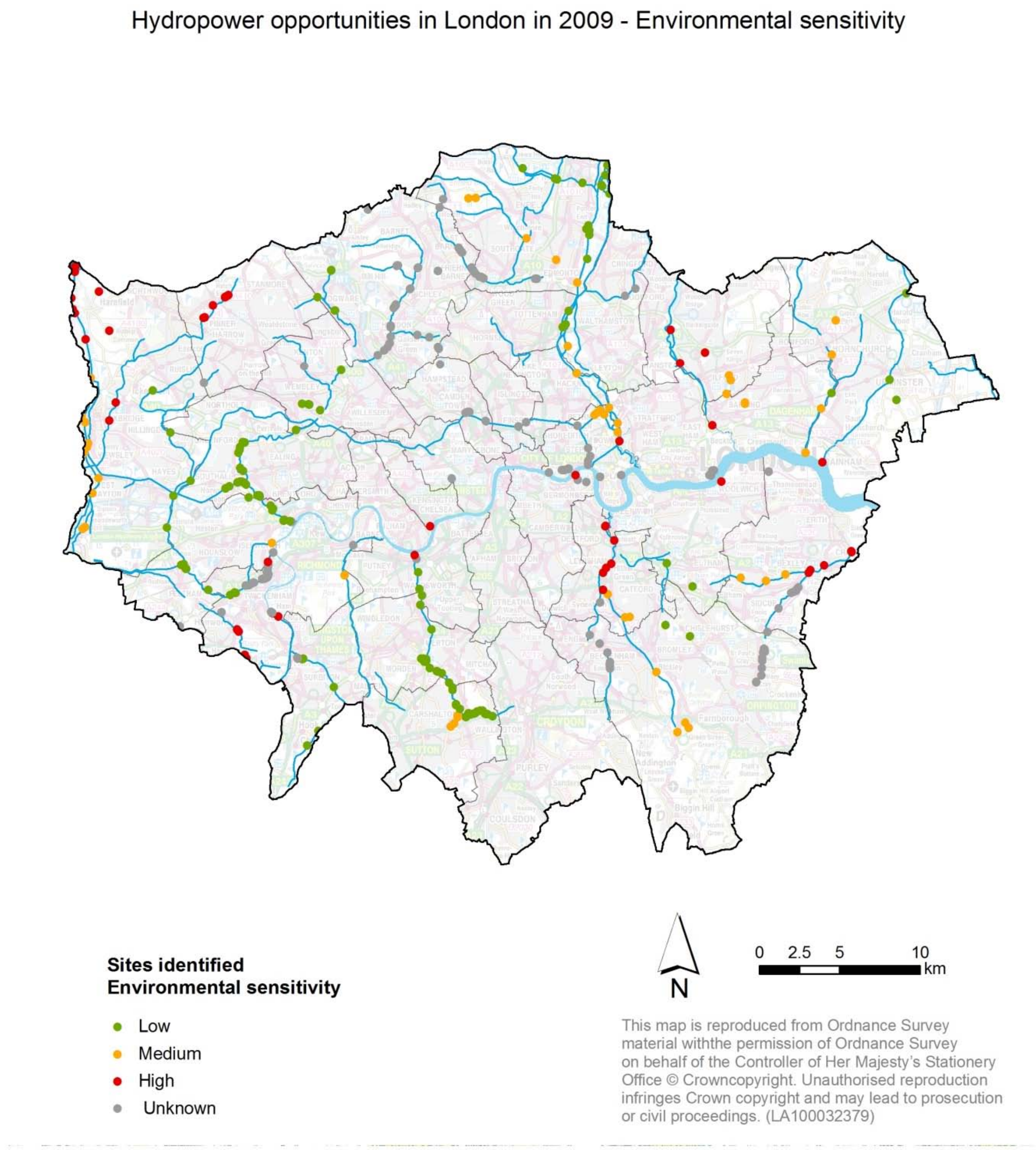

Figure 8-2: Hydropower opportunities defined by their environmental sensitivity, 2009

The EA report presents an "overall opportunity matrix" based on the power potential and sensitivity of the sites (see Figure 8-3). The best opportunities exist at locations where there is high hydropower potential and low environmental sensitivity, whilst the least attractive opportunities are those with low hydropower potential and high sensitivity. Sites were grouped into four sensitivity categories, and seven power output capacity bands. An opportunity matrix based on the EA approach has been replicated for the sites identified within Greater London. The matrix, which uses 28 (4 by 7) combinations, has been summarised into the five final generalised combinations as shown in Figure

8-4: good opportunities, moderate opportunities (not shown in the Figure 8-3), marginal choices, difficult choices and bad opportunities.

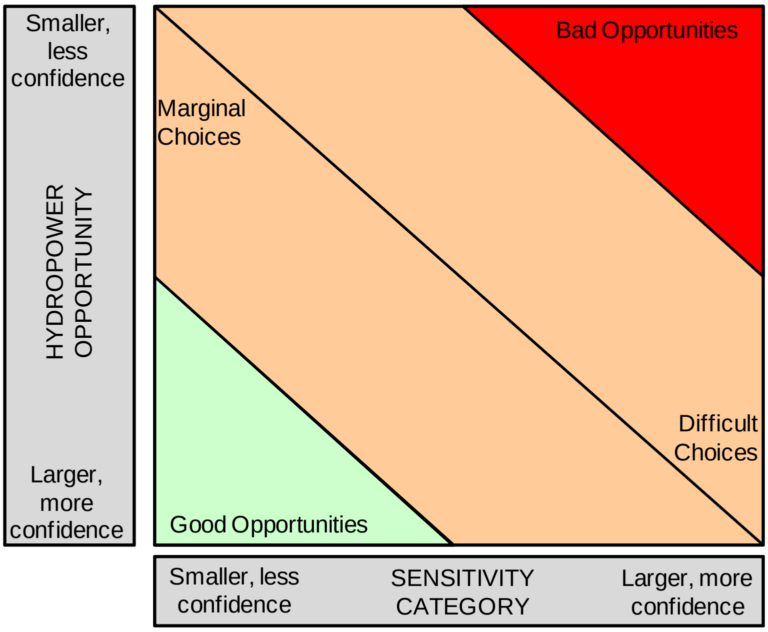

Figure 8-3: Hydropower opportunity categorisation matrix (Source: Entec, 2009[57])

[57] Entec (2009) Mapping hydropower opportunities in England and Wales: http://www.environment-agency.gov.uk/shell/hydropowerswf.html

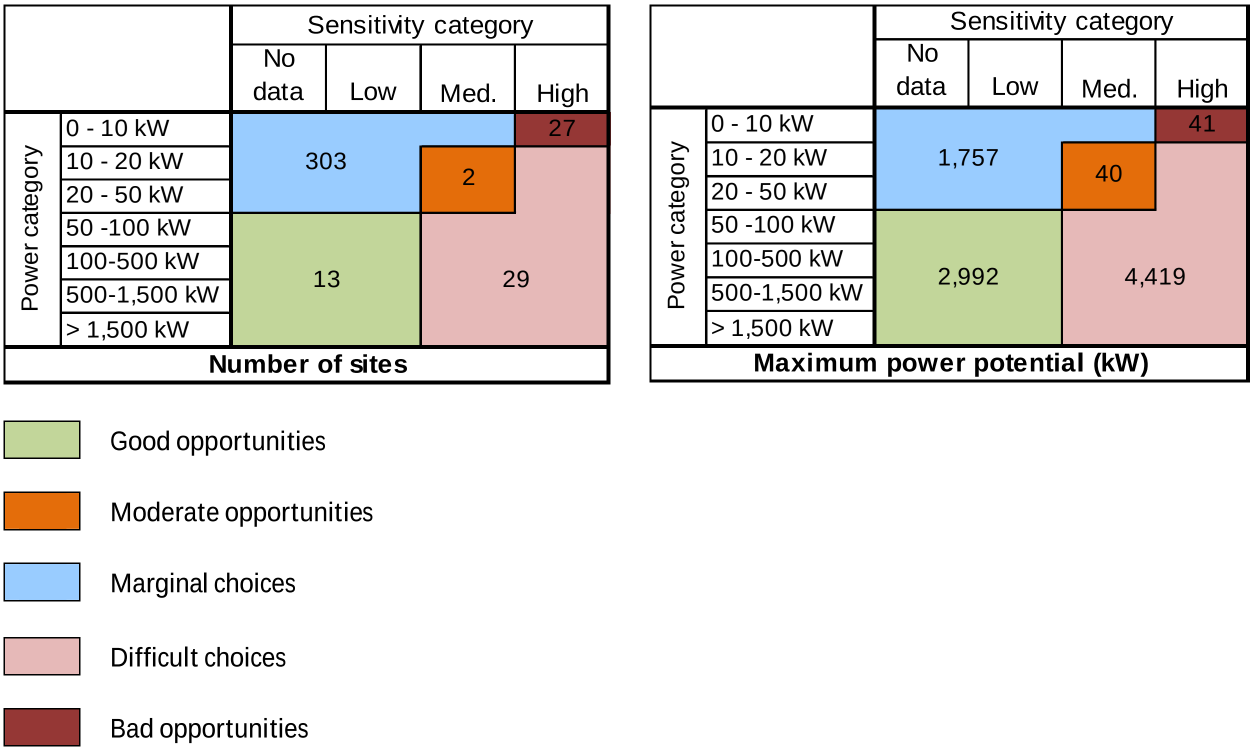

Figure 8-4: Hydropower opportunity categorisation matrix for London

Fifteen sites (4% of the total) fall within the good and moderate opportunities categories which are used to calculate the technical potential[58]. This represents a potential installed capacity of approximately 3.0MW, or 33% per cent of the total maximum power potential for all the sites assessed. If a hydropower scheme is built on each of these 15 sites, this will generate approximately 23.9GWh, assuming a 90% availability factor.

8.3 Technical potential of hydropower

Table 8-1 summarises the technical potential of hydropower in London.

[58] These sites are listed in the 'Technical potential_hydropower' datasheet which accompanies this report

	Values
Installed capacity (MW)	3.0
Electricity generation (GWh)	23.9
Carbon savings ($MtCO_2$)	0.009
% of London's electricity demand, 2008	0.06%

Table 8-1: Technical potential of hydropower, 2010

9 Tidal potential

9.1 Overview of approach

There are two main technologies appropriate for generating energy from the tides: tidal range and tidal stream. Tidal range (or head) driven technologies operate by delaying the flow of water between high-tide and low-tide to create a store of gravitational energy. They are most effective in environments where there is a significant inter-tidal range. Tidal stream driven technologies harness kinetic energy from the movement of water between high and low tide. The two technologies and their potential in London are discussed below. There is no requirement to assess tidal energy potential in the DECC methodology.

9.2 Overview of the tailored methodology for assessing tidal barrage potential

The Thames Estuary has a tidal range of between 4m and 5m at the Spring tide making it potentially appropriate for a tidal barrage[59]. The London Climate Change Agency (LCCA) commissioned a report investigating the potential for a Thames barrage in February 2008[60]. The proposed barrage would perform a flood defence function alongside its energy generation capability. To model the potential, four points were selected within the boundaries of the study (from the present location of the Thames Barrier down to Cliffe, just upstream of the new London Gateway Container Terminal)[61]. The locations of these sites are shown in Figure 9-1 and the specifications of each proposal are presented in Table 9-1.

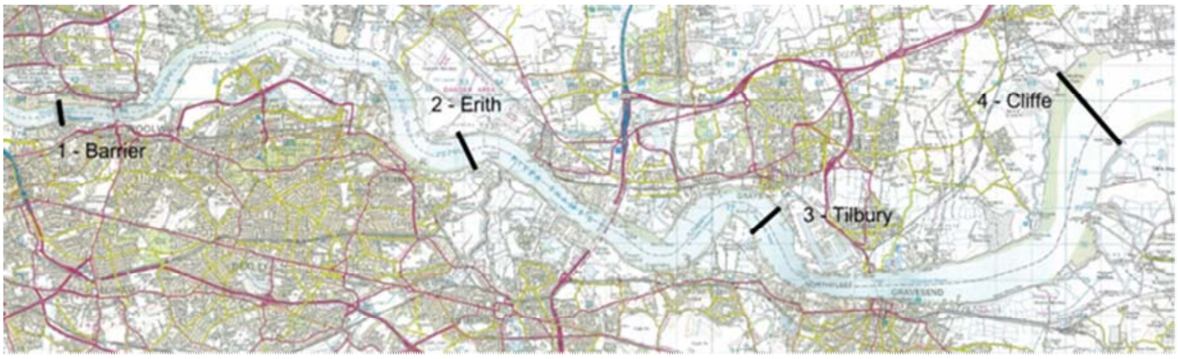

Figure 9-1: Four sites along the Thames at which energy generation potential has been modelled (© Crown copyright. All rights reserved (LA100032379) (2011))

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[59] Tidal barrages are constructed across the full width of an estuary creating a basin on the landward side of the barrage in which water can be held. At low tide, sluice gates are opened which allow the basin to flood as the water level rises to high tide. At high tide the sluice gates are closed, holding the water level in the basin. When the water on the seaward side recedes turbines are driven by the flow of water from the basin back to sea. This is known as ebb-generation as the power is generated on the ebb. Power can also be generated on the flood tide.

[60] Renewable Energy Systems and Sir Robert McAlpine Design Group (2008) Thames Barrage Final Report

[61] The first and fourth sites represent the boundaries of the study area and the second and third are approximately equally spaced between these. These locations were chosen for modelling purposes and are not identified as potential sites for a barrage.

Location	No. of Turbines	Power for one lunar cycle (GWh)	Annual energy generation (GWh)[62]	
			Theoretical	Realistic
1. Thames Barrier	10	5.4	141	110
2. Erith	24	10.2	266	210
3. Tilbury	36	14.7	382	300
4. Cliffe	60	22.1	577	460

Table 9-1: Theoretical potential capacity of a barrage at four points along the Thames

The results are theoretical outputs; the actual output of the barrage would depend on the final site chosen and the operation of the barrage. Assuming it was located upstream of the docks at Tilbury the barrage proposed in the report would have around 36 to 44 turbines each of 3MW, representing an average capacity of 120MW capable of generating approximately 300GWh per year. This represents the technical potential of the scheme.

However, the LCCA ruled out this technical potential on a test of cost effectiveness; the scheme would be very expensive and the electricity generated would not justify the investment. Should a barrage also be required for flood protection then this could significantly change this assessment. However, the EA has estimated that the current Thames Barrier will remain operational until 2070[63], and therefore any potential energy from a new Thames barrage equipped with tidal power equipment would likely not be forthcoming until well after 2031.

9.3 Overview of the tailored methodology for assessing tidal stream potential

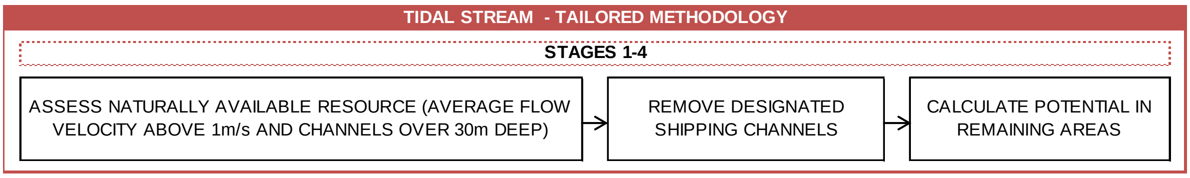

Figure 9-2: Overview of the tailored methodology for assessing tidal stream potential

The combination of shallow water depth, low tidal stream velocities and busy shipping lanes make the part of the Thames Estuary which falls within London unsuitable for the large-scale deployment of tidal stream technologies.

Sites which are most suited to tidal stream technologies have an average tidal current greater than 1m/s and have a minimum water depth of 30m. Tidal devices may be feasible in shallower channels provided that vessel movements are excluded or where development of the device results in a very

[62] The terms 'theoretical' and 'practical' are taken from RES 2008[60] and can be considered to correspond with DECC stages 1-2 and 3-4 respectively. They are technical assessment figures and do not take into account an economic or deployment assessment of a barrage across the outer Thames. The 'realistic' potential is simply 80% of the 'theoretical' potential which allows for a 20% reduction in capacity for a barrage in practice.

[63] EA (2010) Thames barrier project pack: http://www.environment-agency.gov.uk/static/documents/Leisure/Thames_Barrier_2010_project_pack.pdf

low water depth requirement[64]. The potential for tidal flow technology has been assessed using a similar approach as the DECC methodology by first assessing the naturally available resource and then assessing the technically accessible resource. The naturally available resource, represented by the average tidal stream power in the Thames estuary, is between 0.01-0.05 kW/m^2 [65].

In order to determine the technically accessible resource, the thresholds of 1m/s average tidal current and channel depth of 30m were applied. Bathymetry data showed that the majority of the Thames is less than 20m deep. The Thames is also a major shipping route[66] and hence in the deepest areas it is unlikely that it will be possible to place a turbine in the channel. Spring tidal flow data for the Thames Estuary shows a mean velocity under 1m/s[67] which also does not meet the selected criteria.

9.4 Technical potential of tidal energy

Table 9-1 summarises the potential for tidal power in London and is based upon the assessment of the technical potential for a barrage across the Thames located at Tilbury from the LCCA Thames Barrage report[68]. The technical potential figures are taken from the study's 'realistic' assessment of the technical potential of a barrage located at Tilbury of 300GWh per year.

Tidal energy	Tidal barrage	Tidal stream
Installed capacity (MW)	120	0
Electricity generation (GWh)	300	0
Carbon savings (MtCO$_2$)	0.1	0
% of London's electricity demand, 2008	0.8%	0

Table 9-2: Technical potential of tidal energy, 2010

[64] The Scottish Government (2010) Regional Locational Guidance for Marine Energy: http://www.scotland.gov.uk/Resource/Doc/295194/0096885.pdf

[65] BERR (2008) Atlas of UK Marine Renewable Energy Resources: Atlas Pages, A Strategic Environmental Assessment Report: http://www.renewables-atlas.info/downloads/documents/Renewable_Atlas_Pages_A4_April08.pdf

[66] London is the third largest port in the UK with annual freight of over 50 Mt (Source: LCCA / Renewable Energy Systems and Sir Robert McAlpine Design Group (2008) Thames Barrage Final Report)

[67] Calculated at mid-depth in the water column

[68] LCCA / Renewable Energy Systems and Sir Robert McAlpine Design Group (2008) Thames Barrage Final Report

10 Geothermal potential

10.1 Overview of approach

The potential for harnessing energy from both hot dry rocks (where there is an elevated thermal gradient), also known as engineered geothermal systems (EGS), and deep borehole geothermal water heating from aquifers was investigated but neither source was found to be viable at the current time. There is no requirement to assess geothermal energy potential in the DECC methodology.

10.2 Overview of the tailored methodology for assessing engineered geothermal system potential

EGS harnesses the natural heat flux from rocks, present mainly through radioactive decay. The heat is captured by introducing a fluid, often using an artificially enhanced series of fractures. This hot fluid is then used to drive a turbine and generate electricity. The British Geological Survey (BGS) describes EGS applications as possible where 'intrusive granites are blanketed by low conductivity sedimentary rocks'. In general the greatest potential in the UK is in the South West and North East[69]. The bedrock beneath London is primarily chalk (see Table 10-1) and offers no significant potential for EGS energy.

Era	Group	Formation	Thickness (m)
Palaeogene	Thames	Bagshot Formation	10 – 25
		Claygate Member London Clay	30 - 90
		Harwich Formation	0 - 10
	Lambeth	Woolwich and Reading Beds	10 - 20
		Upnor Formation	5 - 7
	Thanet Sands		0 - 30
Cretaceous	Chalk		180 - 245

Table 10-1: Geology of the London Basin (Source: EA, 2010[70])

10.3 Overview of the tailored methodology for assessing deep borehole geothermal heating potential

The potential for deep borehole geothermal heating is directly linked to the amount of naturally occurring energy which is available. However, there are relatively low levels of natural heat flux

[69] Busby. J, (2010) Geothermal Prospects in the United Kingdom, *Proceedings World Geothermal Congress 2010:* http://b-dig.iie.org.mx/BibDig/P10-0464/pdf/1638.pdf

[70] EA (2010) Management of the London Basin Chalk Aquifer, Status Report 2010: http://publications.environment-agency.gov.uk/pdf/GETH0710BSVT-e-e.pdf

beneath London – 50-60mW/m^2 – in comparison to other parts of the UK. This heat flux corresponds to a capacity of around 80MW or 700GWh annually. However, this resource is spread throughout London and its diffuse nature makes it impractical to capture.

At greater depths below the surface the naturally occurring thermal gradient means that the undisturbed ground temperature increases accordingly. Theoretically, it is possible to drill down into the ground and harvest this energy but, due to the lack of heat flux into the system, over time the temperature of this energy source could decline and eventually become exhausted. At this stage a new system would be required with new wells drilled in a different area. This is discussed further in the DE section of the report as it is not considered renewable.

10.4 Technical potential of geothermal energy

There is no practically viable or significant technical potential for renewable sources from geothermal energy in the London area.

11 Summary of technical potential

11.1 Renewable energy technical potential under the DECC methodology

Table 11-1 summarises the results for the existing technical potential of RE technologies across London under the DECC methodology. The building integrated microgeneration technologies provide the greatest potential. Biomass and wind power have a smaller, but not insignificant, overall potential.

RE sources in London can technically meet up to 12% of the capital's electricity consumption. The technical potential for heat generating technologies is estimated at around 57% of London's heat demand, with the vast majority of this potential coming from heat pumps. Biomass is identified as being able to meet around 4% of London's electricity demand and 4% heat (around 4,000GWh). At present the availability of additional energy from waste from solid recovered fuel is relatively limited. However the latter source is expected to grow significantly by 2031, from 196GWh in 2010 to 1,226GWh per year by 2031.

Technology	Installed capacity (MW)	Energy generation (GWh)		Carbon savings ($MtCO_2$)	% of London's energy demand, 2008	
		Electricity	Heat		Electricity	Heat
Photovoltaics	2,108	1,744	-	0.7	4.4%	-
Solar water heating	796	-	512	0.1	-	0.8%
Heat pumps	28,687	-	34,654	0.03	-	52.5%
Wind (small-scale)	11.4	14.2	-	0.006	0.04%	-
Wind (commercial-scale)	735	1,529	-	0.6	3.9%	-
Biomass (London)	-	1,401	2,524	1.1	3.5%	3.8%
Hydro	3.0	23.9	-	0.009	0.06%	-
Total	**32,341**	**4,712**	**37,689**	**2.5**	**11.8%**	**57.1%**

Table 11-1: Renewable energy technical potential in London using the DECC methodology, 2010[71]

11.2 Renewable energy technical potential under the tailored methodology

The existing technical potential of RE technologies across London, calculated under the tailored methodology, is outlined in Table 11-2, which shows that the technical potential for generating electricity is 34%, and the technical potential for generating heat is 49%, of annual energy consumption. The technical potential amounts to around 5.4$MtCO_2$ of carbon savings per year, with a further 0.4$MtCO_2$ from biomass imported from the Greater South East.

[71] Note: The DECC methodology uses a single set of parameters for solar energy and does not provide guidance on the breakdown of this potential between PV and SWH. In order to avoid double counting when combining generation and carbon savings, a split of 2/3 and 1/3 for PV and SWH is applied to the results derived using the DECC methodology.

PV and ASHP have the greatest resource in London with the capacity to supply 19% of London's power and 35% of London's heat respectively. The technical potential for electricity generation is significantly higher compared to the DECC methodology. The difference is primarily due to the much greater PV and wind potential. The heat potential (excluding biomass from the Greater South East and SRF) is significantly less than that estimate using the DECC methodology. The difference is largely due to the reduced technical potential of heat pumps, which is lower due to assumptions regarding their suitability for use in thermally inefficient buildings.

Technology	Installed capacity (MW)	Energy generation (GWh)		Carbon savings ($MtCO_2$)	% of London's energy demand, 2008	
		Electricity	Heat		Electricity	Heat
Photovoltaics	9,247	7,647	-	3.0	19.2%	-
Solar water heating	-	-	930	0.2	-	1.4%
Air source heat pumps	18,981	-	22,928	-0.7	-	34.7%
Ground source heat pumps	4,889	-	5,906	0.005	-	8.9%
Wind (commercial-scale)	2,197	4,099	-	1.6	10.4%	-
Wind (small-scale)	11.4	14.2	-	0.006	0.04%	-
Biomass (London)	-	1,401	2,524	1.1	3.5%	3.8%
Tidal	120	300	-	0.1	0.8%	-
Hydro	3.0	23.9	-	0.009	0.06%	-
Geothermal	-	-	-	-	-	-
Total	**35,447**	**13,485**	**32,288**	**5.4**	**33.8%**	**48.9%**
Biomass (Greater South East)	-	583	972	0.4	1.5%	1.5%
Total (including biomass in Greater South East)	**35,447**	**14,069**	**33,260**	**5.9**	**35.3%**	**50.4%**
Fossil fraction of solid recovered fuel	-	73.5	122	-	0.2%	0.2%
Total (including solid recovered fuel)	**35,447**	**14,142**	**33,382**	**5.9**	**35.5%**	**50.6%**

Table 11-2: Renewable energy technical potential under the tailored methodology, 2010[72]

Table 11-3 below shows the technical potential of RE technologies across London in 2031, calculated under the tailored methodology. The technical potential for electricity generation increases to 35%, whilst the technical potential for heat generation increases to over 70%, of annual energy consumption. This is primarily due to a higher potential for the deployment heat pumps.

[72] Note: The figures presented in Table 11-2 for PV differ from those presented in Section 5.4.1. This is because the potential from SWH has been deducted from the PV potential as these technologies compete for the same roof space.

Technology	Installed capacity (MW)	Energy generation (GWh)		Carbon savings ($MtCO_2$)	% of London's energy demand, 2031	
		Electricity	Heat		Electricity	Heat
Photovoltaics	9,422	7,792	-	3.1	19.8%	-
Solar water heating	-	-	1,293	0.3	-	1.9%
Air source heat pumps	26,564	-	32,089	-0.9	-	46.3%
Ground source heat pumps	11,624	-	14,042	0.01	-	20.2%
Wind (commercial-scale)	2,197	4,099	-	1.6	10.4%	-
Wind (small-scale)	11.4	14.2	-	0.006	0.04%	-
Biomass (London)	-	1,548	2,748	1.1	3.9%	4.0%
Tidal	120	300	-	0.1	0.8%	-
Hydro	3.0	23.9	-	0.009	0.06%	-
Geothermal	-	-	-	-	-	-
Total	**49,941**	**13,777**	**50,172**	**5.3**	**35.1%**	**72.3%**
Biomass (Greater South East)	-	583	972	0.4	1.5%	1.4%
Total (including biomass in Greater South East)	**49,941**	**14,360**	**51,144**	**5.7**	**36.6%**	**73.7%**
Fossil fraction of solid recovered fuel	-	460	766	-	1.2%	1.1%
Total (including solid recovered fuel)	**49,941**	**14,820**	**51,910**	**5.7**	**37.7%**	**74.8%**

Table 11-3: Renewable energy technical potential under the tailored methodology, 2031

Figure 11-1 compares the current technical potential of RE under the tailored methodology with London's energy demand in 2008. It is important to note that the deployment of heat pumps at scale will increase electricity demand significantly – by 32% in London.

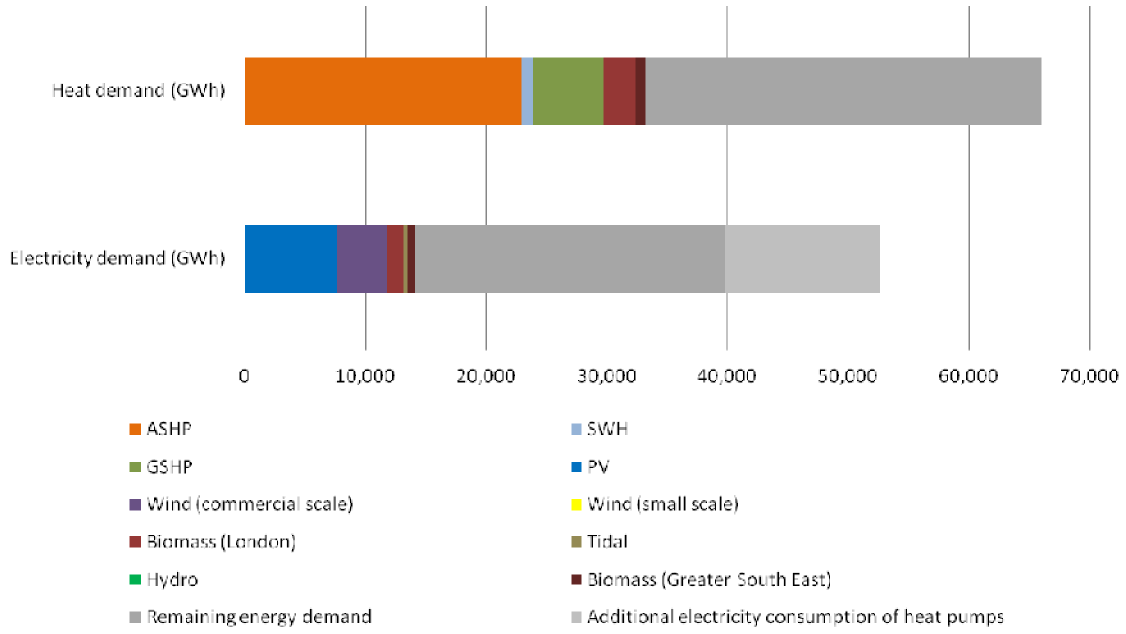

Figure 11-1: Renewable energy technical potential under the tailored methodology against 2008 energy demand by technology, 2010

11.3 Renewable energy technical potential under the tailored methodology by borough

Figure 11-2 illustrates the technical potential of RE in each of the London boroughs. The borough with the greatest RE potential is Havering, mainly due to its substantial wind potential. Figure 11-3 compares the renewable potential to each of the boroughs' energy demand.

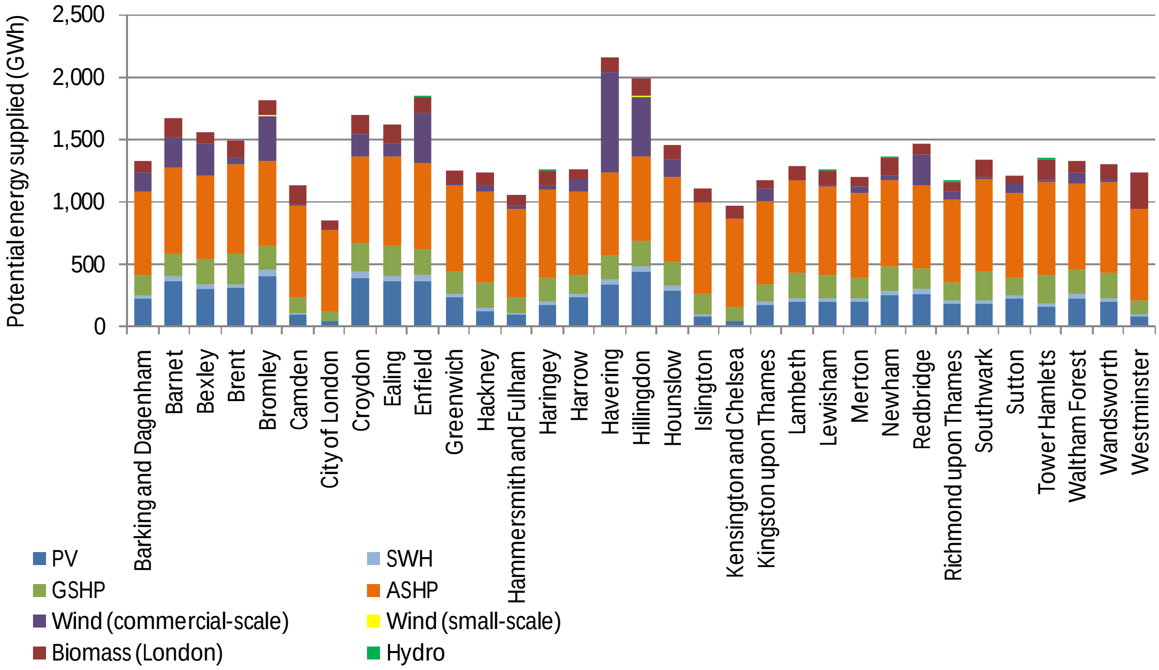

Figure 11-2: Renewable energy technical potential under the tailored methodology by borough, 2010

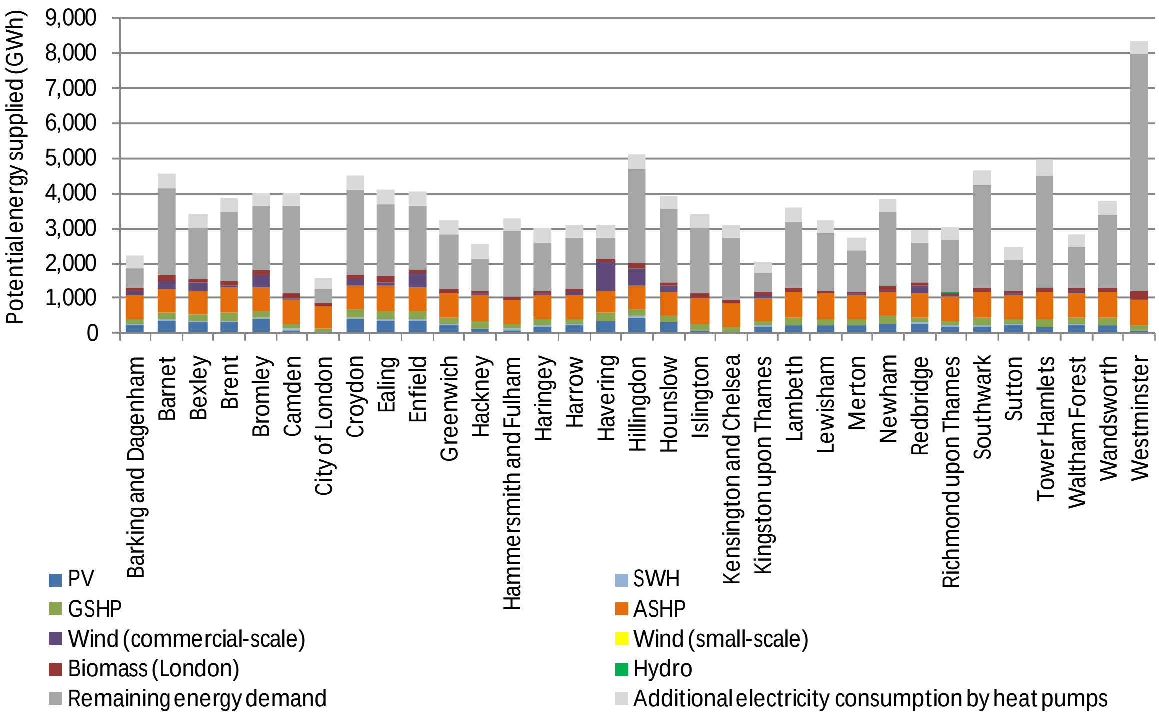

Figure 11-3: Renewable energy technical potential under the tailored methodology against 2008 energy demand by borough, 2010

SECTION B – DECENTRALISED ENERGY POTENTIAL

12 Methodology

12.1 Overview of DE study methodology

This section describes the methodology for assessing the technical potential of DE (See Figure 12-1). It follows a staged approach in line with the DECC methodology for assessing the RE potential taking into account 'technical constraints' (stages 1-2) and 'practical considerations' (stages 3-4).

The two key elements of DE – heat generation and heat distribution – are broken down as follows:

Heat generation (supply side) – assessing the technical potential for various different low and zero carbon heat generation, split into:

- Conventional heat generation
- Alternative heat generation (e.g. possible future sources)

Heat distribution (demand side) – assessing the technical potential for heat networks in London, split into:

Large-scale heat networks

Local-scale heat networks using anchor heat loads

These two elements were combined using a DE model to determine the potential taking into account technical constraints. A summary of the model is shown in Figure 12-2. Further details are provided in Section 12.4.

The supply side of DE in the UK has been dominated by the previously abundant reserves of North Sea natural gas. The demand side assessment of DE potential is fundamentally linked to economic viability; assuming abundant low carbon heat is available (e.g. natural gas CHP). However, Phase 1 is limited to establishing technical viability. The assessment of technical potential therefore makes use of a minimum threshold of heat demand density to determine technical feasibility for heat networks in a given area. In practice this threshold heat demand density is determined by several factors, including the cost of heat distribution, policy incentives and the cost of heat generation from conventional and alternative sources. Based on heat mapping data and a literature review, Section 14 develops minimum heat demand densities for heat networks in London.

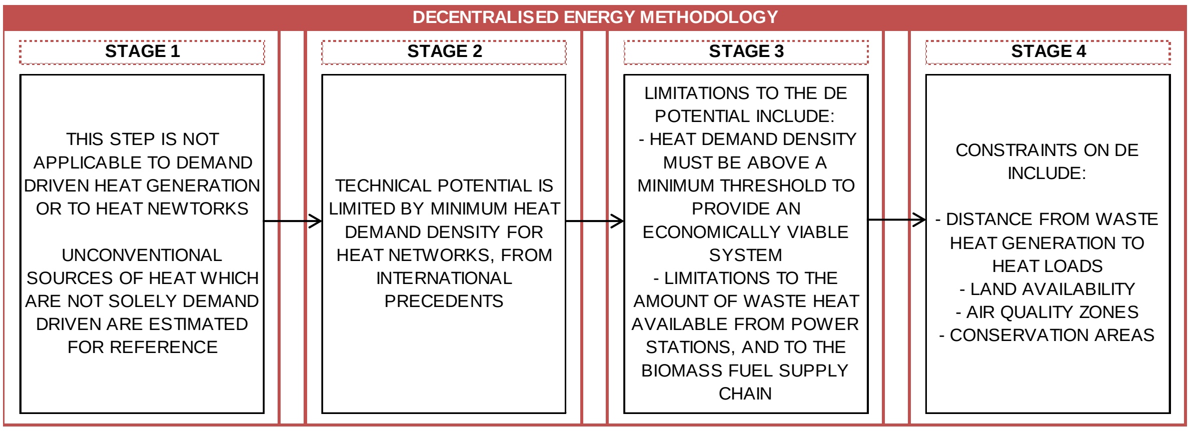

Figure 12-1: Overview of the methodology for assessing decentralised energy technical potential

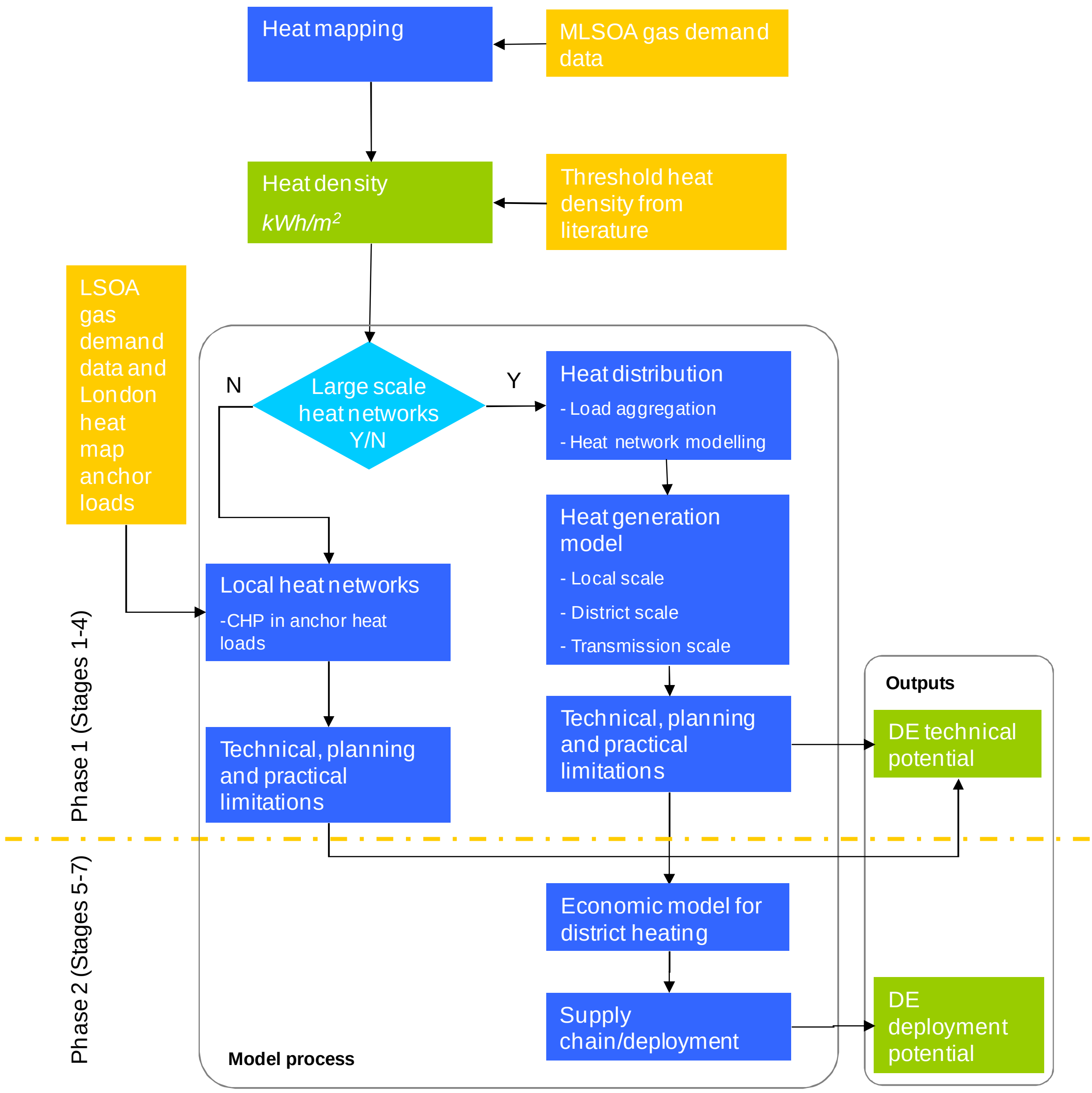

Figure 12-2: Overview of the decentralised energy modelling methodology for Phases 1 and 2

12.2 Literature review

12.2.1 Reference study methodologies for decentralised energy potential estimation

Four reference methodologies which have attempted to quantify the potential for CHP and heat networks in the UK or London have been reviewed. Table 12-1 summarises their applicability.

Reference methodology	Methodology summary	Strengths	Weaknesses	Applicability to study
GLA, London Community Heating Development Study (Source: GLA, 2005[73])	High level heat demand mapping; identification of priority areas; specific project identification and development	High level overview of areas most suitable for DE Projects identified are realistic and practical	Specific project identification is beyond the scope of this study on a London-wide basis	Does not provide an overall estimation of DE potential
Advantage West Midlands, Heat mapping and DE feasibility study (Source: Advantage West Midlands, 2008[74])	Detailed level heat mapping; estimate of DE potential based on disaggregating data to LSOA level	Identifies total potential CHP capacity GIS based outputs	No consideration given to heat networks; heat demand categories treated individually; does not include scale benefits for DE	Sets out a total potential CHP capacity but this doesn't allow for benefits of scale or costs associated with heat networks Methodology is useful in low heat density areas where district heating networks are unlikely to be viable

[73] GLA (2005) London Community Heating Development Study: http://static.london.gov.uk/mayor/environment/energy/docs/comm-heating-summary.pdf

[74] Advantage West Midlands (2008) Heat mapping and DE feasibility study: http://www.advantagewm.co.uk/Images/Heat%20and%20decentralised%20energy%20feasibility%20study_tcm9-17941.pdf

Reference methodology	Methodology summary	Strengths	Weaknesses	Applicability to study
DECC, Potential and costs of district heating networks (Source: DECC, 2009[75])	High level societal economic model of total UK-wide potential for district heating Based on heat density for housing stock categories	Identifies total potential CHP capacity. Includes cost and benefits of using district heating networks	No spatial element in terms of outputs Does not distinguish between regions Heat densities calculated for housing typologies, then used to inform overall model	Sets out total potential CHP and district heating capacity with robust economic assumptions Would need to be adapted to be London specific and to develop regional spatial models and outputs
IEA District Heating and Cooling Annex VII Report – Comparison of distributed CHP/DH with large-scale CHP/DH (Source: IEA, 2005[76])	Development of heat loads by postcode area Model for district heating network costs and performance Model for heat generation plant	Spatially led study Model for district heating based on density of city area	Based on notional city	Methodology to develop heat distribution model is directly applicable, and used as the basis for UK wide studies as discussed in Section 12.2.2

Table 12-1: Summary of a literature review of methodologies for assessing decentralised energy potential

12.2.2 London specific CHP targets from previous studies

Various studies have been undertaken into the potential for CHP and heat networks in London. One study quotes the potential in the UK as supplying 20% of homes, with 27% of these homes in London, corresponding to around 1.2 million homes[77]. The DECC (2009) report on the potential costs of district heating networks[75], listed in Table 12-1, is the most recent study and concludes that unless there is a shift in the market or regulatory environment there will be no significant uptake of district heating for the existing building stock, irrespective of the source of heat. This conclusion is likely to

[75] DECC (2009) Potential and costs of district heating networks, Pöyry/Faber Maunsell: http://www.decc.gov.uk/assets/decc/What%20we%20do/UK%20energy%20supply/Energy%20mix/Distributed%20Energy%20Heat/1467-potential-costs-district-heating-network.pdf

[76] IEA (2005) IEA Implementing Agreement on District Heating and Cooling Annex VII Comparison of distributed CHP/DH with large scale CHP/DH: http://www.iea-dhc.org/Annex%20VII/8dhc-05-01_distributed_vs_large-scale_chp-dh.pdf

[77] Hinnells, M (2008) Combined heat and power in industry and buildings, Energy Policy 36 (2008) 4522–4526, Environmental Change Institute, Oxford University: http://www.bis.gov.uk/assets/bispartners/foresight/docs/energy/energy%20final/hinnells%20paper-section%206.pdf

be as valid for London as elsewhere in the UK. Two London specific studies which estimate the DE potential are summarised below. Both studies show a very high sensitivity to discount rate.

In 2003, the Building Research Establishment (BRE) published a study into the potential for CHP and heat networks in the UK[78]. The study used a similar methodology as the IEA (2005) study[76] to build a representative heat network model and assess the cost of heat production versus a base case of individual gas boilers in buildings. CHP with heat networks was considered viable where the cost of heat was lower than that from the base case. The potential for London using gas engines as the heat generation technology was estimated as shown in Table 12-2. The viable CHP electrical capacity at a discount rate of 9% increased from 460 MWe to 1,805 MWe when larger scale, more efficient CHP plant (natural gas fired combined cycle gas turbine (CCGT)) was used in place of gas engines.

In 2007, Defra published a study on the UK potential for CHP which included a potential CHP capacity for London[79]. This study drew on the methodology developed for the IEA (2005) study[76]. The potential estimated for London is summarised in Table 12-2.

Discount rate		3.5%	6%	9%	12%
CHP potential (MWe)	BRE, 2003[78]	-	2,448	460	206
	Defra, 2007[79]	2,336	2,026	85	-

Table 12-2: Summary of CHP potential in London from previous studies

12.3 Installed CHP capacity in London

Table 12-3 sets out the installed capacity of CHP in London, based on statistics from DECC. It shows that in 2009, there 161 schemes operational in London generating 756 GWh and 2,414 GWh of electricity and heat respectively.

[78] BRE (2003) The UK Potential for Community Heating with Combined Heat & Power, Client report number: 211-533: http://www.energysavingtrust.org.uk/uploads/documents/housingbuildings/UK%20CH%20potential%20report_CTFinal.pdf

[79] Defra (2007) Analysis of the UK Potential for Combined Heat and Power: http://www.decc.gov.uk/assets/decc/what%20we%20do/uk%20energy%20supply/energy%20mix/emerging_tech/chp/potential-report.pdf

Parameter	Data
Number of CHP schemes	161
Electrical capacity (MWe)	198
Heat capacity (MWth)	490
Fuel used (GWh)	4,444
Electricity generated (GWh)	746
Heat generated (GWh)	2,414
Load factor (derived from total power output and total power capacity)	48.7%
Electrical capacity of schemes greater than 1MWe (MWe)	173

Table 12-3: Installed CHP capacity in London, 2009 (Source: DECC, 2010[80])

12.4 Description of the decentralised energy model

12.4.1 Overview of the decentralised energy model

The DE model is designed to assess the viability of various types of heat generation combined with heat networks by calculating a discounted whole life cost of heat for a given area and comparing this to the discounted whole life cost of heat from a 'business as usual' heat source. The economic modelling forms part of Phase 2. In Phase 1 the viability test is limited to setting a minimum requirement for heat demand density within any given area.

The model follows steps shown in Figure 12-3 and summarised as follows:

- Heat load agglomeration[81] – determining the MSOAs[82] to be served by heat networks by selecting those above a minimum level of heat demand density between 0 and 200 kWh/m^2 in 10 kWh/m^2 steps[83] and combining adjacent MSOAs above this threshold until no further areas can be added. The results of this analysis are shown in Section 15.
- Heat distribution model – modelling the heat distribution network for each agglomeration (see Figure 12-4).
- Heat generation model – modelling the operation of the heat sources (including selecting the heat generation technology based on cost of heat. The heat generation sources are ordered according to the cost of heat from the 2009 district heating study commissioned by DECC[75]).
- Constraints – applying practical and planning constraints to determine the technical potential.

[80] DECC (2010) Combined heat and power in Scotland, Wales, Northern Ireland and the regions of England in 2009: http://www.decc.gov.uk/en/content/cms/statistics/publications/trends/articles_sub/articles_sub.aspx

[81] Heat network areas which spread over more than one MSOA are termed 'agglomerations'

[82] A MSOA is a geographical area used by the ONS representing a population of around 7,500

[83] Measured in annual heat consumption per unit of land area (kWh/m^2). This is discussed in detail in Section 14

The key data inputs and outputs for the DE model are shown in Table 12-4. Refer to Section 12.5 for details of data sources.

Primary Data	Derived data	Final output
Domestic and non-domestic gas and electricity consumption Number of dwellings and meters MSOA land area Technology input data Benchmark energy consumption	Residential / non-residential heat split Heat density Length of DE network piping Agglomeration heat profile Size and type of CHP	Carbon savings DE potential Cost of heat generation (Phase 2 only) Cost of heat supply (Phase 2 only)

Table 12-4: Decentralised energy model – overview of key data inputs and outputs

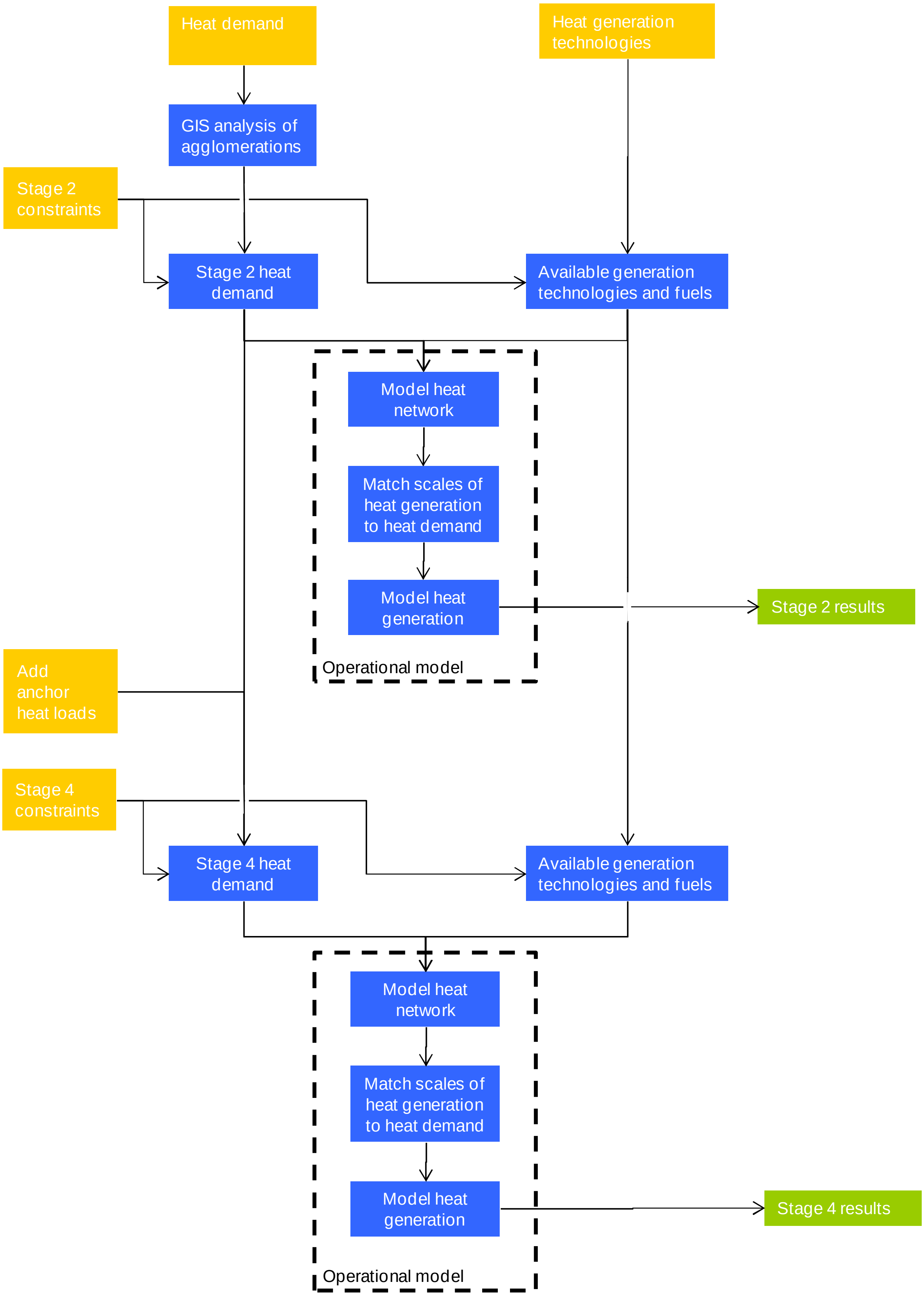

Figure 12-3: Detailed decentralised energy model flow chart

12.4.2 Overview of approach to heat networks in DE model

Modelling heat networks is one key function of the DE model. Heat network length establishes technical and economic parameters including heat loss from the network and capital cost. For each MSOA the heat network model determines the network length by applying an algorithm (developed for the IEA[76] and BRE[78] CHP studies) based on the area of the MSOA and the number of heat network connections within the MSOA. The derivation of the algorithm is based on a 'notional heat network', shown graphically in Figure 12-4. The algorithm determines the length *L* of a heat network that connects *x* points over an area of *A*, as shown in Equation 12-1. The 'notional heat network' represents a main branch into an area, side branches running up each 'street' and service pipes running to each connection. This was applied at three different scales to get lengths of transmission pipes, distribution piping and local network piping, all of which were given characteristic heat losses.

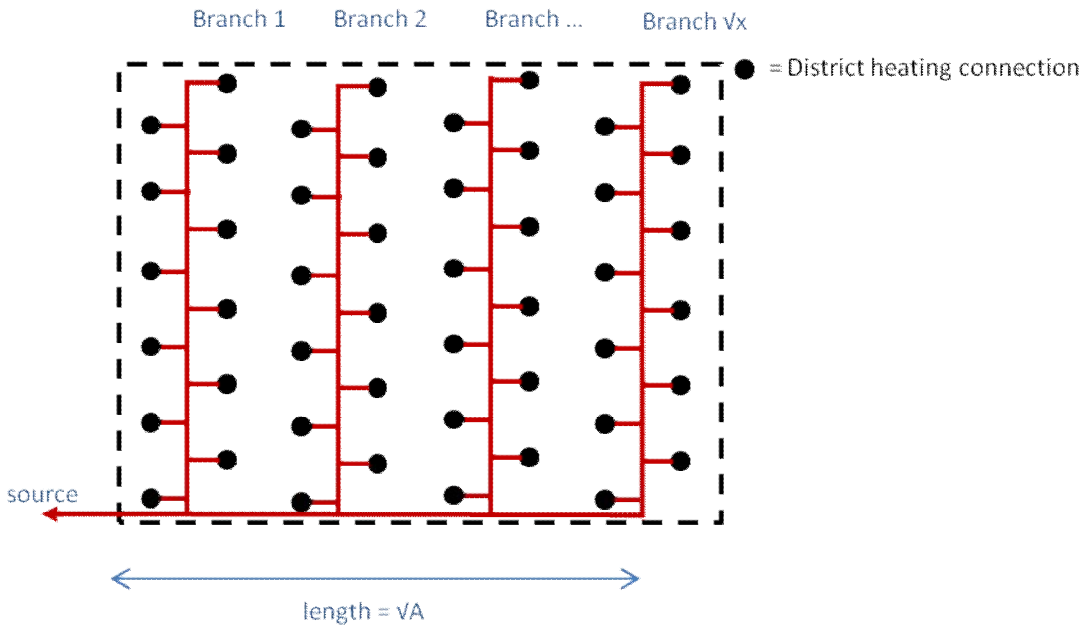

Figure 12-4: Distribution network notional grid model

$$L = \sqrt{A}\left(\sqrt{x} + 1 - \frac{3}{2\sqrt{x}}\right)$$

Equation 12-1: Network trench length algorithm

This approach to heat network modelling was verified by testing it against five geographical areas and comparing the results to a manual estimate, measured on a scaled map. Table 12-5 summarises the comparisons of the five sample MSOA areas selected and shows discrepancies between +6% and -17%. This assessment can only give an approximation to a real heat network, hence the range in accuracies across different types and sizes of test area. However, without undertaking a very detailed study it is considered the most appropriate approach.

MSOA	Area (km^2)	Measured length of network (km)	Predicted length of network (km)	Discrepancy
Westminster 013	1.29	47.6	39.5	-17%
Bromley 022 (part of MSOA only)	0.106	4.75	4.78	<1%
Camden 027 (part of MSOA only)	0.057	3.79	3.93	4%
Westminster 018 (part of MSOA only)	0.031	1.84	1.96	+6%
Harrow 016 (part of MSOA only)	0.112	6.16	5.68	-8%

Table 12-5: Comparison of predicted and measured network length using the network length algorithm

12.4.3 Overview of approach to heat generation in decentralised energy model

The operational model for calculating heat generation plant sizes as part of the overall DE model is shown in Figure 12-5. This section briefly describes how the model works. For each MSOA heat losses are attributed to each pipe size to generate a total network heat loss. This heat loss is then added to the heat demand to determine a gross heat demand. Representative load profiles for domestic and non-domestic heat demand are used to build up a load profile for each heat network agglomeration. From this profile a representative annual heat consumption (in MWh) for each technology is selected based on a notional period of 5000 running hours per year. This is used to give a rated thermal output required for heat generation (in MW).

Technology selection is based on the scale of the rated thermal output calculated and a prioritisation based on lowest cost of heat. Once a technology is selected the actual annual heat output from the heat source is calculated using a technology specific figure for running hours. The following are calculated for each heat agglomeration using a range of parameters (efficiencies, etc.) for the selected heat generation technology[84]:

- Top-up heat from central boilers (linked to heat networks)
- Heat from decentralised heat generation source
- Electricity from decentralised source
- Carbon emissions from DE plants
- Baseline carbon emissions assuming that existing gas boilers are upgraded to 85% efficiency.

[84] A detailed breakdown of the parameters used is given in the 'Phase 1_Decentralised energy' datasheet which accompanies this report.

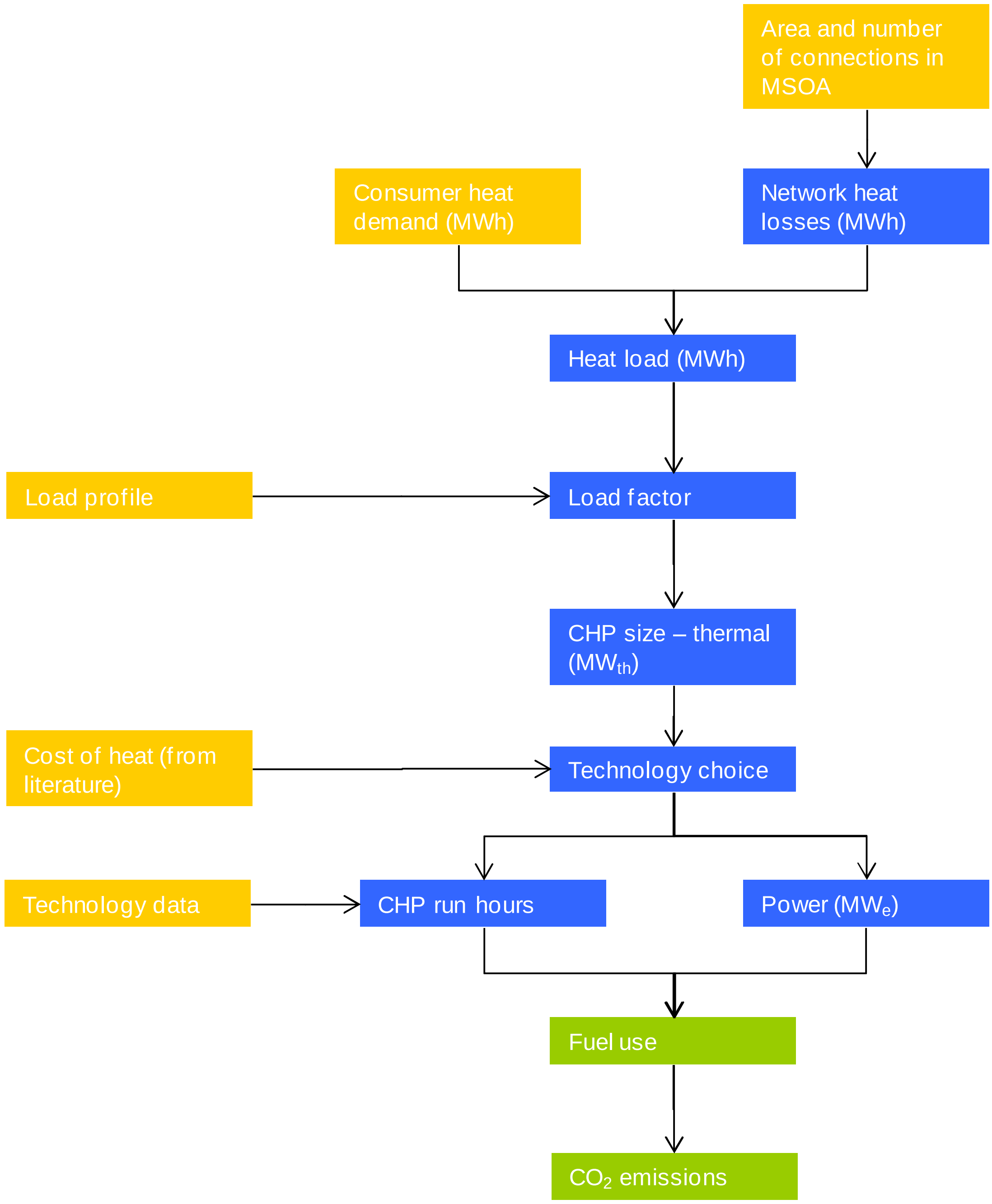

Figure 12-5: Operational model for CHP plant sizing and technology selection in Phase 1

12.4.4 Overview of approach to local-scale heat networks using anchor heat loads in decentralised energy model

It is possible that building-scale CHP schemes with links to local heat loads may be viable in areas which do not support a large-scale heat network. Many DE schemes will grow from local-scale heat networks in high density areas where large heat users (anchor loads) can support the initial phases. These anchor head loads include hospitals, prisons, hotels, fire stations, sports centres and local and central government estate.

In order to assess the size and extent of these schemes, LSOA level data on gas consumption[85] was combined with major heat load data from the London Heat Map to represent anchor loads[86]. The model assumes that a scheme is technically viable where there is an anchor heat load big enough to house a CHP system and make use of the heat output, with the potential to link to local residential areas. This also ensures a balance between the load profiles of residential and non-residential buildings.

Assumptions were made about the consumption of some of the major heat loads as the dataset was incomplete. Where only floor area was available, benchmarks were used to determine heat consumption, as shown in Table 12-7. Where a building floor area was not given for a major heat load, an average of the other heat loads of the same building type was used.

The MSOAs selected as suitable for larger scale heat networks were discounted. The heat demand of the anchor heat loads was added to LSOA residential heat demand (except where the anchor was residential) and the heat density calculated for all LSOAs. LSOAs were then selected and agglomerated with adjacent areas where the heat densities were above the threshold heat demand density for technical potential of 50kWh/m^2 (see Section 14.4) and where at least one LSOA in the agglomeration contained at least one anchor heat load.

12.5 Key input data

12.5.1 Domestic and non domestic gas consumption

Residential and non-residential gas consumption data at MSOA level was used to map heat demand[87]. The advantage of this dataset is that it differentiates between residential and non-residential properties, which is important as they have complementary load profiles which, when combined, may improve the viability of certain heat generation technologies. They also have different baseline emissions and costs of heat.

Included in the DECC dataset is an indicator for each Local authority (LA) of the percentage of unallocated consumption. This percentage averages about 0.2% and therefore a decision was made by the project team to discount this information. The average consumption of an individual MSOA is equivalent to a gas engine CHP unit of approximately 2MWe in output, representing the lower scale of the heat generation technologies to be assessed.

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[85] DECC (2010) LSOA domestic gas consumption, 2008: http://www.decc.gov.uk/en/content/cms/statistics/regional/mlsoa_llsoa/mlsoa_llsoa.aspx

[86] LDA (2010) London Heat Map dataset. Heat map is shown at: http://www.londonheatmap.org.uk/Mapping/

[87] DECC (2010) MSOA electricity and gas consumption: 2008: http://www.decc.gov.uk/en/content/cms/statistics/regional/mlsoa_llsoa/mlsoa_2008/mlsoa_2008.aspx (non-residential gas consumption is not available at LSOA level)

12.5.2 Number of connections and meters

Data from the Office for National Statistics (ONS) was used to identify the number of connections necessary per MSOA[88]. It is assumed that each detached house has one connection and each semi detached or terrace house has one connection per two dwellings (a meter per dwelling has been assumed). Non-residential meters are assumed to be one per connection. For multi-address residential buildings (flats), an average number of dwellings (meters) per connection was established using the ONS dataset for each LA[88]. This data was also used to calculate the number of meters per heat network connection for each MSOA.

12.5.3 MSOA land area

This was based on ONS Land Use Statistics[89].

12.5.4 Technology input data

Key input data used in the DE model are given below. Further details are given in the 'Phase 1_Decentralised energy' datasheet which accompanies this report.

Parameter		Value	Units	Source
Baseline	Efficiency of new boiler	0.85	-	CIBSE, 2007[90]
	Reference EER	3	-	
Other Inputs	Lifetime of individual boilers	15	years	DECC, 2009[91]
	Lifetime of peak load heat network boilers	15	years	
	Heat loss – minor pipes	15	W/m of pipe	Bohm, 2001[92]
	Heat loss – medium pipes	30	W/m of pipe	
	Heat loss – major pipes	40	W/m of pipe	

Table 12-6: Input data for the decentralised energy model

[88] ONS (2004) Accommodation Type – Household Spaces (UV56): http://www.neighbourhood.statistics.gov.uk/dissemination/datasetList.do?$ph=60&updateRequired=true&step=1&CurrentTreeIndex=-1&Expand9=1

[89] ONS (2005) Land Use Statistics (Generalised Land Use Database): http://www.communities.gov.uk/publications/planningandbuilding/generalisedlanduse

[90] CIBSE (2007) Guide F: Energy efficiency in buildings, Section 20, Second Edition. London: CIBSE

[91] DECC (2009) Potential and costs of district heating networks: http://www.decc.gov.uk/assets/decc/what%20we%20do/uk%20energy%20supply/energy%20mix/distributed%20energy%20heat/1_20090505121831_e_@@_204areportprovidingatechnicalanalysisandcostingofdhnetworksv30.pdf

[92] Bohm, B. (2001) Experimental Determination of Heat Losses from Buried District Heating Pipes in Normal Operation, *Heat Transfer Engineering*, Volume 22, Number 3, 1 June 2001 , pp. 41-51(11)

'Anchor load' building type	Benchmark heat demand, typical practice ($kWh/m^2/year$)
Central government estate	205
Churches	150
Education facilities	154
Fire stations	540
Hotels (> 99 units or 4,999 m2)	400
Local government estate	180
Museums and art galleries	142
NHS	500
Police stations	410
Prisons	22,034 (kWh/prisoner/year)
Sport and leisure facilities	598

Table 12-7: Benchmarks for anchor heat loads (Source: CIBSE, 2007[93])

[93] CIBSE (2007) CIBSE Guide F: Energy efficiency in buildings, Section 20, Second Edition. London: CIBSE

13 Heat generation

13.1 Overview of approach

This section of the report sets out the heat generation sources which have been considered:

- Conventional heat generation
  - Large-scale heat networks
  - Local-scale heat networks using anchor heat loads
- Alternative heat generation

Broadly, conventional heat generation includes technologies which are currently recognised as either being commercially used in CHP plant (gas turbines, combined cycle plant, steam turbines and reciprocating engines), sources of waste heat (energy from waste, anaerobic digestion, existing power stations, large scale heat pumps) and other plant installed to meet low carbon planning and building regulations requirements (biomass boilers). Supply side constraints were not considered for these technologies as natural gas was assumed to be widely available. The exceptions to this are waste heat, energy from waste and biomass CHP plant where capacity was assumed to be limited by fuel availability.

Local-scale DE generation includes plant that can operate in a single building and act as an anchor load to the development of smaller networks. This building can be a hospital, leisure centre or education campus or similar building with a larger and constant heat demand. Plant suitable for this type of operation must be less than $2MW_e$ and be able to be building integrated without special facilities. Suitable technologies are biomass CHP, biomass boilers, small gas engines and heat pump-led alternative heat sources.

Alternative heat generation includes waste heat from power stations outside of London, off-peak electricity from new nuclear power stations, and using heat pumps to access low grade heat from sources such as sewage outflows and building air conditioning plant. The impacts of planning policy and land constraints on DE technical potential were also considered.

13.2 Conventional heat generation – large-scale heat networks

The range of technologies considered in the DE model, listed in Table 13-1, and their performance figures are largely based on the DECC (2009) district heating study[75]. Each technology splits into a number of power categories which correspond to scales of heat network[94]. Biomass potential has been considered based on modelling the technologies which make use of the different biomass fuel sources separately. Table 13-2 gives more information on this.

[94] The full detailed breakdown by technology of the data used can be found in the 'Phase 1_Decentralised energy' datasheet which accompanies this report

Technology type	Scale of power generation (or heat output for thermal only)					
	250-100 MW_e	100-50 MW_e	50-20 MW_e	20-2 MW_e	2-0.5 MW_e	0.5-0.1 MW_e
Waste heat (large CCGT)	✓					
Biomass CHP			Large	Medium		
Energy from waste (EfW)			Incineration	Gasification		
CCGT		Medium	Small (30-50 MWe)			
Gas engine				Large	Small	
Anaerobic digester					✓	
Biomass heat only boiler					✓	✓
Large scale heat pumps using waste heat				✓		

Table 13-1: Conventional heat generation and scales of operation

Heat generation technology	Waste Incineration Directive compliant technology	Gate fees from fuel	Fuel resources	Basis of fuel costs
Anaerobic digester	Y	Y	Wet animal manures, Poultry litter, MSW - Food waste, C&I - food waste	Gate fees for waste handling
Biomass CHP – large	N	N	Imported biomass	International biomass
Biomass CHP – medium	N	N	Energy crops, forestry residues, coppiced material, crop residues – straw, biomass in the Greater South East	Local and regional biomass
Biomass district heating	N	N	Biomass outside London	International biomass
CCGT – medium	N	N	Grid gas	Gas wholesale price
CCGT – small	N	N	Grid gas	Gas wholesale price
Energy from waste – gasification	Y	Y	Residual waste, wood waste and biomass	Gate fees for waste handling
Energy from waste – incineration	Y	Y	Residual waste, wood waste and biomass	Gate fees for waste handling
Gas engine – medium (including multi-engine)	N	N	Grid gas	Gas wholesale price
Gas engine – small	N	N	Grid gas	Gas wholesale price
Large-scale heat pumps using waste heat	N	N	Waste heat from power station	The lost revenues from reduced electricity output
Waste heat (from large-scale CCGT and existing energy from waste)	N	N	Waste heat from power station	Gas used to provide heat (to reflect the effect of changing gas prices on the provision of heat from existing power stations)

Table 13-2: Description of technologies used in decentralised energy analysis

13.2.1 Overview of practical constraints

The amount of waste heat has been limited to that known to be currently available within London from the five large power stations identified in Table 13-3. Power stations in and around London are listed in Appendix 8. Using heat from power stations located outside of Greater London is considered in Section 13.3.

Power plant	Power output (MWe)	Thermal output (MWth)	Estimated heat generation (GWh)	Comments
Barking Power Station (CCGT) (Source: LDA, 2008[95])	1000	200	986	The figure of 200MWth is for retrofitting of the existing power plant. This could be increased by 400MWth should a proposed extension be purpose built to supply heat networks[96].
Enfield Power Station (CCGT)	400	100	370	Based on similar heat take off approach as Barking
SELCHP (EfW)	30-35	70	497	Existing EfW plant with significant residual life
Belvedere (EfW)	66	50	355	Under construction
Edmonton (EfW)	32	30	213	EfW plant expected to close in 2020 after which it is expected to be replaced by advanced energy recovery facilities such as gasification or pyrolosis.
Total	**1498**	**450**	**2420**	

Table 13-3: Capacities of existing large power plants in London (Source: Defra, 2007[97])

Waste heat from power plants is likely to be one of the most cost effective sources of heat but is limited in its supply and geographical location. The power stations listed in Table 13-3 were tested against a 10km radius of transmission network coverage[98] (see Figure 13-1). This shows that within this radius there is sufficient heat demand to utilise all of the waste heat available. In the long term the availability of heat demand within this distance is therefore less of a constraint to heat network development than the availability of waste heat.

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95 LDA (2008) Capacity data supplied to Buro Happold Ltd whilst undertaking a study for the LDA regarding the London Thames Gateway Heat Network

96 LDA (2008) Email correspondence with Peter North, Head of Energy Supply at the LDA, April 2009

97 Defra (2010) Incineration of Municipal Solid Waste: http://archive.defra.gov.uk/environment/waste/residual/newtech/documents/incineration.pdf

98 Based on the London Thames Gateway Heat Network which is designed to serve sites up to around 10km away

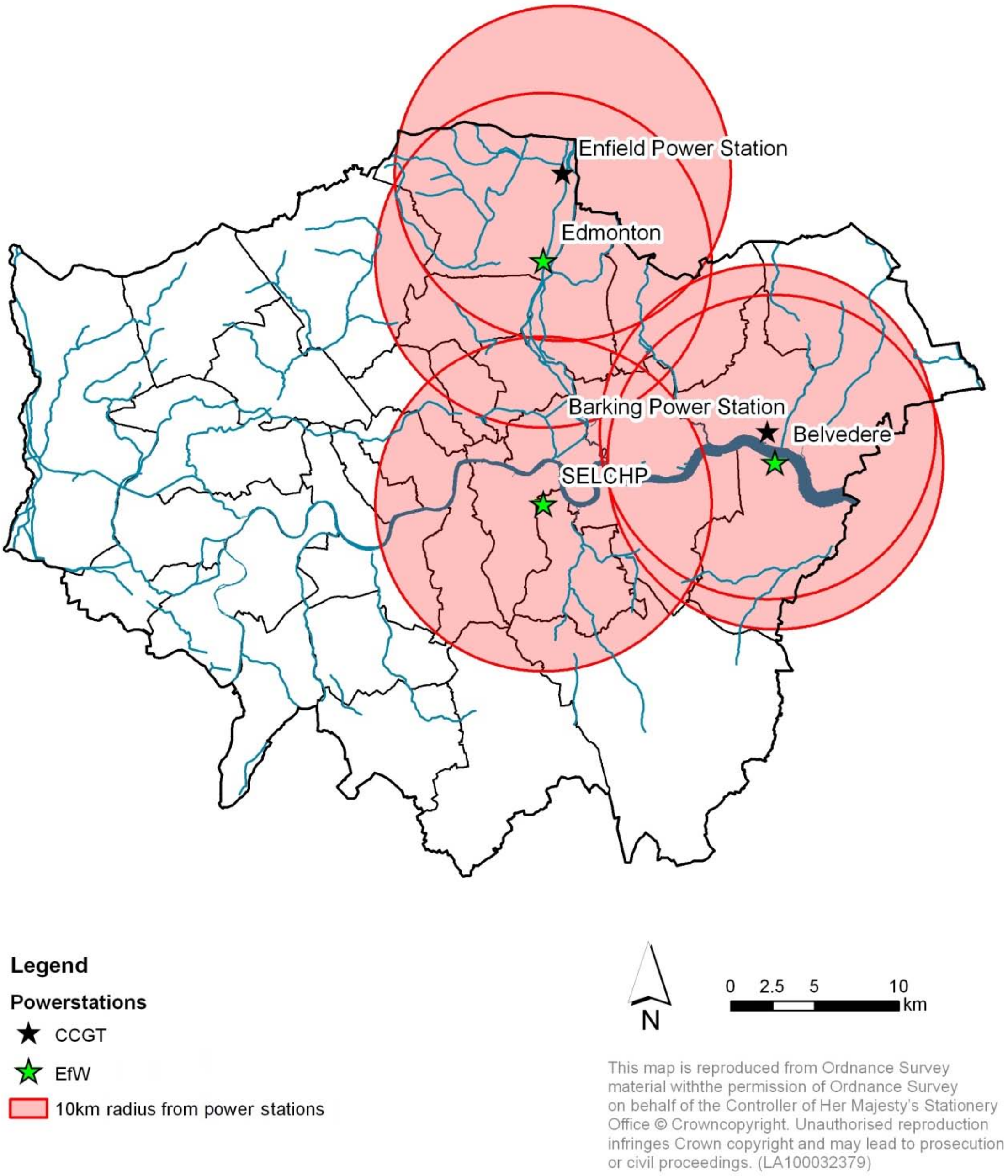

Figure 13-1: Proximity of heat loads to large power plants

13.3 Conventional heat generation – local-scale heat networks

Local-scale networks will primarily be heated by biomass and small-scale gas CHP (of a capacity less than 2MW$_e$). It is assumed that such plants are associated with serving anchor load buildings or groups of buildings. Heat networks can be extended to connect other local buildings within the LSOA where the anchor load is situated. Constraints to the development of these plants are limited due to their relatively compact nature and integration into existing buildings or new development. Even biomass boilers at this scale require relatively low volumes of fuel and can operate with weekly or twice weekly deliveries. Air quality might be of concern but even at this scale plants could be fitted with emissions abatement technologies.

13.4 Alternative heat generation

The following section summarises the potential for other currently under-utilised sources of heat for distribution using heat networks. Although not currently developed for use in DE systems, it is envisaged that future energy prices, constraints to emissions from fossil fuel use and the development of large-scale heat networks can bring the heat generation technologies listed in Table 13-4 into consideration[99].

Alternative heat generation	Description
Geothermal deep bore heat pumps	Using the natural temperature of the ground at depths >1,000m where the thermal gradient raises the ground temperature significantly. The ground temperature is not recharged naturally and so with time the heat source will become exhausted.
Electrical grid overspill	Effectively large-scale immersion heaters at local energy centres, operated using intermittent and off-peak low cost electricity
Waste heat from nuclear plant	Utilising the large amounts of waste heat associated with nuclear power generation
Waste heat from power stations outside Greater London	Using waste heat from power plants outside London, including potential new carbon capture and storage equipped plant replacing existing power stations due to be decommissioned under the Large Combustion Plant Directive
Heat recovery from sewage	Making use of the heat available in sewage plant outflows
Heat rejection from air conditioning	Making use of the heat rejected from building cooling and refrigeration systems

Table 13-4: Alternative heat generation by technology

13.4.1 Geothermal heat pumps

As described in Section 10.4 the natural heat flux in London is too low and diffuse to use as an energy source. At depths of 2km the thermal gradient means a temperature of around 50°C is reached and it is theoretically possible to extract this heat. However, this will eventually deplete the natural ground temperature over time. Once exhausted a new well in a different area would be required. Large-scale heat pumps will be needed to step up the temperature to that suitable for a heat network serving existing buildings (around 85°C). An assessment of the technical potential, based on a notional scheme, estimates that 5,395GWh/yr of heat is theoretically available (see Table 13-5).

[99] Full calculations for each of the technologies can be found in the 'Phase 1_Alternative technologies' datasheet which accompanies this report as well as references for the figures used

Practical considerations

There are myriad technical challenges that make this option completely impractical and limit the potential to zero. The main issue is that at the depths required to reach useful temperatures there is no aquifer. It would therefore be necessary to create an artificial one by injecting water into the ground at very high pressures to cause artificial fractures. Whilst this is done in enhanced geothermal systems used for electricity generation the scale of the artificial aquifers required in this application would be much larger, and it is therefore not considered practical.

Variable	Value	Unit
Reservoir height	100	m
Reservoir diameter	200	m
Delta T - average over life	20	°C
Porosity	0.3	ratio
Heat stored per well	22	GWh
Separation (diameter/2)	100	m
Area per well	16	ha
Wells in London (Source: GLA, 2010[100])	9813	no.
Total energy resource	215,788	GWh
Time period for extracting energy	40	yrs
Annual heat energy available	5,395	GWh/yr

Table 13-5: Geothermal deep bore heat pump technical potential [101]

13.4.2 Electrical grid overspill

Electricity demand varies significantly between winter and summer, weekdays and weekends and day and night. If the UK transitions to a higher proportion of electricity from sources which are difficult or impossible to modulate (e.g. wind or nuclear) then matching this variable demand will become more challenging. At times of low load and high output there will be an excess of electricity generation. One approach to utilising this energy will be to convert it to heat and store it for use during the day. In, France where around 75% of electricity demand is supplied by nuclear power[102], extensive use is made of off-peak water heating and storage heaters (around 8 million[103]) at the domestic scale.

[100] GLA (2010) Land Area and Population Density, Borough: http://data.london.gov.uk/datastore/package/land-area-and-population-density-borough

[101] References for this table can be found in the datasheets which accompany this report

[102] World Nuclear Organisation (2010) Nuclear Power in France: http://www.world-nuclear.org/info/inf40.html

[103] Orphelin, M (1998) Improvements in methods for reconstructing water heating aggregated load curves: http://www-cep.ensmp.fr/english/themes/mde/pdf%20J%20Adnot/pdf2.pdf

Currently 10GW of nuclear capacity is installed in the UK. All but one of the existing plants will be decommissioned by 2025. One of the DECC 2050 Pathways describes an ambitious but achievable increase in nuclear power capacity that would be one part of a concerted effort to reduce carbon emissions (level 2 activation which is part of pathway alpha). This increase predicts that an average of 1.2GW a year of new nuclear capacity will be required for a sustained period after 2025, delivering a total installed capacity of 39GW of nuclear power capacity by 2050[104].

One possible approach to storage is to use surplus electricity generation at night to run industrial-scale heat pumps or electrode boilers that charge thermal stores linked to buildings by heat networks. The heat pumps would be local to the heat demand as losses due to transportation of electricity are lower than for heat, but buildings may not be able to accommodate large thermal stores. Space and weight constraints apply potentially requiring heat networks to enable use of this heat source.

The peak electricity demand is approximately 40GW in summer and 60GW in winter. A typical summer electricity profile for the whole of the UK is shown in Figure 13-2. There is a diurnal variation of 15GW between maximum and minimum demand and the peak lasts for approximately 16 hours. Should this summer diurnal variation become available, the allocation of this surplus is unclear. Assuming that half of this capacity will be available for heating gives 43,800GWh/yr of electricity which, when converted at a COP of 2.5[105], gives 109,500GWh/yr of heat for the UK. London consumes 13% of UK electricity. Assuming access to the surplus electricity in proportion to this, gives a technical potential of 14,235GWh per year of heat (when turned to heat via heat pumps). This equals 21% of London's gross heat demand in 2031.

[104] DECC (2010) 2050 Pathways Report: http://www.decc.gov.uk/en/content/cms/consultations/2050pathways/2050pathways.aspx

[105] This is a conservative assumption for a large-scale air-to-water heat pump

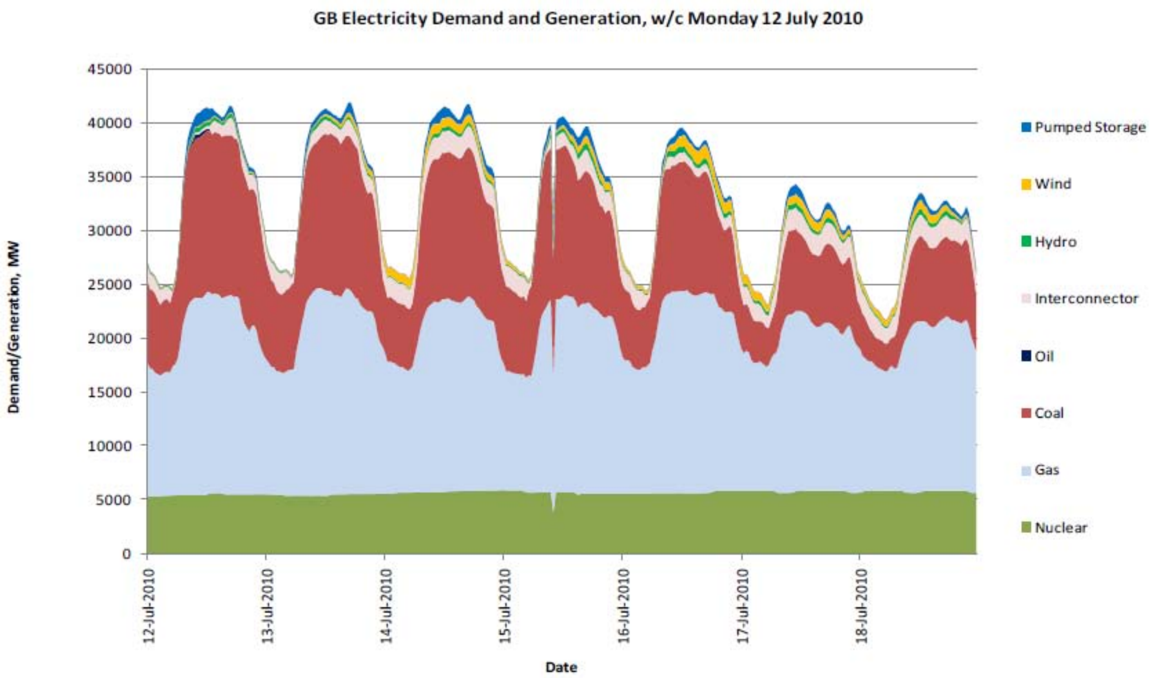

Figure 13-2: Great Britain's electricity supply over a one week period during the summer (Source: DECC, 2010[106])

Practical considerations

At present the electrical system is heavily reliant on fossil fuel plants capable of modulating to meet demand. Therefore the practical potential of this approach to low carbon heat generation is assumed to be zero. Depending on the electricity generation mix in the future, however, it could have a significant potential by 2031. One disadvantage of this approach is that there may be less energy available in winter when most heat is required.

13.4.3 Waste heat from nuclear plant

Research is underway into capturing waste heat from power stations in summer and storing it in large scale underground stores for use during the winter[107].

[106] DECC (2010) Energy Trends, September 2010, p51: http://www.decc.gov.uk/assets/decc/Statistics/publications/trends/558-trendssep10.pdf

[107] Energy Technologies Institute (2010) ETI To Investigate Feasibility Of Storing And Using Waste From Power Stations or Use in British Homes: http://www.energytechnologies.co.uk/home/news/10-11-29/ETI_To_Investigate_Feasibility_Of_Storing_And_Using_Waste_From_Power_Stations_or_Use_in_British_Homes.aspx

Nuclear sites near London	Distance to centre of London (km)	Status
Sizewell	140	Plant A: due to be decommissioned Plant B: commenced operation in 1995 New build planned
Bradwell	75	Original plant shutdown New build planned
Dungeness	100	Plant A: shutdown Plant B: due to be decommissioned Not selected as one of new nuclear build sites

Table 13-6: Nuclear plant near London

Low grade waste heat is produced continuously from existing nuclear plant such as Sizewell B. The Sizewell B plant, near Leiston in Suffolk, has a load factor of around 93% and generates around 10,000GWh of electricity annually[108]. Based on a typical efficiency of 39% this would provide around 15,138GWh of low grade waste heat (or around 23% of London's current heat consumption). In practice the amount of heat available at usable temperatures would be much less, at best around half (7,569GWh). A new nuclear plant at the same site (the proposed 'Sizewell C') could be designed as a CHP plant, with a heat capacity of around 13,000GWh. A further plant at Bradwell could deliver the same capacity.

Practical considerations

In practice there are no precedents in mainland Europe of heat being transmitted more than around 70km, half the distance to Sizewell; therefore the capacity from Sizewell is likely to be impractical. This leaves a technical potential of 13,000GWh in 2031, should a new nuclear reactor be built at Bradwell and a heat transmission main of 75km be practical. There is no fundamental technical barrier to this economic viability and policy support would be the key determinant.

13.4.4 Waste heat from power stations outside Greater London

There is approximately 2,500MW of large-scale power generation close to London at Littlebrook and Tilbury (see Appendix 8). Some of this is due to close and it may not be practical to transmit this waste heat due to the distance and the technical feasibility of conversion to operate in CHP mode. A load factor of 48%[109] and a heat to power ratio of 0.2[110], gives an available technical potential of 2,100GWh per year in 2010. It is likely that both of these power plant sites will be de-commissioned by 2031. If they are replaced with new plant, enabled with carbon capture and storage they can potentially provide 6,570GWh of low carbon heat. It is assumed that the capacity remains the same

[108] British Energy (2010) Sizewell B: http://www.british-energy.com/pagetemplate.php?pid=96

[109] DECC (2010) Digest of UK energy statistics, 2009, Table 5.10 Average power plant load factors: http://www.decc.gov.uk/assets/decc/Statistics/publications/dukes/311-dukes-2010-ch5.pdf

[110] This assumes a conversion at the same heat-to-power ratio as the proposed works to Barking Power Station. This conversion is understood to be on the basis of extracting steam from a medium pressure steam header limiting the available heat to 100MW, versus a power capacity of 500MWe per block (total of 2 blocks) (Source: LDA (2008) Capacity data supplied to Buro Happold Ltd whilst undertaking a study for the LDA regarding the London Thames Gateway Heat Network)

but the new plants are designed as dedicated CHP units to achieve a heat-to-power ratio of 0.5, and operate as base load plants with a load factor of 60%.

Practical considerations

At present there are no extensive heat networks in place into which these power stations could supply heat. However, by 2031 will likely be different. The technical potential in 2010 is therefore considered to be zero, but the technical potential in 2031 is 6,570GWh.

13.4.5 Sewage output – heat recovery

Heat can be recovered from the outflow of sewage treatment plants. An analysis of the potential in London is shown in Table 13-7. The potential is significant and there are precedents for using this method of heat generation[111], though none in the UK.

Variable		Value	Unit
Delta T		5.0	K
Daily water usage	Non-domestic	1,217,000,000	l/day
	Domestic	492,000,000	l/day
	Total	1,709,000,000	l/day
Proportion of water usage which is captured as sewage		90%	
Total sewage volume		1,538,100,000	l/day
Daily energy available		32,300,100,000	kJ/day
		8,972,250	kWh/day
		9.0	GWh/day
Annual heat energy available		3,275	GWh/yr

Table 13-7: Technical potential of heat from sewage works

Practical considerations

In practice the large potential resource could be difficult to access without extensive heat networks in place, which makes the potential in 2010 very limited. Further limitations include the potential requirement to upgrade buildings to deal with lower temperature heat and the possibility that water use per capita will decline. However, there are no clear reasons to reduce the potential beyond that calculated in Table 13-7 by 2031, assuming heat networks are in place by this time and heat can be supplied to buildings which have been upgraded to achieve higher levels of thermal efficiency (see Section 7).

[111] Stowa (2010) Heat pumps: http://www.stowa-selectedtechnologies.nl/Sheets/Sheets/Heat.Pumps.html

13.4.6 Heat rejection from air conditioning

The cooling delivered to buildings in London in 2004 was just under 4,500GWh, which equates to 1,600GWh of energy consumed. This is predicted to almost double by 2030 to a delivered cooling load of 8,500GWh and 3,100GWh of energy consumed[112]. The temperature of the rejected heat is likely to be low (around 35°C) but it should be possible to use the rejected heat as a source for heat pumps (i.e. rather than air or ground source heat pump systems). This can potentially yield 4,500GWh in 2010 or 8,500GWh by 2031 without taking any losses into account. In practice, therefore, the potential will be lower than this. The obvious limitation to this approach is that peak heat loads are unlikely to coincide with peak heat rejection from cooling plant. Significant thermal storage will thus be required.

Practical considerations

In the absence of an extensive heat network, the technical potential in 2010 is assumed to be zero. Further limitations include the potential requirement to upgrade buildings to deal with lower temperature heat available. However, until more is understood about how these systems might function in relation to heat networks; and more is understood about when this energy is available, there are no clear reasons to reduce the potential beyond that calculated above. For example, small-scale condensing water loops may be possible in new build mixed use developments with simultaneous heating and cooling demands.

13.4.7 Total technical potential for alternative heat generation

Table 13-8 summarises the technical potential for alternative heat generation. The potential by 2031 is very significant, though it is highly dependent on establishing heat networks. Around 60% of this potential is dependent on broader assumptions about the potential to use off peak and intermittent electricity and waste heat from new build low carbon power plant. The availability of these sources is subject to a very high degree of uncertainty.

[112] Day, A (2009) Forecasting future cooling demand in London, *Energy and Buildings 41*: 942-948

Heat generation	Technical potential (GWh)			
	Technical constraints (Stages 1-2)		Practical considerations (Stages 3-4)	
	2010	2031	2010	2031
Geothermal deep bore heat pumps	5,395	5,395	0	0
Electrical grid overspill	0	14,235	0	14,235
Waste heat from nuclear plant	0	33,569	0	13,000
Waste heat from power stations outside Greater London	2,102	6,570	0	6,570
Heat recovery from sewage	3,275	3,275	0	3,275
Heat rejection from air conditioning	4,500	8,500	0	8,500
Total	**15,272**	**71,544**	**0**	**45,580**
% of London's heat demand, 2008	**23%**	**103%**	**0%**	**66%**

Table 13-8: Technical potential of alternative sources of heat

13.5 Planning and regulatory constraints

In line with the DECC methodology for RE, an assessment of the impact of planning and regulatory constraints relating to DE plants has been undertaken. The main planning and regulatory constraints for DE are likely to relate to any new build CHP, biomass and EfW plants. Constraints will relate to the location, size and design of large energy centres and consideration of flue heights and emissions. Most of these can be managed on a case-by-case basis, but in areas of London with a high degree of constraint, this is likely to lead to higher installation costs and reduced capacity.

This analysis covers conservation areas, land availability and air quality. It was concluded that none of these represent a fundamental constraint to the development of DE, and therefore no reduction in the technical potential has been made. However, it is recognised that on an individual project basis these constraints could prevent a project from being developed in a specific location.

13.5.1 Conservation areas

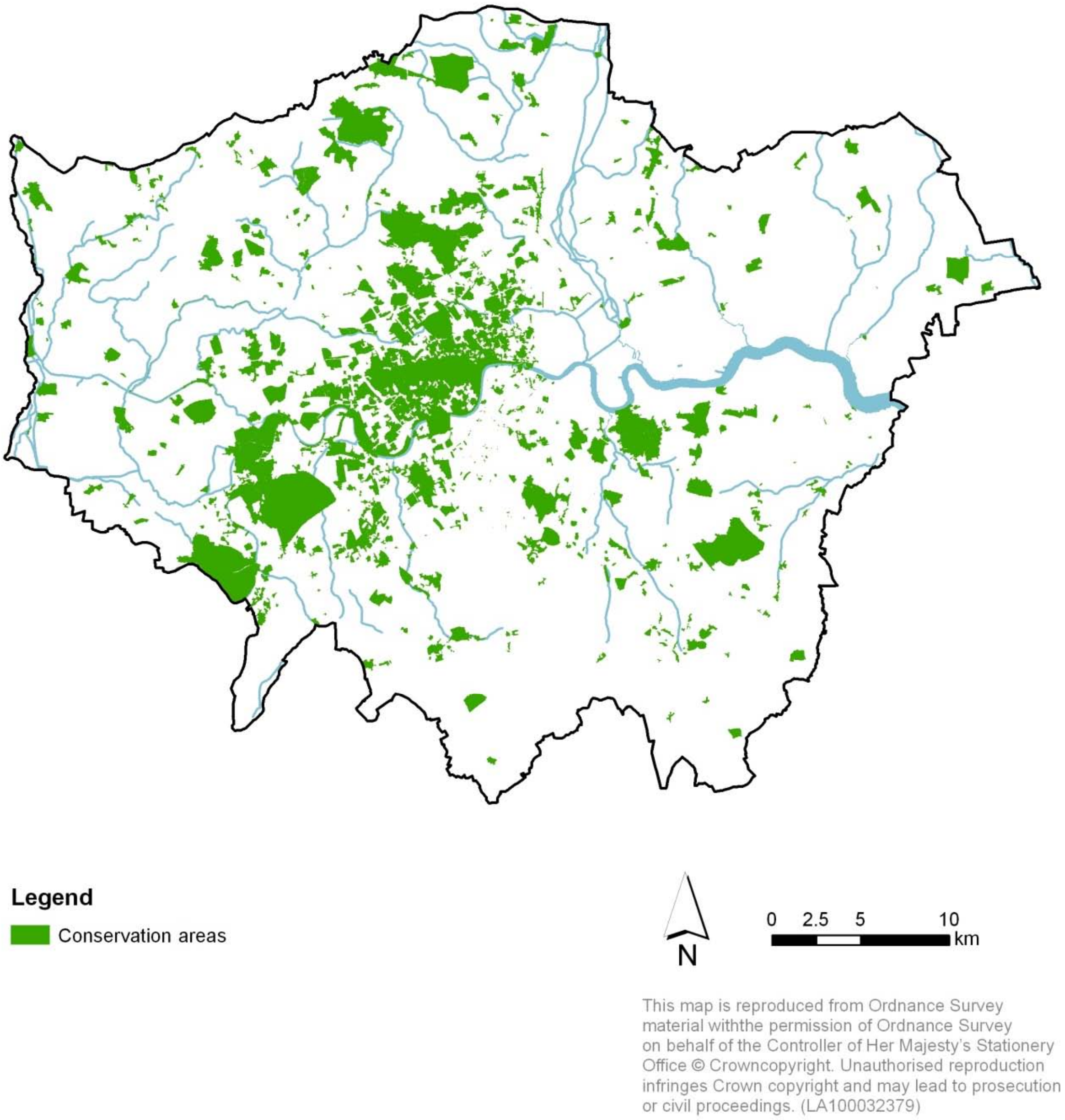

Figure 13-3: Conservation areas in London (Source: GLA, 2010[113])

Figure 13-3 shows all the conservation areas in London which will have strict planning restraints. Apart from central London (Westminster, Kensington and Chelsea) these areas are often dominated by parks which break up building density and so are not well suited to heat networks.

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[113] Landmark (2008) Land Use Contraints Data: www.landmark.co.uk © Landmark Information Group Limited and/or its Data Suppliers (All rights reserved 2010)

13.5.2 Brownfield sites

CHP, particularly gas CCGT, medium gas engine CHP, energy from waste and biomass plants may be constrained by the availability of land, especially where the most viable technology is large scale and situated in a densely built up area. Figure 13-4 shows the locations of land designated as brownfield sites greater than 0.1ha in London[114]. Figure 13-5 and Figure 13-6 show the land which is available once the following filtering criteria are applied:

- Sites above 2.5ha (large enough for energy from waste or biomass CHP plants of 10MWe capacity)
- Land not designated for housing
- Sites which are not 'type D'[115]
- Sites in public ownership

The maps show a quickly diminishing number of larger brownfield sites which are not designated for housing or other uses, and an even smaller proportion of these which are publicly owned. However, it is likely that the number of large-scale (>10MWe) plants using solid fuels, such as biomass CHP and energy from waste will be relatively low. Although the technical potential is significant (see Section 4) commercial operators tend to favour large plants, resulting in fewer individual plants for a given fuel resource. This in turn limits the number of sites required. The total electrical potential of all biomass sources of 2,008GWh/yr of electricity as calculated in Section 4 (see Table 4-3), is equivalent to around twenty-seven 10MWe capacity plants. Based on this, it is not considered that land availability is a fundamental constraint to developing these technologies in London. However it can constrain the locations chosen for them. The most likely areas appear to be in East London due to the higher density of brownfield land sites which are not likely to be developed for housing.

[114] Note: This analysis does not allow for the possibility to use sites which are currently designated as having other uses and is likely to underestimate the area of land available

[115] Type D land is in use or allocated to a purpose already and so cannot be used for building CHP plants

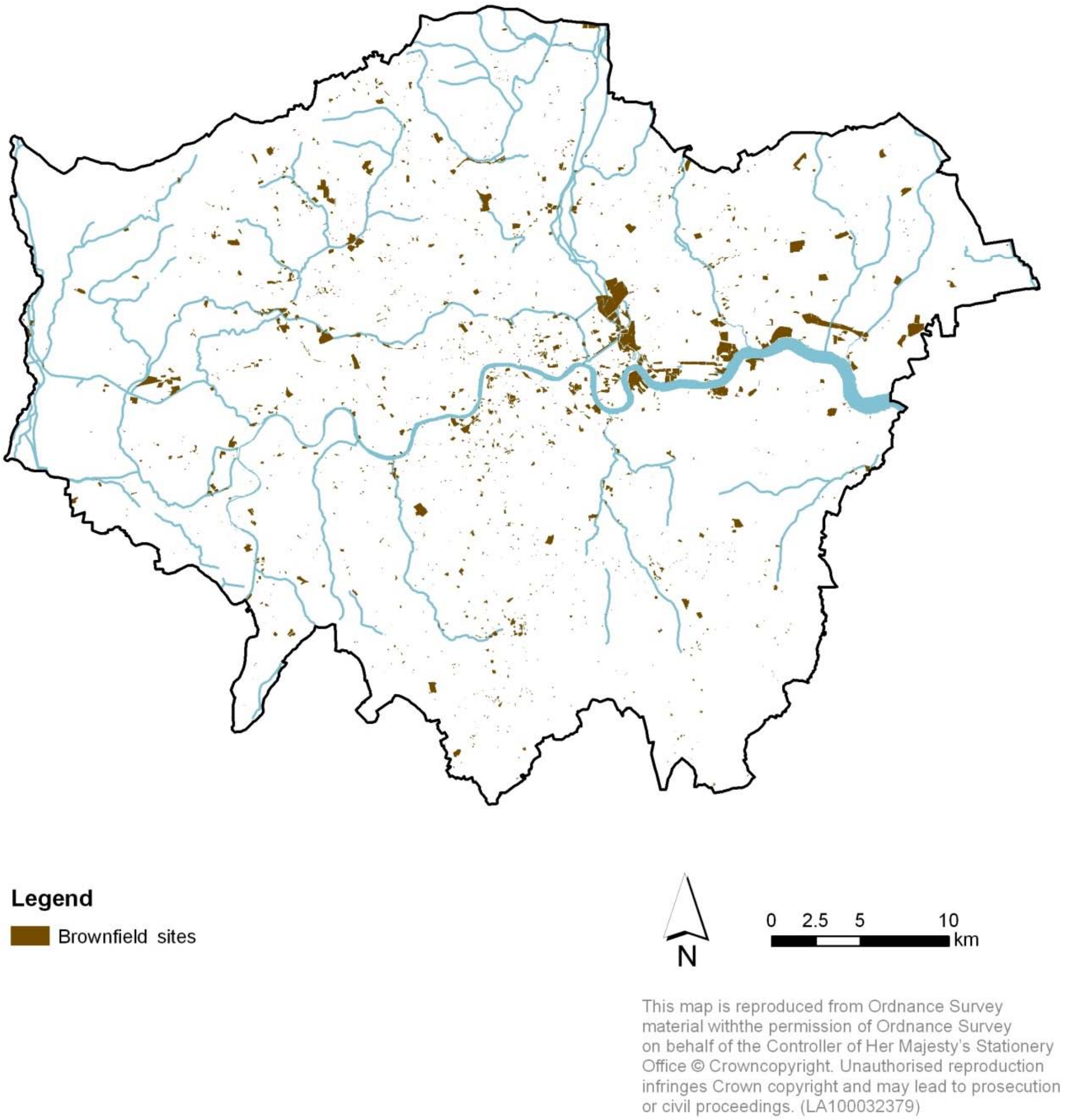

Figure 13-4: Brownfield sites greater than 0.1ha[116] (Source: LDA, 2010[117])

[116] 0.1ha is considered a minimum size for a decentralised energy plant of the types considered in this report

[117] LDA (2010) Brownfield land database

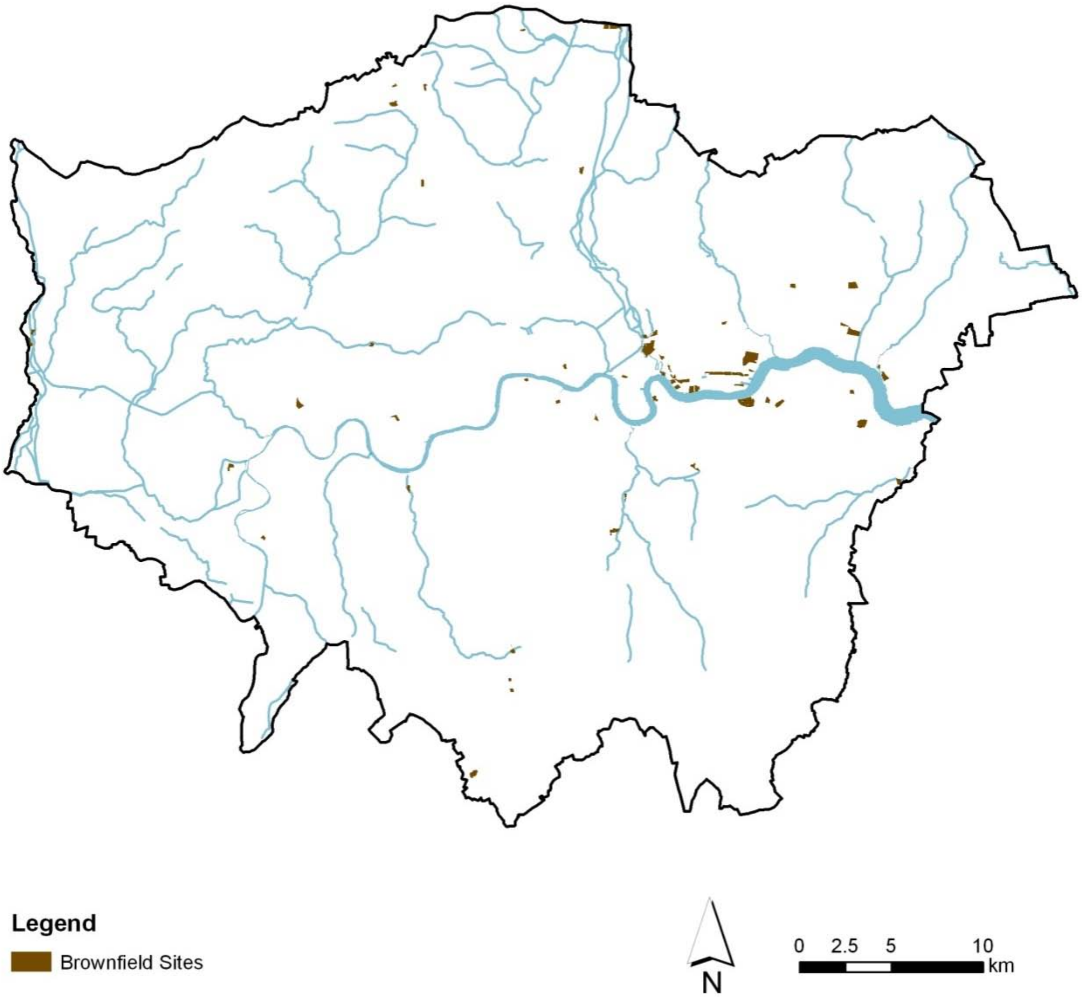

Figure 13-5: Brownfield sites large enough for large-scale solid fuel CHP plant (Source: LDA, 2010[117])

Figure 13-6: Brownfield sites large enough for large-scale solid fuel CHP plant and under public ownership (Source: LDA, 2010[117])

13.5.3 Air quality

The following section summarises some key air quality issues relating to the siting of DE plants[118,119]. Large combustion plants (above 20MWth) and those burning waste material are subject to strict

[118] AEA (2008) Technical Guidance: Screening assessment for biomass boilers: http://uk-air.defra.gov.uk/reports/cat18/0806261519_methods.pdf

emission limits set out in either the Waste Incineration Directive (WID) or the Large Combustion Plant Directive (LCPD). As a result, these plants are considered less of a concern to local air quality than the installation of a large numbers of smaller systems. Table 13-9 lists common combustion-based energy generation technologies and the pollutants of concern.

Technology	Pollutant	Notes
Gas fired CHP	NO_2 is the primary concern	For NOx, it is difficult to determine the proportion of NOx that will convert to NO_2
Biomass CHP/boilers	NO_2 and PM10 (to a lesser extent SO_2 but this is not usually an issue as long as clean biomass is used)	For biomass appliances emissions test results are normally given in NOx and TSP (total suspended particulates) or 'dust'. Only a small portion of the TSP or dust is actually PM10 (the smallest part) but it is not possible to determine reliably what proportion of dust is PM10 (it is normally assumed it is all PM10) As a general rule of thumb biomass boilers fuelled by clean, new wood have lower emissions than coal, roughly equivalent emissions to oil, but higher emissions than equivalent gas fired boilers
Energy from waste	Various	Incineration raises significant concerns but emissions are strictly regulated by the EA under the WID Advanced thermal treatment technologies such as gasification generate much lower emissions and so require less post-combustion clean up treatment

Table 13-9: Common pollutants from combustion based energy plant

A study into the impacts of biomass plants as part of a wider RE study by DECC modelled the potential air quality impacts of a large increase in biomass heat in the UK[120]. The study models several scenarios and concludes that impacts can be reduced to a manageable level, and not exceed air quality standards (Appendix D of Environmental Protection UK report[121]) if:

Plant is of high quality (best performing units currently on the market)

Biomass heat uptake replaces or displaces existing coal and oil fired heating

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[119] Defra (2007) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland: http://www.official-documents.gov.uk/document/cm71/7169/7169_i.pdf

[120] DECC (2009) Renewable Energy Strategy: http://www.decc.gov.uk/publications/basket.aspx?FilePath=What+we+do%5cUK+energy+supply%5cEnergy+mix%5cRenewable+energy%5cRenewable+Energy+Strategy%5c1_20090717120647_e_%40%40_TheUKRenewableEnergyStrategy2009.pdf&filetype=4

[121] Environmental Protection UK (2008) Biomass and Air Quality guidance for Local Authorities England and Wales: http://www.environmental-protection.org.uk/assets/library/documents/Biomass_and_Air_Quality_Guidance.pdf

Uptake is located off the gas grid and away from densely populated urban areas

Uptake where the LA has declared an Air Quality Management Area (AQMA) is substantially lower than other areas[122].

Potentially this poses restrictions for biomass fuelled CHP in London: all boroughs in London have declared an AQMA; all of London is densely populated and there is limited use of coal or oil for heating. However, as discussed in Section 13.5.2, the number of large-scale solid fuel plants in London is likely to be relatively small. By using fewer, larger and more efficient plants, with the best available emissions abatement systems, the impact on air quality should not pose a significant constraint to the technical potential of DE.

13.5.4 Conclusions on planning and regulatory constraints for new CHP plants

No significant limitations to the technical potential in London were found based on an assessment of land availability, planning constraints and air quality. There will be other overriding factors which drive the technical potential, mainly based on availability of fuel and economic factors. One impact which may be significant but has not been considered is the likelihood that plant developers may consider it more attractive to develop plants outside of London where obtaining planning permission may be perceived as lower risk. These plants are unlikely to be CHP schemes if they are located away from dense urban areas.

13.6 Summary of technical potential

For the reasons stated in Section 13.5 it is not proposed to reduce the technical potential due to planning and regulatory constraints.

[122] Defra (2010) Areas declared as AQMA: http://aqma.defra.gov.uk/maps.php

14 Heat distribution

14.1 Context

This section uses heat mapping to establish the areas where DE is more likely to be technically viable. A minimum heat demand density required for viable heat networks is established and then applied to London. The results show the areas most suited to heat networks. This information is used in the modelling of DE to establish technical potential. The GLA's Decentralised Energy Master Planning (DEMaP) project has begun the process of obtaining detailed data on heat demand by area, with data at a per-building level[123]. At the time of publication, however, the coverage of data available only extends to around half of the 33 boroughs. Therefore, for the purposes of this study, data for gas and electricity usage at MSOA level has been used to ensure a consistent approach across London. When a more complete dataset is available, the DEMaP data should be used. Figure 14-1 shows heat demand density by MSOA in 10kWh/m^2 steps.

[123] LDA (2010) London Heat Map: http://www.londonheatmap.org.uk/Content/home.aspx

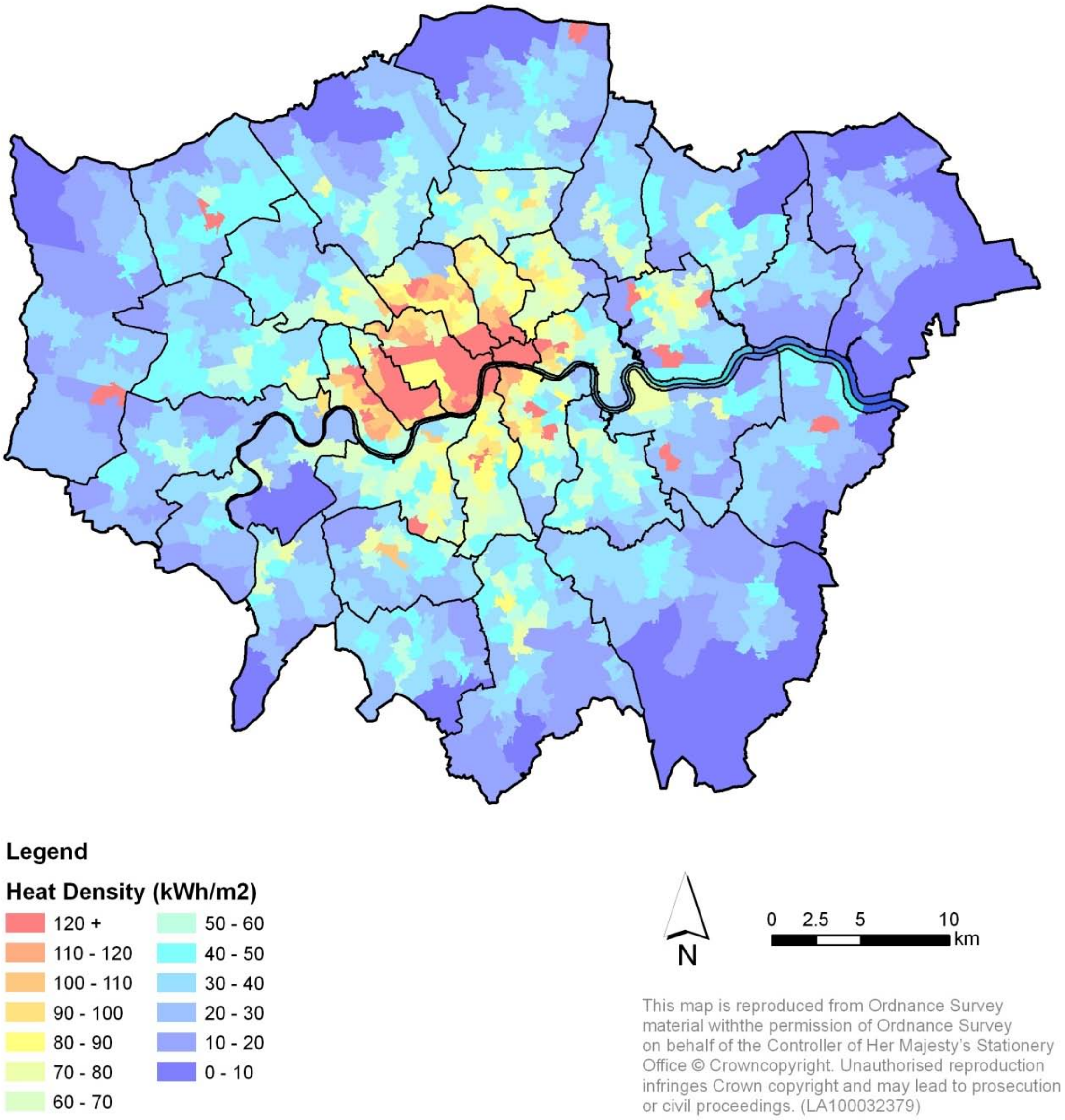

Figure 14-1: Heat demand density by MSOA

14.2 Literature review – heat demand density for district heating

14.2.1 Literature review

A significant amount of research has been undertaken on low density heat networks, particularly in Sweden, Denmark and by the International Energy Agency[124]. This section captures some key thresholds used to establish where heat networks are likely to be technically feasible. Table 14-1 shows minimum thresholds for technical potential.

[124] IEA (2008) Annex VIII: District heating distribution in areas with low heat demand density: http://www.iea-dhc.org/reports/pdf/Energiteknik_IEA-Final-report-5.pdf

Threshold area heat demand density (kWh/m²)	Threshold line heat demand density (MWh/m of trench length)	Reference	Notes
10	0.3	IEA (2008)[124]	This represents the very lowest level of technically viable heat density, requiring very small service pipes, building to building networks and reduced trenching costs (through soft landscape). It is highly unlikely that this level of heat density could be considered economically or technically viable in the UK under current conditions
Not reported	0.15-0.2	Kristjansson et al. (2004)[125]	Heat losses can be as much as 80% in low density areas unless special measures are taken which can limit losses to 32%
Not reported	0.28-0.84	IEA (2008)[124]	The majority of Danish systems lie in this band, with losses of 10-20% of annual heat supplied. Heat losses at small diameters varies between 10-15 W/m
50	Not reported	IEA (2008)[124]	Core heat densities in dense urban centres are reported as often being higher than this threshold. Once heat networks are established in the core, heat networks can be extended to adjacent areas on a marginal cost basis
25	0.8	Larsson et al (2002)[126]	Average line heat demand densities in low density areas in Sweden are around 0.8 MWh/m, corresponding to around 25 kWh/m² in heat demand density for detached homes. Around 250,000 such homes are heated by district systems in Sweden
Not reported	0.2	Froling (2004)[127]	This study found that reductions in fuel use through CHP drop off dramatically below this level (based on the Swedish power grid carbon intensity of 0.1kgCO_2/kWh (Source: Vattenfall, 2010[128]))

Table 14-1: Minimum thresholds for heat demand density

[125] Kristjansson, H., Bruus, F., Bøhm, B., Vejen, N.K., Rasmussen, J., Christensen, K.P. and Bidstrup, N. (2004): Fjernvarmeforsyning af lavenergiområder (District heating supply for low energy density areas), Energiforskningsudvalg for produktion og fordeling af el og varme, Technical University of Denmark [in Danish]: http://www.et.web.mek.dtu.dk/Publications/Benny%20B%C3%B8hm/EFP%202001.pdf (Referenced in IEA (2008) Annex VIII: District heating distribution in areas with low heat demand density)

[126] Larsson L., Andersson S., and Werner S. (2002) The present situation for sparse district heating, FoU 2002:74, Swedish District Heating Association, Stockholm [in Swedish]

[127] Fröling, F. (2004) *Kemiteknik och miljövetenskap* (How sparse can sparse district heating be – Environmental aspects regarding sparse district heating based on today's techniques in comparison with an oil-boiler for detached houses), FOU 2004:9, Chalmers, Värmegles [In Swedish]

[128] Vattenfall (2010) CO_2 Free Power and Plug-in Hybrids in the Nordic Countries: http://www.driving.is/presentations/6_Vattenfall.pdf

Based on the data summarised in Table 14-1, the minimum heat demand density for technically viable heat networks appears to be around 10kWh/m^2/year. However, as will be discussed in the following section, this requires a number of factors to be in place which are not present in London. The level is likely to be significantly higher in London, and is more likely to reflect best practice in Sweden (which has a lower market penetration of heat networks than Denmark) where heat demand densities of 25kWh/m^2/year are common. Further to this the IEA (2008) study identifies core areas for the establishment of heat networks as having a heat demand density of at least 50kWh/m^2 [124]**.** As the market penetration of heat networks is very low in the UK the latter figure is more likely to represent a practical minimum for areas where heat networks will be established, whilst the 25kWh/m^2 number represents a minimum threshold above which heat networks could theoretically be viable.

14.2.2 Prerequisites for low heat demand density areas

A number of factors were identified in the literature as being prerequisites for lower levels of heat demand density to be cost effectively served by heat networks[129].

An economic and policy context that makes the cost of heat from DE competitive with alternatives

High heat consumption per connection

Low marginal heat generation costs (i.e. limited or no additional plant capacity is required)

Low relative heat losses from the heat network

Low service and maintenance costs for the heat network

Low discount rate (cost of finance) applied to the investment in the heat network

Capital costs per connection are minimised (e.g. short pipe lengths per connection)

Most of the above factors are currently not present in London, thus reducing the viability of DE in areas of low heat demand density. Based on this analysis, it is assumed that the minimum heat demand density for heat networks to be technically viable in London is above those outlined in Table 14-1 and closer to the levels stated above representing typical core heat demand densities.

14.3 Line heat density versus area heat density

Section 12.4.2 above outlines the methodology used for assessing heat network length based on area heat demand density. Line heat density is a better proxy for the cost of heat distribution than area heat demand density; however, area heat demand density has been used since the modelling method used in this study derives line heat density from area heat demand density. Figure 14-2 shows the relationship between area and line heat demand densities and the strong correlation between them.

[129] Reidhav, C (2007) Profitability of Sparse District Heating, Applied Energy, Volume 85, Issue 9, September 2008, Pages 867-877

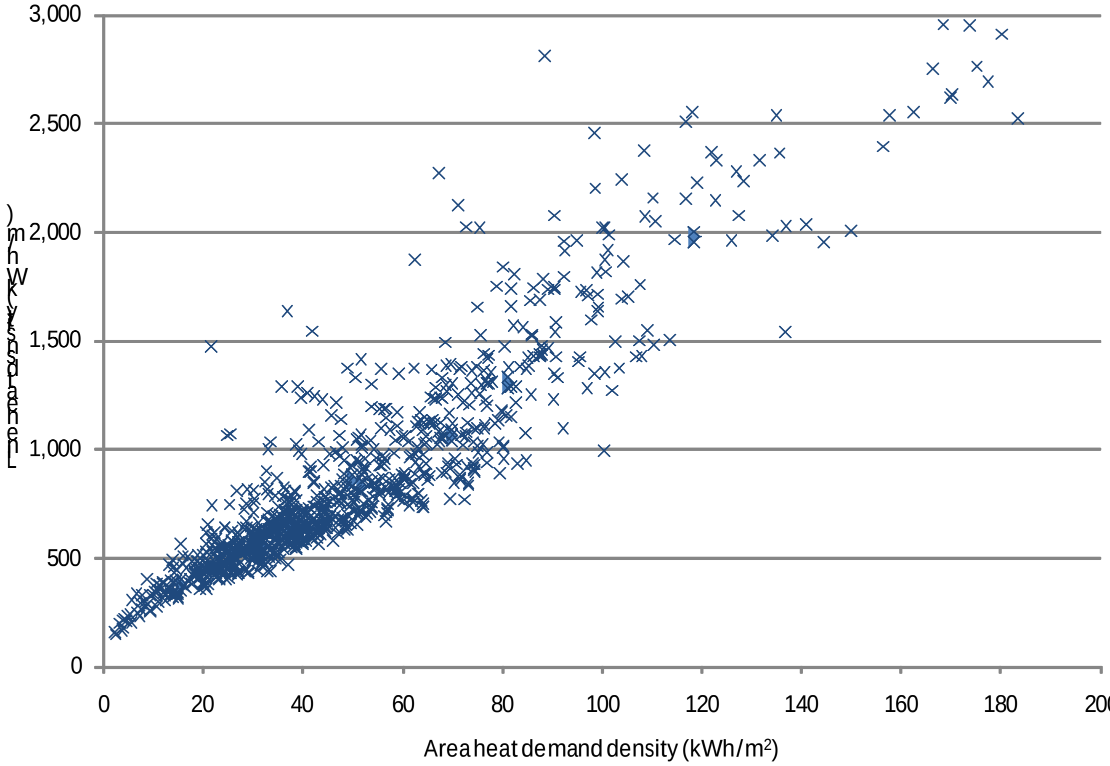

Figure 14-2: Relationship between area heat demand density and line heat demand density

It should be noted that heat demand density analysis at MSOA level is only intended to provide guidance as to the areas where heat networks are more likely to be technically and economically viable. The granularity of data at this level can and does miss large point heat loads which may be economically linked to sources of low cost heat. Areas with lower heat demand density may contain within them heat loads and heat generation which could be connected to give a high enough line heat density to make a viable system.

14.4 Determination of viable heat densities

Based on the findings of the literature review outlined in Section 14.2, the following heat demand densities have been selected as minimum thresholds for assessing the technical potential of DE. These will be reassessed in Phase 2. The thresholds are expressed to the nearest 10kWh/m^2 for ease of data processing. The stages are equivalent to those in the DECC methodology for assessing RE technical potential.

- Stage 1-2: 'Technical constraints' of DE threshold heat density. A technical threshold heat density of 30kWh/m^2 has been established from the literature, together with an allowance for the fact that London does not meet some key requirements for heat networks to be viable in very low heat demand density areas.

- Stage 3-4: 'Practical considerations' of DE threshold heat density. Considering practicality and the low level of penetration of heat networks in London indicates that 50kWh/m^2 is a more likely practical minimum threshold, described within the literature as forming core areas for heat networks. Where there are no heat networks present, new projects must not only give low marginal costs for heat supply versus conventional sources, but also recoup capital and financing costs for the initial system, and are therefore more likely to be limited to areas with relatively high heat demand density in inner London or high density town centre and housing estate locations in outer London.

14.5 Heat demand density mapping

Figure 14-3 shows the frequency of MSOAs above given heat demand density levels. This shows that around 90% of MSOAs in London have a heat demand density in the range 0-100kWh/m^2. This means that the technical potential for DE is very sensitive to the minimum threshold of heat demand density selected.

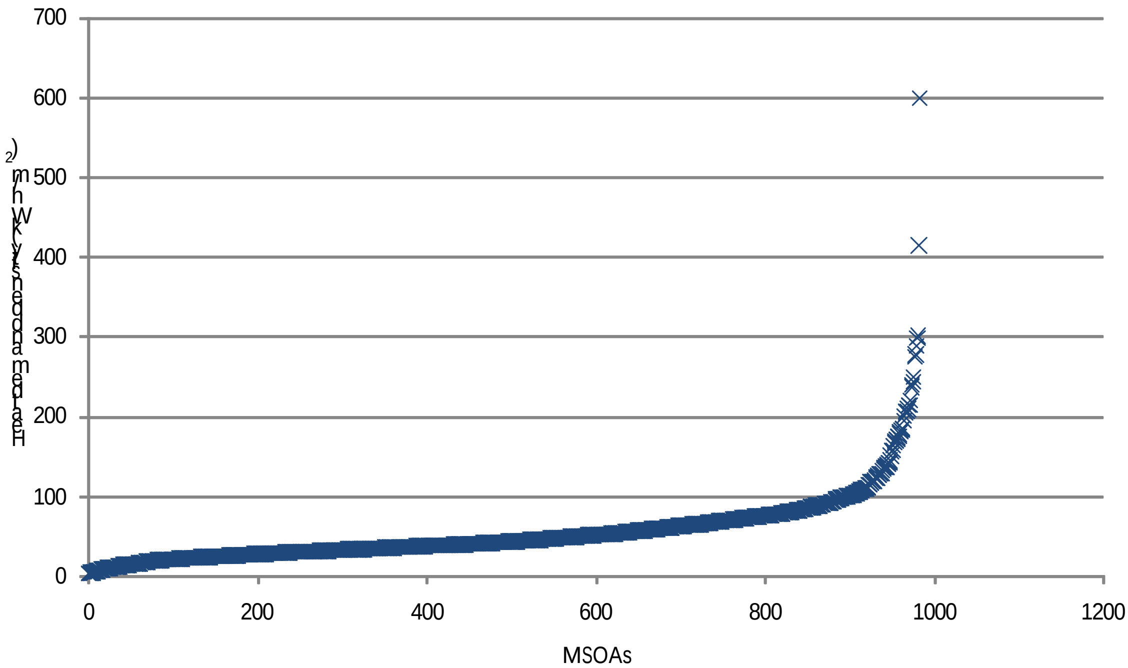

Figure 14-3: Heat demand density distribution of MSOAs

Figure 14-4 shows the agglomeration of adjacent MSOAs where the heat demand density is above a range of minimum thresholds from 10-120kWh/m^2. Every MSOA in the agglomeration has to have a heat density above the threshold heat density. Around 65% of MSOAs are above the 30kWh/m^2 minimum heat demand density for technical constraints, dropping to 40% of MSOAs above the 50kWh/m^2 minimum threshold for the technical potential including practical considerations. This shows that provided favourable economic incentives are in place there is no fundamental technical reason why a large proportion of London's heat demand can not be supplied via heat networks.

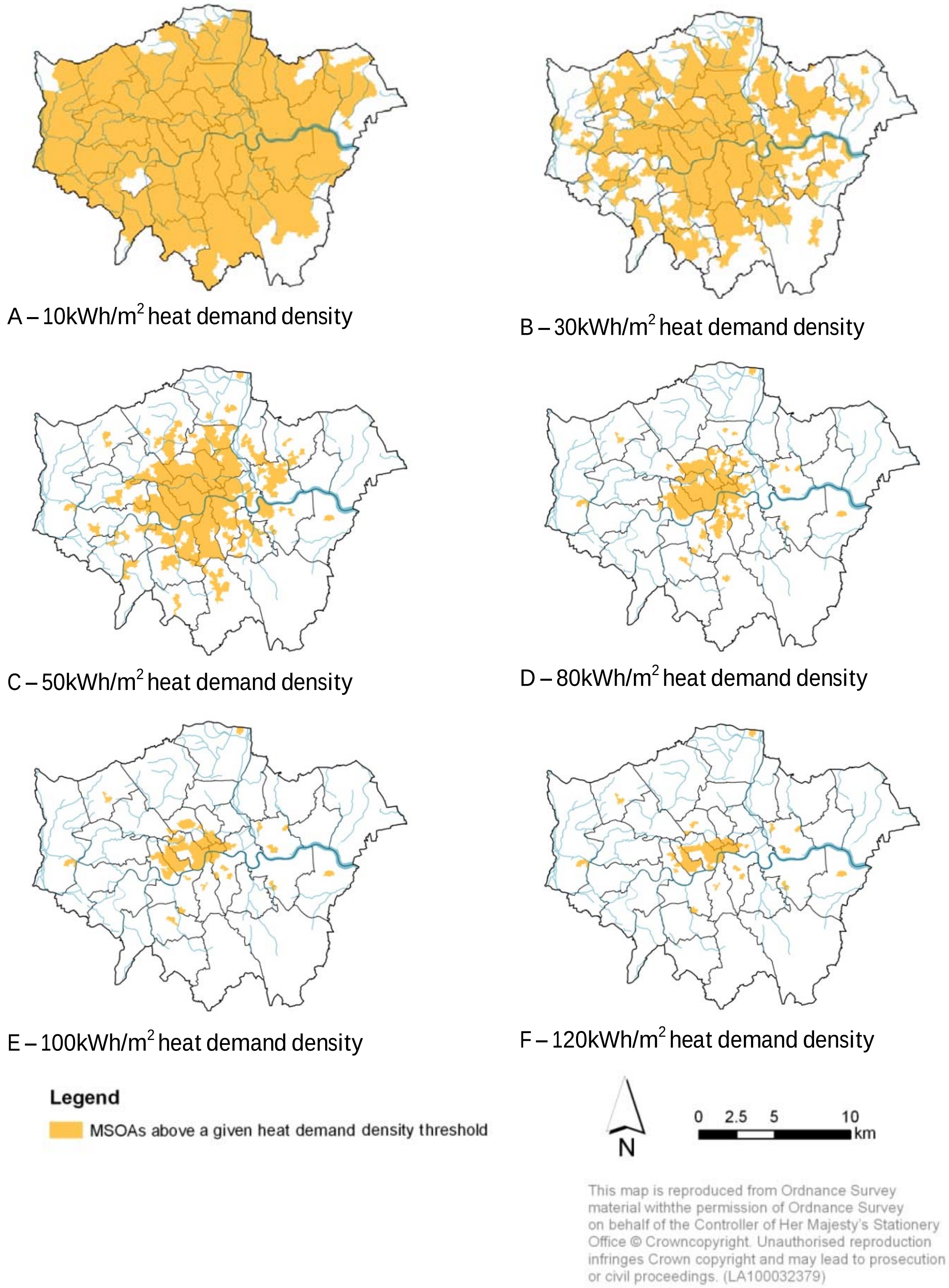

Figure 14-4 A-F: MSOA agglomerations at various heat demand density thresholds

15 Summary of technical potential

15.1 Technical potential of decentralised energy using large-scale heat networks

This section sets out the results of the DE model for large-scale heat networks. The graphs also validate the minimum threshold heat densities selected in the previous section. The two stages of assessment – technical constraints; and practical considerations – are shown. The selection of the minimum heat demand density threshold has a key effect on the proportion of DE delivered in London. This will be further developed in Phase 2 by incorporating an economic model to determine viability.

Figure 15-1 shows the variation of CHP heat output capacity by heat demand density based only on technical constraints (equivalent to Stages 1-2 of the DECC methodology). Figure 15-2 shows that at this stage of the assessment 36% of London's energy demand in 2008 can be supplied. This drops to 20% when practical considerations are included (heat demand density >50kWh/m^2; equivalent to Stages 3-4 of the DECC methodology). In the latter case the availability of waste heat has been limited to match the supply identified in Section 13.2.1, which reduces the technical potential at each level of heat demand density.

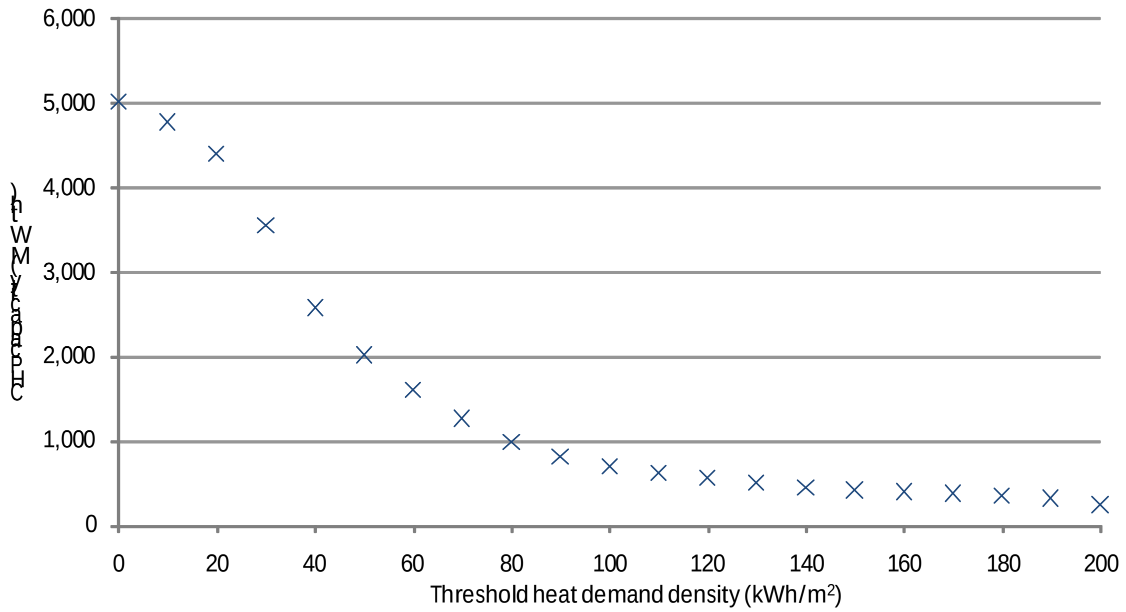

Figure 15-1: CHP capacity against minimum threshold of heat demand density (stages 1 and 2) for large-scale heat networks

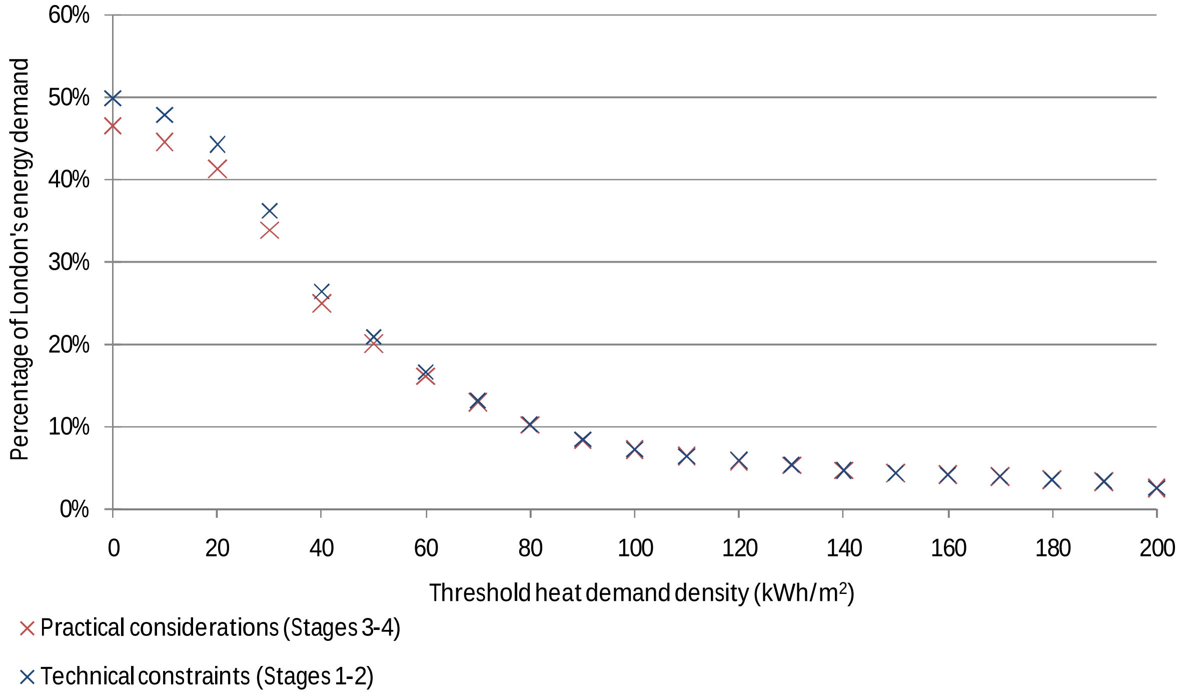

Figure 15-2: Decentralised energy as a percentage of London's energy demand, 2008, against minimum threshold of heat demand density for large-scale heat networks[130]

Gas engine CHP plants are typically sized to meet between 40-70% of the total heat demand, with carbon emissions from this heat some 25-40% lower than from gas boilers. The resulting carbon savings therefore range between 10-30%. Overall carbon savings for a system using gas fired CHP can therefore easily be negated if heat losses are above these levels. Figure 15-3 demonstrates the trade off between network heat losses and heat demand density (plotted by MSOA). The trendline shows that at a heat demand density of 30kWh/m^2 heat losses are around 35%, negating carbon savings from CHP plants. This supports the minimum heat demand density selected as representing the technical constraint to where heat networks are viable

Figure 15-4 shows that the carbon emission savings from adding more DE capacity are negative below a heat demand density of around 30kWh/m^2. Below a heat demand density of 50kWh/m^2 the marginal carbon emission savings begin to reduce. Where lower carbon sources of heat are available the thresholds selected can be lower, however it is likely that most heat networks are established using gas engine CHP. Therefore, in the short term the development of heat networks in areas below these heat demand density thresholds is unlikely. Table 15-1 summarises the technical potential for DE using large-scale heat networks at both stages of the assessment.

[130] The practical considerations limit the amount of waste heat available

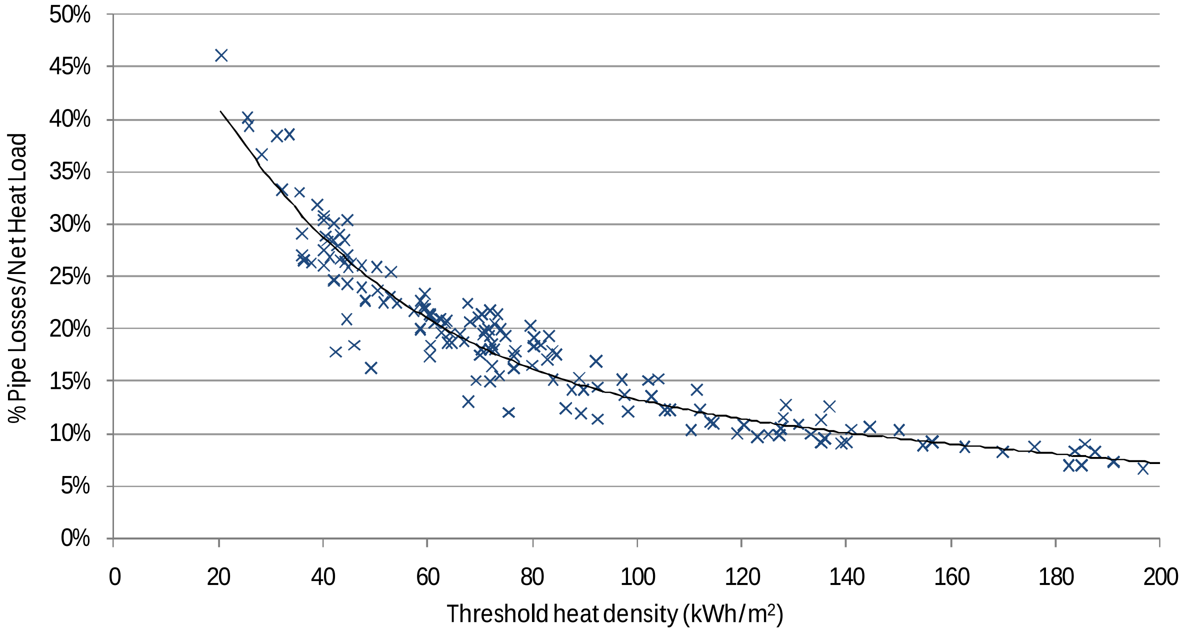

Figure 15-3: Heat losses versus heat demand density (stages 3-4) for large-scale heat networks

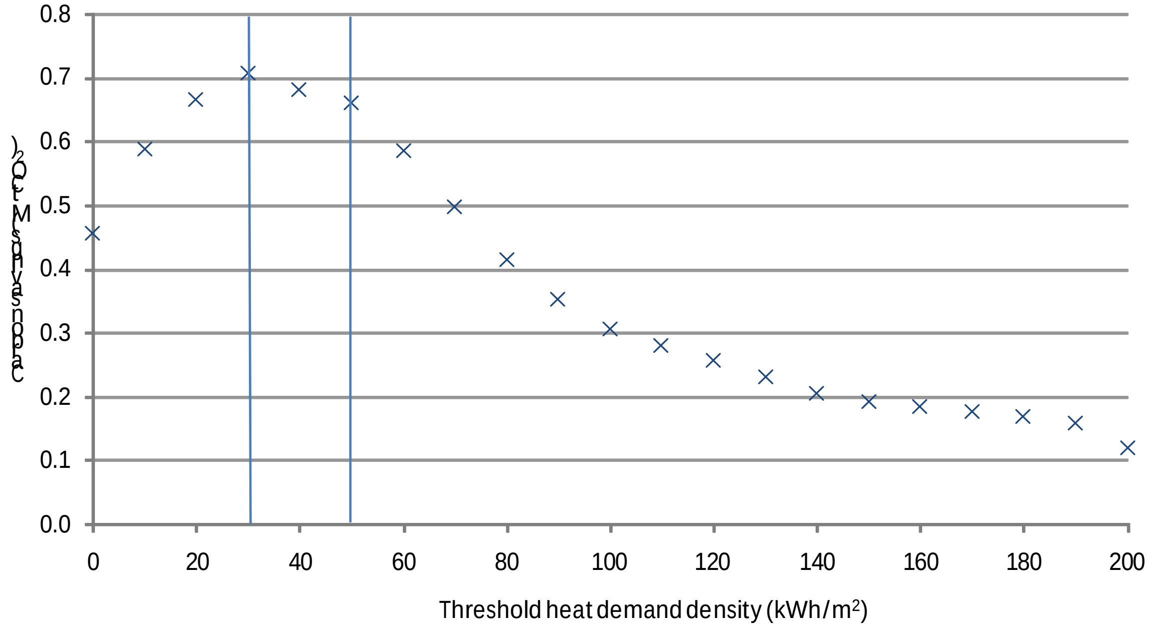

Figure 15-4: Carbon savings versus threshold heat densities (stages 3-4) for large-scale heat networks

Large-scale heat networks		Technical potential	
		Technical constraints (Stages 1-2)	Practical considerations (Stages 3-4)
Threshold heat demand density (kWh/m^2)		30	50
CHP capacity (MWth)	Electrical	3,551	2,042
	Thermal	3,546	1,887
Carbon savings ($MtCO_2$)		0.3	0.7
Energy generation (GWh)	Electricity	20,897	10,939
	Heat	20,928	11,836
% of London's energy demand, 2008[131]		36.2%	20.1%
Approximate heat network length (trench length, km)		29,843	12,748
Number of buildings connected		636,822 connections 2,278,877meters	278,860 connections 1,275,262 meters

Table 15-1: Technical potential for large-scale heat networks, 2010

15.2 Technical potential of local-scale heat networks using anchor heat loads

Figure 15-5 and Table 15-2 show the results of the assessment of the technical potential of DE using local-scale heat networks in LSOAs with a minimum demand density threshold of 30 kW/m^2 and located outside of those MSOAs where large-scale heat networks are deemed viable. Many of the viable areas are relatively close to areas where large-scale heat networks are considered viable. In these cases it may be possible to provide future connections to the large scale networks. This process is included in Phase 3 of the regional assessment.

[131] This does not include heat from central gas boilers that meet peak heat demand

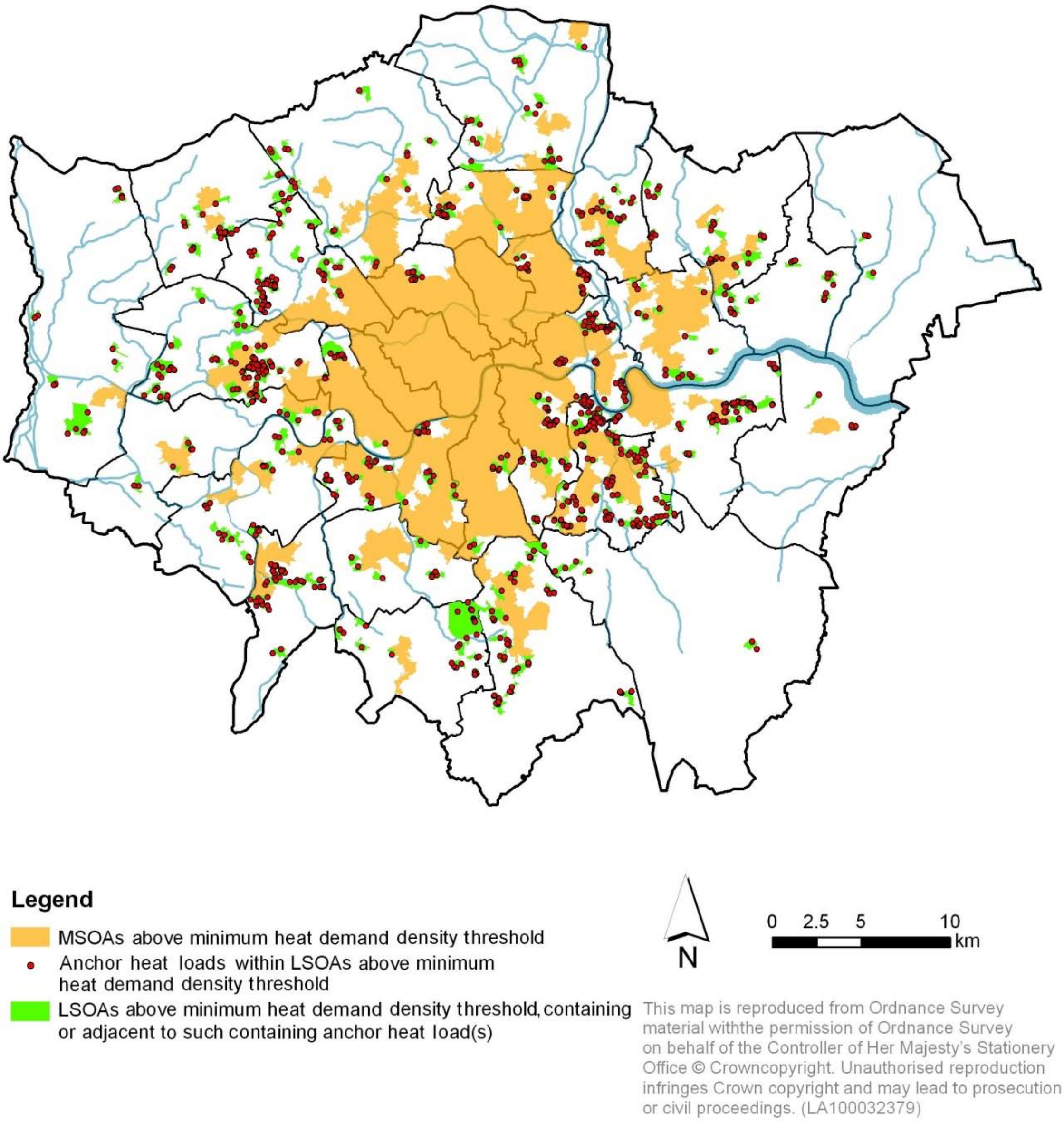

Figure 15-5: Technical potential for local-scale heat networks using anchor heat loads, 2010

Local-scale heat networks		**Technical potential**
CHP capacity (MWth)	Electrical	525
	Thermal	210
Carbon savings ($MtCO_2$)		0.1
Energy generation (GWh)	Electricity	1,214
	Heat	2,132
% of London's energy demand, 2008		2.8%
Approximate heat network length (trench length, km)		2,942
Number of buildings connected		74,003 connections 238,862 meters

Table 15-2: Technical potential of local-scale heat networks using anchor heat loads, 2010

15.3 Overall technical potential

Table 15-3 summarises the combined technical potential from DE from large-scale heat networks and local-scale heat networks using anchor heat loads. The analysis shows that 20% of London's energy demand can be met from large-scale heat networks in areas where DE is viable. A further 3% can be met by local-scale heat networks outside of these areas. Based on the ranking of technologies by lowest cost of heat the majority of heat supply will be from gas fired CHP plant and waste heat sources.

An assessment of alternative heat generation suggests that by 2031, 45,580GWh/yr of heat can be available representing 66% of London's heat demand. In practice this will rely on using waste heat from large power stations located outside London as well as storing off-peak and intermittent electricity production in centralised thermal stores. There are many issues to resolve which limit the deployment of these sources of heat generation; however there are no fundamental technical limitations to this.

The coarse level of data available means that smaller pockets of higher heat demand density and schemes with high line heat density will not have been identified e.g. where large individual heat users can be connected together with relatively short lengths of heat network. The minimum heat demand density thresholds selected should therefore only be considered as guidance. Schemes such as the London Thames Gateway Heat Network demonstrate that at the project level sufficiently high line heat densities can be obtained outside areas with high heat demand density.

		Technical Potential		
		Large-scale heat networks	Local-scale heat networks	Total
Threshold heat demand density (kWh/m^2)		50	50	-
CHP capacity (MWth)	Electrical	2,042	525	2,567
	Thermal	1,887	210	2,097
Carbon savings ($MtCO_2$)		0.7	0.1	0.8
Energy generation (GWh)	Electricity	10,939	1,214	12,153
	Heat	11,836	2,132	13,968
% of London's energy demand, 2008	Electricity	27.4%	3.0%	**30.5%**
	Heat	17.9%	3.2%	**21.2%**
	Total	21.5%	3.2%	24.7%
Approximate heat network length (trench length, km)		12,748	2,942	15,690
Number of buildings connected		278,860 connections 1,275,262 meters	74,003 connections 238,862 meters	352,863 connections 1,514,124 meters

Table 15-3: Summary of decentralised energy technical potential, 2010

15.4 Results by borough

Figure 15-6 illustrates the technical potential for DE in each of the London boroughs. The borough with the greatest DE potential is Westminster due to the fact that the heat demand density is above 50kWh/m^2 throughout the borough, as is also the case with the City of London. 13 boroughs have a DE technical potential of greater than 50% and 20 boroughs show potential for satisfying at least a quarter of their heat demand through DE.

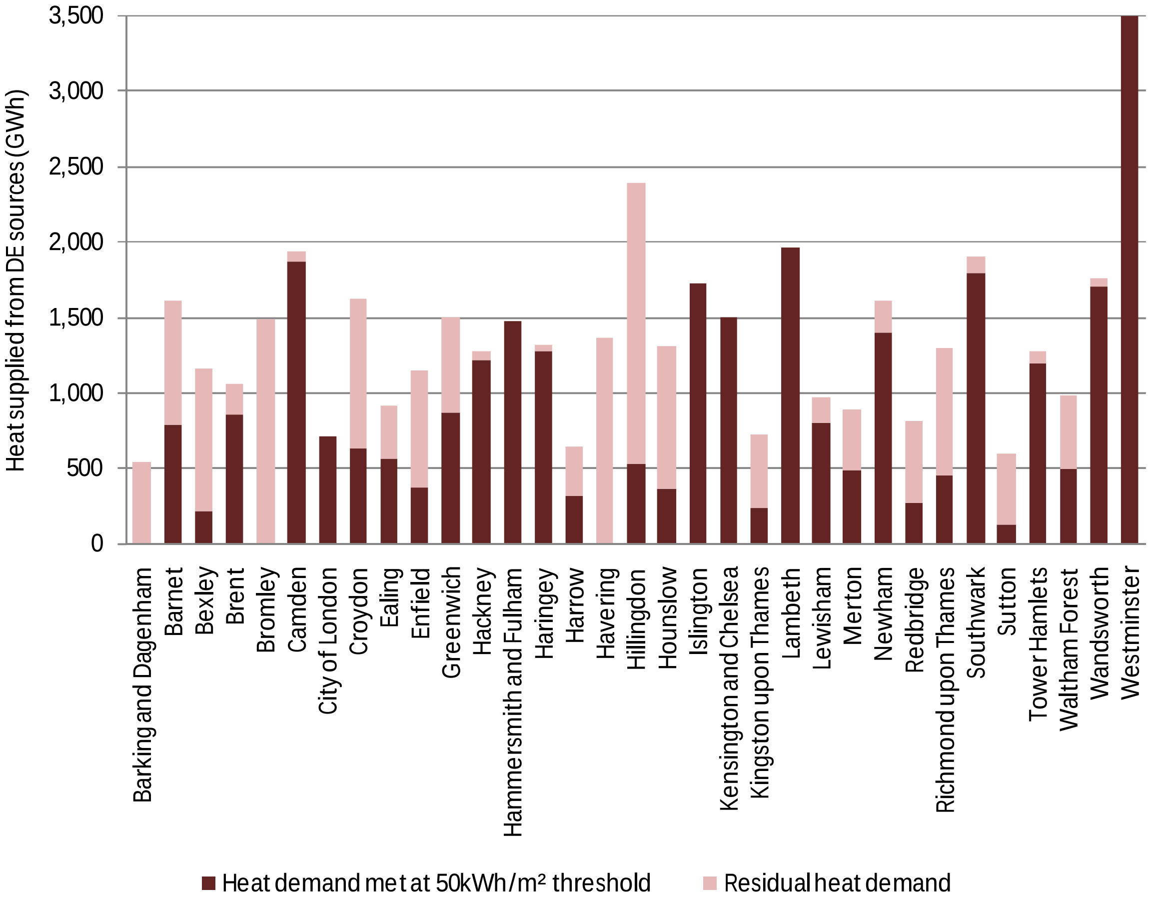

Figure 15-6: Decentralised energy technical potential and total heat demand by borough

SECTION C – CONCLUSIONS

16 Overall Conclusions

Key findings are presented in this section. In addition to these conclusions an assessment of the combined technical potential from both RE and DE is included.

16.1 Renewable Energy

- Under the DECC methodology up to 12% and 57% of London's consumption of electricity and heating respectively could technically be met by RE sources from within Greater London, in 2010 (see Table 11-1).
- Under the tailored methodology up to 34% and 49% of London's consumption of electricity and heating respectively could technically be met by RE sources from within Greater London, in 2010 (see Table 11-2).
- The tailored methodology estimates significantly greater technical potential for certain types of RE than the DECC methodology. For example, in 2010, for large-scale wind turbines the estimated potential using the DECC methodology is 735MW rising to 2,197MW for medium- and large-scale wind turbines using the tailored methodology. The DECC methodology predicts 2,108MW of PV capacity whilst the tailored methodology estimates PV capacity at 9,247MW (see Table 11-1 and Table 11-2).
- Under the tailored methodology PV and heat pumps have the greatest technical potential of any individual RE technologies, providing 19% of electricity consumption and 44% of heat consumption respectively in 2010 (see Table 11-2).
- GSHP and ASHP could respectively contribute some 4,889MW and 18,981MW of undiversified peak heating capacity under the tailored methodology (see Table 11-2).
- Across all technologies carbon emission reductions of 2.5MtCO_2/yr and 5.4MtCO_2/yr are estimated by the DECC and tailored methodologies respectively in 2010 using resources from within Greater London (see Table 11-1 and Table 11-2).
- Whilst the analysis indicates a high technical potential for PV and ASHP, no consideration has been made of any changes required to the electrical distribution network required to accommodate the much higher levels of peak generation and demand. To realise significant reductions in carbon emissions through ASHP, decarbonisation of the electricity supply is required, or the performance of these systems (their COP) must significantly improve.
- Biomass is able to meet around 4% of London's heat and electricity demand in 2010 (around 4,000GWh). At present the availability of additional energy from waste from SRF is relatively limited (around 200GWh) but is set to grow significantly, with an increase to around 1,230GWh by 2031 (see Table 4-). This assumes the resource is used in CHP facilities, which require extensive heat networks to be developed. The technical potential for biomass increases to over 5% in 2010 by including wood fuel from the Greater South East (see Table 11-2).

16.2 Decentralised Energy

- The technical potential of DE using large-scale heat networks, considering only technical constraints (equivalent to Stages 1-2 of the DECC methodology), is 36% of London's energy demand in 2008, or 3,551MWth and 3,546MWe of CHP thermal and electrical output respectively (see Table 15-1). This reduces to 20%, or 2,042MWth and 1,887MWe of CHP thermal and electrical output respectively, when practical considerations are taken into account (equivalent to Stages 3-4 of the DECC methodology) (see Table 15-1). The majority of this is gas fired CHP combined with waste heat from existing power stations.
- The technical potential of DE using local-scale heat networks (in areas where large-scale heat networks are not considered viable) is 3% of London's energy supply in 2010, or 525MWth and 210MWe of thermal and electrical output respectively (see Table 15-3). This capacity is made up of small-scale gas fired CHP and heat-only biomass boilers.
- The combined technical potential of DE using the above mix of heat generation sources gives carbon savings of 0.8MtCO_2/yr. A different grid carbon factor and mix of generating technologies will easily alter this figure.
- It is estimated that around 450MW of waste heat capacity is practically available from existing power stations and energy from waste plants in the London area (see Table 13-3). This capacity represents a stepping stone to the use of low and zero carbon heat generation sources if used to establish the infrastructure required for heat distribution.
- An assessment of alternative heat generation sources shows that by 2031 around 45,580GWh of heat can be available for use in London representing 66% of the capital's heat demand in 2031 (see Table 13-8). Sources include waste heat from industry, power stations, sewage treatment plants and cooling systems. The potential in 2010 is assumed to be zero.

16.3 Combined technical potential

The combined technical potential of RE and DE in 2010 under the tailored methodology is approximately 53% and 44% of London's demand of electricity and heating respectively (see Table 16-1). This delivers combined carbon savings of 6.3MtCO_2/yr. This is not a straight forward addition as DE and individual thermal RE technologies (such as solar water heating) are unlikely to be compatible as they both serve the same heat load. In high density areas, solar water heating can only supply a low proportion of heat demand, whereas heat networks are most viable in these areas. Conversely in low heat demand density areas heat networks have a lower technical potential, whereas building integrated RE sources are able to meet a greater proportion of demand. A technology preference is therefore likely to emerge based on spatial factors. It is therefore assumed that in areas where it is considered viable, DE supply displaces 80% of the thermal microgeneration RE sources. As a result, the technical potential of PV increases slightly due to a lower uptake of SWH, whilst the technical potential of heat pumps is significantly reduced.

The technical potential of biomass is assumed to be supplied via heat networks. However the technical potential and carbon savings have been adjusted to reflect heat network losses. It is assumed that biomass from the Greater South East is prioritised for use in local-scale heat networks.

The technical potential of DE using large-scale heat networks is adjusted to account for the displacement of gas-fired CHP by biomass fired CHP.

Technology	Installed Capacity (MW)	Energy generation (GWh)		Carbon savings ($MtCO_2$)	% of London's energy demand, 2008	
		Electricity	Heat		Electricity	Heat
Photovoltaics	9,611	7,948	-	3.1	19.9%	-
Solar water heating	-	-	627	0.1	-	1.0%
Air source heat pumps	18,981	-	12,602	-0.4	-	19.1%
Ground source heat pumps	4,889	-	3,473	0.003	-	5.3%
Wind (commercial-scale)	2,197	4,099	-	1.6	10.3%	-
Wind (small-scale)	11.4	14.2	-	0.006	0.04%	-
Biomass (London) - included in DE	-	1,401	2,524	1.1	3.5%	3.8%
Tidal	120	300	-	0.1	0.8%	-
Hydro	3.0	23.9	-	0.009	0.1%	-
Geothermal	-	-	-	-	-	-
Total renewable energy potential	35,812	13,787	19,226	5.8	34.6%	29.1%
Renewable energy potential excluding biomass	35,812	12,385	16,703	4.7	31.1%	25.3%
Biomass potential adjusted for heat network losses (including biomass in Greater South East)	n/a	1,511	3,031	1.1	3.8%	4.6%
Decentralised energy potential excluding biomass component	1,872	7,288	9,079	0.6	18.3%	13.8%
Total combined technical potential of renewable and decentralised energy	**37,685**	**21,184**	**28,812**	**6.3**	**53.1%**	**43.7%**

Table 16-1: Combined results of renewable and decentralised energy technical potential under the tailored methodology, 2010

APPENDICES

Appendix A – Wind assessment methodology details

High level assessment of commercial-scale wind energy within designated landscapes and nature conservation areas

Figure A1-1 shows international and national designations in London and the area of opportunity for commercial-scale wind development identified by the initial constraints analysis i.e. before considering designated areas.

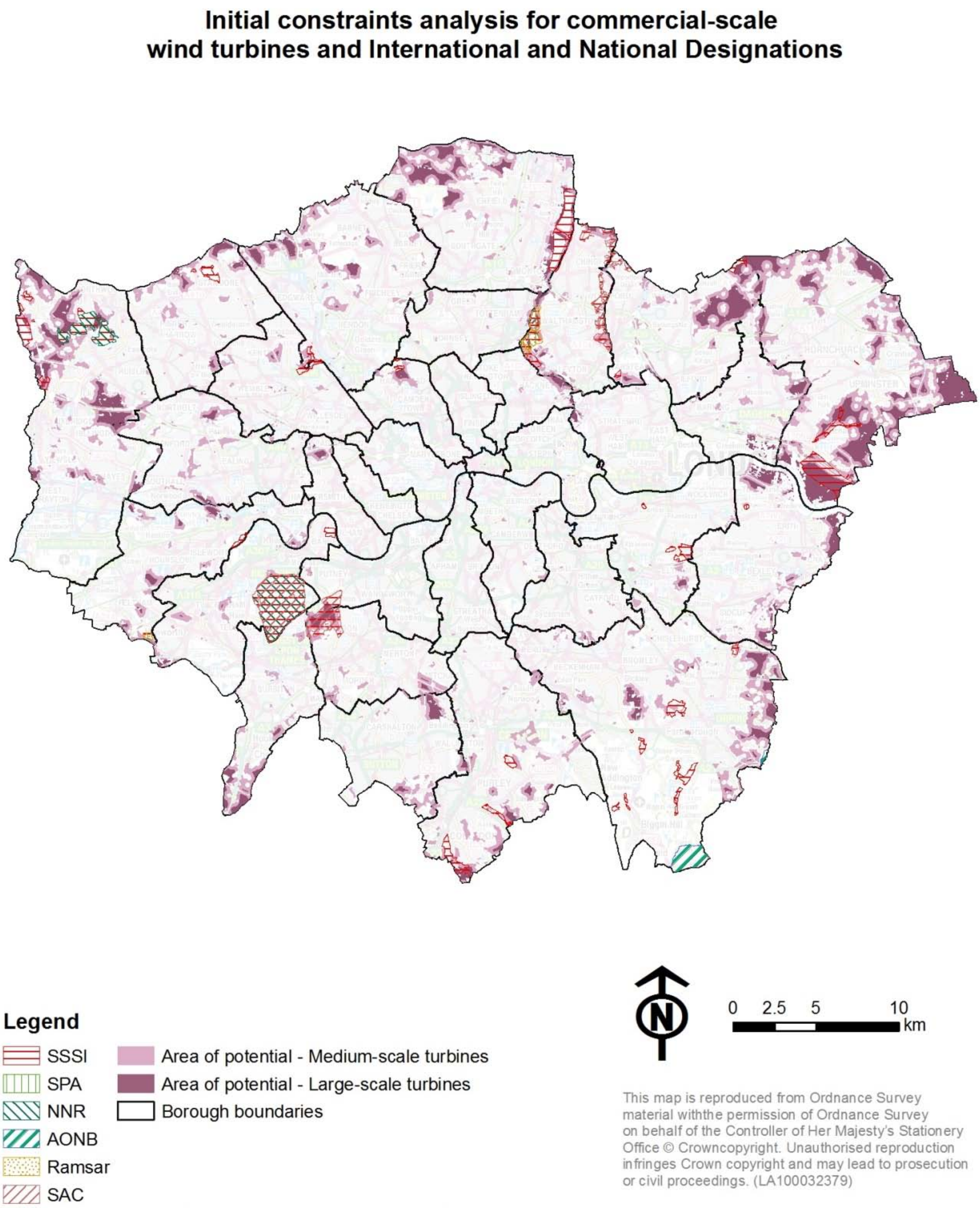

Figure A1-1 Constraints mapping for wind turbines

The majority of the designations where areas of opportunity were identified provide habitats to important bird species that could be put at risk by commercial-scale wind developments. The available evidence suggests that poorly sited turbines can harm birds in three possible ways: disturbance, habitat loss or damage (both direct and indirect), and collision. Wind developments in these sites have the potential to affect the integrity of these designations given the threat imposed to the bird populations they support. For this and other reasons, this study has considered these designations as constraints to commercial-scale wind developments. An overview of the reasons for the designation of these areas is provided below.

As shown in Table A1-1, excluding sites within these designated areas does not have a significant impact on the results of overall technical potential. Only 5.8% of the potential installed capacity identified by the initial constraints analysis is associated with sites within designated areas.

	Potential - Including sites within designated areas			Potential - Excluding sites within designated areas		
	Large-scale only	Medium-scale only	Combined	Large-scale only	Medium-scale only	Combined
Land area (ha)	4,479	14,257	14,257	4,043	13,299	13,299
Number of turbines	456	6,794	5,227	426	6,406	4,953
Installed capacity (MW)	1,140	1,699	2,333	1,065	1,602	2,197
Power generation (MWh)	2,371,770	2,826,983	4,356,983	2,215,733	2,665,537	4,099,417

Table A1-1: Wind energy potential within designated areas

Designated areas

North-East London

Lee Valley – Ramsar and SPA: The Lee Valley Ramsar site[132] is also designated as a Special Protection Area (SPA). SPAs are strictly protected sites classified in accordance with Article 4 of the EC Directive on the conservation of wild birds (79/409/EEC). They are classified for rare and vulnerable birds, listed in Annex I of Directive and for regularly occurring migratory species. The Lee Valley SPA is designated for internationally important numbers of breeding and wintering wildfowl, especially Gadwall and Shoveler and for wintering Bittern.

Walthamstow Reservoirs (Hackney, Haringey and Waltham Forest) - SSSI: The majority of this Site of Special Scientific Interest (SSSI) overlaps with the Lee Valley Ramsar and SPA. The Walthamstow Reservoirs contain one of the country's major heronries and a particularly large concentration of breeding wildfowl. The reservoirs are also an important gathering area for moulting tufted duck (Royal Society for the Protection of Birds (RSPB) amber status[133]). In the winter, nationally significant populations of wildfowl and other wetland birds are also attracted to the area. Due to the ornithological interest in this area, it is unlikely that wind turbines would be permitted at this site.

Walthamstow Marshes (Hackney, Haringey and Waltham Forest) - SSSI: This marshland adjoins the Walthamstow Reservoirs and is also designated as an SSSI as it supports several species of breeding birds such as reed bunting (RSBP amber status), reed, sedge and willow warblers. Migratory birds and finches are also attracted to the area to feed on the seeds of the tall herbs.

[132] The Ramsar Convention is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources: http://www.ramsar.org/cda/en/ramsar-about-mission/main/ramsar/1-36-53_4000_0__

[133] All information relating to the status of these birds is taken from the RSPB Bird guide. RSPB amber status: Species of European conservation concern; RSPB red status: Globally threatened: http://www.rspb.org.uk/wildlife/birdguide/name/t/tuftedduck/index.aspx

Chingford Reservoirs (Enfield, Waltham Forest and Epping Forest) - SSSI: This site has been designated an SSSI owing to the variety of bird populations which the reservoirs support, these include migratory wildfowl, gulls and other wetland birds. Due to the presence of these birds, it is unlikely that wind turbines would be permitted on this site.

Epping Forest (Epping Forest, Waltham Forest and Redbridge) – SSSI, SAC: Epping Forest supports at least 48 breeding species including nightingale, all three species of woodpecker, sparrowhawk, woodcock, wood warbler, tree pipit (RSPB red status) and tawny owl. Due to the presence of these larger birds, and birds already under threat, it is likely that wind turbines would not be permitted. Besides, this area is also a designated as a Special Area of Conservation (SAC). Epping Forest is one of only a few remaining large-scale examples of ancient wood-pasture in lowland Britain and has retained habitats of high nature conservation value including ancient semi-natural woodland, old grassland plains and scattered wetland. Potential loss and degradation of these habitats also make unlikely that wind developments would be permitted.

East London

Inner Thames Marshes (Havering and Thurrock) – SSSI: Natural England describe this area as being of particular value for its diverse ornithological interest and especially for the variety of breeding birds and the numbers of wintering wildfowl, waders, finches and birds of prey, with wintering teal (amber status) populations reaching levels of international importance.

Ingrebourne Marshes (Havering) – SSSI: This area supports a diverse breeding bird population including redshank, tufted duck, pochard, reed bunting and kingfisher (all identified as Amber status) and also lapwing, yellow wagtail and cuckoos (all identified as globally threatened - red status).

South-West London

Wimbledon Common (Wandsworth and Merton) – SSSI and SAC: Woodland and scrub in Wimbledon common supports a community of breeding birds including green woodpecker and Kestrel (RSBP amber status) and lesser spotted woodpecker (RSPB red status).

West London

Denham Lock Wood and Fray's Farm Meadows (Hillingdon) – SSSIs: Fray's Farm Meadows are one of the last remaining examples of relatively unimproved wet alluvial grassland in Greater London and the Colne Valley. Due to the loss of washland areas throughout London, the site has become increasingly valuable as a relict habitat. Denham Lock Wood is a diverse area of open mire and wet woodland which shows a zone of wetland habitats occurring rarely in Greater London. Commercial-scale wind development would require drainage for access and around the turbines' foundations. In view of the potential impact on the overall hydrology of the site, it is unlikely that wind developments would be permitted.

Ruislip Woods (Hillingdon) – SSSI, NNR: The Ruislip Woods is a National Nature Reserve (NNR) and breeding ground for birds including all three British species of woodpecker (green woodpecker – RSPB amber status; lesser spotted woodpecker – RSPB red status), the willow tit and the hawfinch (RSPB red status) and the less common woodcock (RSPB amber status). The large extent of the woods and the presence of adjoining open habitats provide particularly suitable conditions for several of the less common breeding species.

Appendix B – Biomass data sources

Forestry and agricultural co-products, residues and wastes

Forestry residues

The Forestry Commission Research tool suggested by the DECC methodology as a data source, only provides combined data for the South East Region and London. Figure A2-1 outlines the approach used in this study to estimate the potential tonnage of forestry residues that could be made available for bioenergy.

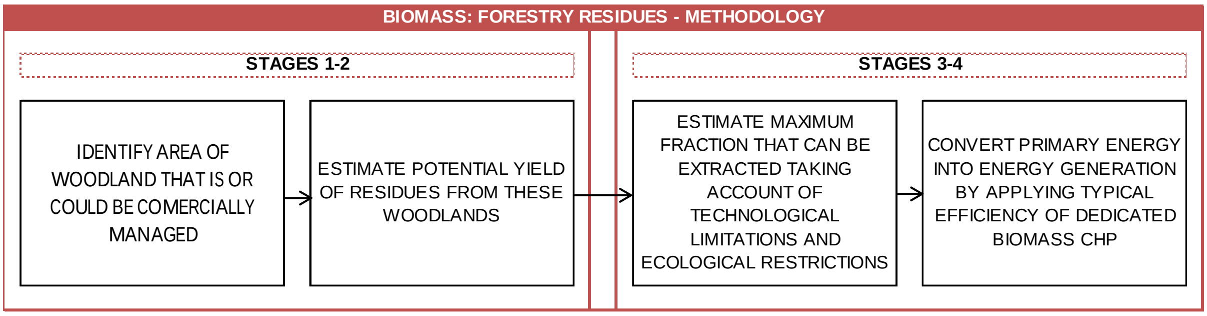

Figure A2-1: Overview of the methodology for assessing the amount of forestry residue available for biomass

The breakdown of woodland area in London by species and forest type has been taken from the National Inventory of Woodlands and Trees[134]. The total area of high forest in Greater London is 5,329ha, of which 4,880ha are classified as High Forest Category 1 and 450ha as High Forest Category 2. It has been assumed that only woodlands classified as High Forest Category 1 are or could be commercially managed. The area of High Forest Category 2 in London comprises mostly woodlands of mixed broadleaves. It has been assumed that these woodlands are and will be managed under minimum intervention with conservation objectives and therefore the amount of residues generated will be very limited and largely scattered. Besides, biodiversity objectives would limit even further the amount of residues that could be extracted.

The volume of residues generated per hectare of managed woodland has been derived for each species using parameters from Cannel and Dewar (1995)[135] and Forestry Commission's Yield Tables (1981)[136]. The total volume of residues generated from thinnings and final harvest is then divided by the rotation period to derive annual residues yield in oven-dried tonnes (ODT/year). Therefore, it is assumed that for each species all age classes are represented equally.

The total yield of residues has been reduced by 30% to take account of environmental and technical constraints. A fraction of residues needs to be left on-site to maintain nutrient cycle and soil structure, avoid soil losses when the slope is high, and maintain biodiversity. The maximum amount

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[134] Forestry Commission (2002) National Inventory of Woodlands and Trees, Regional Report for London: http://www.forestry.gov.uk/pdf/nilondon.pdf/$FILE/nilondon.pdf

[135] Cannell, M.G.R. and Milne, R. (1995) Carbon pools and sequestration in forest ecosystems in Britain,.Forestry 68: 361-378

[136] Edwards, P.N. and Christie, J. M. (1981) Yield models for forest management. Forestry Commission, Booklet 48

of residues that can be physically extracted from the field depends largely on the slope of the site but also on the nature of the intervention and how it is planned and carried out. The maximum recovery in relatively flat land is around 80%; when the slope is over 30^{o}, only residues near forest roads can be extracted

Energy crops

The scenario defined in this study to estimate the potential contribution of energy crops matches the "Medium scenario" suggested by the DECC methodology. The approach is outlined in Figure A2-2.

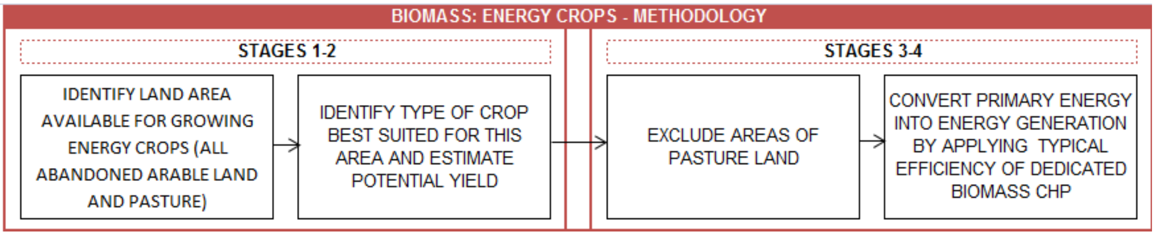

Figure A2-2: Overview of the methodology for assessing the energy crops available for biomass

The principle in calculating the technically available resource under the "Medium scenario" is to assume that energy crops are planted in all abandoned arable land and pasture. Areas of permanent pasture/grassland have been then excluded from the assessment in order to estimate the physically accessible and practically viable resource.

Total areas of bare fallow and pasture have been taken from Defra's June 2010 Agricultural Survey[137]. Miscanthus has been selected as the species to use based on Defra's Energy Crop Opportunity Maps[138], which show better suitability for Miscanthus crops than for Short Rotation Coppice in areas of bare fallow within Greater London. Defra's map suggests that Miscanthus crops could achieve medium/high yields within these areas, therefore a yield of 15ODT/ha/yr has been assumed.

The DECC methodology suggest that areas where energy crops may not be permitted should be excluded in Stage 4, these include: buffer zones around public rights of way (3 to 5 metres depending on crop), Common Land and nature conservation and historic designations. The geographical boundaries of arable land currently out of production are unknown and therefore the GIS analysis to account for these constraints could not be carried out. However, based on the arable land identified by land use maps produced in 2007, it is anticipated that these constraints will not imply a material reduction of the technical potential for energy crops.

Crop residues – straw

The approach followed to estimate the availability of straw for bioenergy is outlined in Figure A2-3.

[137] Defra (2010) Survey of Agriculture and Horticulture, June 2009: http://www.defra.gov.uk/evidence/statistics/foodfarm/landuselivestock/junesurvey/results.htm

[138] Defra (2007) Opportunities and optimum sitings for energy crops: http://archive.defra.gov.uk/foodfarm/growing/crops/industrial/energy/opportunities/

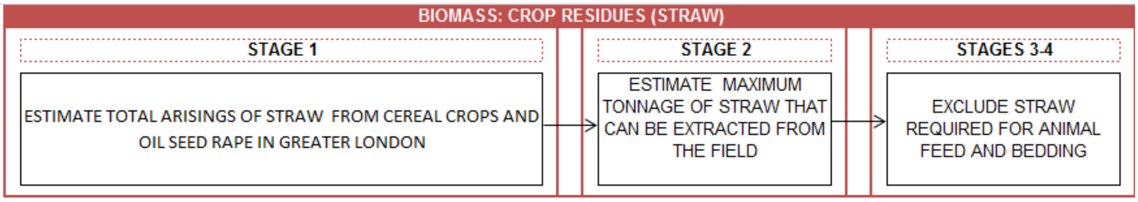

Figure A2-3: Overview of the methodology for assessing the crop residues available for biomass

The area of land dedicated to cereal and oilseed rape crops in London has been taken from Defra's June 2010 Agricultural Survey. Total arisings have been calculated based on yields of 3.5t/ha for cereals (assuming wheat yield for all crops) and 1.5t/ha for oilseed rape, as suggested by the Biomass Energy Centre.

A recoverability factor of 60% has been applied to estimate the maximum tonnage of straw that can be extracted from the field (E4Tech 2009[139]), to account for technology limitations and amount of straw that should be left on site to ensure that the nutrient cycle and soil structure are not disturbed. It should be noted that the DECC methodology does not take account of this constraint.

The tonnage required for cattle feed and bedding has been calculated based on the number of heads of dairy cattle in London (as reported in Defra's June 2010 Agricultural Survey) and estimated requirements of 1.5t/head/yr as suggested by the DECC methodology.

<u>Agricultural animal waste</u>

Wet manure collected from cattle, pigs and laying hens can be treated in anaerobic digestion plants to generate biogas. However, the low moisture content of poultry litter (approximately 40%), makes this waste typically unsuitable for anaerobic digestion. Poultry litter consists of the wood shavings or straw used in deep litter broiler houses and the accumulated droppings. The most common energy application for poultry litter is combustion.

Figure A2-4 outlines the approach used to estimate potential generation from wet manure and poultry litter.

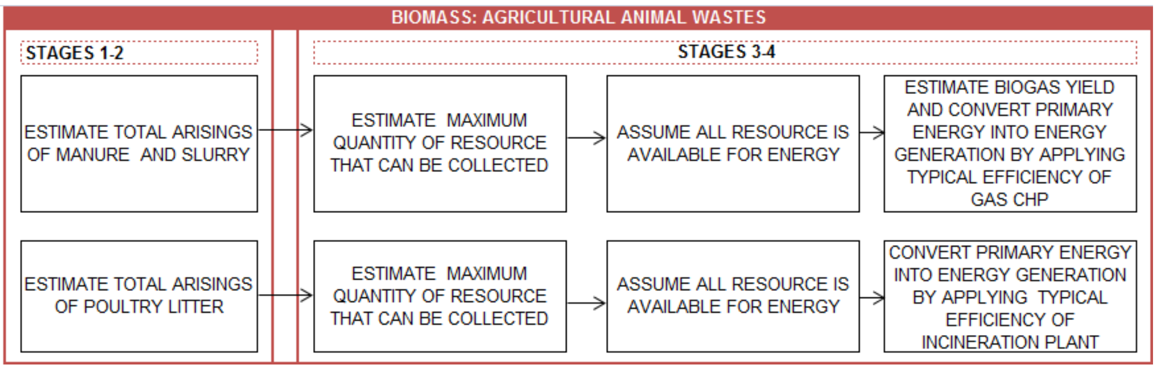

Figure A2-4: Agricultural animal waste estimation methodology

139 E4Tech (2009) Biomass supply curve for the UK: http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/res/res.aspx.

Livestock numbers have been taken from Defra's June 2010 Agricultural Survey and estimates of manures generated during housing periods have been derived from ADAS Manure Management Database (MMDB). In line with the DECC methodology, it has been assumed that 80% of the total quantity of manure generated during housing period can be collected adhering to health and safety regulations.

Biomass materials in municipal solid waste (MSW)

The DECC methodology considers incineration as the conversion technology for all components of MSW, providing a benchmark of 10,000 tonnes of MSW per annum required for 1MW of installed capacity. The approach taken in this study considers the different components of MSW individually, assuming that paper/card and wood waste will be incinerated, and kitchen/food waste and green waste will be sent to anaerobic digestion plants. This is outlined in Figure A2-5 below.

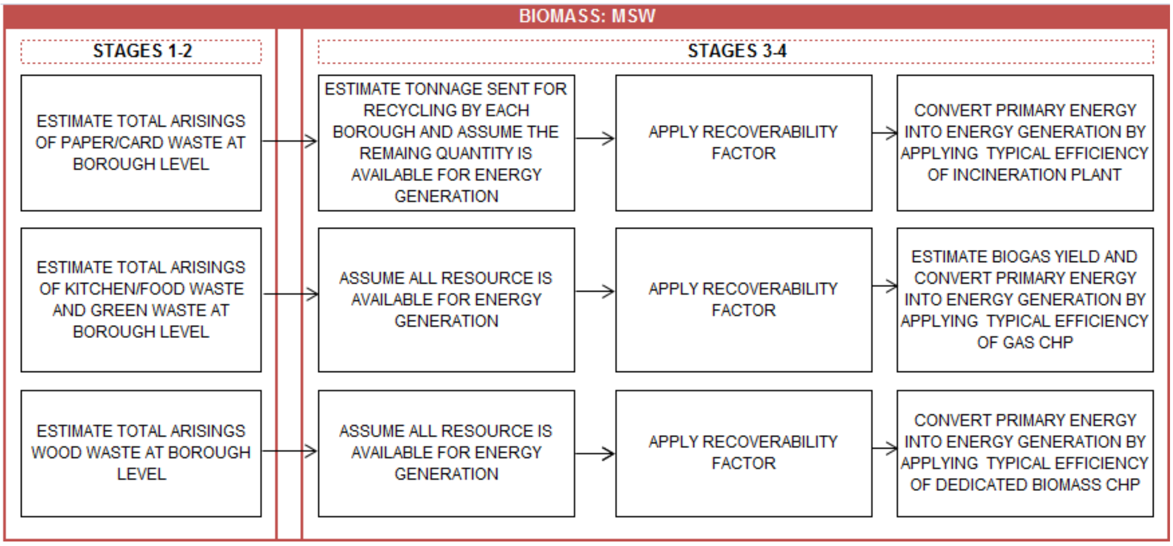

Figure A2-5: MSW estimation methodology

The main assumptions and data sources used to assess the potential of these biomass materials are summarised below:

Arisings for 2010 of each material have been estimated for each borough based on figures of total MSW arisings by Borough taken from Defra Waste Statistics 2009[140] and the breakdown of MSW by material used in the Mayor's Draft Municipal Waste Management Strategy (see Figure A2-6).

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[140] Defra (2009) Municipal Waste Statistics 2008/9: http://www.defra.gov.uk/evidence/statistics/environment/wastats/index.htm

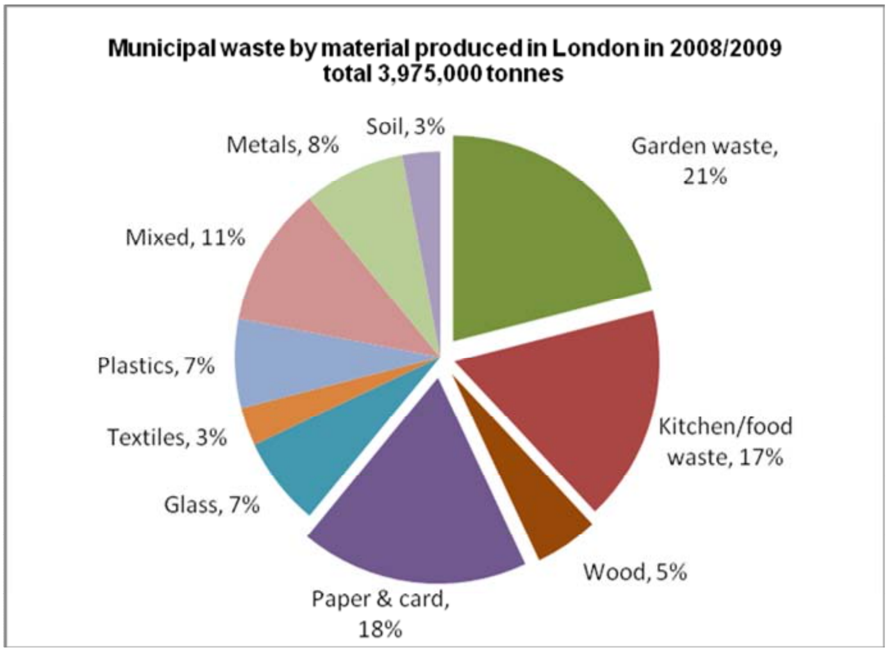

Figure A2-6: MSW by material breakdown (Source: Mayor's draft Municipal Waste Strategy, 2010[141]).

Projected arisings of each material have been estimated based on the GLA's MSW forecasts[142] and assuming the composition of MSW will not change

As shown in Figure A2-5, only the fraction of paper and card waste that is not recycled is assumed to be available for bioenergy i.e. card and paper landfilled or already diverted for energy recovery (through direct incineration of MSW or as part of SRF produced in the existing MBT facilities)

Tonnage of paper and card sent for recycling by each borough have been taken mainly from Waste Data Flow[143]. Where data was missing, the tonnage sent for recycling has been estimated based on the borough's overall recycling rate and the breakdown of materials sent for recycling at regional level, both taken from Defra Municipal Waste Statistics[140]

The projected tonnage of paper and card sent for recycling in 2031 has been estimated based on the recycling targets set by the Mayor's Draft Municipal Waste Management Strategy[144], GLA's forecasts of total MSW arisings and composition of MSW

It has been assumed that all wood in MSW is available for energy generation. The Waste Strategy for England 2007 sets actions to stimulate energy recovery of wood waste rather than recycling. From the waste strategy, it is clear that wood has relatively low embodied energy (energy consumed in extraction) but high calorific value. Although for some kinds of wood waste re-use

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[141] Defra (2007) Waste Strategy for England: http://archive.defra.gov.uk/environment/waste/strategy/strategy07/documents/waste07-strategy.pdf

[142] GLA (2010) Future Waste Arisings in London 2010-2031: http://www.london.gov.uk/shaping-london/london-plan/docs/waste-arisings-note.pdf

[143] Chartered Institute of Waste Management (2010): http://www.wastedataflow.org

[144] GLA (2010) The Mayor's Draft Business Waste Strategy for London: http://www.london.gov.uk/sites/default/files/BWMS_STRATEGY_FINAL%20DRAFT.pdf

or recycling are better options, use as a fuel generally conveys a greater greenhouse gas benefit than recovering the material as a resource (and avoiding primary production). This is also recognised in the Mayor's Draft Municipal Waste Management Strategy

Composting of green waste has not been considered as a competing demand and therefore the full resource is assumed to be available for energy generation in Stage 4. The availability of the resource for energy generation will be considered further in the Stage 6 (estimation of deployment potential)

A maximum recoverability factor of 90% has been applied to the estimated quantity of each material available for bioenergy. This has been taken from a report prepared by ERM[145] to inform the Waste Strategy for England 2007.

Biomass materials in commercial and industrial (C&I) waste

The materials considered from this waste stream are the same as those considered from MSW. The approach only differs in the reduction of the food and wood waste resource in the C&I stream applied to take account of alternative uses, as outlined in the figure below. Whilst the majority of the wood in MSW is likely to be contaminated, a considerable fraction of wood waste in the C&I stream in London can be expected to be untreated and best suited for recycling or reuse, largely arising from the secondary wood processing industry. Similarly, unlike household kitchen/food waste, organic waste materials arising from the food processing industry and retail are suitable for recycling and reuse e.g. as animal feed (see Figure A2-7).

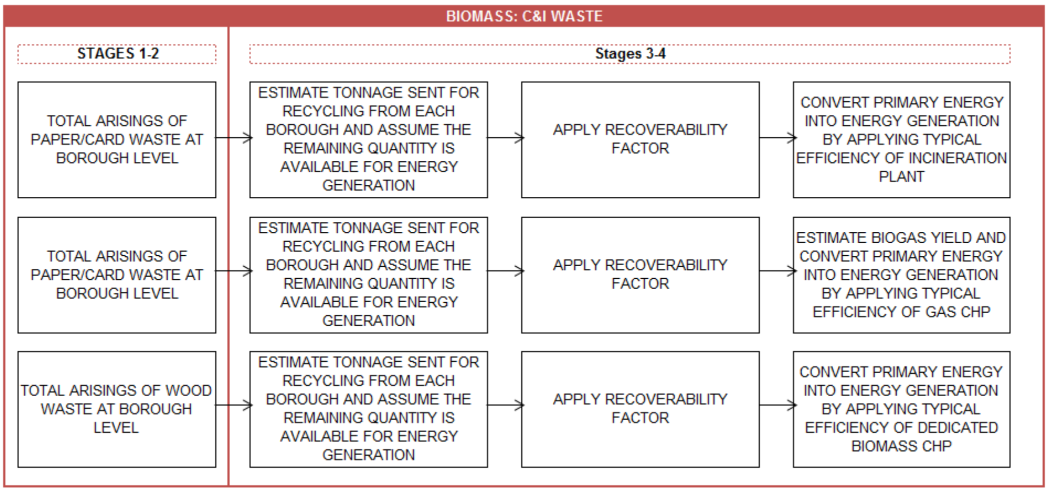

Figure A2-7: C&I waste estimation methodology

The main assumptions and data sources used to assess the potential of these biomass materials are summarised below:

Arisings and proportions sent for recycling/reuse of food and wood wastes at Borough level have been taken directly from the Commercial and Industrial Waste Study[146] commissioned by the

[145] ERM (2006) Carbon Balances and Energy Impacts of the Management of UK Wastes: http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=14644

LDA. Turner and Townsend's study assumes that paper and card make up to 41% of the mixed fraction of C&I waste. Based on the project team's experience, the proportion of paper and card in mixed C&I has been reduced to 17% to estimate total arisings of this material. The tonnage of paper and card sent for recycling from each borough has been taken directly from Turner and Townsend's study[147]

It has been assumed that only the fractions of these materials currently not recycled could be made available for energy generation

Future availability of these materials has been estimated based on the GLA's forecasts of total C&I waste arisings[142], current composition of C&I waste taken from Turner and Townsend's study and recycling targets set by the Mayor's Draft Business Waste Management Strategy[148]

As for materials in MSW, a maximum recoverability factor of 90% has been applied to the estimated quantity of each material available for bioenergy

Construction and Demolition (C&D) wood waste

The approach taken to estimate the potential contribution to energy generation from wood in the C&D waste stream is outlined in the figure below. The data sources and assumptions used are as follows:

Total arisings of C&D waste have been taken from the Mayor's Draft Business Waste Management Strategy

It has been assumed that wood materials make up to 3.3% of C&D waste arising, as suggested by a survey of C&D waste in Wales carried out by the EA[149]

In line with the DECC methodology, it has been assumed that 50% of the resource would be available for energy generation.

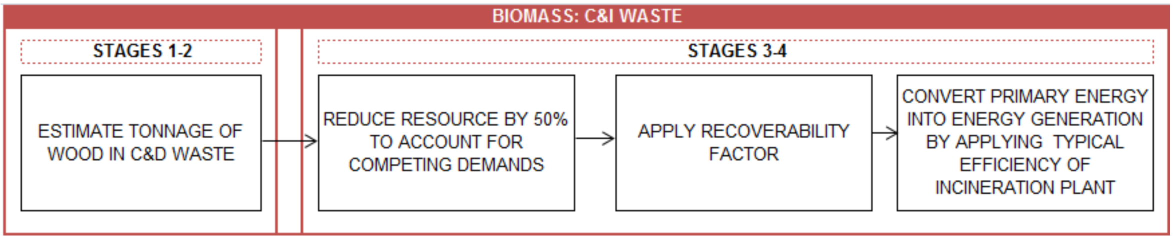

Figure A2-8: C&I waste wood estimation methodology

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146 Turner and Townsend (2009) Commercial and Industrial Waste Research Study [not published]

147 It should be noted that Turner & Townsend's study refers to animal and plant waste and not to food waste. This study assumes that the contribution of green waste to this category is negligible and therefore can be taken as equivalent to food waste

148 GLA (2010) The Mayor's Draft Business Waste Strategy for London: http://www.london.gov.uk/sites/default/files/BWMS_STRATEGY_FINAL%20DRAFT.pdf

149 EA (2007) A survey on the arising and management of construction and demolition waste in Wales 2005-06 http://www.environment-agency.gov.uk/research/library/publications/33979.aspx

Breakdown of current total resource and technical potential

Note that the MWh figures shown in Table A2-1 below refer to primary energy and not potential generation. Potential generation associated with each biomass material is shown in Section 4 of the report.

Breakdown of projected total resource and technical potential in 2031

Note that the MWh figures shown in the Table A2-2 below refer to primary energy and not potential generation. Potential generation associated with each biomass material is shown in Section 4 of the report.

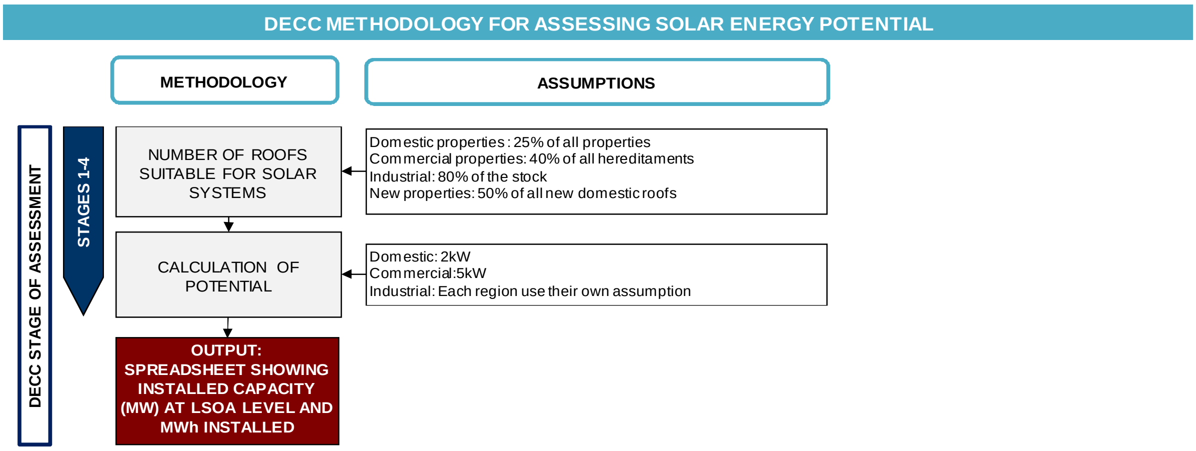
Feedstock	Stages 1 and 2: Naturally and technically accessible resource			Stage 3 and 4: Technical potential		
	Oven dry tonnes	Primary energy		Oven dry tonnes	Primary energy	
		MWh	%		MWh	%
Agriculture and Forestry						
Energy crops	109,839	396,641	3.2%	15,029	54,272	1.0%
Forestry residues	2,806	13,018	0.1%	2,806	13,018	0.2%
Coppiced material	579	3,057	0.02%	463	2,446	0.05%
Crop residues - Straw	8,114	38,561	0.3%	2,709	12,820	0.2%
Wet animal manures	1,627	2,339	0.02%	1,241	1,750	0.03%
Poultry litter	95	416	0.003%	95	416	0.008%
Municipal and C&I waste						0.000%
C&I - paper and card waste	1,793,368	5,479,734	44.1%	483,436	1,477,165	27.4%
MSW - paper and card waste	667,823	2,040,572	16.4%	342,658	1,047,011	19.4%
C&I - waste wood	148,800	694,400	5.6%	61,885	288,795	5.4%
C&D - waste wood	260,358	1,215,003	9.8%	117,161	546,752	10.2%
MSW - waste wood	157,878	736,763	5.9%	142,090	663,087	12.3%
MSW - green waste	165,772	370,143	3.0%	149,195	333,128	6.2%
MSW - food waste	127,486	620,106	5.0%	114,738	558,095	10.4%
C&I - food waste	168,772	820,921	6.6%	79,291	385,680	7.2%
Total biomass fuels	**3,613,317**	**12,431,673**	**100%**	**1,512,798**	**5,384,434**	**100%**
Biomass feedstocks	-	-	-	1,512,798	5,384,434	96%
SRF - Non-biomass fraction	-	-	-	51,850	244,847	4.3%
Total biomass + low-carbon fuels				**1,564,648**	**5,629,281**	**100%**

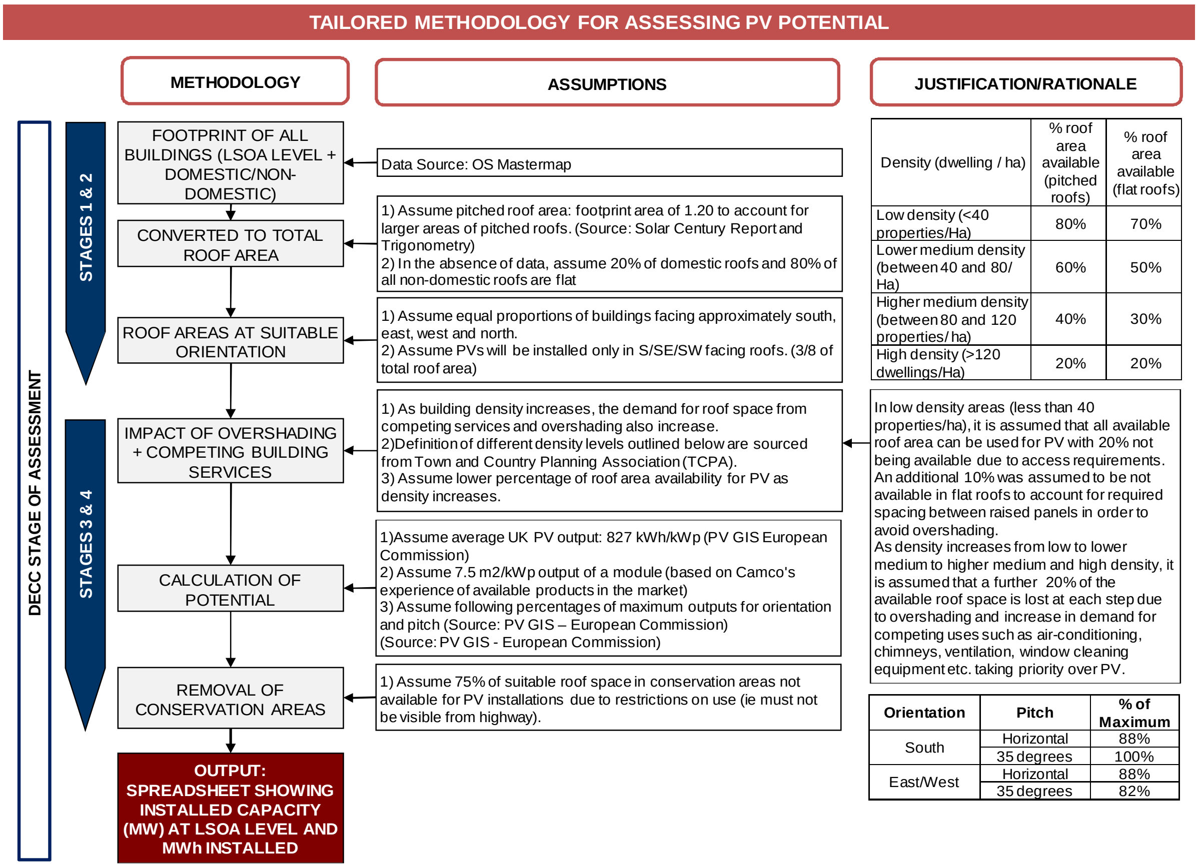
Table A2-1: Breakdown of biomass resources by primary energy source in 2010

Feedstock	Stages 1 and 2: Naturally and technically accessible resource			Stage 3 and 4: Technical potential		
	Oven dry tonnes	Primary energy		Oven dry tonnes	Primary energy	
		MWh	%		MWh	%
Agriculture and Forestry						
Energy crops	109,839	396,641	2.9%	15,029	54,272	0.9%
Forestry residues	2,806	13,018	0.1%	2,806	13,018	0.2%
Coppiced material	579	3,057	0.02%	463	2,446	0.04%
Crop residues - Straw	8,114	38,561	0.3%	2,709	12,820	0.2%
Wet animal manures	1,627	2,339	0.02%	1,241	1,750	0.03%
Poultry litter	95	416	0.003%	95	416	0.007%
Municipal and C&I waste						
C&I - paper and card waste	1,820,975	5,564,090	40.3%	491,663	1,502,304	26.2%
MSW - paper and card waste	864,274	2,640,836	19.1%	311,138	950,701	16.6%
C&I - waste wood	151,091	705,090	5.1%	56,554	293,241	5.1%
C&D - waste wood	296,129	1,381,937	10.0%	133,258	621,872	10.8%
MSW - waste wood	204,320	953,493	6.9%	183,888	858,144	14.9%
MSW - green waste	214,536	479,026	3.5%	173,774	388,011	6.8%
MSW - food waste	164,988	802,519	5.8%	133,641	650,040	11.3%
C&I - food waste	171,370	833,558	6.0%	80,512	391,617	6.8%
Total biomass fuels	**4,010,743**	**13,814,580**	**100%**	**1,586,772**	**5,740,650**	**100%**
Biomass feedstocks	-	-	-	1,586,772	5,740,650	79%
SRF - Non-biomass fraction	-	-	-	324,550	1,532,595	21.1%
Total biomass + low-carbon fuels	**-**	**-**	**-**	**1,911,322**	**7,273,245**	**100%**

Table A2-2: Breakdown of biomass resources by primary energy source in 2031

Appendix C – Photovoltaics methodology details

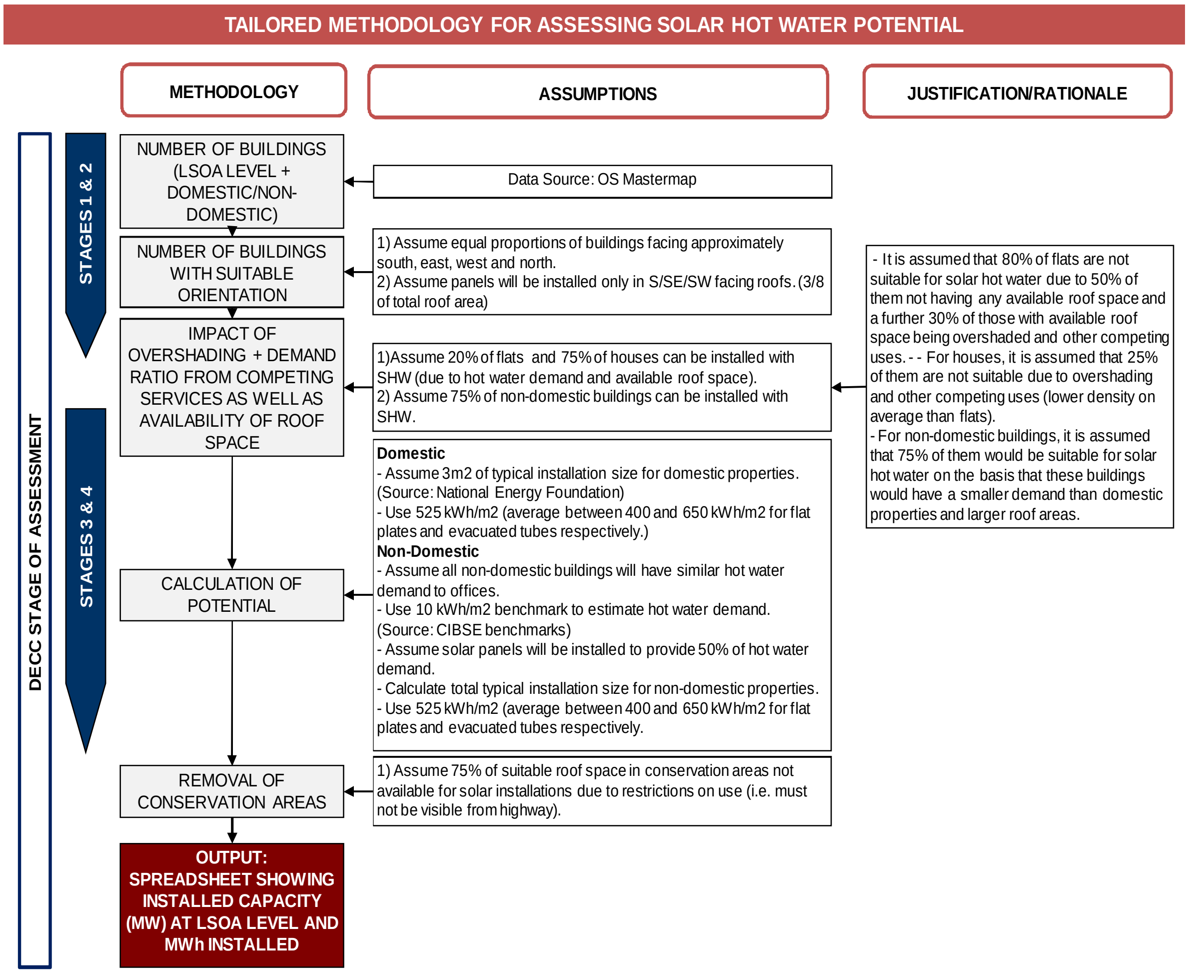




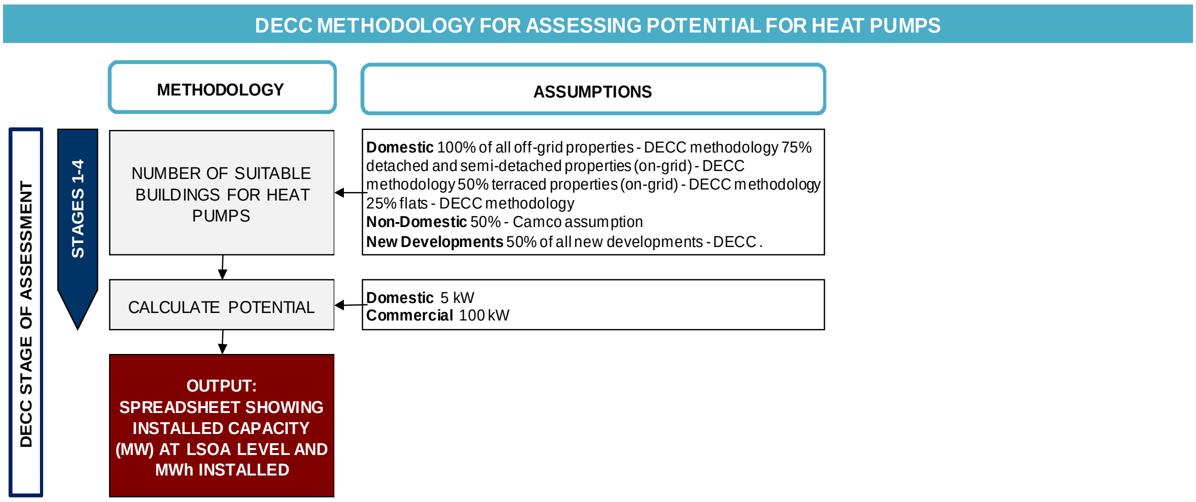
Density (dwelling / ha)	% roof area available (pitched roofs)	% roof area available (flat roofs)
Low density (<40 properties/Ha)	80%	70%
Lower medium density (between 40 and 80/ Ha)	60%	50%
Higher medium density (between 80 and 120 properties/ ha)	40%	30%
High density (>120 dwellings/Ha)	20%	20%

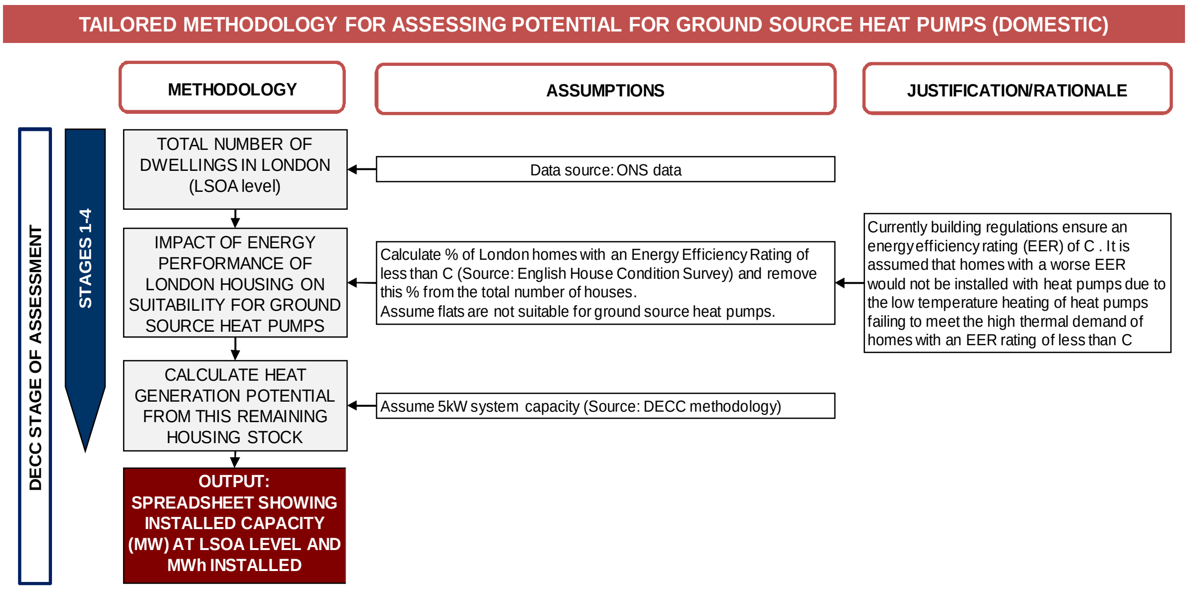
Orientation	Pitch	% of Maximum
South	Horizontal	88%
	35 degrees	100%
East/West	Horizontal	88%
	35 degrees	82%

Appendix D – Solar water heating methodology details

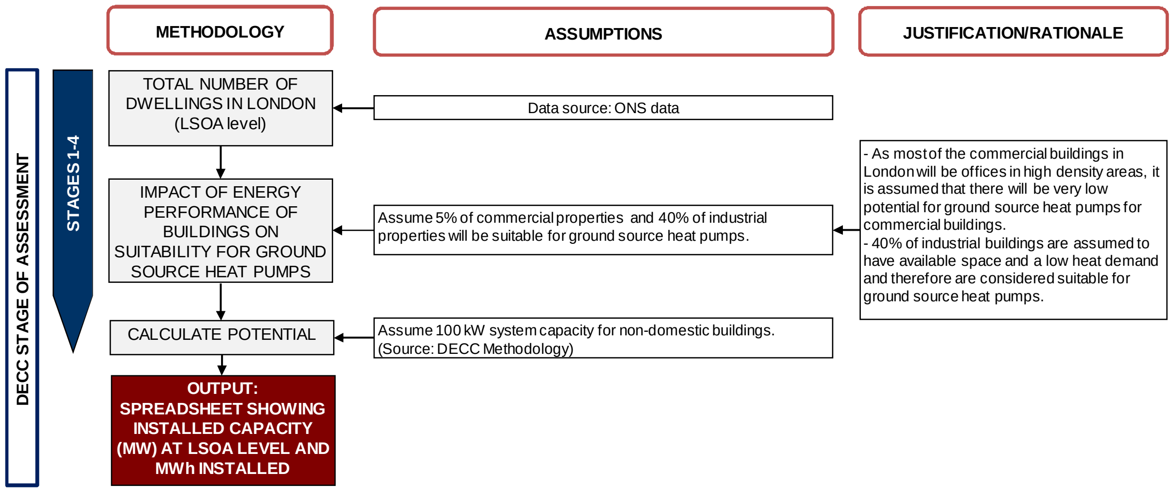


Appendix E – Heat pumps methodology details

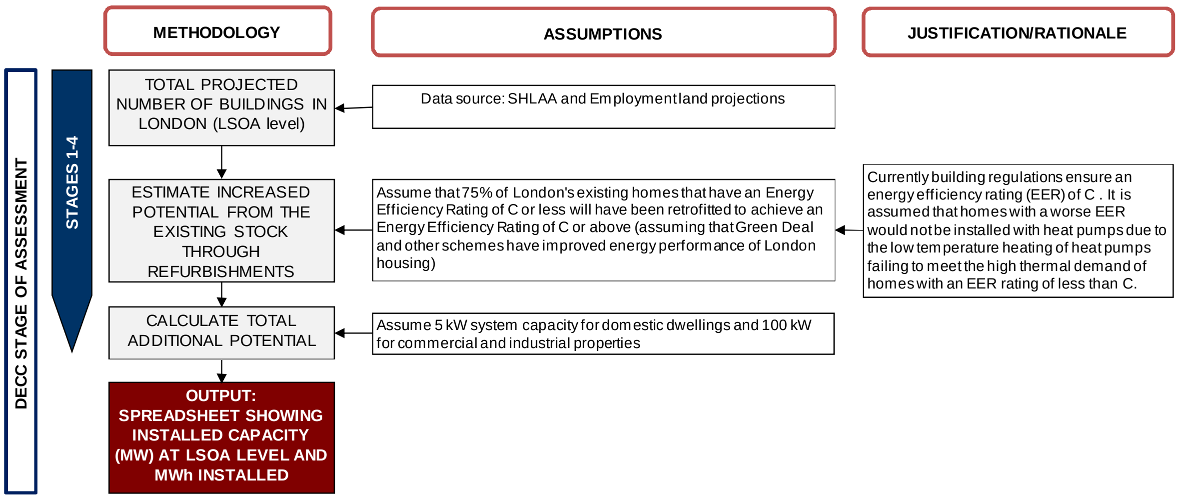


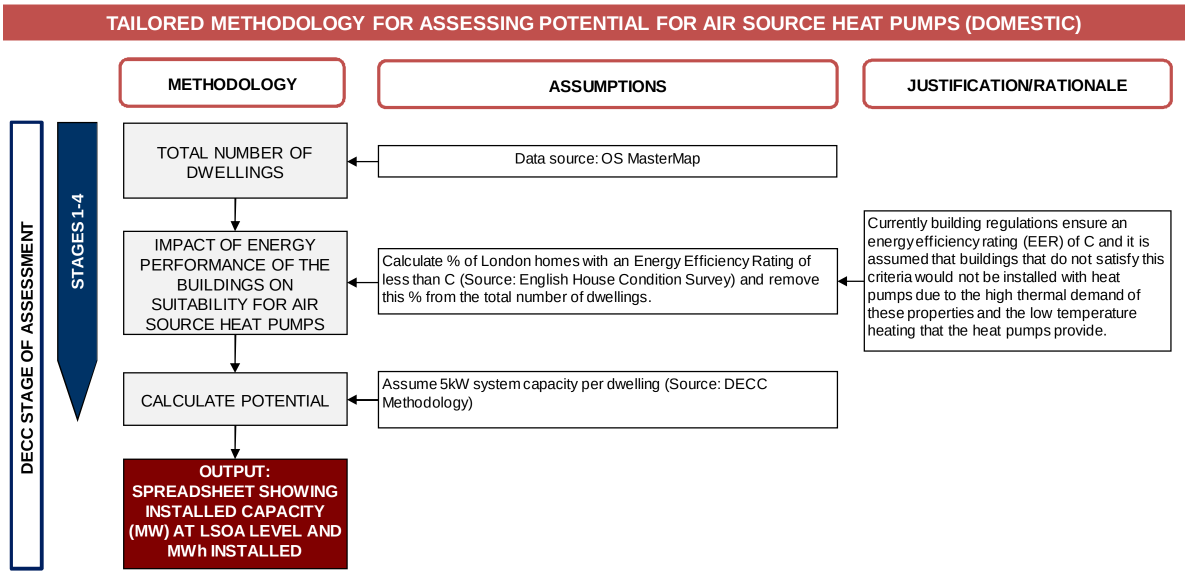


TAILORED METHODOLOGY FOR ASSESSING POTENTIAL FOR GROUND SOURCE HEAT PUMPS (NON-DOMESTIC)

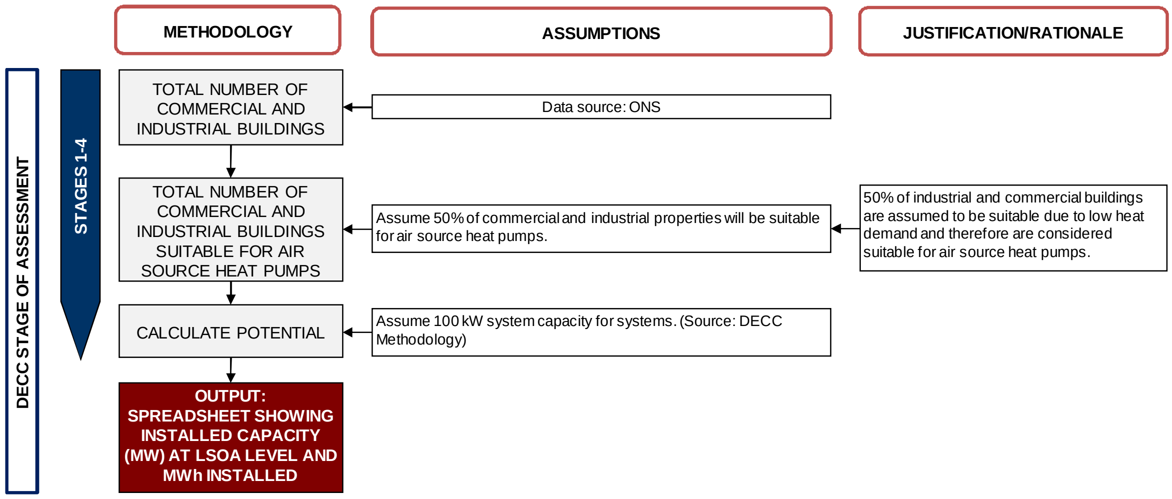


TAILORED METHODOLOGY FOR ASSESSING 2031 POTENTIAL FOR GROUND SOURCE HEAT PUMPS




TAILORED METHODOLOGY FOR ASSESSING POTENTIAL FOR AIR SOURCE HEAT PUMPS (DOMESTIC)
METHODOLOGY
ASSUMPTIONS
JUSTIFICATION/RATIONALE
DECC STAGE OF ASSESSMENT
STAGES 1-4
TOTAL NUMBER OF DWELLINGS
Data source: OS MasterMap
IMPACT OF ENERGY PERFORMANCE OF THE BUILDINGS ON SUITABILITY FOR AIR SOURCE HEAT PUMPS
Calculate % of London homes with an Energy Efficiency Rating of less than C (Source: English House Condition Survey) and remove this % from the total number of dwellings.
Currently building regulations ensure an energy efficiency rating (EER) of C and it is assumed that buildings that do not satisfy this criteria would not be installed with heat pumps due to the high thermal demand of these properties and the low temperature heating that the heat pumps provide.
CALCULATE POTENTIAL
Assume 5kW system capacity per dwelling (Source: DECC Methodology)
OUTPUT: SPREADSHEET SHOWING INSTALLED CAPACITY (MW) AT LSOA LEVEL AND MWh INSTALLED

TAILORED METHODOLOGY FOR ASSESSING POTENTIAL FOR AIR SOURCE HEAT PUMPS (NON-DOMESTIC)



Appendix F – Summary of parameters for renewable assessment

Main input parameters for renewable energy potential calculations	Values	Source
Solar energy (DECC methodology)		
Total number of domestic buildings	3,279,601	Office for National Statistics (2008)
Total number of commercial properties	388,080	
Total number of industrial properties	46,669	
Total number of new developments	525,533	
PV (tailored methodology)		
Total footprint of buildings (m2)	216,974,805	OS MasterMap (2010)
Total roof area suitable for PV based on orientation (m2)	147,632,803	Derived from OS MasterMap (2010)
Total footprint of buildings in conservation areas (m2)	23,158,837	OS MasterMap (2010)
Total number of buildings in SHLAA	503,503	Strategic Housing Land Availability Assessment and Housing Capacity Study (2009)
Total number of buildings in projected employment land	22,030	London Employment Sites Database (2009)
SWH (tailored methodology)		
Total number of domestic buildings	3,279,601	Office for National Statistics (2008)
Total floor area of non-domestic buildings	71,089,000	
Total number of buildings suitable for SWH based on orientation	1,229,850	Derived from Office for National Statistics (2008)
Total floor area of non-domestic buildings suitable for SWH	26,658,375	
Total number of buildings in SHLAA	503,503	Strategic Housing Land Availability Assessment and Housing Capacity Study (2009)
Total number of buildings in projected employment land	22,030	London Employment Sites Database (2009)
Average percentage of buildings removed due to conservation areas	13%	Derived from OS MasterMap data (2010)
Heat pumps (DECC methodology)		
Total number of detached and semi-detached properties	797,118	Office for National Statistics (2001 and 2008)
Total number of terraced properties	776,363	
Total number of flats	1,615,711	
Total number of non-domestic properties	434,749	Office for National Statistics (2008)
GSHP (tailored methodology)		
Total number of houses suitable for GSHP (EER banding of C or higher)	216,306	English House Condition Survey (2007) and Office for National Statistics (2008)
Percentage of houses that have an EER banding of C or higher	13%	English House Condition Survey (2007)

COP of GSHP	2.5	EST (2010)
ASHP (tailored methodology)		
Total number of dwellings suitable for GSHP (EER banding of C or higher)	426,348	English House Condition Survey (2007) and Office for National Statistics (2008)
Percentage of houses that have an EER banding of C or higher	13%	English House Condition Survey (2007)
COP of ASHP	2.2	EST (2010)
Projection of domestic and non-domestic buildings by 2031		
Total number of buildings in SHLAA	503,503	Strategic Housing Land Availability Assessment and Housing Capacity Study (2009)
Total number of buildings in projected employment land	22,030	London Employment Sites Database (2009)
Carbon factors used for calculating carbon savings (kgCO2/kWh)		
2010-2025 marginal grid electricity carbon factor	0.394	DECC (2010)
2008 five-year rolling average grid electricity carbon factor	0.542	DECC/DEFRA (2010)
Natural gas carbon factor	0.185	

Table A6-1: Parameters for renewable energy assessment

Borough	% of conservation areas
Kensington and Chelsea	70%
Westminster	69%
Camden	57%
Hammersmith and Fulham	45%
City of London	44%
Islington	39%
Richmond upon Thames	26%
Wandsworth	25%
Haringey	25%
Lewisham	16%
Greenwich	15%
Merton	13%
Southwark	12%
Barnet	11%
Hounslow	10%
Ealing	9.1%
Bromley	8.8%
Brent	8.8%
Hackney	8.7%
Kingston upon Thames	8.6%
Redbridge	6.1%
Harrow	5.8%
Hillingdon	5.5%
Enfield	4.0%
Sutton	3.2%
Lambeth	2.5%
Newham	2.4%
Waltham Forest	2.4%
Croydon	2.3%
Bexley	2.3%
Havering	1.9%
Tower Hamlets	0.3%
Barking and Dagenham	0.2%

Table A6-2: Percentage of land area covered by a conservation designation by borough

Appendix G – Heat demand profiles for CHP modelling

Heat demand profiles

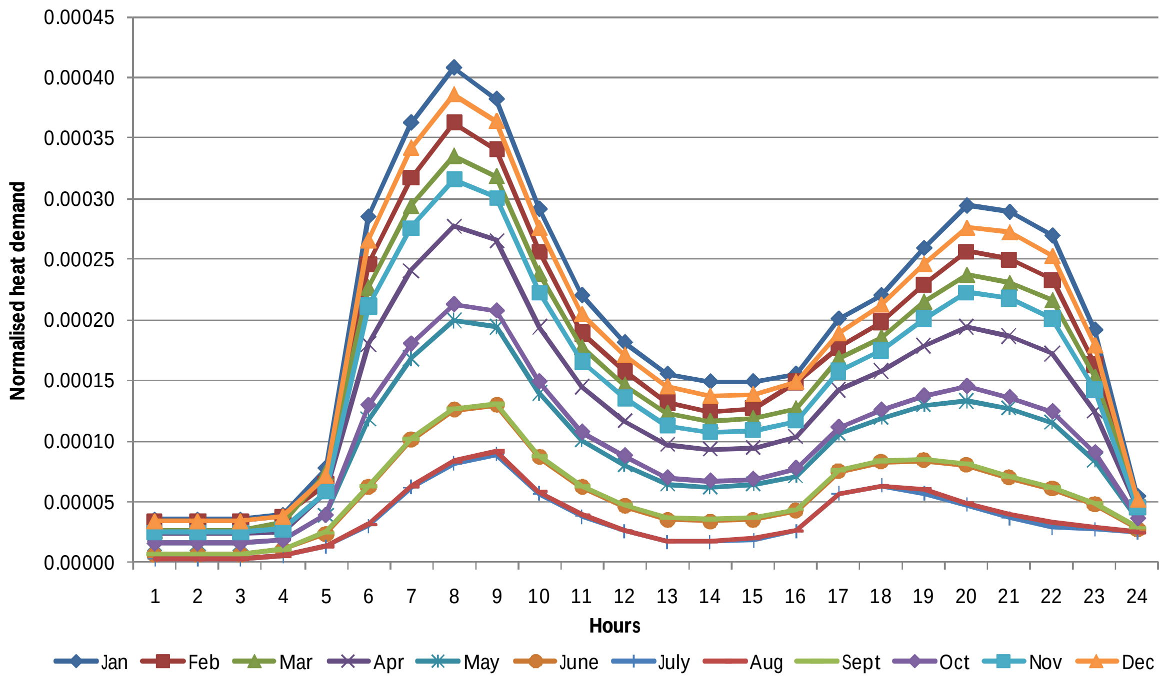


Figure A7-1: Normalised residential heat consumption profile[150]

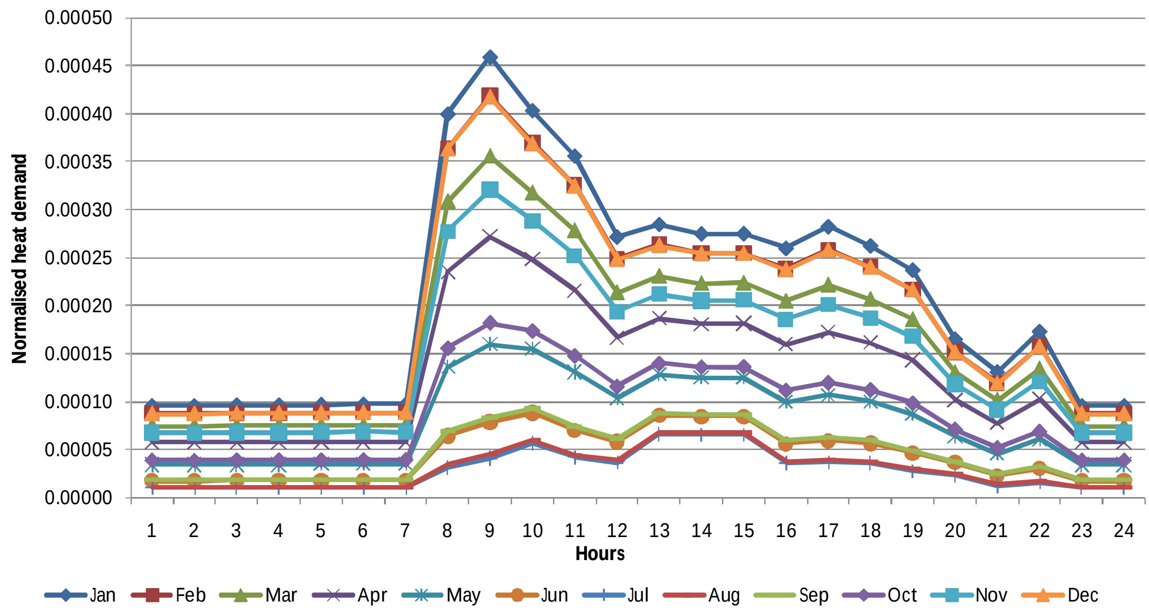


Figure A7-2: Normalised non-residential heat consumption profile[151]

[150] Buro Happold (2006) Measured data

Appendix H – Existing power stations and CHP plant in and around London

Figures A8-1 and A8-2 show power stations and CHP plants respectively in and around London[152]

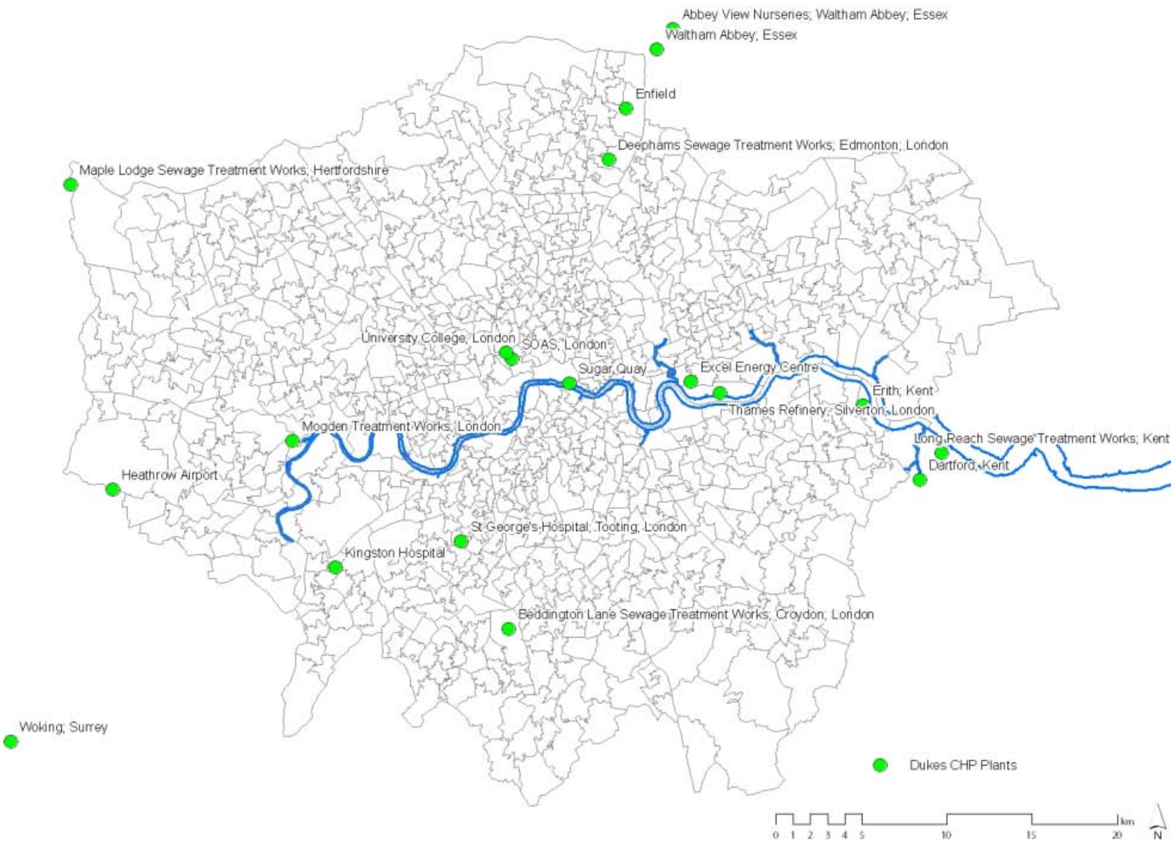


Figure A8-1: CHP plant in and around London

151 Buro Happold (2010) Thermal modelling results for typical commercial building

152 DECC (2010) Digest of UK energy Statistics 5.12: http://www.decc.gov.uk/assets/decc/statistics/publications/dukes/311-dukes-2010-ch5.pdf

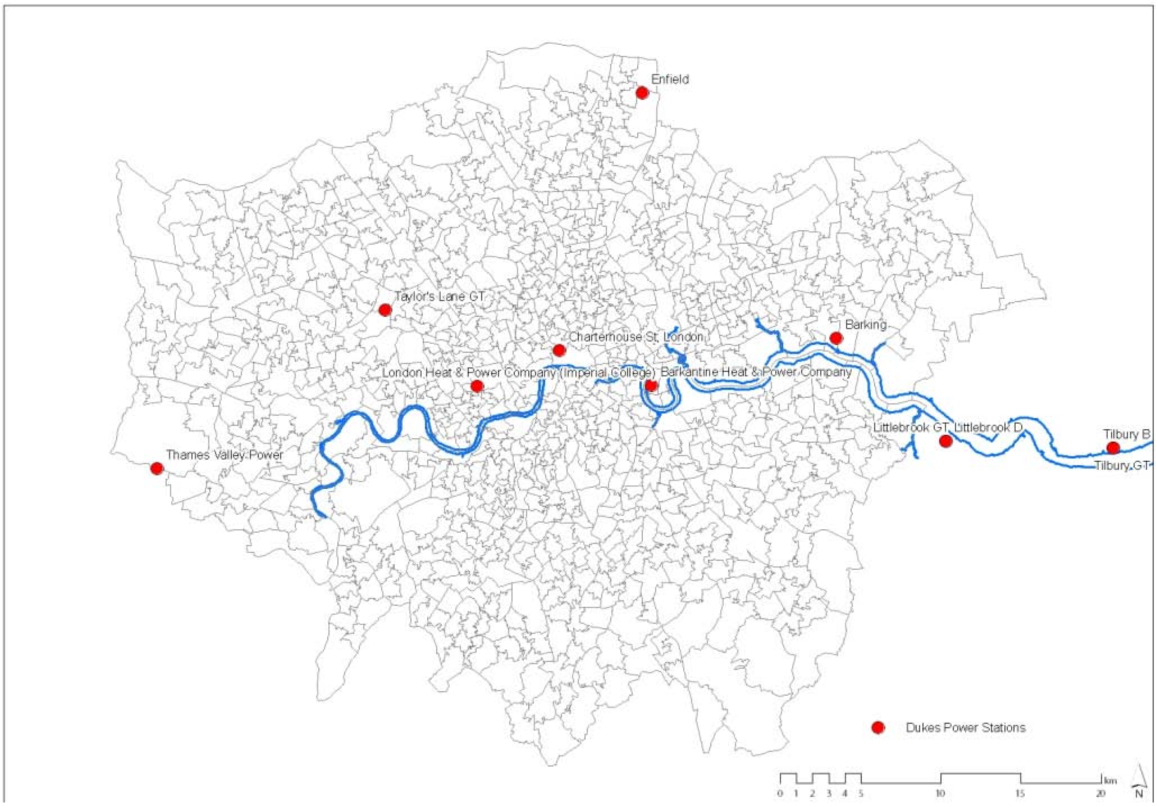


Figure A8-2: Power stations in and around London[153]

[153] DECC (2010) Digest of UK energy Statistics 5.11: http://www.decc.gov.uk/assets/decc/statistics/publications/dukes/311-dukes-2010-ch5.pdf

Operator	Location / name	Fuel	Electric Output
Power plants			
RWE Npower Plc	Littlebrook GT (outside London)	gas oil	105
RWE Npower Plc	Littlebrook D	oil	1,370
RWE Npower Plc	Tilbury B (outside London)	coal	1,063
RWE Npower Plc	Tilbury GT	gas oil	68
Barking Power *(2)*	Barking	CCGT	1,000
Citigen (London) UK Ltd	Charterhouse St, London	gas/gas oil CHP	31
EDF Energy	Thames Valley Power	Gas/Gas oil CHP	15
EDF Energy	London Heat and Power Company	gas CHP	9
EDF Energy	Barkantine Heat and Power Company	Gas CHP	1
E.On UK	Taylor's Lane GT	gas oil	132
E.On UK	Enfield	CCGT	392
Combined Heat and Power Ltd	SELCHP ERF	waste	32
Combined heat and power plants			
Archer Daniels Midland Ltd	Erith, Kent	-	14
Arjo Wiggins Ltd	Dartford, Kent	-	10
Atkins Power	Waltham Abbey, Essex	-	3
Atkins Power	Waltham Abbey, Essex	-	3
Barkantine Heat and Power Company	Barkantine, Barkantine Heat and Power Company	-	1
Bloomsbury CHP	SOAS, London	-	1
Dalkia Utilities Services	Kingston Hospital	-	1
Imperial College of Science, Medicine and Technology	Kensington, London	-	9
Johnson Matthey	Enfield	-	3
Kodak Limited	Harrow Site, Kodak Limited	-	12
St Georges's Healthcare NHS Trust	St George's Hospital, Tooting, London	-	4
Tate and Lyle Europe	Thames Refinery, Silverton, London	-	20
Thames Valley Power Ltd	Heathrow Airport	-	15
Thames Water Utilities	Deephams Sewage Treatment Works, Edmonton, London	-	3
Thames Water Utilities	Beddington Lane Sewage Treatment Works, Croydon, London	-	3
Thames Water Utilities	Mogden Treatment Works, London	-	8
Utilicom Ltd	University College, London	-	3

Table A8-1: Power plants and CHP plants in London (Source: DECC, 2010[152,153])