GREATER**LONDON**AUTHORITY

Decentralised energy capacity study

Phase 2: Deployment potential

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Glossary

ASHP	Air source heat pump
BAU	Business as usual
C&I	Commercial and industrial
CAPEX	Capital expenditure
CCC	Committee on Climate Change
CCGT	Combined cycle gas turbine
CHP	Combined heat and power
COP	Coefficient of performance
CO_2	Carbon dioxide
DE	Decentralised energy
DECC	Department for Energy and Climate Change
EER	Energy Efficiency Rating
EfW	Energy from waste
EST	Energy Saving Trust
FIT	Feed-in tariff
GLA	Greater London Authority
GSHP	Ground source heat pump
GWh	Gigawatt hour
IRR	Internal rate of return
IEA	International Energy Agency
LEGGI	London Energy and Greenhouse Gas Inventory
MSOA	Middle layer super output area
MSW	Municipal solid waste
MW	Megawatt
MWe	Megawatt electric

MWth	Megawatt thermal
MWh	Megawatt hour
NPV	Net present value
ONS	Office for National Statistics
OPEX	Operational expenditure
PV	Photovoltaic
RE	Renewable energy
RHI	Renewable Heat Incentive
ROC	Renewable Obligation Certificate
SWH	Solar water heating
WID	Waste Incineration Directive
WHI	Waste heat initiative

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 deployment potential for renewable energy (RE) and decentralised energy (DE) up to 2031, which comprises Phase 2 of the regional assessment. The approach is based on a standardised methodology developed by DECC which has been modified to reflect Greater London's urban nature. An assessment of the technical potential was made in Phase 1 of the study.

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. In Phase 2 the potential for energy from biomass feedstocks is accounted for within the DE analysis. Biomass includes the organic fraction of municipal and commercial and industrial (C&I) waste as well as wood and agricultural arisings. The DE analysis also looks at using waste heat from power stations outside of London.

To assess the impact of a range of market and policy conditions on the deployment of RE and DE, five scenarios have been developed. They show that the Mayor's Climate Change Mitigation and Energy Strategy target to supply a quarter of London's energy from decentralised sources by 2025[1] is achievable. However, realising this level of ambition requires significant changes to national policy and a concerted effort across all levels of government and the private sector. Depending on the mix of DE technologies deployed and the carbon intensity of the electricity grid, this can reduce London's CO_2 emissions by 4.2million tonnes per year.

Methodology

Detailed modelling of the economic potential of a range of RE and DE energy sources has been undertaken, building on the assessment of technical potential carried out in Phase 1 of the study. For the RE sources, the economic potential results per technology are used as the input into a deployment model which assesses the likelihood of installation based on constraints including: the probability of achieving planning permission, the probability of investment versus alternatives and supply chain limitations. The DE model calculates the lifecycle unit cost of heat generation for each technology, as well as the lifecycle unit cost of heat distribution by area. DE is considered viable in areas where the sum of the cost of heat generation and cost of heat distribution is less than a baseline cost of heat from gas boilers. DE deployment is constrained by the build out rate of heat networks.

Five scenarios are modelled including business as usual policy and energy price; ambitious policies and scarcity of natural gas; and co-ordinated action across all sectors. These scenarios are indicative and used to highlight the impact of different economic conditions and policy levers.

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

Scenario 1 - Business as usual (BAU)

Energy prices and grid carbon intensities from 2010 are assumed along with a 9% discount rate, reflecting a private sector driven investment model with limited risk mitigation. Roll out rates for RE technologies and heat network installation are assumed to be low. Energy demand in the BAU scenario is higher than the other scenarios where significant improvements in the energy efficiency of buildings are modelled.

Scenario 2 - National action

This scenario reflects a situation where gas prices increase due to supply constraints, and the cost of electricity also increases due to significant decarbonisation of the electrical grid, reaching 0.192kgCO_2/kWh by 2031. A medium discount rate reflecting some form of public sector risk sharing or finance, more favourable roll out assumptions and energy costs based on DECC 'high' energy price forecasts are assumed.

Scenario 3 – Regional action

Scenario 3 assumes there is only limited reduction in the carbon intensity of the electrical grid, but local and regional government policy is favourable towards RE and DE. Energy prices are based on 2010 levels, and grid carbon intensity is assumed to reach 0.296kgCO_2/kWh by 2031. In this scenario a low discount rate reflecting funding from the London Green Fund or similar, together with increased planning approval rates, is used.

Scenario 4 – Ambitious action

Scenario 4 assumes that ambitious policy is in place across all levels of government, and that natural gas is very expensive. The carbon intensity of electricity is the same as in the National action scenario. Electricity prices are assumed to reach DECC's 'high-high' forecast, the discount rate is low and planning approval rates are very high. Deployment rates of heat networks and microgeneration are very high. This scenario is unlikely in the short term, however, it provides an opportunity to assess the alternatives to natural gas.

Scenario 5 – Coordinated action

Scenario 5 assumes a combination of national and regional action with high levels of grid decarbonisation and high levels of planning support. The potential for DE is supported by the assumption that electricity prices follow the DECC 'high-high' forecast, but natural gas prices are based on the DECC 'high' forecast. The discount rate is medium, matching the Regional action scenario, with a medium rate of heat network deployment.

Overview of scenario results for 2031

Table i gives an overview of the results obtained for the deployment potential of RE and DE in 2031. Note that the energy demand in the BAU scenario is assumed to be higher than the other scenarios due to improvements in energy efficiency in the other scenarios.

Deployment potential (GWh)		**BAU**	**National**	**Regional**	**Ambitious**	**Coordinated**
Renewable energy – technologies not connected to heat networks						
Photovoltaic		1,646	1,844	2,940	3,957	2,793
Solar water heating		348	402	599	952	565
Ground source heat pump		124	186	246	480	256
Air source heat pump		856	1,279	1,583	2,799	1,533
Wind (commercial-scale)		59	65	125	181	126
Wind (small-scale)		1.9	2.1	4.5	6.4	4.3
Hydro		5.9	12.0	14.3	17.9	14.3
Energy generation	Electricity	1,713	1,923	3,084	4,162	2,938
	Heat	1,328	1,867	2,428	4,230	2,354
	Total	**3,041**	**3,790**	**5,512**	**8,392**	**5,292**
% of London's energy demand, 2031	Electricity	4.0%	4.9%	7.8%	10.6%	7.5%
	Heat	1.5%	2.7%	3.5%	6.1%	3.4%
	Total	2.3%	3.5%	5.1%	7.7%	4.9%
Carbon savings (MtCO$_2$)		**0.7**	**0.7**	**1.5**	**1.6**	**1.1**
Non-renewable energy linked to heat networks						
CCGT – medium		2,050	1,206	3,183	-	16,954
CCGT – small		7.3	-	0.9	-	-
Electrical grid overspill		-	-	-	-	-
Energy from waste – gasification		134	1,195	210	962	1,130
Energy from waste – incineration		-	-	-	-	-
Gas engine – medium		-	-	-	-	-
Gas engine – small		1,482	1,472	1,210	506	964
Heat recovery from sewage		-	-	-	-	-
Heat rejection from air conditioning		-	-	-	-	-
Waste heat from existing energy from waste plant[2]		-	-	-	1,186	-
Waste heat from existing power plant[2]		7.3	-	0.8	-	-
Waste heat from power stations outside Greater London[3]		-	-	-	17,720	-
Energy generation	Electricity	1,780	1,629	2,405	10,821	10,943
	Heat	1,899	2,232	2,197	8,803	8,093
	Total	**3,679**	**3,861**	**4,602**	**19,624**	**19,036**
% of London's energy demand, 2031	Electricity	4.1%	4.1%	6.1%	27.5%	27.8%
	Heat	2.1%	3.2%	3.2%	12.7%	11.7%
	Total	2.8%	3.6%	4.2%	18.1%	17.5%

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[2] Based on the proportion of waste heat from existing energy from waste plant or CCGT as determined in the Phase 1 report

[3] Combination of waste heat from nuclear and other power stations outside Greater London as determined in the Phase 1 report

Carbon savings (MtCO_2)[4]		**0.2**	**-0.04**	**0.3**	**0.8**	**-0.3**
Renewable energy linked to heat networks						
Anaerobic digester		29.5	263	46.4	213	249
Biomass Combined Heat and Power (CHP) – large		-	4,730	-	5,270	-
Biomass CHP – medium		47.0	1,385	2.4	1,116	1,308
Biomass district heating		193	1,491	296	1,361	1,596
Energy from waste – gasification		218	1,950	342	1,570	1,843
Energy from waste – incineration		-	-	-	-	-
Energy generation	Electricity	99	2,661	138	3,029	1,039
	Heat	391	7,171	551	7,250	3,969
	Total	**489**	**9,832**	**689**	**10,279**	**5,008**
% of London's energy demand, 2031	Electricity	0.2%	6.8%	0.4%	7.7%	2.6%
	Heat	0.4%	10.3%	0.8%	10.5%	5.7%
	Total	0.4%	9.0%	0.6%	9.5%	4.6%
Carbon savings (MtCO_2)		**0.11**	**2.0**	**0.17**	**2.1**	**1.1**
Total decentralised energy (all energy from heat networks)						
Energy generation	Electricity	1,878	4,290	2,544	13,850	11,981
	Heat	2,290	9,403	2,748	16,053	12,062
	Total	**4,168**	**13,693**	**5,291**	**29,903**	**24,044**
% of London's energy demand, 2031	Electricity	4.4%	10.9%	6.5%	35.2%	30.5%
	Heat	2.5%	13.6%	4.0%	23.1%	17.4%
	Total	3.1%	12.6%	4.9%	27.5%	22.1%
Carbon savings (MtCO_2)		**0.3**	**2.0**	**0.4**	**2.9**	**0.8**
Total						
Energy generation	Electricity	3,591	6,212	5,627	18,013	14,920
	Heat	3,618	11,270	5,176	20,283	14,416
	Total	**7,209**	**17,483**	**10,803**	**38,295**	**29,336**
% of London's energy demand, 2031	Electricity	8.3%	15.8%	14.3%	45.8%	37.9%
	Heat	4.0%	16.2%	7.5%	29.2%	20.8%
	Total	5.4%	16.1%	9.9%	35.2%	27.0%
Carbon savings (MtCO_2)		**1.0**	**2.7**	**1.9**	**4.6**	**1.8**

Table i: Summary of deployment potential of decentralised energy by source and scenario, 2031

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[4] There are no carbon savings attributed to the non-renewable fraction of biomass and energy from waste technologies by definition

Deployment potential

The deployment potential of RE (excluding RE connected to heat networks) varies between 2-8% of London's energy demand in 2031, with a potential of 5% under the Coordinated action scenario. This represents around 18% of the technical potential. DE potential varies even more widely. Under business as usual conditions the deployment potential is as low as 3%, rising to 28% under the Ambitious action scenario. Under the Coordinated action scenario, DE deployment potential is 22%. This is equivalent to over half a million dwellings or non-domestic buildings being connected to heat networks. Within the DE potential, use of biomass feedstocks (including waste, woody biomass and agricultural arisings) represents 5% of London's energy demand in 2031 in the Coordinated action scenario.

The combined deployment potential of RE and DE by 2031 varies between 5% and 35%. Under the Coordinated action scenario the combined deployment potential is 27%, which suggests that it is feasible to achieve the Mayor of London's Climate Change Mitigation and Energy Strategy target to source 25% of London's energy from decentralised sources by 2025. This represents an investment of the order of £15.6billion and £8.3billion in RE and DE respectively.

Technology

The modelling shows that a mix of technologies is required to deliver on London's ambitions for RE and DE deployment. In terms of RE not linked to heat networks, photovoltaics (PV) and heat pumps have the highest potential. Solar water heating (SWH) has limited potential, mainly due to being restricted to supplying only hot water demand. Wind, hydro and tidal energy have limited potential for deployment in London. DE has high deployment potential subject to certain conditions being present which facilitate the deployment of extensive heat networks. Waste heat, biomass (including waste to energy plants and wood fuelled plants of various types), and particularly CCGT plant deliver the highest potential.

Larger-scale DE technologies generally provide heat at a lower cost, with the exception of systems which use waste arisings as fuel – these can be economic even at relatively small scales, for example anaerobic digestion. The potential for DE is concentrated in central areas of London, as well as some outlying town centre areas. This suggests that widespread interconnection is physically possible, which can increase the proportion of energy delivered by DE and enable connection to larger and lower cost sources of heat. RE potential is more evenly spread, but can provide a higher proportion of energy demand in lower density areas.

Reductions in carbon emissions

The estimated reductions in carbon emissions from RE and DE are between 1.0 and 4.6MtCO_2/yr. Under the Coordinated action scenario these are split 1.1MtCO_2/yr and 0.8MtCO_2/yr between RE and DE respectively. Of the latter, 1.1MtCO_2/yr is from RE linked to heat networks indicating that gas-fired DE has negative carbon savings when grid electricity is highly decarbonised. Gas-fired combined heat and power (CHP) provides significant carbon emission reductions under the BAU scenario, but these become negative when the electricity grid carbon intensity reduces below 0.2tCO_2/MWh as has been modelled in the Coordinated action scenario. Between 2025 and 2031, despite a projected increase in deployment, carbon savings in the Coordinated action scenario reduce from 1.4MtCO_2/yr to 0.8MtCO_2/yr as the electricity grid is decarbonised. At this stage a greater switch to low carbon sources of heat, such as energy from waste, waste heat or biomass will be required to maintain a net level of carbon savings relative to the electricity grid. For biomass this is likely to entail imports from outside of the Greater South East. Other opportunities include the alternative heat sources identified in Section 13.4 of the Phase 1 report. While these technologies, including importing heat from power stations outside of London, reduce emissions they only start to become economically viable when the alternative cost of heat is above £100/MWh.

It is important to note that the potential carbon reductions are highly dependent on future grid decarbonisation. In the case of heat pumps, for example, carbon savings move from being negative (based on 2010 values used in the BAU scenario) to highly positive (based on values used in the Coordinated action scenario). Other energy sources, such as PV, remain effective regardless of grid decarbonisation but the size of the savings will be affected.

Analysis, risks and policy implications

The deployment potential of RE is influenced much more strongly by deployment constraints than economic viability. The subsidies available under the feed-in tariffs (FITs) and the renewable heat initiative (RHI) make RE systems more economically viable than conventional sources such as individual gas boilers or grid electricity. The energy efficiency of London's building stock is a major constraint as heat pumps represent the highest technical potential, but they are not suitable for installation in thermally inefficient buildings. In order to facilitate higher deployment of heat pumps London will need to retrofit a significant number of buildings. A further constraint which has not been modelled in detail is the ability of the electricity distribution network to assimilate the impact of the deployment of heat pumps and PV. This impact could result in significant reinforcement costs, of a similar order of magnitude to the cost of heat networks.

Realising the potential of DE in London will require connecting a significant proportion of existing buildings to heat networks. The potential for DE in new buildings is limited to less than 2% of London's energy demand. The modelling assumes that heat networks are connected to 70% of the heat demand within specific areas. Such high levels of market penetration will require strong policy support. Similarly, the discount rate is a major factor influencing the DE deployment potential. Policy approaches must either support higher rates of return on heat network investment, or reduce the risk associated with these investments. Incentives can include reform of the electricity market to enable DE generators to capture more of the value chain through cost reflective distribution charging and 'Licence Lite' electricity supply arrangements. Finally, the supply chain for DE, and particularly the rate at which heat networks can be installed, is a significant risk and deploying at scale will require the establishment of a heat network supply chain with a significantly higher capacity than currently exists in the UK.

1 Introduction

This report forms part of a regional assessment of the potential for renewable and low carbon energy in Greater London which 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 deployment potential for renewable energy (RE) and decentralised energy (DE) up to 2031, which comprises Phase 2 of the regional assessment. An assessment of the technical potential was made in Phase 1 of the study

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. In Phase 2 the potential for energy from biomass feedstocks is accounted for only within the DE modelling as heat networks are considered essential in maximising their deployment. Unlike in Phase 1 therefore there is no consideration of biomass feedstocks in the RE modelling. Biomass includes the organic fraction of municipal and commercial and industrial (C&I) waste as well as wood and agricultural arisings. Thus, the results and discussions of RE exclude those sources which are connected to heat networks unless otherwise stated. However, the RE and DE results from the two models are additive and can be combined to give total deployment potential.

In line with the DECC methodology (Figure 1-1), the approach taken to assess London's renewable and low carbon energy potential involves applying progressive layers of analysis to London's theoretical potential, in order to establish a more realistically achievable potential. Stages 1 to 4 of the assessment were carried out in Phase 1 and provide an estimate of the technical potential of renewable and low carbon energy in London using a standardised methodology developed by DECC (the DECC methodology) as well as a modified approach to reflect the urban nature of Greater London (the tailored methodology).

Phase 2 of the study builds on the Phase 1 results of the technical potential under the tailored methodology and addresses the economic and supply chain constraints (Stages 5 to 7). Although Figure 1-1 illustrates all 7 recommended stages of the assessment, the DECC methodology does not provide any guidance or criteria to evaluate economic viability, deployment constraints and regional ambition. The methodology developed is outlined in Section 2. In addition, five scenarios are modelled for 2031 to reflect variations in policy, incentives, regional ambition and energy costs. Rollout trajectories are then calculated to determine deployment rates between 2010 and 2031. These are covered in more detail in Section 1.3.

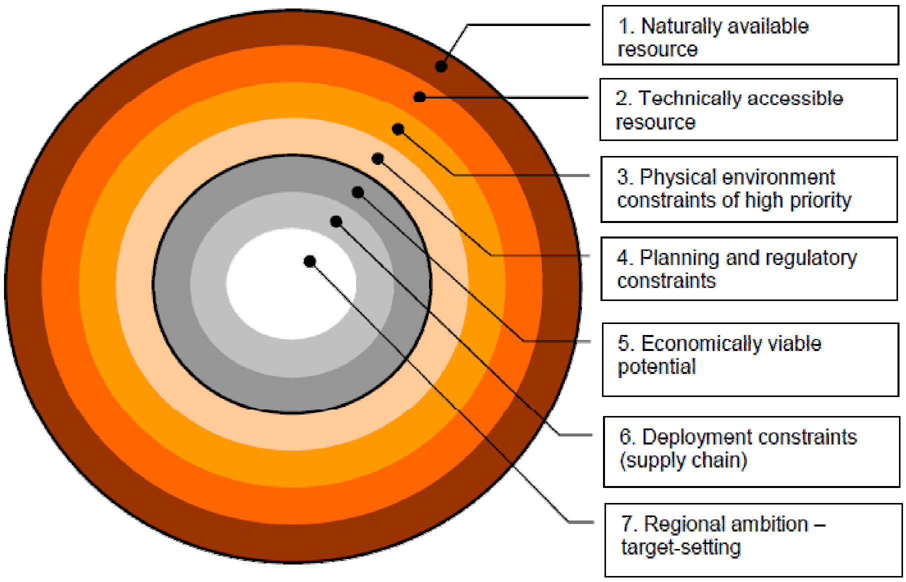

Figure 1-1: The DECC methodology for estimating renewable and low carbon energy capacity (Source: SQW Energy[5])

1.1 Technical assessment

Phase 1 estimates the technical potential of RE and DE in London in 2010. Under the tailored methodology, RE can meet 34% and 49% of London's 2008 demand for electricity and heating respectively, whilst DE[6] can supply 31% and 21% of London's 2008 demand for electricity and heating respectively. When these figures are combined in accordance with the London Plan energy hierarchy[7], the potential for RE drops as DE systems are prioritised in areas where they are viable. Table 1-1 summarises the combined technical potential in 2010. Please note that Stages 5 and 6 of this assessment use the separate technical potentials for RE and DE, as shown above.

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[5] 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

[6] Note: The technical potential for DE is calculated using a demand driven methodology rather than supply driven. This is explained further in the Phase 1 report

[7] GLA (2008) The London Plan: http://www.london.gov.uk/thelondonplan/docs/londonplan08.pdf

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	-	0.01	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%
Total 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 1-1: Combined results for technical potential of renewable and decentralised energy under the tailored methodology, 2010 (from Table 16-1 in the Phase 1 report)

1.2 Methodology

Building on the results from Stages 1-4 of the tailored methodology, Phase 2 continues the analysis, covering Stages 5 and 6. In Stage 5, all the costs associated with each technology are calculated and benchmarked against a base case in order to limit the potential to those schemes which are economically viable. Stage 6 looks at the roll-out of these schemes and calculates the capacity of RE and DE that can be implemented by 2031. With regard to new build, it is assumed that 95% of new developments outside of viable networks can have a DE system installed. Unless otherwise stated, all figures in this report relate to 2031 and include any additional capacity created through new build. In general, values are presented to one decimal place; where totals in tables do not match the sum of individual values, this is due to rounding errors.

1.3 Scenarios

Five scenarios have been developed to test a wide range of variables which affect the economics and carbon emissions of energy supply to buildings. The scenarios are indicative and the results produced by the modelling are not intended to provide a prediction of the future development of energy supply in London. Instead, they show a range of outcomes to help better understand the cost effectiveness of different technologies and their combinations, their impact on carbon emissions, and the effect of different policy levers and external influences. The five scenarios developed are listed below:

1. Business as usual (BAU)
2. National action
3. Regional action
4. Ambitious action
5. Coordinated action

1.3.1 Parameters used in scenarios

Reference to the DECC 2050 Pathways work was made in order to understand how some of the key variables might develop[8]. Two pathways were chosen, the 'reference pathway' and 'Pathway Alpha'. The former represents a 'business as usual' case, whilst the latter represents a possible route to de-carbonising energy supplies by 2050 assuming a concerted level of action across all sectors of the economy. In the reference pathway, little or no attempt is made to decarbonise, and possible new technologies are not utilised. Emissions targets are not met and security of supply is considered to be at risk. Conversely, in Pathway Alpha, a concerted effort to reduce energy use is assumed. Three large-scale sources of low carbon electricity are deployed (nuclear, carbon capture and storage, and renewables) resulting in a low carbon intensity of electricity imported from the grid. In addition, imports of sustainable bio-energy are realised, emissions targets are met and energy supplies are resilient to security of supply shocks. This analysis directs the parameters that were identified in order to develop the five scenarios. These are summarised in Table 1-2 below:

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

Parameter	Description
Discount rate	This is effectively the cost of capital and varies between 6% and 9%
Incentives/support	This allows modelling of fiscal incentives including feed-in tariffs (FITs), renewable heat initiative (RHI), waste heat initiative (WHI) and renewable obligation certificates (ROCs)
Planning support	The likelihood of gaining planning permission for RE
Activism/promotion	The degree of non-fiscal policy support reflected in RE uptake rates
Energy prices	Wholesale, non-residential and residential rates for gas and electricity. These influence which of the technologies are most economically viable as well as changing the baseline cost of heat and electricity
Energy demand	The gas and electricity demand for London in 2031. This includes a consideration of the levels of energy efficiency improvements and new build achieved by 2031
Carbon intensity	The carbon intensity of the gas and electricity grids with a separate figure for exported electricity (also known as the marginal rate). This is altered according to the predicted generation mix in 2031 for each scenario
DE build out rate	This affects the Stage 6 results by analysing how much heat network pipe work can be laid per year. Measured in maximum trench length per year and number of years required to reach this maximum rate

Table 1-2: Table of key parameters considered in scenarios

Table 1-3 shows how these key parameters vary by scenario. A brief rationale for each scenario is provided below and a more detailed summary is included in the ‘Phase 2_DE Stage 5’ datasheet which accompanies this report. Energy prices are inclusive of VAT and the Climate Change Levy, where the latter is applicable.

Parameter	BAU	National	Regional	Ambitious	Coordinated
Discount rate	9.0%	7.0%	6.0%	6.0%	7.0%
Incentives/support	ROCs, FITs, RHI			ROCs, FITs, RHI, WHI	ROCs, FITs, RHI
Planning support	25% planning approval rate for wind, 100% for micro generation as assumed to be permitted development		50% for wind 100% for micro-generation	70% for wind, 100% for micro-generation	50% for wind, 100% for micro-generation
Activism/promotion	Low		High		
Energy price – gas (£/MWh)					
Wholesale	16	26	16	120	26
Non-residential	20	35	20	120	35
Residential	38	43	38	120	43
Energy price – electricity (£/MWh)					
Wholesale	67	75	67	90	90
Non-residential	85	115	85	133	133
Residential	132	132	132	149	149
Energy demand (GWh/yr)					
Electricity	43,041	39,329	39,329	39,329	39,329
Heat	90,472	69,364	69,364	69,364	69,364
Total	133,513	108,693	108,693	108,693	108,693
Carbon factors (kgCO$_2$/kWh)					
Electricity	0.542	0.192	0.296	0.192	0.192
Electricity (exported)	0.394	0.251	0.394	0.251	0.251
Gas	0.185	0.176	0.185	0.176	0.185
DE build-out rate (km$_{trench}$/yr)	20	200	40	550	250

Table 1-3: Summary of key parameters by scenario

The economic potential of DE sources up to 2031 is most affected by the cost of borrowing money (discount rate) and energy prices; a higher baseline cost of energy for heat (natural gas) and a greater price differential between gas and electricity prices make DE sources more competitive. The deployment potential, on the other hand, is most affected by the network build rate.

1.3.2 Energy consumption in London

Throughout this report, energy consumption figures are taken from the London Energy and Greenhouse Gas Inventory (LEGGI) for 2008. The baseline projected future energy consumption of London's built environment was calculated by extrapolating the LEGGI dataset in accordance with the DECC 2050 Pathways Analysis 'Pathway Alpha'[8], except in the BAU scenario where the reference pathway was used (see Table 1-4).

Energy consumption in London		GWh	Total	Source
2008 (LEGGI)	Electricity	39,869	105,875	LEGGI 2008[9].
	Heat	66,006		
2031 (BAU)	Electricity	43,041	133,513	As above, extrapolated according to DECC reference pathway (BAU scenario)
	Heat	90,472		
2031 (Pathway Alpha)	Electricity	39,329	108,693	As above, extrapolated according to DECC 'Pathway Alpha' (National, Regional, Ambitious and Coordinated action scenarios)
	Heat	69,364		

Table 1-4: London energy consumption figures

1.3.3 Description of scenarios

Business as Usual

The business as usual scenario is intended to reflect the DECC reference pathway. The discount rate is based on a typical rate of return for a utility type project, and slightly above the rate of return on which subsidies such as FITs are based. The incentives assumed are ROCs, FITs and a RHI which is set at 2010 consultation values and it is assumed that there is no maximum expenditure cap. Applications for wind turbines are assumed to achieve a 25% planning approval rate, other RE technologies are assumed to be permitted developments and are therefore given a 100% approval rate. (Note that conservation areas have already been excluded in calculating the technical potential). Energy prices and carbon factors are based on 2010 figures to reflect the BAU approach and the energy demand has been extrapolated according to the DECC reference pathway. The build out rates are calibrated with the roll out of photovoltaic (PV) panels in Germany with FITs and the DE build out reflects approximately one major scheme a year akin to the Olympic Park, with a further 5km in new build or retrofit.

National action

This scenario is intended to reflect a concerted effort towards decarbonisation at national level. A high level push towards the deployment of RE and low carbon technologies is assumed. This includes changes in incentives and energy prices, but no change in the planning system at a local level. The discount rate is set at 7% to reflect the availability of lower cost finance, or that investments could be considered relatively low risk. Planning support and activism are assumed to be the same as in the BAU scenario, as these are considered to be influenced more by local rather than national policies although the roll out rate of district heating networks is increased ten-fold from the BAU scenario based on 50% of the maximum rate achieved by the Thames Water mains replacement programme. Gas and electricity prices are selected to reflect a higher future cost of energy. They are assumed to be in line with the DECC high projection in the 2050 Pathways Analysis. The projected energy demand reflects significant improvements in energy efficiency from the BAU scenario (around 19%). Due to anticipated decarbonisation of the grid, lower carbon intensities are assumed. The gas figure assumes 5% 'green gas' as a proportion of the natural gas supplied.

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

Regional action

This scenario is intended to be an alternative to the national action scenario, with regional activism and promotion rather than improved national policies. It was chosen to reflect a situation in London where green policies are in place regionally, but without equivalent support at national level. In particular, the proposed de-carbonisation of the electrical supply is assumed to be less radical than in the national and ambitious scenarios. The discount rate is set at 6% assuming that a London energy fund will be available at a European Investment Bank discount rate with a local margin. A 50% planning approval rate for commercial-scale wind is assumed, reflecting the current approval rate on appeal, with a 100% approval rate for microgeneration. Activism and promotion is assumed to be high with the roll-out curves for renewable technologies following an accelerated trajectory, due to the higher economic potential. Energy prices are unchanged from the BAU scenario and energy demand is unchanged from the national action scenario. The roll out rate for DE technologies is double what is expected to be achieved in the BAU scenario.

Ambitious action

This optimistic scenario is intended to reflect concerted change in national and local policy, essentially a combination of national and regional action. An additional low carbon or waste heat incentive for sources not covered under the RHI is included as an incentive and a 70% planning approval rate is used reflecting a high level of political support, together with a 100% approval rate for microgeneration. Electricity prices are set at DECC high-high values. However, in this scenario a scarcity of natural gas is assumed, reflected by very high gas prices, meaning natural gas is effectively unaffordable for space heating and electricity generation. Energy demand is unchanged from national and regional action. Carbon intensities match the national action scenario. DE roll out reflects the estimated maximum roll out achieved in Denmark during the expansion of their heat networks.

Coordinated action

This scenario effectively combines national and regional action. The carbon factors are set at the national action levels as are gas prices but electricity prices are high-high as in the ambitious scenario to reflect some form of support which increases the value of electricity outputs from DE sources. The build out rate is about 60% of the maximum rate achieved by Thames Water in their mains replacement programme. This reflects an assumption of a favourable policy and regulatory framework for heat networks.

2 Methodology

2.1 Overview

In order to assess the deployment potential for RE and DE systems, a two-stage approach was followed. These form Stages 5 and 6 as recommended in the DECC methodology:

- Stage 5 – Economic potential: Economic modelling was applied to the technical potential for each technology and considers the economics of investment including incentives and consumer response to returns from RE investments. For DE, the model tested whether a DE system provides a lower cost of heat than heat provision from a baseline source (individual gas boilers).
- Stage 6 – Deployment constraints: Modelling of deployment constraints was applied to the economic potential for each technology. For RE, the modelling considers installation challenges, consumer behaviour and the influence of local planning and energy efficiency policy in helping to overcome installation challenges. For DE, heat network build out rate was used as a proxy for all deployment constraints.

This section sets out the methodology and key assumptions used in the modelling. Further detailed descriptions of the models developed for each RE technology, and more generally for the DE model, are contained in Appendices A-F.

2.2 Comparison of renewable energy modelling and decentralised energy modelling

The approaches taken to modelling RE and DE use the same baseline and scenario data. However, there are some fundamental differences. RE deployment potential is largely a market-based supply and demand question which can be modelled using assumptions about economic potential, policy support and aggregated consumer preferences to compare the cost of RE sources to baseline sources of energy, particularly at domestic or commercial levels.

At present there is limited policy support in place for DE. In general the support is insufficient to offset the high upfront capital costs of the heat network infrastructure required to utilise many DE heat sources. The roll out of DE networks is therefore akin to the establishment of a new utility network infrastructure, and can be considered a natural monopoly. As discussed in previous policy work by London First[10], DECC[11], and Hawkey[12], DE does not lend itself to a market-based analysis. It is only realistic to model significant uptake rates or market penetration of heat networks where a supportive regulatory regime exists as a condition precedent. Without supportive policy measures in place the potential of DE remains extremely limited.

The most recent UK estimate of economic potential under BAU conditions predicts that only 0.3% of the UK's heat demand will be met from DE between 2008 and 2050[11]. DE systems are therefore modelled to demonstrate their potential by assuming that measures are in place to address the above barriers. This means that deployment rates are based on their economic potential and physical roll-out constraints, assuming a supply chain develops capable of deploying heat networks

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[10] London First (2008) Cutting the capital's carbon footprint: http://www.london-first.co.uk/documents/Cutting_the_Capital's_Carbon_Footprint_FULL_Low_res_FINAL.pdf

[11] DECC (2010) The potential and costs of district heating networks: http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/distributed_en_heat/district_heat/district_heat.aspx

[12] Hawkey, D. (2009) Will "district heating come to town?", an analysis of current opportunities and challenges in the UK: http://www.sps.ed.ac.uk/__data/assets/pdf_file/0019/55531/Hawkey_-_2009_-_District_Heating_UK.pdf

at scale. Should these barriers remain, the levels of deployment potential identified in the scenario modelling cannot be reached. The differences between the RE and DE modelling approaches is reflected in the percentage of technical potential included in the deployment potential. These percentages are shown in Table 3-1 and Table 3-2. The deployment of heat networks is further considered in Phase 3 of the regional assessment.

2.3 Renewable energy modelling methodology

This section sets out the methodology used to determine the economic and deployment potential of all RE technologies except for biomass feedstocks (including energy from waste) which are assumed to be delivered through heat networks and are therefore covered in the DE deployment modelling outlined in Section 2.4. An overview of the RE methodology is provided below, followed by a detailed description by technology. For further detail about the methodology for each technology please refer to Appendices A to E.

2.3.1 Summary of renewable energy deployment modelling

Figure 2-1 summarises the key steps involved in the methodology for RE technologies. The BAU scenario is used as a benchmark against which the deployment constraints for the other scenarios are calibrated using economic modelling and assumptions around roll out and policy support. The roll out of each technology in the BAU scenario is based on the best available precedent or reference point, such as the historic roll out of renewables in other countries with a similar policy and market framework to the UK.

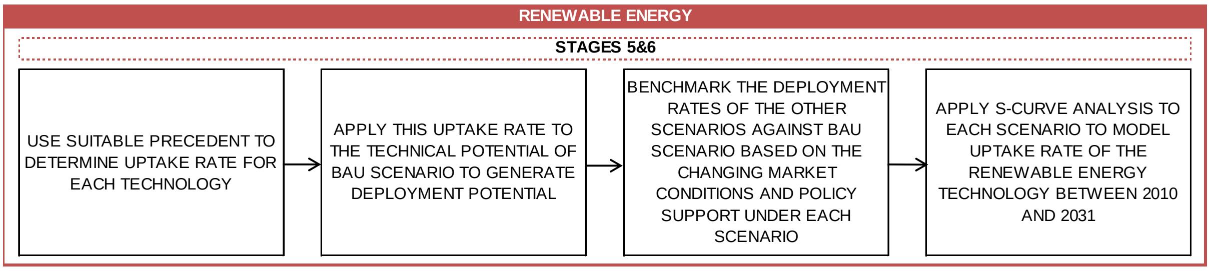

Figure 2-1: Modelling deployment potential of renewable energy technologies

For the PV and solar water heating (SWH) assessment, uptake is based on the empirical evidence of the percentage of the PV technical potential that has been installed in Germany during ten years of their feed-in tariff policy[13]. As there is no suitable evidence base for heat pump uptake rates, the uptake of energy efficiency measures is used as a proxy for installing heat pumps.

The deployment rates of the other scenarios are benchmarked against the BAU scenario based on the different market and policy conditions within each scenario. The benchmarking process involves economic modelling and constraints modelling so as to develop estimates of deployment potential for each technology under each scenario. Table 1-2 summarises the key economic and deployment parameters that have been modelled.

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[13] German Solar Industry Association (2010) Development of the German PV Market: http://en.solarwirtschaft.de/fileadmin/content_files/pv_germ_market.pdf

2.3.1.1 Modelling economic potential

The subsidy provided by FITs and the RHI enables RE technologies to be considered economically viable in most locations where they are technically viable. However, whether they are installed in any given location is dependent on the economic decision making of individual consumers and organisations. For example, the decision to invest in RE is dependent on having access to capital and the alternatives to investing this capital. The economic potential is derived through a two-step process; the internal rate of return (IRR) for each technology was first calculated to assess the attractiveness of the investment opportunity (with varying discount rate, energy price and level of subsidy across each scenario) and then the probability of a consumer investing in the RE technology was calculated based on the 'share of utility rule'[14] outlined in Equation 2-1. The share of utility rule assesses the probability of a consumer investing in a particular investment by comparing the rate of return on that investment with that of an alternative investment. The economic modelling uses the share of utility rule to compare the return on the RE investment with the alternative of investing the money in the bank. For example, where the IRR for the investment in the RE technology is equal to that of the interest rate on the bank investment (which is equal to the discount rate chosen for each scenario) then the probability of RE investment is 50%.

$$\text{Probability of investment} = \frac{\text{IRR}_{\text{(renewable investment)}}}{\text{IRR}_{\text{(renewable investment)}} + \text{IRR}_{\text{(alternative investment)}}}$$

Equation 2-1: Share of utility rule – the probability of a consumer investing in renewable energy

2.3.1.2 Modelling deployment and uptake rate

Deployment coefficients have been produced for each of the scenarios to model the impact of the deployment parameters outlined in Table 1-2 on the uptake of the RE technologies. The deployment parameters include differing levels of local and central government support, readiness of the wider market for RE installations (such as capacity of local electric grid to accept distributed power generation or increased electrical demand from heat pumps) and planning approval rates for larger scale installations. The deployment coefficients, and all underlying assumptions, for each technology are outlined in Appendices A-F.

The deployment potential calculated for each scenario is modelled on uptake over the next ten years, and generates a deployment figure for 2020. The deployment potential for 2015, 2025 and 2031 are then derived by applying a sigmoid function (S-curve) as a model of market growth. S-curves describe the initial slow market growth of a product through early adopters which is then followed by an increased uptake rate as the technology gets established and its economics improve. The final stage is a slowdown of the growth rate as the market reaches saturation (or support mechanisms decrease). The shape of the S-curve is calibrated to the German PV market as an example of a RE technology market's growth pattern with government support.

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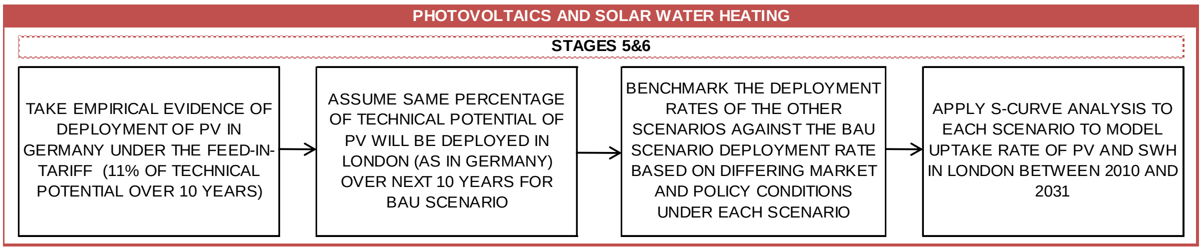
[14] Trafford Publishing (2007) Principles of Marketing Engineering: http://www.mktgeng.com/downloadfiles/technotes/tn09%20-%20conjoint%20analysis%20technical%20note.pdf

2.3.2 RE modelling methodology by technology

2.3.2.1 Photovoltaics and solar water heating

Figure 2-2 summarises the methodology for calculating the deployment potential for PV and SWH in Stages 5 and 6. For further details about the methodology for estimating the deployment potential of SWH and PV refer to Appendices C and D respectively.


PHOTOVOLTAICS AND SOLAR WATER HEATING

STAGES 5&6

TAKE EMPIRICAL EVIDENCE OF DEPLOYMENT OF PV IN GERMANY UNDER THE FEED-IN-TARIFF (11% OF TECHNICAL POTENTIAL OVER 10 YEARS)

ASSUME SAME PERCENTAGE OF TECHNICAL POTENTIAL OF PV WILL BE DEPLOYED IN LONDON (AS IN GERMANY) OVER NEXT 10 YEARS FOR BAU SCENARIO

BENCHMARK THE DEPLOYMENT RATES OF THE OTHER SCENARIOS AGAINST THE BAU SCENARIO DEPLOYMENT RATE BASED ON DIFFERING MARKET AND POLICY CONDITIONS UNDER EACH SCENARIO

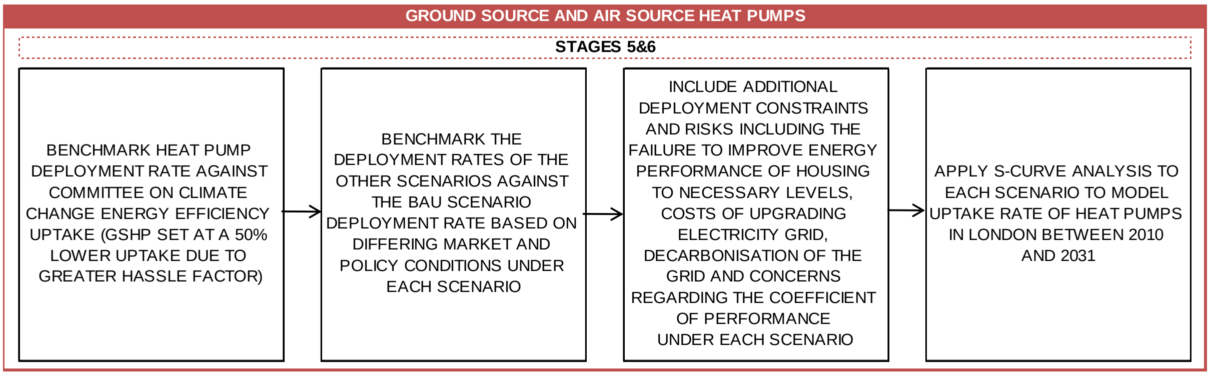
APPLY S-CURVE ANALYSIS TO EACH SCENARIO TO MODEL UPTAKE RATE OF PV AND SWH IN LONDON BETWEEN 2010 AND 2031

Figure 2-2: Methodology for quantifying deployment potential of PV and SWH

Based on the technical potential calculations carried out for Phase 1, it was estimated that Germany achieved 11% of its technical potential within 10 years of implementation of the FITs. The German FITs are set at similar rates to the UK tariffs[15] and given the similar levels of affluence and market conditions between the two countries, it is assumed that similar rates of growth for PV installations are likely in the UK. It is also assumed that SWH has the same rate of growth as PV as it has similar deployment characteristics (i.e. it is a solar, roof-top technology) and, in the same way as PV is supported by the FIT, SWH will be supported by the RHI in both non-domestic and domestic buildings from 2012 onwards.

2.3.2.2 Heat pumps

The methodology for estimating the deployment potential of ASHP and GSHP is presented in Figure 2-3. For further detail please refer to Appendices A and B.


GROUND SOURCE AND AIR SOURCE HEAT PUMPS

STAGES 5&6

BENCHMARK HEAT PUMP DEPLOYMENT RATE AGAINST COMMITTEE ON CLIMATE CHANGE ENERGY EFFICIENCY UPTAKE (GSHP SET AT A 50% LOWER UPTAKE DUE TO GREATER HASSLE FACTOR)

BENCHMARK THE DEPLOYMENT RATES OF THE OTHER SCENARIOS AGAINST THE BAU SCENARIO DEPLOYMENT RATE BASED ON DIFFERING MARKET AND POLICY CONDITIONS UNDER EACH SCENARIO

INCLUDE ADDITIONAL DEPLOYMENT CONSTRAINTS AND RISKS INCLUDING THE FAILURE TO IMPROVE ENERGY PERFORMANCE OF HOUSING TO NECESSARY LEVELS, COSTS OF UPGRADING ELECTRICITY GRID, DECARBONISATION OF THE GRID AND CONCERNS REGARDING THE COEFFICIENT OF PERFORMANCE UNDER EACH SCENARIO

APPLY S-CURVE ANALYSIS TO EACH SCENARIO TO MODEL UPTAKE RATE OF HEAT PUMPS IN LONDON BETWEEN 2010 AND 2031

Figure 2-3: Methodology for quantifying deployment potential of heat pumps

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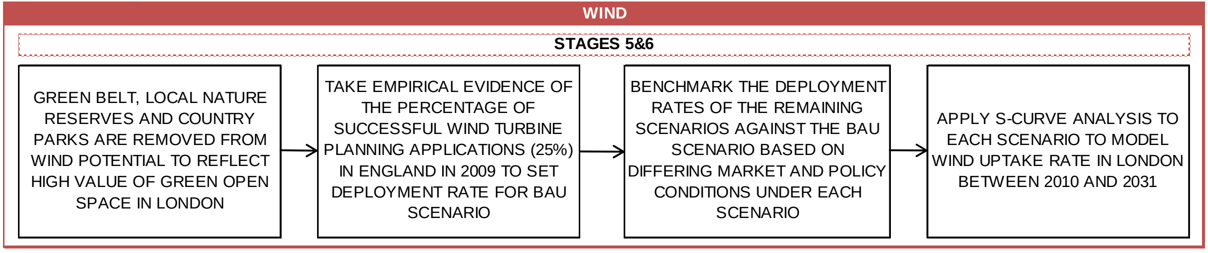
[15] E-Parliament (2010) Feed-in tariffs support renewable energy in Germany: http://www.e-parl.net/eparlimages/general/pdf/080603%20FIT%20toolkit.pdf

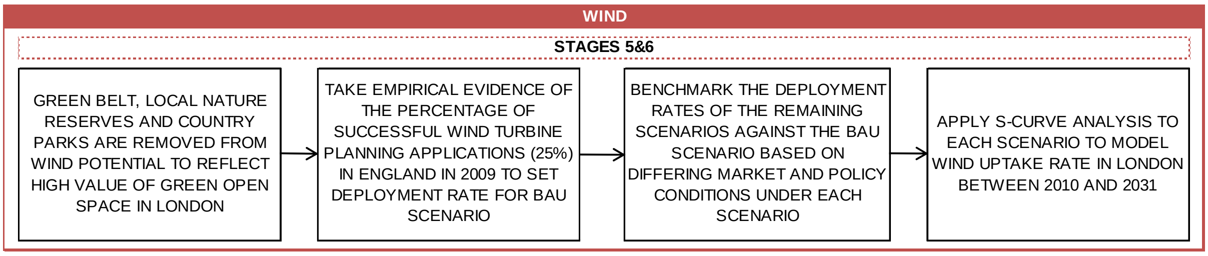
Due to a lack of empirical evidence regarding the mainstream roll out of heat pumps, the scenarios have modelled the impact of the various deployment challenges for heat pumps. Energy efficiency uptake is used as a proxy for installing heat pumps as they typically require a number of changes within the property. Heat pump installations are typically more complex and involved than PV or SWH as they require external space for locating the heat pump in addition to the internal components, the heating/ radiator system may need adjusting to a low temperature system, they are a less well known technology and they are directly competing against incumbent gas boilers in London. Heat pump uptake is benchmarked against the Committee on Climate Change's (CCC) Uptake of Energy Efficiency in Buildings report[16] as this is a key national report looking at the potential for energy efficiency and carbon reductions in buildings.

The large-scale deployment of heat pumps in London will require investment in the local electricity grid to cope with an increased demand for power. This grid investment cost is factored into the economic appraisal of heat pump deployment by assuming a charge of £1,000 for every property installing a heat pump. The actual extent and costs of the reinforcement which will be required are unclear. The Phase 1 technical potential assessment assumes that 75% of London's housing stock will be suitable for installing heat pumps by 2031 due to a large-scale low carbon refurbishment programme over the next twenty years. However, fewer homes will be suitable for the installation of heat pumps in the deployment scenarios as they assume lower levels of domestic retrofit between 40% to 60% of London's housing stock over the next twenty years GSHP are assumed to have lower deployment rates than ASHP, on the basis that the installation process is more disruptive than ASHP, requires external space for installing pipework, and is subject to additional risks due to ground conditions.

2.3.2.3 Wind

The methodology for estimating the deployment potential of commercial and small-scale wind turbines is presented in Figure *2-4*. Further detail can be found in Appendix E. Micro-scale wind turbines is not considered.





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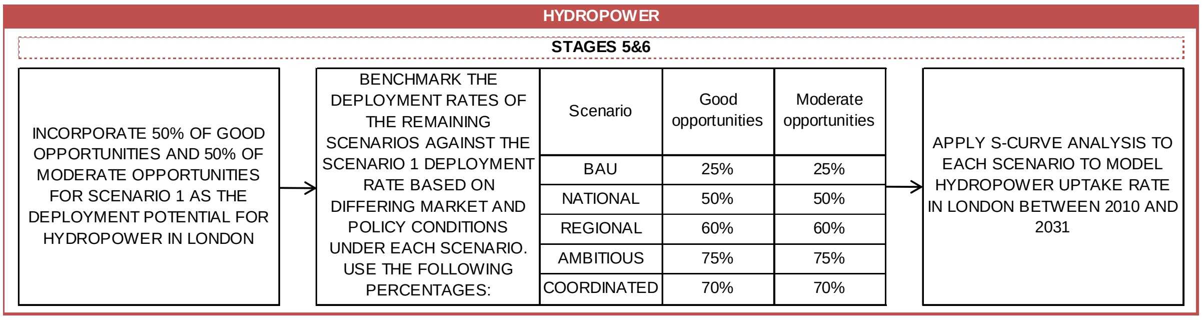
[16] Committee on Climate Change (2009) Uptake of Energy Efficiency in Buildings: http://downloads.theccc.org.uk/docs/Element%20Energy_final_efficiency_buildings.pdf

Figure 2-4: Methodology for quantifying deployment potential of wind turbines

To reflect the extremely high value of green open space in London, it is assumed that turbines are not sited in green belt areas, nature reserves or country parks, and the buffer around dwellings has been increased. Only 25% of planning applications for wind turbines were successful in England in 2009[17], and this empirical evidence is used to set the deployment rate for the BAU scenario. Higher planning permission rates are assumed for the other scenarios, with 70% assumed for the Ambitious scenario, and these rates have been informed by the higher proportion of wind turbine applications (62%) that were successful upon appeal in England in 2009.

2.3.2.4 Hydropower

The methodology for estimating the deployment potential of hydropower is presented in Figure 2-5.



INCORPORATE 50% OF GOOD OPPORTUNITIES AND 50% OF MODERATE OPPORTUNITIES FOR SCENARIO 1 AS THE DEPLOYMENT POTENTIAL FOR HYDROPOWER IN LONDON

BENCHMARK THE DEPLOYMENT RATES OF THE REMAINING SCENARIOS AGAINST THE SCENARIO 1 DEPLOYMENT RATE BASED ON DIFFERING MARKET AND POLICY CONDITIONS UNDER EACH SCENARIO. USE THE FOLLOWING PERCENTAGES:

Scenario	Good opportunities	Moderate opportunities
BAU	25%	25%
NATIONAL	50%	50%
REGIONAL	60%	60%
AMBITIOUS	75%	75%
COORDINATED	70%	70%

APPLY S-CURVE ANALYSIS TO EACH SCENARIO TO MODEL HYDROPOWER UPTAKE RATE IN LONDON BETWEEN 2010 AND 2031

Figure 2-5: Methodology for quantifying deployment potential of hydropower

The technical potential of hydropower is extremely limited and based on the 15 ‘good’ and ‘moderate’ hydropower installation opportunities identified by the Environment Agency[18]. The financial and deployment viability of these schemes will be very site specific, and determined mainly by the cost and extent of engineering works, as well as flow variability over any given year. The BAU scenario assumes that 25% of good and moderate opportunities are developed and this increases to 75% under the Ambitious scenario to reflect the improved market and policy conditions under this scenario.

2.4 Decentralised energy modelling methodology

This section sets out the methodology used to determine the economic and deployment potential for DE. An overview of the methodology is provided in Figure 2-6, followed by a description of specific elements of the methodology. A more detailed flow diagram is included in Appendix F. The methodology calculates the cost of heat from DE and compares this against a baseline cost of heat, typically individual gas boilers. The cost of heat from DE is determined by calculating the cost of heat distribution (the heat networks) and the cost of heat generation (the heat production plant and peak load/backup boiler plant) on a whole life cost basis over 40 years. DE potential is determined at middle super output area (MSOA)[19] level and includes new build. In MSOAs where DE is not viable,

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[17] British Wind Energy Association (2009) State of the industry report: http://www.bwea.com/pdf/publications/Industry_Report_08.pdf
[18] Entec UK (2010) Mapping Hydropower Opportunities in England and Wales, report for the Environment Agency: http://www.warwickshire.gov.uk/Web/Corporate/Pages.nsf/Links/AF861E015721F387802572FB004AADF6/$file/hydro+3.pdf
[19] MSOA is a geographical area used by the Office for National Statistics (ONS) representing a population of around 7,500

the viability of standalone DE in new developments is also considered. The results in this report, therefore, include new build potential unless otherwise stated. The local-scale heat networks modelled in Phase 1 are not considered in Phase 2 due to their relatively small technical potential.

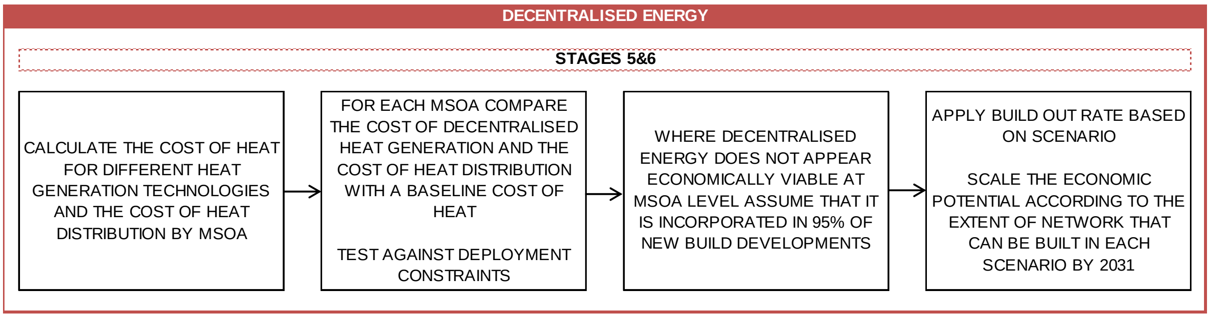

Figure 2-6: Overview of the decentralised energy modelling methodology

2.4.1 Economic and deployment potentials

The test of economic potential is based on the cost of heat distribution per unit heat delivered added to the cost of heat generation per unit heat delivered (both the low carbon technology and the peak load boiler plant assumed to provide the balance of the heat demand). For DE to be viable in a given MSOA these values must total less than the price assumed for the baseline cost of heat, modelled as a local natural gas boiler. This measure of viability is shown in Equation 2-2, where X is the unit cost of heat.

$$X_{\text{distribution}} + X_{\text{generation}} < X_{\text{baseline}}$$

Equation 2-2: Test of economic viability for DE sources

This measure of viability is more easily satisfied in areas of high heat density and areas with higher levels of non-domestic heat users because they have a low unit cost of heat distribution and a lower baseline cost of heat respectively (see Section 5 for further details on these points).

For each MSOA, the baseline cost of heat minus the cost of heat distribution is calculated, and the MSOAs ranked in descending order. This can be thought of as the difference left to pay for heat generation. This ranking is then compared with the cost of heat generation sources from lowest to highest. The lowest available cost of heat generation source is used to meet demand in each MSOA, working down the ranking. MSOAs are deemed to be viable for DE up until the condition in Equation 2-2 is no longer satisfied. Within the economic model, the deployment constraints set out in Table 2-1 are also considered.

Constraint	Description
Location factor	Location specific technologies such as existing power stations are given an additional capital cost and auxiliary energy consumption to account for necessary transmission networks
Maximum fuel availability or plant capacity	Where there is a limited supply of fuel (e.g. waste for incineration) or a limit on the total installed capacity of a technology, this is reflected in the model by capping the economic potential at the appropriate level (e.g. a limit of 2,000MW for new build large-/medium-scale CCGT is assumed
Uptake rate of connection to heat networks in a given MSOA	It is assumed that 70% of buildings in any given MSOA are connected to the heat network in that area. This is the same for all scenarios
Uptake rate for new build	New build developments are assumed to have a DE uptake rate of 95% provided they are above a minimum scale for DE
Threshold for new developments	Commercial new build developments are only given potential for CHP where the estimated heat demand of the development is over 2.5GWh/year. Residential developments are considered where the estimated heat demand is greater than 1.24GWh/year. These are both based on a CHP size of 150kWth

Table 2-1: Deployment constraints in the decentralised energy economic model

2.4.2 Cost of heat distribution

The Phase 1 report sets out a methodology for determining the length of heat network required to serve any given MSOA in Greater London based on its physical area and the number of connections to be served. This method is carried into the Phase 2 analysis, which combines capital costs (CAPEX) and operating costs (OPEX) over a 40 year lifetime using a discounted cash flow model to calculate the cost of heat distribution (see Figure 2-7). The latter includes maintenance costs of 0.5% of capital and operating costs of £50 per meter. The heat exchanger and heat meter cost is £2,300 per meter[20]. A unit cost of heat per MSOA is calculated for each scenario and used to feed into the assessment of economic potential. Since the MSOAs are of different sizes, with different heat demands and heat demand densities the cost of heat distribution varies considerably by MSOA.

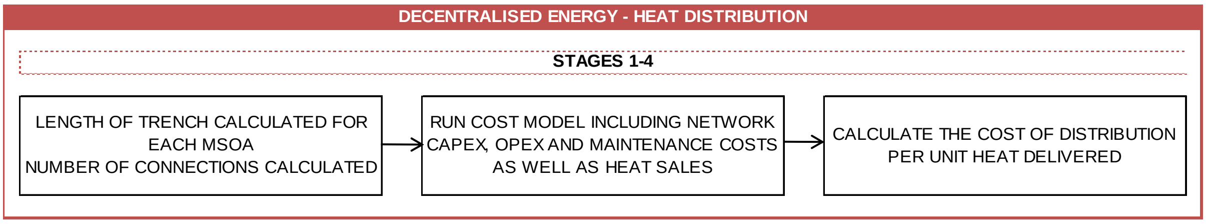

Figure 2-7: Methodology for determining cost of heat distribution

A heat network is assumed to consist of connection branch pipes and main distribution pipes. An average pipe diameter is assumed for each type based on the average load served. A cost per unit length of heat network for a given pipe diameter is used to calculate the total heat network cost for each MSOA (see Figure 2-8). The length of the heat network is calculated using the method discussed in Section 12.4 of the Phase 1 report and 70% of possible connections are assumed to be

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[20] DECC (2009), Poyry & Faber Maunsell|AECOM, The 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

connected and generate revenue[21]. The network length is therefore calculated to cover the whole MSOA but connect to only 70% of the available meters. The total heat sales for each MSOA are based on LEGGI energy consumption data for 2008[9] with the non-connected buildings subtracted and heat losses from the network added. All cost assumptions can be found in the datasheet 'Phase 2_DE Stage 5' which accompanies this report.

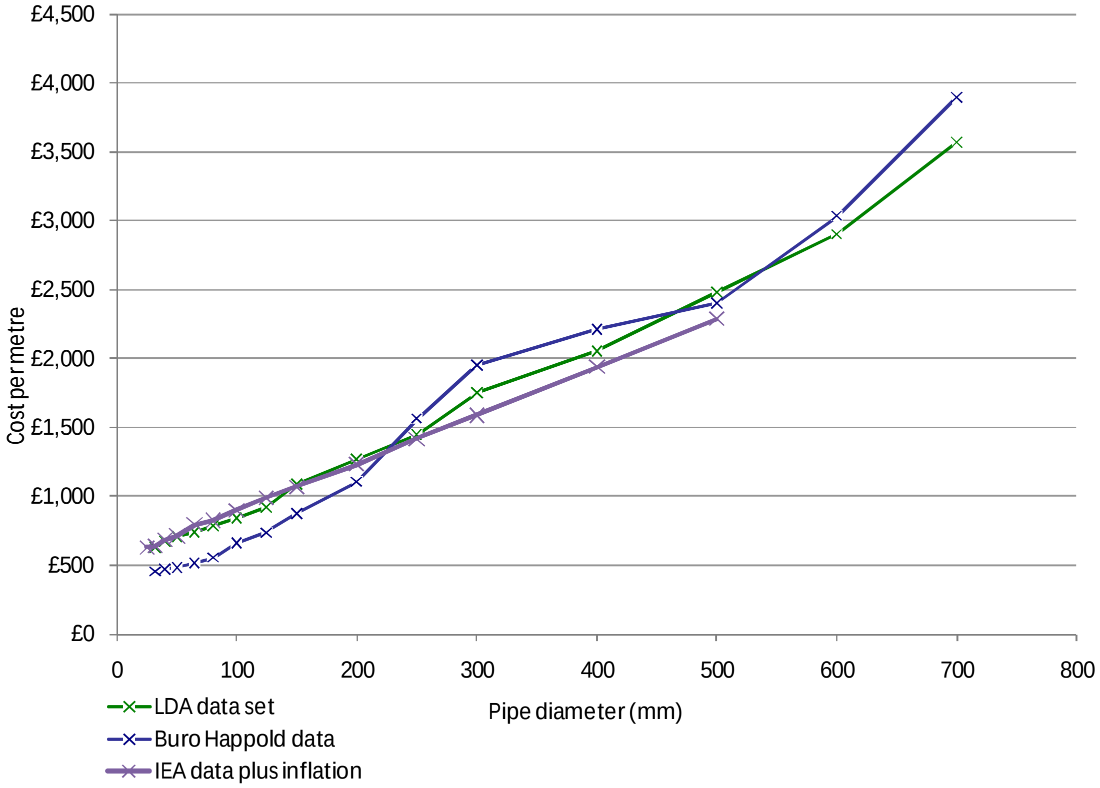

Figure 2-8: Installed pipe cost per unit trench length of heat network (Source: LDA/BH, 2009[22]; IEA, 2005[23]). Note: These figures assume installation in a roadway but do not allow for additional costs due to congestion caused by works to buried services, traffic management costs or other risk items.

2.4.3 Cost of heat generation

Figure 2-9 summarises the methodology for calculating the cost of heat generation. This is predominantly affected by the energy prices set for a given scenario as this affects the baseline cost of heat and therefore the viability of the various technologies. Fuel prices for biomass feedstocks and waste do not vary by scenario.

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[21] 70% was decided upon by the project team following the most recent Pöyry study for DECC which used 80%[11]. This was considered by the project team to be an optimistic assumption and it was decided to use a more conservative figure.

[22] LDA/Buro Happold (2009) Analysis undertaken for the London Thames Gateway Heat Network business case study

[23] IEA (2005) A comparison of distributed CHP/DH with large scale CHP/DH, Figure 6-G (inflation applied @3.5%/annum to 2010): http://www.iea-dhc.org/010601.html

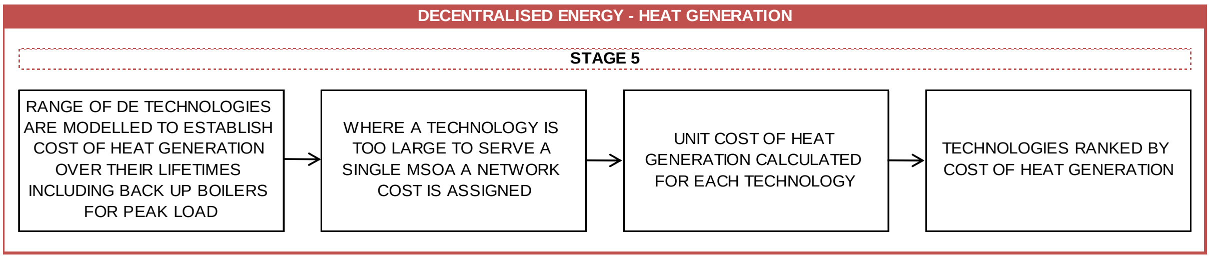

Figure 2-9: Methodology for determining cost of heat generation

Capital and operating costs for each technology are calculated from a variety of sources and are constant across all scenarios. Where a technology is too large to serve a single MSOA, or a cluster of MSOAs, or is likely to be located remotely from the MSOA being served, a network cost is calculated. For further detail see datasheet 'Phase 2_DE Stage 5' which accompanies this report.

After the unit cost of heat by scenario is calculated, heat generation technologies are ranked according by cost and the economic viability is then determined using a discounted cost of heat model. The unit cost of heat supplied is calculated to be equivalent to the price of heat required for the project to have a net present value (NPV) of zero. Equation 2-3 shows how the cost of heat is derived using a discounted cash flow model.

$$NPV_{project} = \text{net present value of project}$$

$$h_i = \text{heat sold in a given year (year i)}$$

$$X = \text{price of heat}$$

$$d_i = \text{the discount factor for a given year (year i)}$$

$$\text{Heat revenues} = \frac{Xh}{d} = NPV_{project} = \sum \frac{xh_i}{d_i} = x\sum \frac{h_i}{d_i} = NPV_{project}$$

$$\text{Equivalent unit} = X = \frac{NPV_{project}}{\sum \frac{h_i}{d_i}}$$

Equation 2-3: Cost of heat equation

The DE technologies used in the Phase 2 analysis are listed in Table 2-2 and Table 2-3 below. These come from Table13-2 and Table 13-4 in the Phase 1 report[24].

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[24] These tables differ from their Phase 1 equivalents in the following ways: 'Waste heat (from large-scale CCGT and existing energy from waste)' and 'Large-scale heat pumps using waste heat' from Phase 1 are not used. 'Waste heat from existing energy from waste plant' and 'Waste heat from existing power plant' are used instead in Phase 2. Alternative sources of heat are discussed in the Phase 1 report (Section 13.4). Geothermal deep bore heat pumps, which have no technical potential in London, are not included here and the waste heat from nuclear plant and power stations outside London used in Phase 1 are combined for Phase 2 into 'Waste heat from power station outside London'.

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
Waste heat from existing energy from waste plant	Y	N	Residual waste and biomass	Avoided electricity revenue
Waste heat from existing power plant	N	N	Natural gas	Avoided electricity revenue (includes link to natural gas wholesale price)

Table 2-2: Conventional sources of heat used in decentralised energy analysis

Heat generation technology	**Description**	**Available resource from Phase 1 report (GWh of fuel)**
Electrical grid overspill	Effectively large-scale heat pumps at local energy centres, operated using intermittent and off-peak low cost electricity	14,235
Heat recovery from sewage	Making use of the heat available in sewage plant outflows	3,275
Heat rejection from air conditioning	Making use of the heat rejected from building cooling and refrigeration systems	8,500
Waste heat from power station outside London	Using waste heat from power plants outside London, including nuclear and potential new carbon capture and storage equipped plant replacing existing power stations due to be decommissioned under the Large Combustion Plant Directive. Estimates of heat loss from large diameter heat transmission pipelines (>600mm diameter) show that less than 10% of heat transmitted is lost[25].	Phase 1 waste heat from nuclear plant: 6,570 Phase 1 waste heat from power stations: 13,000 = 19,570

Table 2-3: Alternative sources of heat used in decentralised energy analysis

The Phase 2 assessment considers a broader range of fuels than those included in the Phase 1 RE assessment, which limits the technical potential of biomass to fuel available in London and the Greater South East. Phase 2 also covers imported biomass from outside the Greater South East and non-renewable waste resources. The different types of biomass and waste fuels are assigned to different types of plant (as shown in Figure 3.9) to determine the cost of heat and amount of fuel available. Gasification and existing incineration plants use both renewable and non-renewable fuels. The available fossil fuel fraction is determined from GLA waste data[26] and added to the fuel sources identified in the Phase 1 assessment, along with the imported biomass. The availability of imported biomass up to 2031 is highly uncertain and driven by global variations in energy prices and energy demands. For the purposes of the modelling it is assumed to be available up to a maximum level equivalent to the fuel demand of 300MW of biomass CHP plant, and assigned to 'Biomass CHP – large' and to 'Biomass district heating'.

2.5 Decentralised energy in new build development

The London Plan[27] requires developers to include DE or RE within new build development. This can be an effective way to bring forward the development of heat networks, particularly where they are located in an area with the potential for a more extensive heat network. The potential for DE in new build development is included in the main DE assessment and deployment potential results. The potential for DE in new build developments outside of MSOAs where DE is viable is calculated separately and added to the deployment potential, on the basis that all new development is required to include DE.

An additional high level assessment of the influence of planning policy on DE potential related solely to new build development across London has been undertaken. The results of this assessment are in

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[25] See Section 3.10 in the Phase 3 report for more detail

[26] GLA (2010) Mayor's draft Municipal Waste Management Strategy 2010. http://www.london.gov.uk/consultation/waste-strategy

[27] GLA (2008) The London Plan: Spatial Development Strategy for Greater London, Policy 4A.5 and 4A.6: http://www.london.gov.uk/thelondonplan/docs/londonplan08.pdf

Table 3-5. This is intended to assess its potential contribution against London's total energy demand and the following section sets out the methodology for each of these assessments.

2.5.1 Energy demand from new build development

The energy demand from new build development is estimated separately to allow for the three assessments outlined above. For MSOA-level DE potential, the MSOA-level energy demand is scaled down so that the overall energy consumption from existing stock and new build development equals the total demand in 2031 as predicted by the 2050 pathways (see Section 1.3.2).

Table 2-4 lists the data sets used for estimating the heat demand from new commercial development between 2010 and 2031. The data sets contain information on additional floor space used or additional jobs created rather than direct energy consumption figures. A conversion is therefore made using the following assumptions:

- Where the building type is not specified a distinction is made between inner and outer borough employment densities to estimate a floor area[28]
- CIBSE TM46 benchmarks are used to assign each development a fossil thermal consumption based on its floor area
- The benchmarks are adjusted using a 44% reduction in demand to account for reductions in energy use associated with improvements to the building regulations. This is based on the likely minimum improvement of buildings under Part L 2013 versus a baseline of Part L 2006

Dataset	Description	Source
London employment sites database 2009, London Development Database	Contains the addresses of new commercial developments, floor areas and jobs created split into building types	GLA (2009)[28]
Glenigan	Contains the addresses of new commercial developments with the total number of jobs created and the overall land use	GLA (2009)[28]
Brownfield data	Contains the addresses of new commercial developments with the total number of jobs created and the overall land use	LDA (2010)[29]

Table 2-4: Datasets used to determine energy demand from new build development in DE model

For new residential development, the Strategic Housing Land Availability Assessment[30] is used as described in the Phase 1 report. This contains address data and projected number of units for new housing developments. An average dwelling size of 75m^2 is assumed, based on typical new developments with apartments, alongside a heat consumption of 55kWh/m^2. This assumes new build flats are designed to meet level 4 under the Code for Sustainable Homes, which uses SAP 2009

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[28] GLA (2009) London Employment Sites Database 2009. Summary paper here: http://www.london.gov.uk/archive/mayor/economic_unit/docs/emp-proj-techpaper1.pdf

[29] LDA (2010) Brownfield land database: http://www.londonbrownfieldsites.org/Content/home.aspx

[30] 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

to determine energy demand[31]. This also compliments the commercial assumptions as it is equivalent to a 44% reduction on Part L 2006.

2.5.2 Economic and deployment potential of DE in new development

The modelling assumes that 95% of new development can make use of DE. In practice this is likely to be significantly lower. Furthermore, for the purposes of this study, a minimum CHP size of 150kW heat output (around 100kW electrical output) is assumed, based on a gas engine CHP unit. Developments with heat demands below this minimum threshold are excluded from the deployment potential. More information can be found in the datasheet 'Phase 2_DE Stage 5' which accompanies this report.

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[31] Based on results of project work by Buro Happold on new build developments in London

3 Deployment potential

3.1 Overview

This section sets out the overall results for the deployment potential, broken down by scenario. The results represent Stage 6 of the DECC methodology. An analysis is provided in Section 4, whilst the methodology and roll-out assumptions for RE and DE technologies are covered in Section 2. All the results are based on economic modelling for 2031, with deployment in earlier years extrapolated from this potential.

3.2 Summary of scenario results

A number of general conclusions emerge from the analysis. The first is that there is no single dominant energy source. Heat pumps and PV have the highest deployment potential of the RE technologies. There is a bias towards gas-based DE in three scenarios. However, in the Ambitious action scenario the heat sources are predominantly waste heat and biomass. Biomass and waste dominate the National action scenario. There is also significant variation between scenarios, particularly with regard to the overall potential suggesting that policy must be carefully tailored to deliver the higher levels of deployment potential.

The analysis also suggests that the Mayor's Climate Change Mitigation and Energy Strategy's target to supply a quarter of London's energy from decentralised sources by 2025[32] is achievable. However, realising this level of ambition will require significant changes to national policy and a concerted effort across all levels of government and the private sector. Beyond 2031, gas-fired DE sources will no longer be effective at reducing emissions relative to a decarbonised electricity grid, and a switch to lower carbon fuels will be required. This is discussed further in Section 4.

3.2.1 Overview by scenario

The overall deployment potential for RE is summarised in Figure 3-1 and Table 3-1. This excludes those technologies linked to heat networks which are included within the DE results. The overall deployment potential for DE is summarised in Figure 3-2 and Table 3-2.

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

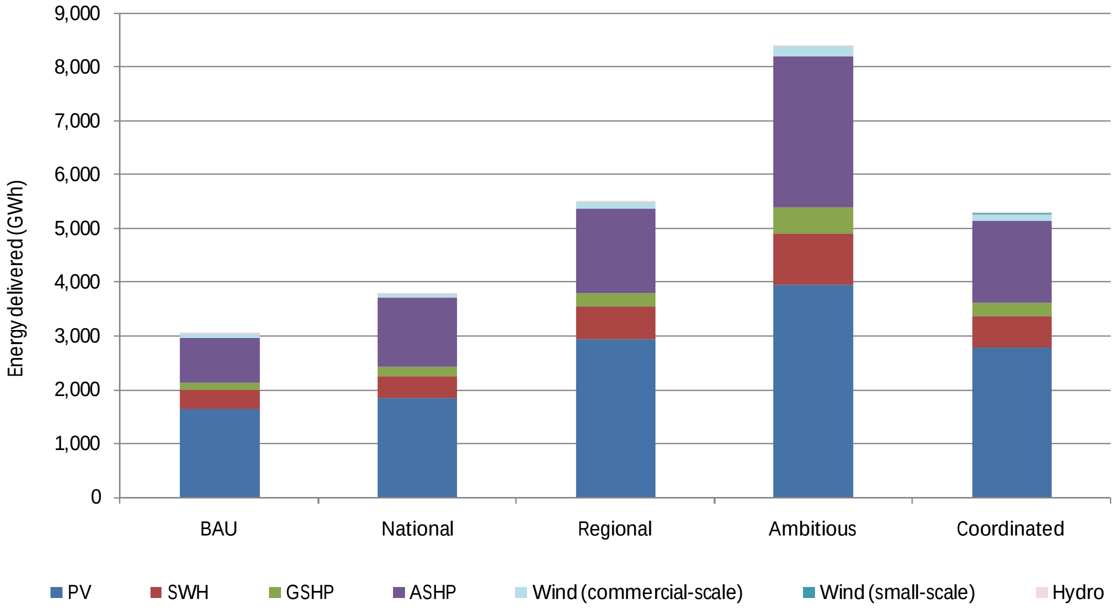

Figure 3-1: Summary of deployment potential of renewable energy (excluding renewable energy connected to heat networks) by source and scenario, 2031

		BAU	National	Regional	Ambitious	Coordinated
Capacity (MW)						
Photovoltaic (PV)		1,991	2,229	3,555	4,785	3,378
Solar water heating (SWH)		542	625	932	1,480	878
Ground source heat pump (GSHP)		103	154	204	397	212
Air source heat pump (ASHP)		708	1,059	1,310	2,317	1,269
Wind (commercial-scale)		35.3	39.0	75.0	109	75.7
Wind (small-scale)		1.5	1.7	3.6	5.1	3.4
Hydro		0.7	1.5	1.8	2.3	1.8
Total	**Electricity**	**2,028**	**2,271**	**3,635**	**4,901**	**3,459**
	Heat	**1,353**	**1,838**	**2,446**	**4,194**	**2,359**
Energy delivered (GWh/year)						
Photovoltaic (PV)		1,646	1,844	2,940	3,957	2,793
Solar water heating (SWH)		348	402	599	952	565
Ground source heat pump (GSHP)		124	186	246	480	256
Air source heat pump (ASHP)		856	1,279	1,583	2,799	1,533
Wind (commercial-scale)		59	65	125	181	126
Wind (small-scale)		1.9	2.1	4.5	6.4	4.3
Hydro		5.9	12.0	14.3	17.9	14.3
Total		**3,041**	**3,790**	**5,512**	**8,392**	**5,292**
% of London's energy demand, 2031		2.3%	3.5%	5.1%	7.7%	4.9%
Deployment potential as a percentage of Stage 4 technical potential		10.5%	13.0%	18.9%	28.9%	18.2%
Deployment potential as a percentage of Stage 5 economic potential[33]		13.3%	13.9%	19.2%	22.5%	18.8%
Carbon savings (MtCO$_2$/year)		**0.7**	**0.7**	**1.5**	**1.6**	**1.1**

Table 3-1: Summary of deployment potential of renewable energy (excluding renewable energy connected to heat networks) by source and scenario, 2031

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[33] The economic potential is for 2020 due to the methodology used for RE. It also does not include hydro power

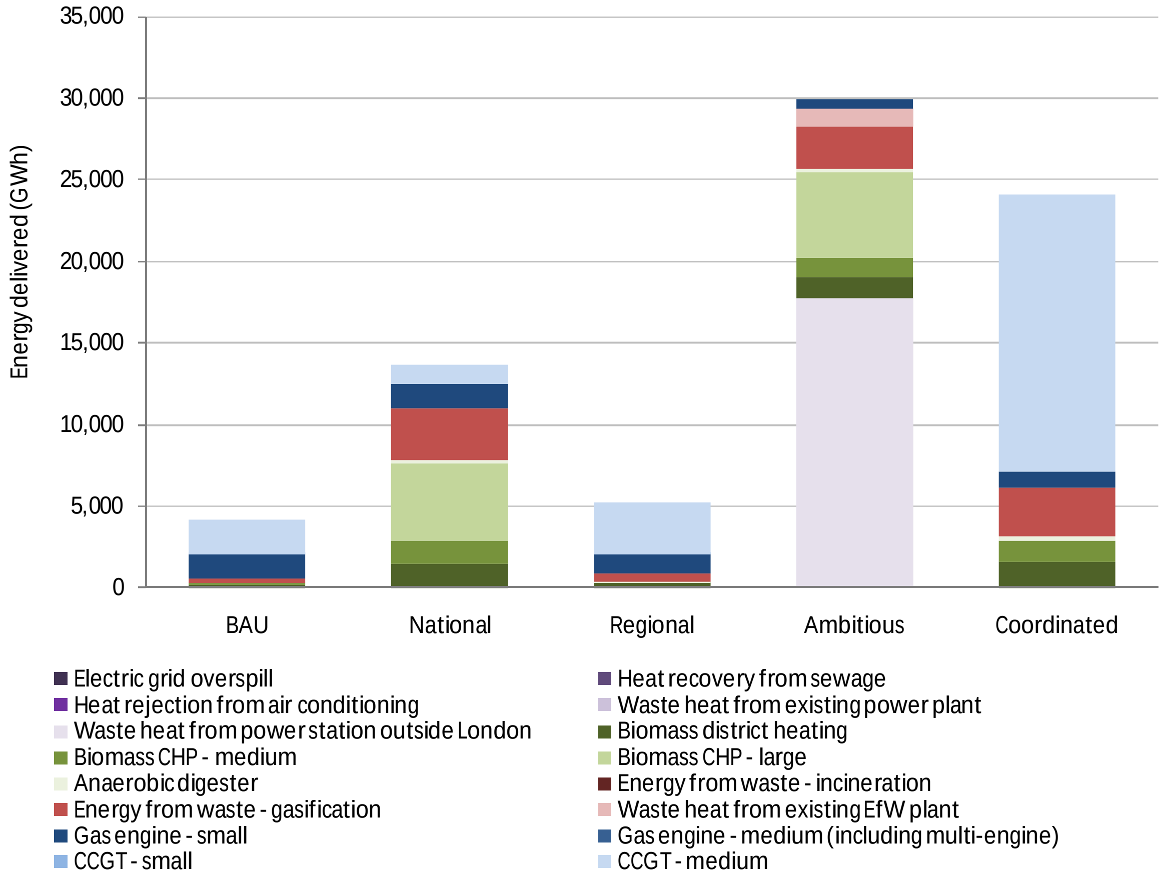

Figure 3-2: Summary of deployment potential of decentralised energy (excluding renewable energy not connected to heat networks) by source and scenario, 2031

		BAU	National	Regional	Ambitious	Coordinated
Capacity (MW)						
Anaerobic digester	Electricity	1.5	13.5	2.4	10.9	12.8
	Heat	2.2	19.3	3.4	15.6	18.3
Biomass CHP – large	Electricity	-	172.3	-	191	-
	Heat	-	402.0	-	446	-
Biomass CHP – medium	Electricity	1.2	36.5	0.1	29.5	34.5
	Heat	4.5	135.4	0.2	109.2	128.0
Biomass district heating	Electricity	-	-	-	-	-
	Heat	73.6	73.6	73.6	73.6	73.6
CCGT – medium	Electricity	184	108	278	-	1,468
	Heat	143	84	216	-	1,142
CCGT – small	Electricity	0.59	-	0.1	-	-
	Heat	0.54	-	0.1	-	-
Electrical grid overspill	Electricity	-	-	-	-	-
	Heat	-	-	-	-	-
Energy from waste – gasification	Electricity	14.4	129	22.5	103	122
	Heat	29.4	262	45.9	211	248
Energy from waste – incineration	Electricity	-	-	-	-	-
	Heat	-	-	-	-	-
Gas engine – medium (including multi-engine)	Electricity	-	-	-	-	-
	Heat	-	-	-	-	-
Gas engine – small	Electricity	90.9	90.2	74.2	31.0	59.1
	Heat	169	168	138	57.6	110
Heat recovery from sewage	Electricity	-	-	-	-	-
	Heat	-	-	-	-	-
Heat rejection from air conditioning	Electricity	-	-	-	-	-
	Heat	-	-	-	-	-
Waste heat from existing energy from waste plant	Electricity	-	-	-	94.2	-
	Heat	-	-	-	94.2	-
Waste heat from existing power plant	Electricity	0.57	-	0.1	-	-
	Heat	0.57	-	0.1	-	-
Waste heat from power station outside London	Electricity	-	-	-	938	-
	Heat	-	-	-	938	-
Total	**Electricity**	**293**	**550**	**377**	**1,398**	**1,696**
	Heat	**422**	**1,638**	**516**	**2,390**	**2,253**
Energy delivered (GWh/year)						
Anaerobic digester		29.5	263	46.4	213	249
Biomass CHP – large		-	4,730	-	5,270	-
Biomass CHP – medium		47.0	1,385	2.4	1,116	1,308

Biomass district heating	193	1,491	296	1,361	1,596
CCGT – medium	2,050	1,206	3,183	-	16,954
CCGT – small	7.3	-	0.9	-	-
Electrical grid overspill	-	-	-	-	-
Energy from waste – gasification	352	3,146	552	2,531	2,972
Energy from waste – incineration	-	-	-	-	-
Gas engine – medium (including multi-engine)	-	-	-	-	-
Gas engine – small	1,482	1,472	1,210	506	964
Heat recovery from sewage	-	-	-	-	-
Heat rejection from air conditioning	-	-	-	-	-
Waste heat from existing energy from waste plant	-	-	-	1,186	-
Waste heat from existing power plant	7.3	-	0.8	-	-
Waste heat from power station outside London	-	-	-	17,720	-
Total	**4,168**	**13,693**	**5,291**	**29,903**	**24,044**
% of London's energy demand, 2031	3.1%	12.6%	4.9%	27.5%	22.1%
Deployment potential as a percentage of Stage 4 DE technical potential	16.0%	52.4%	20.3%	114.5%	92.0%
Deployment potential as a percentage of Stage 5 DE economic potential including new build	15.4%	96.6%	20.4%	74.7%	88.6%
Heat network length (km)	2,007	3,540	2,089	8,316	4,701
Number of connections[34]	46,500	78,811	47,989	189,350	101,211
Number of meters	254,049	457,414	265,995	865,988	575,875
Carbon savings (MtCO$_2$/year)	**0.3**	**2.0**	**0.4**	**2.9**	**0.8**

Table 3-2: Summary of deployment potential of decentralised energy (excluding renewable energy not connected to heat networks) by source and scenario, 2031

3.2.2 Combined potential

Table 3-3 shows the combined potential for DE and RE followed by a summary of the results by scenario.

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[34] The number of connections assumes for example that a semi detached property will share a connection as will a block of flats. This number therefore indicates the number of pipes coming off the main transmission pipe. The number of meters is the number of individual dwellings or commercial buildings who receive the energy. It is assumed that they will each have an individual meter.

Energy delivered (GWh/year)	**BAU**	**National**	**Regional**	**Ambitious**	**Coordinated**
Total renewable energy	3,041	3,790	5,512	8,392	5,292
Renewable energy linked to heat networks	488	9,819	687	9,529	4,996
Decentralised energy (not including renewable energy sources)	3,680	3,874	4,604	20,374	19,048
Total	**7,209**	**17,483**	**10,803**	**38,295**	**29,336**
% of London's energy demand, 2031	5.4%	16.1%	9.9%	35.2%	27.0%
Deployment potential as a percentage of Stage 4 DE technical potential	14.4%	35.0%	21.6%	76.6%	58.7%
Deployment potential as a percentage of Stage 5 economic potential	14.4%	42.2%	19.8%	49.5%	53.1%
Carbon savings (MtCO$_2$/yr)	**1.0**	**2.7**	**1.9**	**4.6**	**1.8**

Table 3-3: Combined deployment potential by scenario, 2031

3.2.3 Summary of scenario results

Further detailed results by scenario are given in Appendix G

Business as usual

Under the BAU scenario the combined deployment potential is low, with that for RE (excluding RE connected to heat networks) similar to DE due to the subsidies in place for the former, but high discount rates reducing the economic potential of the latter. The contributions from PV and ASHP are significant, but the overall deployment potential is limited by uptake constraints. Providing heat from DE is only economically viable in the highest density areas due to the high discount rate, lack of support for electricity generated using CHP and the relatively low baseline cost of heat. This reflects other research that suggests there is almost no business case for investment in DE systems beyond publically controlled schemes or planning policy driven schemes in new development[11]. Limited or no further action would be required, other than the safeguarding of current subsidies for RE, however deployment could be enhanced by mass market mobilisation of the supply chain and awareness raising. The risks associated with this scenario are low, but it does not deliver significant carbon savings.

National action

In the National action scenario more favourable roll out assumptions and a higher baseline cost of energy result in higher RE potential. PV and ASHP are the main RE sources. Higher baseline heat costs and a medium discount rate make DE competitive in areas of high heat demand density. Combined cycle gas turbine (CCGT) CHP provides the majority of DE potential with some input from biomass CHP and energy from waste plant (new and existing). This is a likely scenario should gas prices increase due to supply constraints, alongside an increase in the cost of electricity due to investment in decarbonising the electrical grid. To achieve these deployment potentials significant mobilisation of the supply chain and awareness raising are required as well as providing low cost funding via a green investment bank or local energy efficiency fund. A significant investment in heat networks would be required to deliver the DE potential. The scenario is unlikely without significant intervention at national level to decarbonise the grid. It requires decarbonisation of the grid to ensure savings from ASHP are realised and it requires intervention to increase uptake of heat network connections, as well as a mechanism to reduce the cost of capital.

Regional action

In the Regional action scenario the potential from RE is high due to the favourable roll out assumptions and supportive planning policy. The cost of heat from DE is relatively unattractive due to the low cost of baseline heat, and DE deployment is not significantly enhanced beyond the BAU scenario, with a similar generation mix. This indicates that more nationally influenced parameters such as cost of capital and energy prices have the greatest effect on DE deployment. Deployment of DE is severely constrained by the build out rate of heat networks. The economic framework to support this scenario is in place for RE, but it would require an increase in uptake rates through some form of intervention. It would require low cost funding for DE, but a more favourable combination of energy prices would be required to further increase deployment.

Ambitious action

The potential for RE in the Ambitious action scenario is very high due to the combination of favourable roll out assumptions and high baseline costs of energy (making natural gas unaffordable). DE potential is very high, surpassing the technical potential identified in the Phase 1 report, as the high baseline cost of heat supports higher heat distribution costs, even outside of the highest heat density areas. A mix of generation sources emerges due to the high cost of gas, many of which are resource limited such as waste heat, biomass and energy from waste. Heat network roll out rates are extremely high and do not constrain deployment, but this build rate has very few precedents. This scenario is unlikely while secure and relatively low cost sources of natural gas are available, however in the longer term it demonstrates that a significant part of London’s energy demand could be met via RE and DE. To achieve this requires accelerated roll out of RE technologies. Action is required to ensure the supply chain is in place to react to future demand were natural gas security of supply be compromised. This would also include establishing heat networks in high density areas in order to have sufficient heat demand to utilise large sources of low carbon heat when they become economically viable.

Coordinated action

Under the Coordinated action scenario RE and DE deployment are also high. RE reaches a similar level to the Regional scenario as the roll out assumptions are very similar, whilst the differences in energy prices have a more limited effect. As with the other scenarios PV and heat pumps dominate the potential. The DE potential is high due to energy prices which make gas-fired DE sources competitive, as well as the relatively high heat network roll out rate. Gas-fired DE sources dominate due to the favourable energy prices, with heat from medium scale biomass CHP and biomass district heating providing the majority of emission reductions. Carbon emission reductions are less than half those of the ambitious scenario, and significantly lower than in the national and regional scenarios despite the much higher overall deployment potential. This is due to the very low carbon intensity for electricity under this scenario, together with the DE potential being dominated by gas-fired heat sources. Gas-fired heat sources result in increases in emissions as the carbon intensity of the offset electricity is much lower than the electricity generated. The heat output therefore has a carbon intensity which is higher than heat from gas boilers once network losses are included. A more detailed analysis of this scenario can be found in Section 5.4.

CCGT dominates the results due to a combination of relatively low cost of heat and an abundant amount of heat. Further analysis was therefore undertaken to assess the effect of limiting new build medium-scale CCGT plant to that represented by an extension to Barking Power Station of 500MW. In practice the scope for new build CCGT plant will be more limited due their size and lower land costs outside London. The results (see Figure 3-3) show a more varied mix of technologies with more biomass CHP, energy from waste and waste heat replacing CCGT. In this case the DE potential in the Coordinated action scenario reduces to 16.7% of energy demand by 2031, as the higher cost of heat generation reduces the number of MSOAs where DE is viable. However, the increased use of biomass and waste fuels means DE carbon emissions savings increase from $0.8MtCO_2$ to $2.2MtCO_2$.

Waste heat can be a key enabler of a low carbon heat supply as it can be established with relatively low capital costs. This allows heat network to be built incrementally with minimal investment in the heat generation plant. Once heat networks are established, the marginal cost of heat extraction from the existing power station can be very low as the climate change levy exemption available on the power output can offset the lost electricity generation. As heat networks grow further sources can be added. This analysis is expanded in Phase 3 of the study.

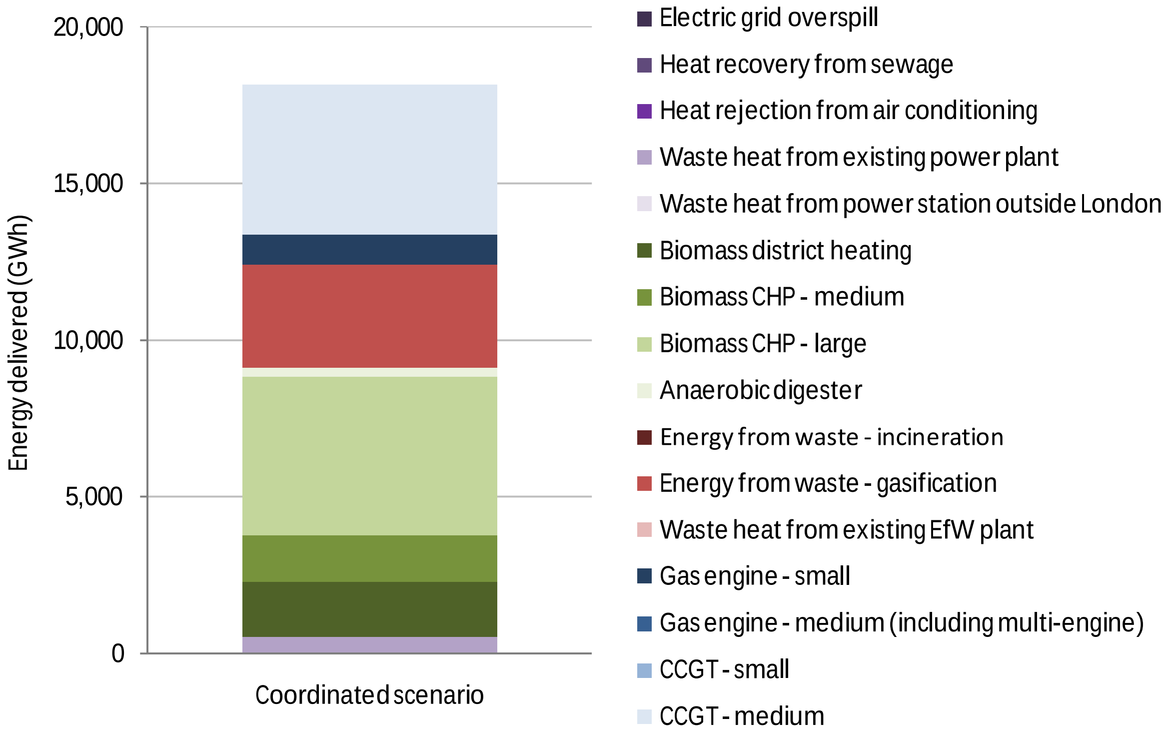

Figure 3-3: Deployment potential of decentralised energy in the Coordinated action scenario with a 500MW limit on new build medium-scale CCGT plant, 2031

3.2.4 Deployment rates

Table 3-4 shows the roll out of RE and DE from 2015 to 2031 in 5 year intervals. See Appendix G for further results and roll out graphs by scenario[35]. The roll out trajectories for RE are calculated using a market deployment model. The DE trajectories assume a ramp up period followed by a constant network build out rate.

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[35] The graphs for RE in Appendix G start with the Phase 1 estimates of installed capacity in 2010. For DE, it is not possible to determine how much of the 2010 installed capacity is linked to heat networks. Therefore the deployment curves for DE start in 2011 with a capacity of zero.

Scenario		2015	2020	2025	2031
BAU	RE potential (GWh)	296	1,566	2,837	3,041
	DE potential (GWh)	370	1,255	2,579	4,168
	Total potential (GWh)	**666**	**2,821**	**5,416**	**7,209**
National	RE potential (GWh)	343	1,938	3,533	3,790
	DE potential (GWh)	816	4,814	11,366	13,693
	Total potential (GWh)	**1,159**	**6,752**	**14,900**	**17,483**
Regional	RE potential (GWh)	452	2,794	5,135	5,512
	DE potential (GWh)	354	1,438	3,189	5,291
	Total potential (GWh)	**806**	**4,232**	**8,325**	**10,803**
Ambitious	RE potential (GWh)	634	4,224	7,815	8,392
	DE potential (GWh)	910	6,663	17,227	29,903
	Total potential (GWh)	**1,544**	**10,888**	**25,041**	**38,295**
Coordinated	RE potential (GWh)	438	2,684	4,930	5,292
	RE carbon savings (MtCO$_2$)	0.1	0.8	1.4	1.1
	DE potential (GWh)	846	5,637	14,315	24,044
	DE carbon savings (MtCO$_2$)	0.07	0.5	1.4	0.8
	Total potential (GWh)	**1,284**	**8,321**	**19,246**	**29,336**
	Total carbon savings (MtCO$_2$)	**0.2**	**1.3**	**2.8**	**1.9**

Table 3-4: Roll out of decentralised energy and renewable energy for each scenario, 2015-2031

3.2.5 Carbon savings

Figure 3-4 and Figure 3-5 show the overall carbon savings for each scenario. DE has relatively low carbon savings in scenarios where gas-fired heat sources provide a lower cost of heat. In the National action and Ambitious action scenarios, where gas-fired DE sources are not competitive, there is a greater proportion of biomass and energy from waste technologies, which gives higher carbon savings. The carbon savings are greater for RE and DE in 2025 than in 2031 due to the assumed changes to the carbon intensity of grid electricity. This has significant implications as it highlights the need to switch to lower carbon sources of fuel for natural gas-fired DE systems as the electricity grid decarbonises.

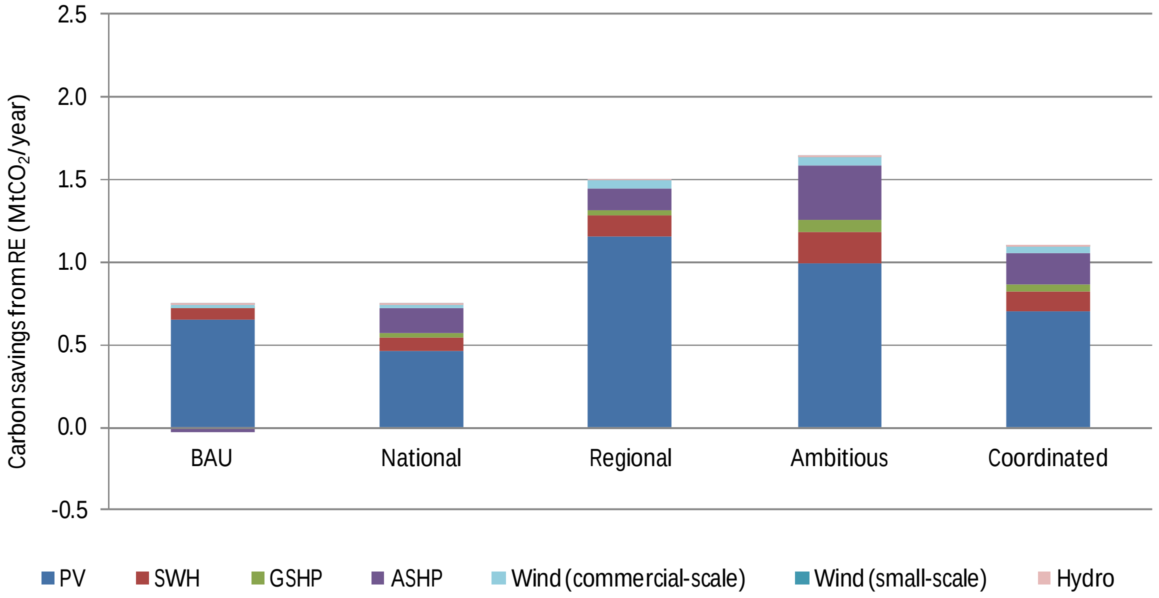

Figure 3-4: Carbon savings from renewable energy (excluding renewable energy connected to heat networks) by scenario, 2031

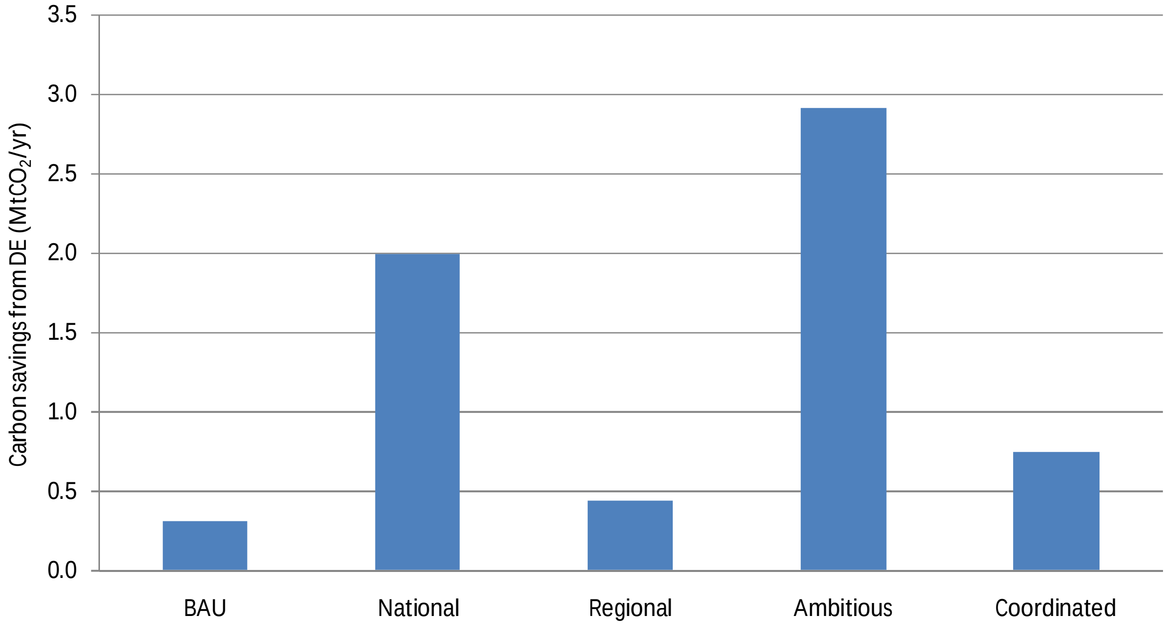

Figure 3-5: Carbon savings from decentralised energy (excluding renewable energy not connected to heat networks) by scenario, 2031

3.2.6 Capital costs

Figure 3-6 and Figure 3-7 show the overall capital costs for each scenario broken down by technology[36]. The combined capital investment of the Coordinated action scenario, for example, is approximately £27 billion, of which RE represents £19.4 billion and DE £8.3 billion. These are purely the capital costs of the technologies and do not include any operational costs or revenues. The

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[36] Note that the axes on these two graphs are not the same so as to make both graphs clear

results suggest that, compared to RE, DE requires lower levels of investment per unit of deployment potential, or per unit of carbon emission reduction. The cost effectiveness of DE on a carbon reduction basis will, however, gradually decline as the electricity grid decarbonises and gas-fired sources continue to be the primary source of energy. This can be mitigated by ensuring a high proportion of renewable fuels and waste heat is included in the generation mix, as demonstrated by the National action and Ambitious action scenarios.

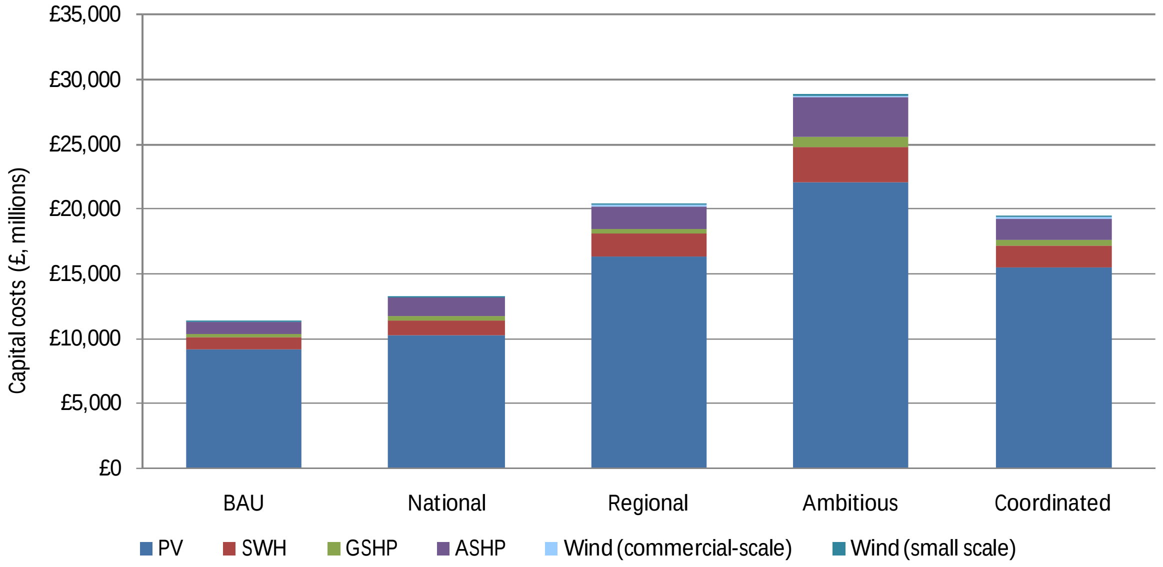

Figure 3-6: Capital costs for renewable energy technologies (excluding renewable energy connected to heat networks) by scenario, 2031[37]

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[37] The RE costs are based on domestic installations and so may represent an overestimation

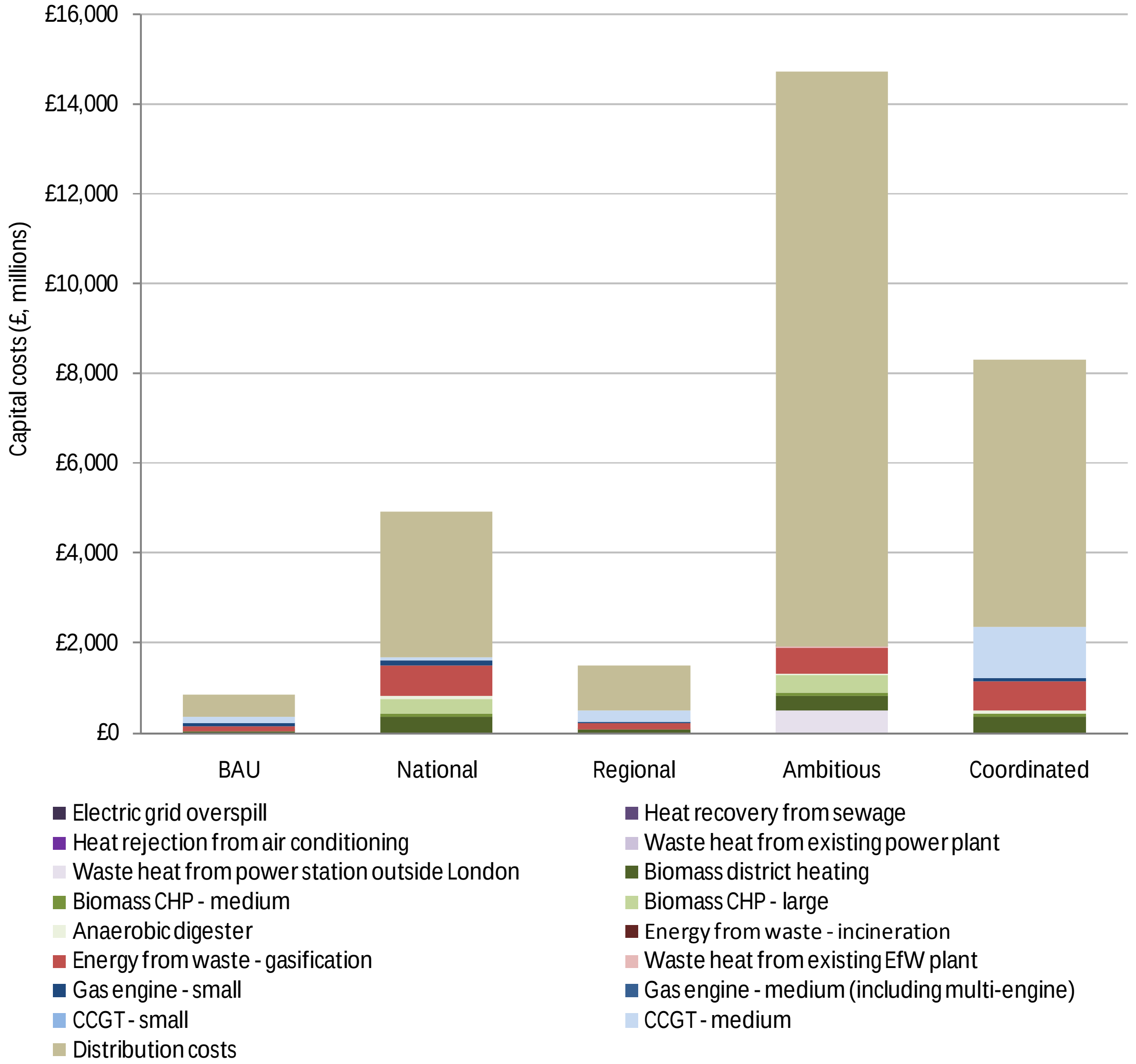

Figure 3-7: Capital costs for decentralised energy technologies (excluding renewable energy not connected to heat networks) by scenario, 2031

3.2.7 Carbon intensity

Figure 3-8 shows the carbon intensities of the DE heat generation technologies by scenario, before losses from heat networks are included. Similar technologies have been grouped to improve the readability of the figure. All of the technologies demonstrate a reduction in emissions against heat from individual gas boilers except gas-fired CHP in the Coordinated action scenario, while those technologies which generate electricity using biomass feedstocks have negative carbon intensities in all scenarios.

The carbon intensity of electricity generated is assumed to be equal to the marginal electrical grid carbon intensity and offset against the total emissions associated with the fuel use. The remainder of the total emissions are assigned to heat generation. The exception to this is energy from waste which is calculated by assuming that 62%[38] of the output is zero carbon with the remaining heat and electricity outputs assigned the marginal carbon intensity of grid electricity and carbon intensity of heat from natural gas boilers respectively. The carbon intensities of the three waste heat technologies are due to electricity lost when heat is extracted at a useful temperature from the steam cycle. For waste heat from existing energy from waste (EfW plants, the lost electricity generation has a very low carbon intensity. For waste heat from existing power plants, it is assumed that the lost electricity is from gas-fired CCGT plant, and so is much higher, though still around half of the carbon intensity of heat from individual gas boilers. For waste heat from power stations outside London, it is assumed the lost electricity generation is equivalent to the marginal electrical grid carbon intensity. See Appendix H for further detail on the above calculations.

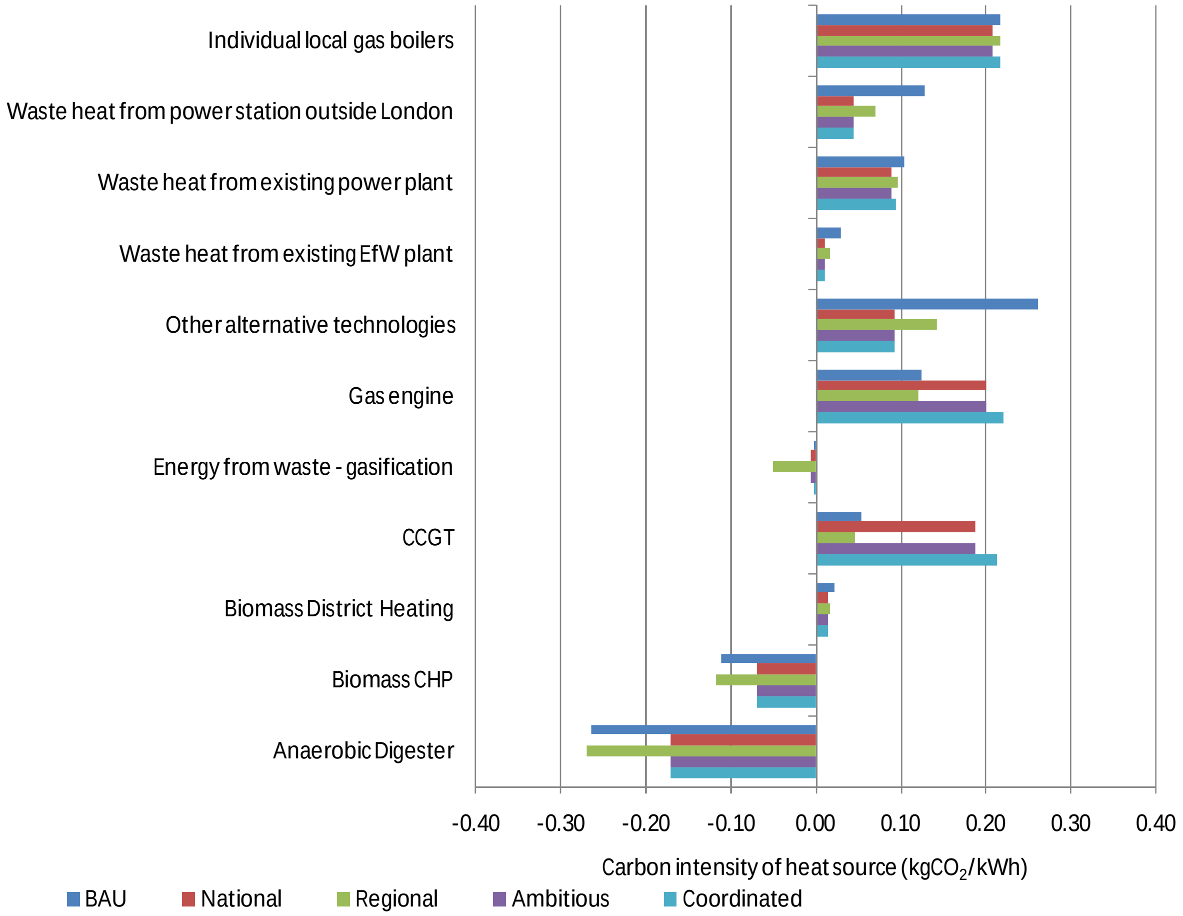

Figure 3-8: Carbon intensity of heat sources by scenario, 2031

3.3 Decentralised energy deployment potential in new development

Table 3-5 summarises the results of the standalone assessment of DE in new development using the methodology outlined in Section 2.5. These results show that DE in new developments using small gas engines (0.5Mwe) can meet up to 1.0% of London's energy demand with carbon savings ranging from 0.05 to -0.005 MtCO2 in 2031 depending on scenario. Marginal and negative carbon savings, in the National action, Ambitious action and Coordinated action scenarios, suggest that these schemes

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[38] See datasheet 'Phase 2_DE Stage 5' for the calculations leading to this number

will need to switch to a low carbon fuel, or connect to a wider heat network, to continue to be effective in reducing emissions. Note: this model does not include an allowance for heat network losses, meaning the carbon emission reductions calculated are likely to be overestimated.

Standalone DE potential in new development – Stage 5-6		**BAU**	**National**	**Regional**	**Ambitious**	**Coordinated**
Installed CHP capacity (MW)	Electricity	68.6				
	Heat	127				
Energy generation (GWh/yr)	Electricity	392				
	Heat	727				
Carbon savings ($MtCO_2$/yr)		0.05	0.00006	0.05	0.00006	-0.005
% of London's energy demand, 2031		0.8%	1.0%			
Heat network length (km)		2,010				
Number of schemes		246				
Number of meters		250,444				

Table 3-5: Summary of deployment potential of decentralised energy in new build development, 2031

3.4 Biomass supply and demand

Figure 3-9 shows the amount of biomass and waste feedstocks available for DE in the Phase 2 analysis. All of the biomass feedstocks identified in Phase 1 are used for energy generation except 50% of the food waste, animal manures and chicken litter which is diverted to compost use. In addition, non-SRF derived, non-biomass waste and woodfuel from outside the UK are included as indicated in Figure 3-9. Table 3-6 shows the proportion of this fuel that is used in each scenario. The fuel use does not reach 100% of the available resource as the Stage 6 analysis constrains deployment based on heat network build out rates which are applied pro-rata across each technology. The analysis suggests that without extensive heat network deployment, which is not achieved in the BAU and Regional action scenarios, significant reserves of biomass feedstocks go unused, and their potential for emissions reduction is not fully realised.

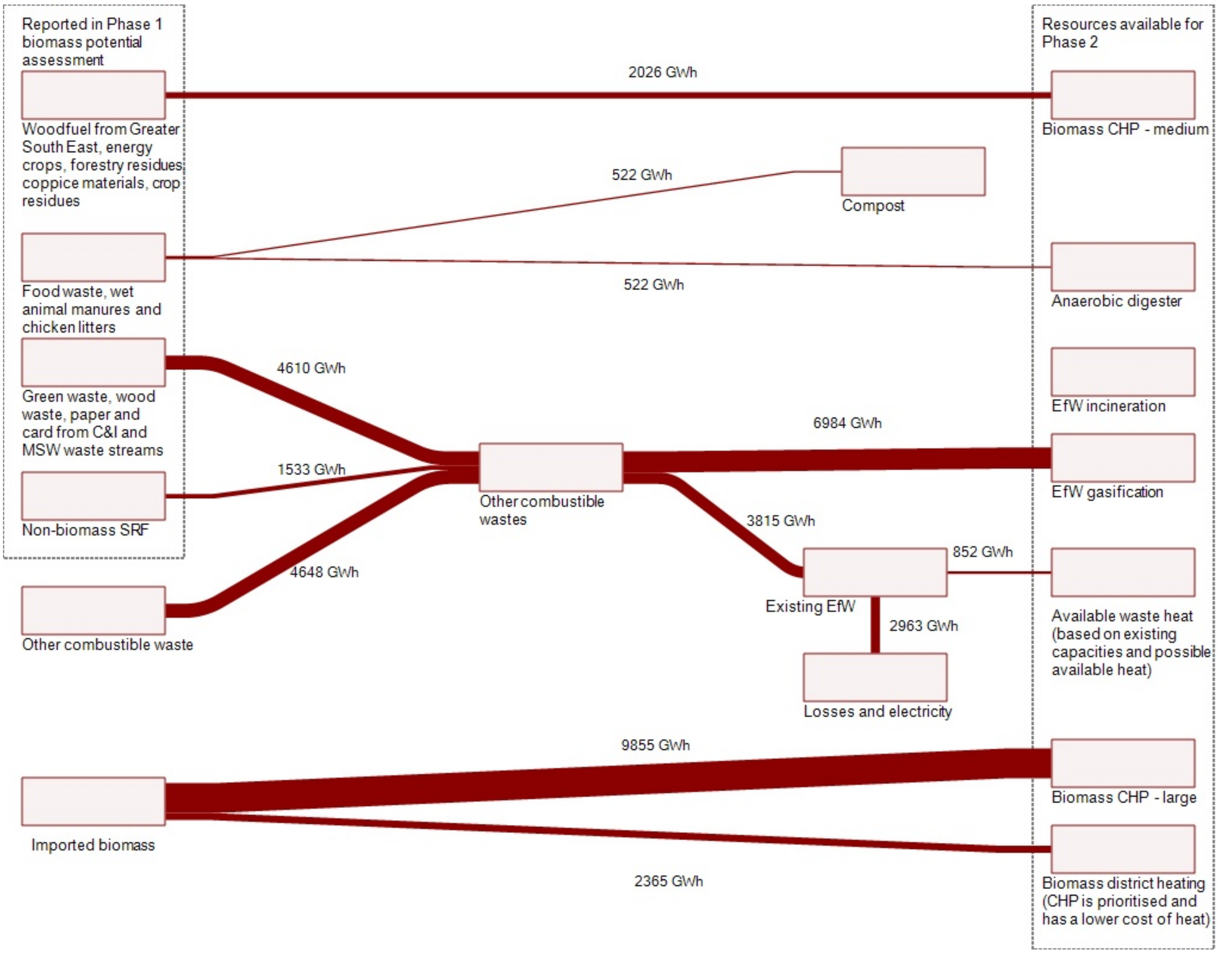

Figure 3-9: Amount of biomass available for energy generation (see Section 4.2 in the Phase 1 report for data sources)

Biomass feedstock	Fuel available (GWh)	Fuel used (% of fuel available)				
		BAU	National	Regional	Ambitious	Coordinated
Anaerobic digester	522	10.2%	92.0%	16.2%	74.0%	86.9%
Biomass CHP – medium	2,026	3.3%	92.0%	0.2%	74.0%	86.9%
Biomass CHP – large	9,855	-	66.0%	-	74.0%	-
Biomass district heating	2,365	10.2%	80.4%	16.2%	74.0%	86.9%
Energy from waste – gasification	6,984	10.2%	92.0%	16.2%	74.0%	86.9%
Energy from waste – incineration	0	-	-	-	-	-
Waste heat from existing EfW plant	852	-	-	-	74.0%	-

Table 3-6: Biomass fuel used in decentralised energy potential by source and scenario, 2031

4 Technology specific analysis

4.1 Overview

This section provides further insight into key aspects of the methodology and assumptions used in the modelling. First, heat pumps and solar technologies are addressed, followed by the cost of heat distribution and generation and their effect on the uptake of DE.

4.2 Renewable energy technologies

The RE technologies with the greatest technical potential in Greater London are ASHP and PV (see Table 1-1). The FIT and RHI have a significant impact on improving the economics of PV and heat pump installations, so that both technologies are economically viable in almost all properties where they are technically viable (following the full implementation of the RHI). The proportion of this technical potential that translates into the deployment potential is therefore governed by the assumptions regarding deployment constraints and uptake rates.

4.2.1 Heat pump deployment constraints

In practice, the large-scale deployment of heat pumps will be extremely challenging due to direct competition from gas boilers over the short- to medium- term and constraints to their mass market uptake. These are incorporated within the scenario modelling and range from local site installation issues to macro-scale system issues such as electrical network capacity. However, there are significant uncertainties around their actual impact. For this reason, the key risks associated with heat pump deployment are set out in Table 4-1. Table 4-2 summarises how these were modelled.

Constraint	Description
Installation hassle compared to gas boiler replacement	The installation of GSHP is particularly disruptive due to the need to install pipes externally. The installation of ASHP is less disruptive than GSHP, but in both cases the whole heating system of the building may need to be re-configured to suit the low temperature output of heat pumps (see below). In addition an external location is required for siting the ASHP.
Energy performance of buildings	Heat pumps only operate efficiently in energy efficient buildings. Building heating systems must be able to make use of heat at low temperatures in order for the carbon saving potential of heat pumps to be realised. The assessment of heat pump technical potential assumes that only houses with an Energy Efficient Rating (EER) of A to C are suitable for heat pump installations. Currently only 13% of buildings in Greater London meet this criteria[39]. Extensive deployment of heat pumps in London will therefore require equivalent levels of energy efficiency upgrades.
Uncertainty over the performance of heat pumps	Research by the Energy Saving Trust (EST) into the performance of heat pumps has found that in practice their performance is worse than manufacturers' claims[40]. The average coefficient of performance (COP) was found to be 2.5 for GSHP and 2.2 for ASHPs. These COP values have been used in the assessment of the technical potential of heat pumps.
Investment in London's electricity distribution network	Heat pumps significantly increase the power demand of a building, particularly during periods of peak heating demand, which tend to coincide with low external air temperatures when the COP of ASHP is reduced. The Phase 1 analysis estimates that delivering the technical potential of heat pumps will lead to 35% rise in London's annual electricity demand.. Significant investment in the electrical distribution network will therefore be required to support the large-scale deployment of heat pumps. Alternatively, heat storage systems can help shift demand away from peak periods by generating heat overnight. These could be integrated with building heating systems or provided on a district basis and linked to buildings via heat networks.
Decarbonisation of the grid	The carbon saving contribution of heat pumps is determined by the carbon intensity of the electrical supply. If electricity generation is not decarbonised as much as anticipated, the carbon emission reductions associated with heat pumps will be greatly reduced.
Dependence on the RHI	The economic viability of heat pumps is dependent on the RHI. If the RHI is capped, stopped early or otherwise limited, the deployment potential of heat pumps will be significantly reduced.

Table 4-1: Constraints to heat pump deployment

4.2.2 Modelling the impact of constraints on heat pump uptake

The uncertainty associated with heat pump deployment is captured in the scenario modelling using the assumptions outlined in Table 4-2. The impact of these constraint assumptions is to reduce the

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

[40] 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

deployment potential for heat pumps. For example, the deployment potential in the BAU scenario is only equal to 1.5% and 0.5% of the technical potential of ASHP and GSHP respectively.

Constraint	Modelling assumptions
Installation hassle compared to gas boiler replacement	The uptake of the heat pump technical potential is based upon the 3% uptake rate of energy efficiency measures, assumed in the Committee on Climate Change (2009) Uptake of Energy Efficiency in Buildings report[41], which is lower than the 11% uptake rate of PV in Germany under the German FIT. In addition, the uptake rate of GSHP is assumed to be half of the ASHP level due to the greater installation challenges.
Energy performance of buildings	Uncertainty over the level of uptake of energy efficiency measures and the energy performance of housing to 2031 is managed by assuming higher levels of uptake under the scenarios with greater policy support. In the BAU scenario it is assumed that 40% of housing meet the required thermal efficiency for heat pumps, rising to 60% in the Ambitious action scenario. The relatively high level of energy efficiency uptake of 40% assumed under BAU is based on the anticipated introduction of the Green Deal in 2012.
Investment in London's electricity distribution network	The electricity distribution network costs associated with an increased power demand from large-scale heat pump deployment are factored into the deployment modelling by levying a £1,000 per property charge on the cost of installing heat pumps, which is an attempt to internalise the network investment costs within the assessment of economic potential.
Decarbonisation of the grid	The carbon content of the electricity grid varies across the scenarios in line with DECC modelling. Deployment of heat pumps is assumed to be higher under scenarios where the carbon intensity of electricity is lower to reflect individuals and organisations taking action to reduce emissions. In these scenarios, the deployment coefficients for heat pumps are increased to model this increase in uptake.

Table 4-2: Approach to modelling deployment uncertainty for heat pumps

4.2.3 Comparing the potential of PV and SWH

The technical potential of PV equates to 20% of London's power demand whereas the technical potential of SWH equates to only 1% of London's heat demand. SWH has a far lower potential because its practical use is constrained by the demand for hot water in the buildings on which it is installed whereas PV can supply power to both the building on which it is installed and export any excess to the grid. This is particularly the case for commercial buildings where hot water demand is small relative to roof space.

4.2.4 Risks to deployment of PV and SWH

The deployment potential for PV and SWH constitutes a larger proportion of the technical potential than is the case for heat pumps, as deployment for both these technologies is benchmarked against the relatively high PV uptake rates achieved under the German FIT. The deployment potential in the

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[41] Committee on Climate Change (2009) Uptake of Energy Efficiency in Buildings: http://www.theccc.org.uk/reports/1st-progress-report/supporting-research-

BAU scenario includes 11% of the technical potential of PV and SWH and this climbs to 18% in the Coordinated action scenario. The latter will generate 2,800GWh of power and 700GWh of heat respectively and corresponds to 1.2 million domestic installations and 100,000 non-domestic installations for PV, and 400,000 domestic installations and 225,000 non-domestic installations for SWH in 2031.

As outlined in the methodology section, PV and SWH are considered to be well known and well understood technologies which are relatively straight forward to install on buildings. Indeed, there has been a significant response in terms of both the supply and demand for PV since the introduction of the FIT in 2010. This response has demonstrated that the market considers PV to be a bankable, relatively straight-forward investment opportunity. However, achieving the estimated deployment potential of both PV and SWH, will require additional support. Key risks to the deployment of solar technologies include:

- Lower appetite for solar technologies in the UK and London than in Germany, and a lower level of interest amongst householders for investing in RE;
- Lack of capital for investing in PV, or competing uses for capital, due to the economic downturn;
- Uncertainty over the future of FIT and RHI funding – the Government has recently reduced the tariff rates for certain larger-scale technologies and the RHI has had a delayed introduction which has affected market confidence in the mechanism.

4.3 Decentralised energy technologies

This section describes in more detail the results of the DE modelling for economic potential and the effect of the uptake rate of heat networks on this potential. The sections on cost of heat distribution and cost of heat generation look at the effect the scenarios have on individual technologies.

4.3.1 Cost of heat distribution results

The cost of heat distribution is largely dependent on capital cost (e.g. cost of meters, building connections and heat network pipes). Figure 4-1 shows that the cost of heat distribution, by MSOA and scenario, is strongly linked to the discount rate selected for each scenario[42]. The baseline cost of heat generation is around 6-8p/kWh depending on scenario, and the cost of heat distribution curves cross the 8p/kWh level where MSOA heat demand density is around 40-60kWh/m^2 depending on scenario, though there is a significant spread in individual MSOA results. This supports the choice of 50kWh/m^2 as a minimum practical threshold heat demand density for heat networks, as at this level of heat distribution, heat generation costs have to be negative. The only exception to this is the Ambitious action scenario where the baseline cost of heat is approximately 15p/kWh. This scenario supports a much lower threshold heat demand density (e.g. 20kWh/m^2).

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[42] Each point on Figure 4-1 represents a data point for the cost of heat in a MSOA in each scenario. The Regional action and Ambitious action scenarios and the National action and Coordinated action scenarios share a trend line, because these scenarios have the same discount rate

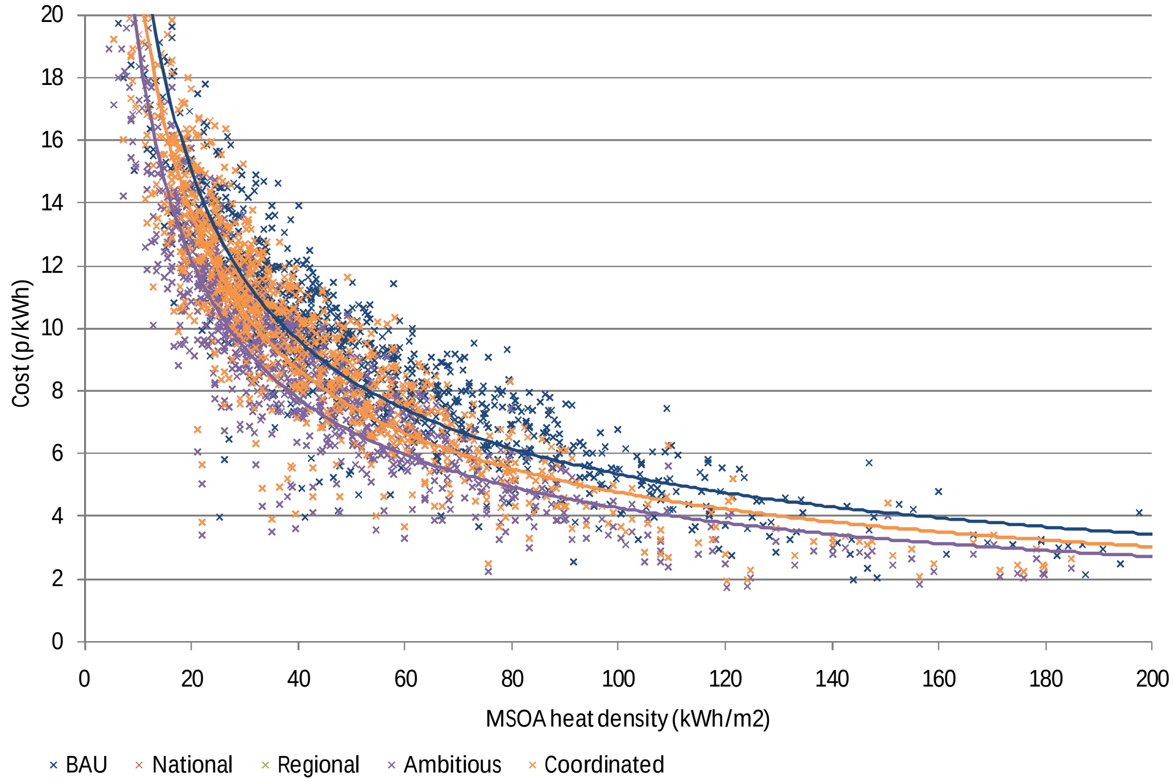

Figure 4-1: Cost of heat distribution by scenario

4.3.2 Cost of heat generation results

Figure 4-2 shows the variation in the cost of heat generation by DE technology and scenario. The key observations are discussed below.

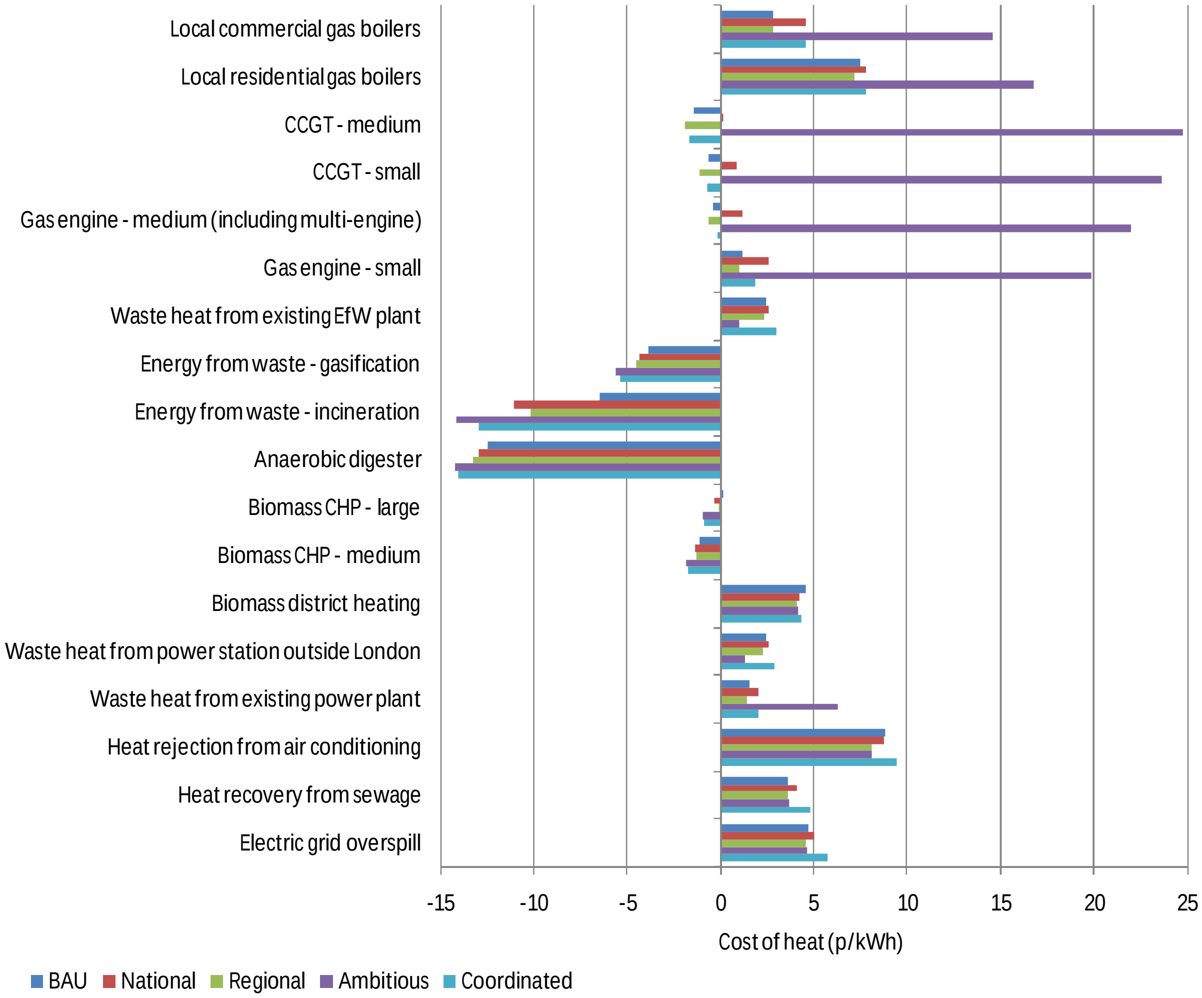

Figure 4-2: Cost of heat generation by decentralised energy technology and scenario

Negative cost of heat generation

Some DE technologies, such as anaerobic digesters and energy from waste, have negative costs of heat generation. This suggests that heat network operators could, in theory, be paid to take heat from heat generators, or that heat sales could be subsidised. This is due to revenues such as gate fees for waste disposal (for energy from waste plants), ROCs, levy exemption certificates and electricity sales. These income generating technologies could therefore be used to offset the cost of heat networks, particularly where the heat generator would receive incentives linked to supplying low carbon heat.

Heat pumps

The RHI on heat pumps has the potential to lower the baseline cost of local heat production making DE less attractive; however this may not reflect the most cost effective form of carbon emissions reduction. Due to the low deployment potential identified for heat pumps in Section 3, natural gas boilers are assumed as the baseline cost of heat in all scenarios. RHI for biomass district heating makes it more cost effective than gas boilers, making it attractive to have as a secondary heat source in a DE system.

CHP

The cost of heat from waste heat sources is influenced by the cost of the lost electricity generation associated with heat extraction. This is similar to the variation in carbon intensity and is explained in Section 3.2.7. Heat from CCGT (designed for CHP) costs less than reconfiguring existing power plants in all scenarios except in the Ambitious action scenario where the high cost of natural gas makes CCGT output very expensive. This is due to the different revenue streams of the two technologies and how they are modelled. Waste heat is considered as an additional financial operation and not integral to the business case for the generator. Therefore it is assumed to be an investment which is independent of the revenues from sales of electricity. For CCGT, which is assumed to be new build, the electricity sales effectively subsidise the cost of heat generation, suggesting that new power plant built in London would be planned as CHP plant, making low cost waste heat available.

4.3.3 Decentralised energy dependency on uptake rate

Uptake rate has a critical effect on the unit cost of heat distribution, and hence deployment potential. The DE model assumes an uptake rate of 70% of heat demand in all MSOAs. To reflect to impact of different uptake rates, the DE model was modified to run multiple iterations. Uptake rates per MSOA of 20%, 40%, 60%, 80% and 100% were modelled for the BAU, Ambitious action and Coordinated action scenarios. Figure 4-3 shows how as uptake levels improve, the cost of heat distribution drops and the potential DE delivered increases.

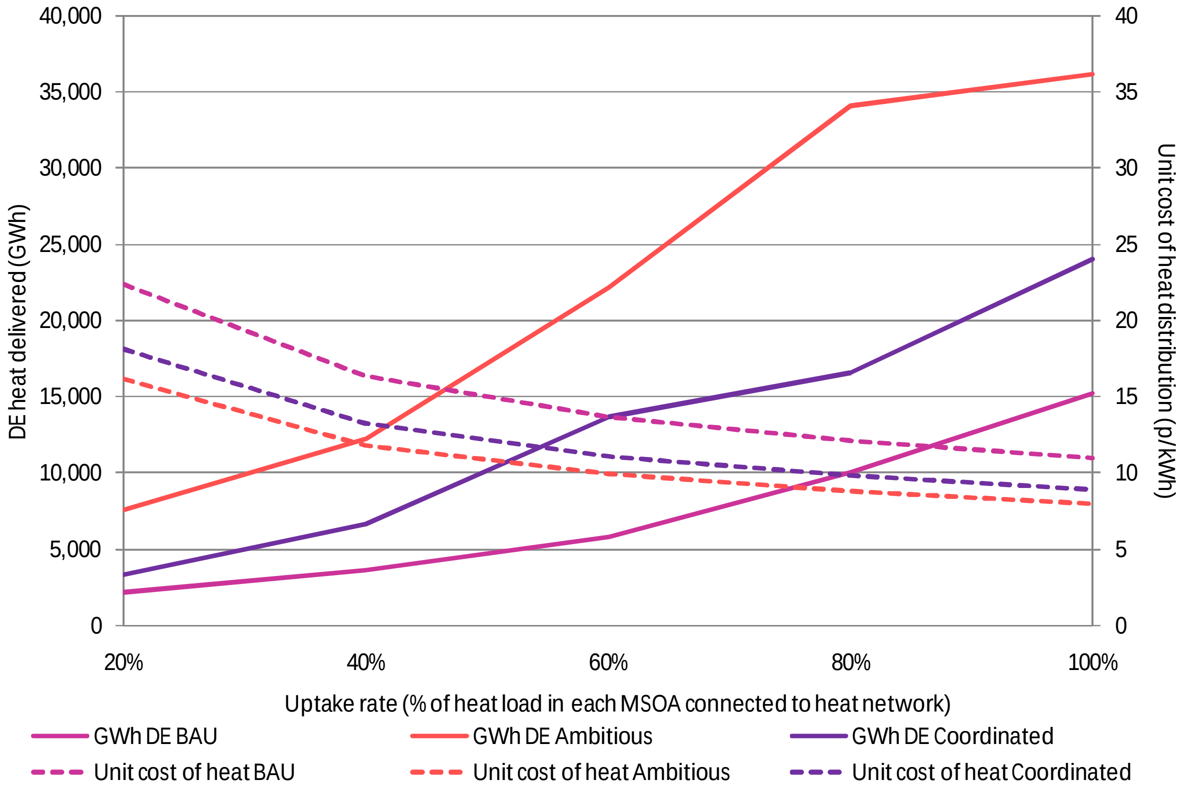

Figure 4-3: Sensitivity of DE potential and unit cost of heat distribution to uptake rate[43]

For any given MSOA, the capital cost of heat distribution is dependent upon the extent of the area supplied and the number of connections. When the uptake rate is varied the number of connection is adjusted but the area over which the network must be built, and hence its length, remains constant. However, revenues depend on the amount of heat supplied via the network therefore the greater the percentage uptake rate in an MSOA the lower the unit cost of heat distribution, as the total heat supplied is greater.

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[43] Note that heat distribution costs shown here are the average across all MSOAs, not the average of viable MSOAs. Therefore the costs are relatively high and the cost difference is less pronounced

5 Analysis and conclusions

This section summarises the overall findings in terms of deployment potential, and draws conclusions about the conditions required to enable delivery to be realised. Technology issues are discussed along with reductions in carbon emissions and constraints to deployment. A summary of the Coordinated action scenario is set out together with policy implications. A brief consideration of action beyond 2031 is also included.

5.1 Overall potential

The scenario analysis shows a wide range of outcomes are possible, depending on the basket of policy measures, energy prices and deployment constraints in question. The deployment potential of RE technologies (excluding those connected to heat networks) varies between 2-8% of London's energy demand in 2031, with PV and ASHP the dominant technologies across all scenarios (Table 3-1). The deployment potential of DE (including RE connected to heat networks) varies even more widely. In the BAU scenario, this is as low as 3%, rising to 28% under the Ambitious action scenario (Table 3-2). Within the deployment potential of DE, use of biomass feedstocks (including waste, woody biomass and agricultural arisings) represents 5% of London's energy demand in 2031 (Table i).

The combined deployment potential of RE and DE in 2031 varies between 5% and 35% of London's projected energy demand. Under the Coordinated action scenario, the deployment potential is 27%, suggesting that, under the policy environment assumed in this scenario, it is feasible to achieve the Mayor's 25% decentralised energy target (Table 3-3). This assumes a number of supporting policy measures are in place, particularly for heat networks, without which this potential cannot be achieved.

The potential reductions in carbon emissions from RE and DE are between 1.0-4.6MtCO_2/yr (Table 3-3). Under the coordinated scenario these are split 1.1MtCO_2/yr and 0.8MtCO_2/yr between RE (not connected to heat networks) and DE respectively (Table 3-1 and Table 3-2). Of the latter 1.1MtCO_2/yr is from renewable energy linked to heat networks which offsets the increased emissions from gas-fired CHP caused by the very low carbon intensity of grid electricity.

The potential carbon reductions are highly dependent on future grid decarbonisation. In the case of heat pumps carbon savings move from being negative (based on BAU values) to highly positive (based on values under the coordinated scenario). Gas-fired CHP provides significant carbon emission reductions under the BAU carbon factors, but becomes negative when the grid carbon intensity reduces below 0.2tCO_2/MWh as per the coordinated scenario. At this stage a switch to low carbon sources of heat, such as energy from waste or biomass is required. Other opportunities include the alternative heat sources identified in Section 13.4 of the Phase 1 report. Energy sources such as DE using biomass feedstocks and PV are effective regardless of grid decarbonisation.

5.2 Coordinated action scenario analysis

The results shows that a mix of technologies is required to deliver the Mayor's target and associated reductions in carbon emissions, with no single technology able to meet London's ambitions.

Renewable energy

In terms of RE not linked to heat networks, PV and heat pumps have the highest potential. SWH has limited potential, mainly due to being restricted to supplying only hot water demand. Wind, hydro and tidal energy currently have limited potential for deployment across London, but may be significant locally. Other areas of the UK are likely to be more suitable for their wider deployment. The deployment potential of commercial-scale wind turbines, for example, is significantly reduced due to the limited success rate of planning applications.

Decentralised energy

DE has the potential for significant deployment, subject to the development of extensive heat networks. Waste heat, biomass (including waste to energy plants and wood fuelled plants of various types), and particularly CCGT deliver the biggest contribution. The deployment potential from CCGT, and other gas-fired CHP plant, is very sensitive to the difference between wholesale gas and electricity prices. Under the Coordinated action scenario a higher difference between gas and electricity prices is modelled. A policy implication of this is that the additional £23/MWh for electricity revenues this represents significantly increases the economic viability of DE. This supports the case for DE electrical output to be eligible for some form of incentive, to emulate these conditions, which recognises the potential carbon reductions and benefits of DE.

Large-scale DE technologies provide a lower cost of heat than smaller scale technologies, but require extensive deployment of heat networks. The exception to this is that, even at relatively small scales, systems which use waste arisings as a fuel can be economic. Anaerobic digestion is particularly cost effective, and can serve single networks covering only a few MSOAs; however the potential is limited by the relatively low output per unit of waste input, and limited fuel available.

Alternative sources of DE

Under certain circumstances transmitting heat from power stations outside of London can allow DE to supply a high proportion of heat demand. This approach is only likely to be viable in circumstances when the costs of the baseline supply of heat are very much higher than current levels e.g. gas prices above 10-12p/kWh as per the Ambitious action scenario. This also demonstrates that DE could provide a significant contribution to London's heat demand should there be constraints on the use of natural gas. Another trigger for this would be the availability of heat from low carbon power stations, particularly as the carbon intensity of the electrical grid reduces dramatically beyond 2020. Such plants are likely to be located in the Thames Estuary area and beyond, perhaps as much as 75km from London. Extensive heat networks are required to provide the large heat loads which reduce unit costs and justify the investment in long distance transmission mains. Whilst it is technically possible to transmit over long distances there are significant uncertainties regarding the cost of such pipelines. This is further addressed in Phase 3 of this study.

Higher levels of interconnection (which increases diversity, smoothing variations in demand) and thermal storage could increase the DE potential significantly by minimising the percentage of heat supplied from peak load boilers through heat networks. In the model this is set to 60-75% depending on technology. In mature heat networks, such as Copenhagen, this figure can be as high as 95%[44].

For DE, the cost of heat distribution rises markedly below a heat demand density of around 40kWh/m^2 [45]. Above a heat demand density of 50kWh/m^2, the cost of heat distribution decreases in

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[44] CTR (2010) The main district heating network in Copenhagen: http://www.ctr.dk/Images/Publikationer/The%20main%20district%20heating%20network%20in%20cph%20-%20UK.pdf

[45] Note, the median heat density for all MSOAs is 35kWh/m^2

an approximately linear way, confirming the selection of 50kWh/m^2 as a sensible threshold for the technical potential of heat networks.

Spatial distribution

DE potential is concentrated in the central areas of London, as well as some outlying town centre areas which are characterised by high heat demand density. The concentration of DE potential in central areas suggests widespread interconnection is physically possible. Interconnection is required to provide sufficient heat loads for larger DE sources, and results in lower cost of heat. RE potential is more evenly spread, but can provide a higher proportion of energy demands in lower density areas. This distinction may suggest that energy policy in London includes some level of spatial differentiation, such as zoning of areas where heat networks are most viable.

The generation of waste heat from existing power stations is assumed to be an investment consideration independent of the revenues from sales of electricity. This reduces the economic viability as the only driver of the project is the additional revenues from heat sales, and climate change levy exemption. In the modelling it is assumed that when new plant is planned, the electrical revenues as well as the heat revenues contribute to the return on investment. This means new build CHP plant is more attractive than the adaptation of existing plant; however the latter does still provide lower cost heat than individual gas boilers.

5.3 Risks to deployment

There are a number of key risks to the deployment of RE and DE within London, some are implicit in the modelling assumptions, whilst others are evident from the results.

Renewable energy

The potential for RE (excluding those connected to heat networks) is influenced much more strongly by deployment constraints than economic viability. The subsidies available under FITs and RHI make RE systems more economically viable than a business as usual approach. Whilst current policy support ensures that economic viability is not a constraint to deployment, changes to these subsidy regimes, or perceptions that the support will be reduced, is likely to impact on the deployment potential of RE. The impacts of the subsidies and cost of capital on RE deployment are stronger than that of energy price variation, as the subsidies available are often significantly more than the energy cost of the alternative.

Despite the strong economic incentives, the deployment potential of RE under the Coordinated action scenario, for example, is only 18% of the technical potential due to constraints to deployment (Table 3-1). The energy efficiency of London's building stock is a major constraint as heat pumps, which represent the highest technical potential, are not suitable for installation in thermally inefficient buildings. In order to facilitate higher deployment of heat pumps, London will need to retrofit a significant number of buildings.

A further constraint which has not been modelled in detail is the ability of the electricity distribution network to assimilate the impact of the deployment of heat pumps and PV. Heat pumps represent a significant increase in demand for electricity which is likely to require widespread reinforcement of the network. An allowance of £1,000 per connection is made in the economic modelling, but much more detailed research is required to validate this assumption. The impact on electrical networks can be limited by providing thermal storage to spread peak demand, installed either as part of building heating systems or more centrally with the heat distributed using heat networks. PV could introduce significant instabilities in network voltage levels, but research on modern networks in Germany found that this was not a problem up to $6kW_p$ per household and that electrical networks in urban areas are less susceptible to other faults caused by PV[46].

Decentralised energy

Within the modelling very significant assumptions regarding DE deployment have been made. These principally relate to market penetration (or uptake rate) and the discount rate.

The modelling assumes that heat networks are connected to 70% of the heat demand within a given areas (i.e. by MSOA). Such high levels of market penetration are likely to require strong policy support, possibly including heat planning, and are also likely to develop over a period of many years.

The discount rate is a major constraint to DE deployment potential. A previous study commissioned by DECC concluded that discount rate is effectively a proxy of project risk and proposed measures to reduce risk[47]. Other approaches to providing low cost investment include allowing local authorities to raise long term bonds against future revenues or providing low cost funding via a green investment bank or local energy efficiency fund.

Reaching high levels of uptake is one way of reducing risk. An alternative approach is to increase the economic viability of DE by providing some form of incentive, ensuring higher discount rates do reduce the deployment potential. These incentives could include reform of the electricity market to enable DE generators to capture more of the value chain through cost reflective distribution charging and 'licence lite' electricity supply arrangements.

The potential for DE in new buildings is relatively limited and to reach the coordinated scenario deployment potential the retrofit of heat networks to hundreds of thousands of existing buildings is required. Similarly the supply chain for DE, and particularly the rate at which heat networks can be installed is a significant risk. The coordinated scenario requires a deployment rate of around 250km/yr for the next 20 years, around 60% of the rate achieved at the peak of the Thames Water mains replacement programme.

Long distance transmission of heat is technically feasible though there may be technical constraints which were not possible to address in this study e.g. room for below ground services. Planning of such infrastructure routes could be part of a safeguarding approach to allow future interconnection of heat networks. Heat losses from transmission pipelines are typically around 2% of the heat supplied, even for distances over 50km (see Phase 3 report Section 3). Much waste heat is available at low temperatures, but this can be upgraded to useful temperatures for heat networks using heat pumps. However, modelling suggests this is a relatively expensive source of heat compared tom for example, extracting heat from CCGT plants. Where the waste heat is from steam cycle plants it is more efficient to extract heat from steam turbines, which operate as a virtual heat pump.

These findings highlight the inherent difference between heat supply technologies that are standalone, and those requiring a network infrastructure. The unit cost of the latter reduces as the number of connections to the network increases; they are a natural monopoly, and policy is likely to

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[46] Intelligent Energy Europe (2007) State-of-the-art on dispersed PV power generation: Publications review on the impacts of PV Distributed Generation and Electricity networks: http://www.pvupscale.org/IMG/pdf/D41_final.pdf

[47] DECC (2010) The potential and costs of district heating networks: http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/distributed_en_heat/district_heat/district_heat.aspx

be more effective if they are considered in this way. The extent of consumer uptake represents a major risk to any investment in DE infrastructure. Managing this risk is key to increasing DE potential. At present DE tends to be restricted to new build development and public sector buildings where uptake can be guaranteed, but the analysis suggests less than 2% of London's energy demand in 2031 can be met using small scale gas-fired CHP in new development.

5.4 Coordinated action scenario analysis and policy implications

This section discusses the overall potential for RE and DE within the constraints of the coordinated scenario.

PV and heat pumps deliver the majority of RE not linked to heat networks, in common with the other scenarios. Planning determination and deployment rates are very high and would require significant increases over the BAU position. This is only likely to be achieved through a combination of measures. These include ensuring that planning authorities and decision makers understand RE technologies and the issues and potential impacts arising, and that planning policy is supportive. This level of deployment implies the installation of the equivalent of 66,000 domestic PV systems per year, or 1,300 per week. This represents a significant supply chain expansion. Initially much of this capacity is likely to be delivered by small businesses and tradesmen such as plumbers and electricians. Support and training for these businesses, including educating apprentices will be required to facilitate deployment.

The modelling of decisions to invest in RE is based on a share of utility rule that assumes that provided the returns are equal there is a 50% chance that a consumer chooses investment in RE over an alternative investment with equivalent rate of return (the scenario discount rates in this case). However, in reality there are a wide variety of alternative investments available, and perhaps more significantly investment decisions may not be made on a rational, utility maximising basis. Consumers may have stronger preferences for other investments in household improvements (e.g. renovations, new kitchens, bathrooms etc) which effectively mean the RE investment is subject to a much higher discount rate than modelled. Some form of third party investment such as the Green Deal[48] may be required to overcome this barrier. Ensuring the provision of clear guidance and information may also play a role in such decision making. Improvements in energy efficiency of domestic buildings are required to enable the deployment of heat pumps. Such measures include wall insulation (cavity or solid wall), modern double glazing and improved air tightness. The deployment of such measures could also be linked to heat pumps, SWH or PV providing a combined package within a single intervention. The Mayor's RE:NEW and RE:FIT programmes could facilitate this, and could be a key part of RE deployment, again linked to the Green Deal.

The model assumes that large roof areas, such as warehouses and retail stores, can accommodate PV systems proportional to their roof area, rather than a fixed capacity per installation (as per the DECC methodology). This implies that maintaining feed in tariffs for larger scale systems at least up to 250kW (equivalent to an approximately 2,500m^2 roof, or medium scale supermarket) should be considered. More generally FITs must be maintained at their present levels, and RHI should provide

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[48] DECC (2011) Green Deal: http://www.decc.gov.uk/en/content/cms/tackling/green_deal/green_deal.aspx for more information

at least as strong an incentive as the values used in the modelling (which are based on the domestic tariffs in the RHI consultation[49]).

The coordinated scenario includes over 22% of DE, the majority of which is provided by CCGT (Table 3-2). As discussed above this is due to CCGT providing a lower cost of heat than most other sources when the difference between wholesale gas and electricity prices is relatively high. This low cost of heat enables many more MSOAs to be viable for heat networks, before deployment constraints are considered. For areas with lower heat demand density this is a key factor in enabling the potential of heat networks.

The energy from waste technologies (anaerobic digestion and gasification) provide a small element of the DE generation mix, using up the all the fuel available in the Stage 6 analysis. Wood fuelled biomass CHP (medium scale) and biomass district heating provide a significant contribution. The former is assumed to use London and South East's available biomass fuel, whilst the latter is reliant on more expensive imported biomass. All of the available resource from London and the South East is used up in the Stage 5 model, but only around 80% is used in the deployment potential due to build out constraints. The RHI means biomass district heating is competitive with natural gas for peak load heating but without this, or some form of planning policy requirement, it is unlikely scheme operators would choose to use biomass. Maximising the use of low carbon fuel is critical in this scenario as the carbon emission reductions from gas-fired CHP are negated by the low carbon intensity of grid electricity. By 2031 the need to switch to lower carbon fuels than gas-fired CHP is apparent. Some form of support for low carbon heat is likely to be required. As a minimum, support (currently via the Renewables Obligation) for energy from waste and wood fuelled biomass CHP plants must be maintained. Some further incentives or regulation may be required to ensure a switch to low carbon heat sources. Options might include: incentives for heat or electricity from other low carbon sources (not just renewables); an emissions performance standard for new plant along with a requirement to be built as CHP units; support for carbon pricing, though previous studies have indicated the effect on the unit cost of heat from networks is not significantly reduced by carbon pricing[11].

As with the other scenarios an uptake rate of 70% was assumed, which implies some form of regulation or heat planning. The relatively low discount rate (7%) used also assumes some form of regulated utility financing, or at least a very low risk investment. Implicit in these assumptions is that constraints to heat network deployment in the UK which have been identified in previous studies are addressed. These include: limited pipework supply chain; high network installation costs compared to other European countries; limited knowledge of DE amongst investors; reliance on new development to deliver DE capacity; need to connect existing buildings cost effectively; the small scale of the UK market; lack of a project integrator to instigate and de-risk the initial phases of project development, and; perception of DE as a risky investment[10,11,12].

Heat planning may not be possible in the UK's liberalised utilities market. However, as a minimum local development frameworks must identify areas where DE can be viable, and set out a long term vision for their deployment. Decisions on individual new development proposals, and new connections in general, would then be made in this longer term context. Public sector procurement decisions are crucial to ensuring that large institutional buildings are able to connect to heat networks. Decision making must be based on a whole life basis and factor the cost of carbon into

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[49] DECC (2010) Consultation on the proposed RHI financial support scheme: http://www.decc.gov.uk/assets/decc/consultations/rhi/1_20100204094844_e_@@_consultationonrenewableheatincentive.pdf

purchasing evaluations, not just the lowest unit cost. Providing guidance and case studies to the Boroughs and other public sector organisations could assist procurement departments in finding the best value solutions. The involvement of public sector organisations may also enable heat network developers to access lower cost funding, increasing potential.

As well as widespread establishment of heat networks interconnection is also a requirement to enable the use of large sources of heat. Standards for heat network design and operation should be established to enable this to occur with minimum cost. In particular operating temperatures and pressures should be standardised. Constructing large pipe network links is likely to be very challenging in the dense central areas of London most suited to DE. Further detail about the cost implications of significant heat network installation works in such areas is required to validate the assumptions in this study. At present there are only limited UK precedents of heat network construction or extension in existing streets. For larger scale connections consideration should be given to identifying and safeguarding future infrastructure sites and network routes to reduce future costs. This could be integrated into local development frameworks.

5.5 Beyond 2031

The development of new technology beyond 2031 is outside the scope of this study. However, it is likely that costs for RE technologies will continue to decline as the market grows and wider deployment drives down unit costs. This could increase the economic potential or allow Government to reduce the subsidies required to make RE competitive with grid electricity. Uncertainty regarding energy prices means commenting on this is highly speculative.

Beyond 2031 the need to switch to low or zero carbon fuel sources to supply heat networks is likely to become more pronounced, even if there are delays to grid decarbonisation prior to this. The analysis in the ambitious scenario suggests that over 30% of London's energy demand in 2031 could be met by non-gas based DE sources and RE (Table 3-1 and Table 3-2). Around 80% of waste and biomass fuel arising within London and the Greater South East respectively are used up in this case. Established heat networks would allow the remaining fuel and imported biomass to be used. The largest proportion of the 30% is provided by importing heat from new low carbon power stations outside of London. The development of such plants is highly uncertain, and reliant on the establishment of carbon capture and storage and nuclear programmes. There is one new nuclear site, as identified in Phase 1, but the prospects for carbon capture and storage rely on unproven technology, and an infrastructure of carbon pipelines which does not exist at present. Sites in the Thames Estuary are close to demand centres and existing grid infrastructure, and could access depleted North Sea gas fields however these programmes will be developed on a UK wide basis, and other sites may be more attractive, leaving London lacking in low carbon heat resource.

Wider deployment of heat networks also implies connecting increasingly lower heat demand density areas. Heat network design in such areas must optimise for reducing heat losses to maximise their benefits. Consideration should be given to providing standards for such designs, based on best practice internationally, along with those which enable interconnection[50].

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

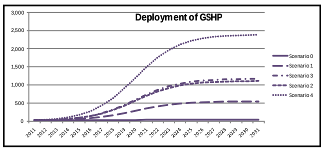
APPENDICES

Appendix A: Ground source heat pump methodology

METHODOLOGY FOR ASSESSING THE DEPLOYMENT POTENTIAL OF GROUND SOURCE HEAT PUMPS (STAGE 5)

DECC STAGE OF ASSESSMENT	METHODOLOGY	ASSUMPTIONS	JUSTIFICATION/RATIONALE
STAGE 5	UNDERTAKE COST-BENEFIT ANALYSIS TO DETERMINE THE INTERNAL RATE OF RETURN OF INVESTING IN GROUND SOURCE HEAT PUMPS AT AN INDIVIDUAL BUILDING LEVEL	Capital cost of GSHP (5kW system): £10,324 Maintenance cost: £44/year Level of RHI and other inputs as defined by the scenarios.	Source: Element Energy (2008) The growth potential for Microgeneration in England, Wales and Scotland.
	CALCULATE THE ECONOMIC COEFFICIENT AS THE PROBABILITY OF INVESTING IN THE TECHNOLOGY BASED ON 'SHARE OF UTILITY' RULE	**Share of utility equation** Economic coefficient = Probability of investing = $\frac{IRR_{\text{(renewable investment)}}}{IRR_{\text{(renewable investment)}} + IRR_{\text{(alternative investment)}}}$ where $IRR_{\text{(alternative investment)}}$ = cost of capital (discount rate)	'Share of utility' rule states that the greater the level of utility that a consumer gains from a product, the higher the probability that the consumer will purchase that product. This assessment uses IRR as the measure of utility for installing a renewable energy technology. Source: Lilien, G.L. and Rangaswamy, A. (2004) Marketing Engineering: computer-assissted marketing analysis and planning.
	CALCULATE THE ECONOMIC POTENTIAL BY MULTIPLYING THE TECHNICAL POTENTIAL AND THE ECONOMIC COEFFICIENT	**Stage 5 economic coefficients** **Scenario 1** 35.4% **Scenario 2** 43.7% **Scenario 3** 45.1% **Scenario 4** 67.1% **Scenario 5** 43.7%	As the IRR of a renewable energy installation varies in line with the changing market conditions under different scenarios, the probability of investing in the renewable technology also changes. This is reflected in the 'economic coefficients' derived from the share of utility equation.

METHODOLOGY FOR ASSESSING THE DEPLOYMENT POTENTIAL OF GROUND SOURCE HEAT PUMPS (STAGE 6)

DECC STAGE OF ASSESSMENT	METHODOLOGY	ASSUMPTIONS	JUSTIFICATION/RATIONALE
STAGE 6	INCORPORATE THE DEPLOYMENT RISK OF POOR UPTAKE OF ENERGY EFFICIENCY MEASURES IN EXISTING HOUSING STOCK JEOPARDISING ABILITY TO INSTALL HEAT PUMPS	Assume the following uptake rates of energy efficiency measures in the housing stock by 2031 (compared to 75% uptake assumption in technical potential assessment): **Scenario 1:** 40% **Scenario 2:** 50% **Scenario 3:** 50% **Scenario 4:** 60% **Scenario 5:** 50%	These percentages are informed by the Committee on Climate Change (CCC) which suggests that under best case conditions, a maximum of 40% of households will undertake low carbon retrofit to achieve an A to C energy rating between now and 2022 and therefore it is assumed that 60% could be achieved by 2031 in scenario 4 (best case). Source: Committee on Climate Change (2009) Uptake of energy efficiency in buildings
	INCORPORATE THE GRID DECARBONISATION RISK AND ADDITIONAL DEPLOYMENT RISK ASSOCIATED WITH GSHP TO CALCULATE DEPLOYMENT COEFFICIENT	Calibrate deployment rate with reference to energy efficiency uptake in non-domestic sector . - Set Scenario 1 deployment coefficient such that **deployment rate for GSHP = 0.5 deployment rate** of energy efficiency measures outlined in CCC report. - Set the deployment coefficients of the remaining scenarios to reflect the differing levels of government policy support to overcome barriers to the installation of heat pumps: **Scenario 2:** 1.25 x Scenario 1 deployment coefficient (green policies, high energy prices) **Scenario 3:** 1.50 x Scenario 1 deployment coefficient (high local support) **Scenario 4:** 2 x Scenario 1 deployment coefficient (high local and national support) **Scenario 5:** 1.5 x Scenario 1 deployment coefficient (high local support)	-The deployment rate percentages are informed by the CCC which suggests that 3% of decision makers in non-domestic buildings are willing to pay for the installation of energy efficiency measures that payback over 10 years. -The installation of energy efficiency measures is a suitable proxy for installing heat pumps due to similar issues and challenges. -The uptake rate for non-domestic buildings in the CCC report has been used as the majority of London's technical potential for heat pumps comes from the non-domestic sector. - The deployment rate for ground source heat pumps was set at half of the above uptake rate given that this technology would have a longer pay back period and additional deployment risks due to space requirements, ground conditions, low field trial performances and grid decarbonisation. The remaining scenarios were benchmarked against Scenario 1 based on the differing market conditions and policy support in each of the scenarios. Source: Committee on Climate Change (2009) Uptake of energy efficiency in buildings
	MULTIPLY ADJUSTED TECHNICAL POTENTIAL BY ECONOMIC COEFFICIENT AND DEPLOYMENT COEFFICIENT TO DETERMINE 2020 DEPLOYMENT RATE	**RESULTS FOR COEFFICIENTS** (see table below)	
	CALCULATE THE INTERIM AND 2031 DEPLOYMENT POTENTIAL BY USING A SIGMOID FUNCTION		The S-curve is used to describe the market development of many technologies where initial slow market growth of a product through early adopters is followed by an increased uptake rate once the technology becomes established and its economics improves. The final stage is a slow down of the growth as the market reaches saturation or support mechanisms decrease. The shape of the curve is callibrated to the German PV market as an example of renewables market growth patterns under support mechanisms. Source: German Solar Industry Association (2010) Development of the German PV Market

RESULTS FOR COEFFICIENTS

	Stage 5 economic coefficient		Stage 6 deployment coefficient		2020 deployment rate
Scenario 1	35.4%	x	1.5%	=	0.5%
Scenario 2	43.7%	x	1.9%	=	0.8%
Scenario 3	45.1%	x	2.3%	=	1.0%
Scenario 4	67.1%	x	3%	=	2.0%
Scenario 5	43.7%	x	2.3%	=	1.0%

Appendix B: Air source heat pumps methodology

METHODOLOGY FOR ASSESSING THE DEPLOYMENT POTENTIAL OF AIR SOURCE HEAT PUMPS (STAGE 5)

DECC STAGE OF ASSESSMENT | **METHODOLOGY** | **ASSUMPTIONS** | **JUSTIFICATION/RATIONALE**

STAGE 5

UNDERTAKE COST-BENEFIT ANALYSIS TO DETERMINE THE INTERNAL RATE OF RETURN OF INVESTING IN AIR SOURCE HEAT PUMPS AT AN INDIVIDUAL BUILDING LEVEL

Capital cost of ASHP (5kW system): £6,569
Maintenance costs: £44/year
Level of RHI and other inputs as defined by the scenarios.

Source: Element Energy (2008) The growth potential for Microgeneration in England, Wales and Scotland.

CALCULATE THE ECONOMIC COEFFICIENT AS THE PROBABILITY OF INVESTING IN THE TECHNOLOGY BASED ON 'SHARE OF UTILITY' RULE

Share of utility equation

Economic coefficient = Probability of investing =

$$\frac{IRR_{(renewable\ investment)}}{IRR_{(renewable\ investment)} + IRR_{(alternative\ investment)}}$$

where

$IRR_{(alternative\ investment)}$ = cost of capital (discount rate)

'Share of utility' rule states that the greater the level of utility that a consumer gains from a product, the higher the probability that the consumer will purchase that product. This assessment uses IRR as the measure of utility for installing a renewable energy technology.

Source: Lilien, G.L. and Rangaswamy, A. (2004) Marketing Engineering: computer-assissted marketing analysis and planning.

CALCULATE THE ECONOMIC POTENTIAL BY MULTIPLYING THE TECHNICAL POTENTIAL AND THE ECONOMIC COEFFICIENT

Stage 5 economic coefficients

Scenario 1	49.1%
Scenario 2	57.3%
Scenario 3	59.2%
Scenario 4	76.5%
Scenario 5	57.3%

As the IRR of a renewable energy installation varies in line with the changing market conditions under different scenarios, the probability of investing in the renewable technology also changes. This is reflected in the 'economic coefficients' derived from the share of utility equation.

METHODOLOGY FOR ASSESSING THE DEPLOYMENT POTENTIAL OF AIR SOURCE HEAT PUMPS (STAGE 6)

DECC STAGE OF ASSESSMENT | **METHODOLOGY** | **ASSUMPTIONS** | **JUSTIFICATION/RATIONALE**

STAGE 6

INCORPORATE THE DEPLOYMENT RISK OF POOR UPTAKE OF ENERGY EFFICIENCY MEASURES IN EXISTING HOUSING STOCK JEOPARDISING THE ABILITY TO INSTALL HEAT PUMPS

Assume the following uptake rates of energy efficiency measures in the housing stock by 2031:

Scenario 1: 40%
Scenario 2: 50%
Scenario 3: 50%
Scenario 4: 60%

These percentages are informed by the Committee on Climate Change (CCC) which suggests that under best case conditions, a maximum of 40% of households will undertake low carbon retrofit to achieve an A to C energy rating between now and 2022 and therefore it is assumed that 60% could be achieved by 2031 in scenario 4 (best case).

Source: Committee on Climate Changee (2009) Uptake of

INCORPORATE THE GRID DECARBONISATION RISK AND ADDITIONAL DEPLOYMENT RISK ASSOCIATED WITH ASHP TO CALCULATE DEPLOYMENT COEFFICIENT

Calibrate deployment rate with reference to energy efficiency uptake in non-domestic sector.
- Set Scenario 1 deployment coefficient such that **deployment rate for ASHP = deployment rate** of energy efficiency measures outlined in CCC report.
- Set the deployment coefficients of the remaining scenarios to reflect the differing levels of government policy support to overcome barriers to the installation of heat pumps:
Scenario 2: 1.25 x Scenario 1 deployment coefficient (green policies, high energy prices)
Scenario 3: 1.50 x Scenario 1 deployment coefficient (high local support)
Scenario 4: 2 x Scenario 1 deployment coefficient (high local and national support)
Scenario 5: 1.5 x Scenario 1 deployment coefficient (high local support)

-The deployment rate percentages are informed by the CCC which suggests that 3% of decision makers in non-domestic buildings are willing to pay for the installation of energy efficiency measures that payback over 10 years.
-The installation of energy efficiency measures is a suitable proxy for installing heat pumps due to similar issues and challenges.
-The uptake rate for non-domestic buildings in the CCC report has been used as the majority of London's technical potential for heat pumps comes from the non-domestic sector.

The remaining scenarios were benchmarked against Scenario 1 based on the differing market conditions and policy support in each of the scenarios.

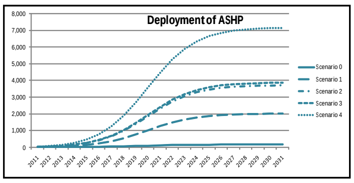
Source: Committee on Climate Change (2009) Uptake of energy efficiency in buildings

MULTIPLY ADJUSTED TECHNICAL POTENTIAL BY ECONOMIC COEFFICIENT AND DEPLOYMENT COEFFICIENT TO DETERMINE 2020 DEPLOYMENT

RESULTS FOR COEFFICIENTS

	Stage 5 economic coefficient		**Stage 6 deployment coefficient**		**2020 deployment rate**
Scenario 1	49.1%	x	3%	=	1.5%
Scenario 2	57.3%	x	3.8%	=	2.1%
Scenario 3	59.2%	x	4.5%	=	2.7%
Scenario 4	76.5%	x	6%	=	4.6%

CALCULATE THE INTERIM AND 2031 DEPLOYMENT POTENTIAL BY USING A SIGMOID FUNCTION



The S-curve is used to describe the market development of many technologies where initial slow market growth of a product through early adopters is followed by an increased uptake rate once the technology becomes established and its economics improves. The final stage is a slow down of the growth as the market reaches saturation or support mechanisms decrease. The shape of the curve is callibrated to the German PV market as an example of renewables market growth patterns under support mechanisms.

Source: German Solar Industry Association (2010)

Appendix C: Solar water heating methodology

METHODOLOGY FOR ASSESSING THE DEPLOYMENT POTENTIAL OF SOLAR WATER HEATING (STAGE 5)

DECC STAGE OF ASSESSMENT | **METHODOLOGY** | **ASSUMPTIONS** | **JUSTIFICATION/RATIONALE**

STAGE 5

UNDERTAKE COST-BENEFIT ANALYSIS TO DETERMINE THE INTERNAL RATE OF RETURN OF INVESTING IN SWH AT AN INDIVIDUAL BUILDING LEVEL

Capital cost of SWH (2kW system): £3,668
Maintenance cost: £44/year
RHI level and other inputs as defined by the scenarios.

Source: Element Energy (2008) The growth potential for Microgeneration in England, Wales and Scotland.

CALCULATE THE ECONOMIC COEFFICIENT AS THE PROBABILITY OF INVESTING IN THE TECHNOLOGY BASED ON 'SHARE OF UTILITY' RULE

Share of utility equation

Economic coefficient = Probability of investing =

IRR $_{\text{(renewable investment)}}$

IRR $_{\text{(renewable investment)}}$ + IRR $_{\text{(alternative investment)}}$

where

IRR$_{\text{(alternative investment)}}$ = cost of capital (discount rate)

'Share of utility' rule states that the greater the level of utility that a consumer gains from a product, the higher the probability that the consumer will purchase that product. This assessment uses IRR as the measure of utility for installing a renewable energy technology.

Source: Lilien, G.L. and Rangaswamy, A. (2004) Marketing Engineering: computer-assissted marketing analysis and

CALCULATE THE ECONOMIC POTENTIAL BY MULTIPLYING THE TECHNICAL POTENTIAL AND THE ECONOMIC COEFFICIENT

Stage 5 economic coefficients

Scenario 1	34.4%
Scenario 2	41.1%
Scenario 3	44.0%
Scenario 4	55.2%
Scenario 5	41.1%

As the IRR of a renewable energy installation varies in line with the changing market conditions under different scenarios, the probability of investing in the renewable technology also changes. This is reflected in the 'economic coefficients' derived from the share of utility

METHODOLOGY FOR ASSESSING THE DEPLOYMENT POTENTIAL OF SOLAR WATER HEATING (STAGE 6)

DECC STAGE OF ASSESSMENT | **METHODOLOGY** | **ASSUMPTIONS** | **JUSTIFICATION/RATIONALE**

STAGE 6

INCORPORATE DEPLOYMENT RISK TO CALCULATE DEPLOYMENT COEFFICIENT

Calibrate deployment rate with reference to German FIT:
- German PV deployment rate in 10 years = 10.7% of technical potential
- Set Scenario 1 deployment coefficient such that **deployment rate for SWH = PV deployment rate in Germany**
- Set the deployment coefficients of the remaining scenarios to reflect the differing levels of government policy support to overcome barriers to the installation of solar water heating:

Scenario 2: Scenario 1 deployment coefficient (green policies, high energy prices)
Scenario 3: 1.5 x Scenario 1 deployment coefficient (high local support)
Scenario 4: 2 x Scenario 1 deployment coefficient (high local and national support)
Scenario 5: 1.5 x Scenario 1 deployment coefficient (high local support)

The deployment rate for the business as usual scenario (Scenario 1) was set at the German PV deployment rate on the basis that this is an established technology and does not have additional deployment risks compared with photovoltaics.

The remaining scenarios were benchmarked against Scenario 1 based on the differing market conditions and policy support in each of the scenarios. The benchmarking of each scenario, and their relative to each other, have been informed by the CCC which has modelled uptake of energy efficiency measures under different conditions.

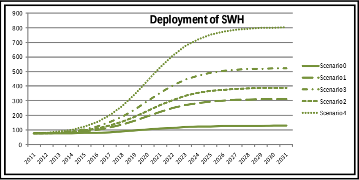
Source: Committee on Climate Change (2009) Uptake of energy efficiency in buildings

MULTIPLY TECHNICAL POTENTIAL BY ECONOMIC COEFFICIENT AND DEPLOYMENT COEFFICIENT TO DETERMINE 2020 DEPLOYMENT RATE

RESULTS FOR COEFFICIENTS

	Stage 5 economic coefficient		Stage 6 deployment coefficient		2020 deployment rate
Scenario 1	34.4%	x	31.1%	=	10.7%
Scenario 2	41.1%	x	31.1%	=	12.8%
Scenario 3	44.0%	x	46.7%	=	20.5%
Scenario 4	55.2%	x	62.2%	=	34.4%
Scenario 5	41.1%	x	46.7%	=	19.2%

CALCULATE THE INTERIM AND 2031 DEPLOYMENT POTENTIAL BY USING A SIGMOID FUNCTION



The S-curve is used to describe the market deployment of many technologies where initial slow market growth is followed by a fast growth rate through to a final slow down as the market reaches saturation or support mechanisms decrease. The shape of the curve is callibrated to the German PV market as an example of renewables market growth patterns under support mechanisms.

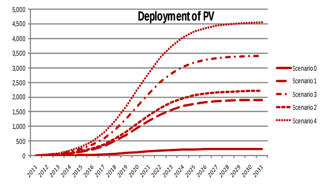
Source: German Solar Industry Association (2010) Development of the German PV Market

Appendix D: Solar photovoltaic methodology

METHODOLOGY FOR ASSESSING THE DEPLOYMENT POTENTIAL OF PHOTOVOLTAICS (STAGE 5)

DECC STAGE OF ASSESSMENT	METHODOLOGY	ASSUMPTIONS	JUSTIFICATION/RATIONALE
STAGE 5	UNDERTAKE COST-BENEFIT ANALYSIS TO DETERMINE THE INTERNAL RATE OF RETURN OF INVESTING IN PV AT AN INDIVIDUAL BUILDING LEVEL	Capital cost of PV: £5,275/kWp Operating cost: £110/year (includes inverter replacement cost) FIT level and other inputs as defined by the scenarios.	Source: Element Energy (2008) The growth potential for Microgeneration in England, Wales and Scotland.
	CALCULATE THE ECONOMIC COEFFICIENT AS THE PROBABILITY OF INVESTING IN THE TECHNOLOGY BASED ON 'SHARE OF UTILITY' RULE	**Share of utility equation** Economic coefficient = Probability of investing = $\frac{IRR_{(renewable\ investment)}}{IRR_{(renewable\ investment)} + IRR_{(alternative\ investment)}}$ where $IRR_{(alternative\ investment)}$ = cost of capital (discount rate)	'Share of utility' rule states that the greater the level of utility that a consumer gains from a product, the higher the probability that the consumer will purchase that product. This assessment uses IRR as the measure of utility for installing a renewable energy technology. Source: Lilien, G.L. and Rangaswamy, A. (2004) Marketing Engineering: computer-assissted marketing analysis and
	CALCULATE THE ECONOMIC POTENTIAL BY MULTIPLYING THE TECHNICAL POTENTIAL AND THE ECONOMIC COEFFICIENT	**Stage 5 economic coefficients** **Scenario 1** 51.8% **Scenario 2** 58.0% **Scenario 3** 61.7% **Scenario 4** 62.3% **Scenario 5** 58.6%	As the IRR of a renewable energy installation varies in line with the changing market conditions under different scenarios, the probability of investing in the renewable technology also changes. This is reflected in the 'economic coefficients' derived from the share of utility equation.

METHODOLOGY FOR ASSESSING THE DEPLOYMENT POTENTIAL OF PHOTOVOLTAICS (STAGE 6)

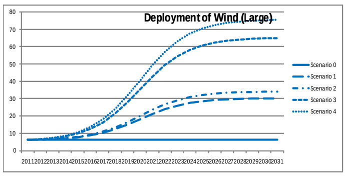
DECC STAGE OF ASSESSMENT	METHODOLOGY	ASSUMPTIONS	JUSTIFICATION/RATIONALE
STAGE 6	INCORPORATE DEPLOYMENT RISK ASSOCIATED WITH PV TO CALCULATE DEPLOYMENT COEFFICIENT	Calibrate deployment rate with reference to German FIT: - German PV deployment rate in 10 years = 10.7% of technical potential - Set Scenario 1 deployment coefficient such that **deployment rate for PV = PV deployment rate in Germany** - Set the deployment coefficients of the remaining scenarios to reflect the differing levels of government policy support to overcome barriers to the installation of photovoltaics based on order of magnitude judgement[1]: **Scenario 2:** Scenario 1 deployment coefficient (green policies, high energy prices) **Scenario 3:** 1.5 x Scenario 1 deployment coefficient (high local support) **Scenario 4:** 2 x Scenario 1 deployment coefficient (high local and national support) **Scenario 5:** 1.5 x Scenario 1 deployment coefficient (high local support)	The deployment rate for the business as usual scenario (Scenario 1) was set at the German PV deployment rate on the basis that FIT in the UK is designed to bring similar rate of returns when compared with Germany's tariffs and has similar prosperity levels which would facilitate the adoption of the technology in similar ways. The remaining scenarios were benchmarked against Scenario 1 based on the differing market conditions and policy support in each of the scenarios. The benchmarking of each scenario, and their relative to each other, have been informed by the CCC which has modelled uptake of energy efficiency measures under different conditions. Source: Committee on Climate Change (2009) Uptake of energy efficiency in buildings
	MULTIPLY TECHNICAL POTENTIAL BY ECONOMIC COEFFICIENT AND DEPLOYMENT COEFFICIENT TO DETERMINE 2020 DEPLOYMENT RATE	**RESULTS FOR COEFFICIENTS** **Stage 5 economic coefficient** x **Stage 6 deployment coefficient** = **2020 deployment rate** **Scenario 1** 51.8% x 20.6% = 10.7% **Scenario 2** 58% x 20.6% = 12.0% **Scenario 3** 61.7% x 31% = 19.1% **Scenario 4** 62.3% x 41.3% = 25.7% **Scenario 5** 58.6% x 31% = 18.2%	
	CALCULATE THE INTERIM AND 2031 DEPLOYMENT POTENTIAL BY USING A SIGMOID FUNCTION		The S-curve is used to describe the market deployment of many technologies where initial slow market growth is followed by a fast growth rate through to a final slow down as the market reaches saturation or support mechanisms decrease. The shape of the curve is callibrated to the German PV market as an example of renewables market growth patterns under support mechanisms. Source: German Solar Industry Association (2010) Development of the German PV Market

Appendix E: Wind methodology

METHODOLOGY FOR ASSESSING THE DEPLOYMENT POTENTIAL OF WIND (STAGE 5)

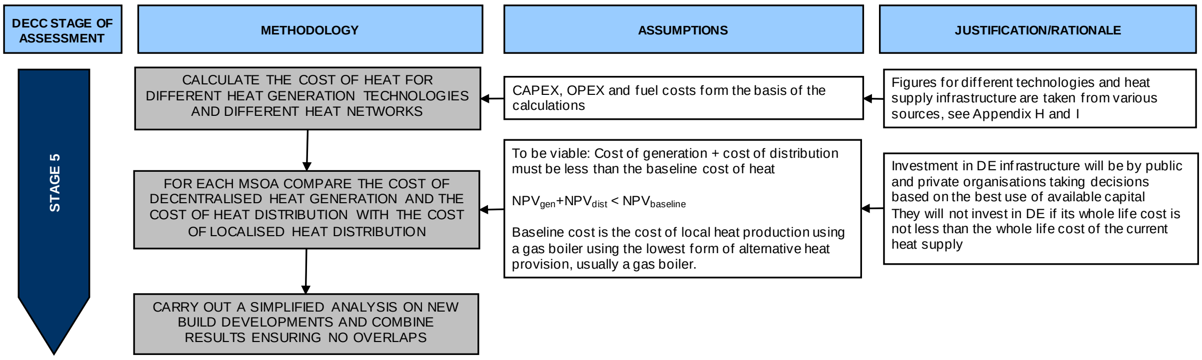
DECC STAGE OF ASSESSMENT	METHODOLOGY	ASSUMPTIONS	JUSTIFICATION/RATIONALE
STAGE 5	UNDERTAKE COST-BENEFIT ANALYSIS TO DETERMINE THE INTERNAL RATE OF RETURN OF INVESTING IN A WIND PROJECT	Capital cost of wind (£/kW): £1,250 Operating costs: £22/year FIT level and other inputs as defined by the scenarios.	Source: Camco wind project experience.
	CALCULATE THE ECONOMIC COEFFICIENT AS THE PROBABILITY OF INVESTING IN THE TECHNOLOGY BASED ON 'SHARE OF UTILITY' RULE	**Share of utility equation** Economic coefficient = Probability of investing= $\frac{IRR_{(renewable\ investment)}}{IRR_{(renewable\ investment)} + IRR_{(alternative\ investment)}}$ where $IRR_{(alternative\ investment)}$ = cost of capital (discount rate)	'Share of utility' rule states that the greater the level of utility that a consumer gains from a product, the higher the probability that the consumer will purchase that product. This assessment uses IRR as the measure of utility for installing a renewable energy technology. Source: Lilien, G.L. and Rangaswamy, A. (2004) Marketing Engineering: computer-assissted marketing analysis and planning.
	CALCULATE THE ECONOMIC POTENTIAL BY MULTIPLYING THE TECHNICAL POTENTIAL AND THE ECONOMIC COEFFICIENT	**Stage 5 economic coefficients** **Scenario 1** 46.8% **Scenario 2** 53.0% **Scenario 3** 56.9% **Scenario 4** 56.9% **Scenario 5** 53.0%	As the IRR of a renewable energy installation varies in line with the changing market conditions under different scenarios, the probability of investing in the renewable technology also changes. This is reflected in the 'economic coefficients' derived from the share of utility equation.

METHODOLOGY FOR ASSESSING THE DEPLOYMENT POTENTIAL OF WIND (STAGE 6)

DECC STAGE OF ASSESSMENT	METHODOLOGY	ASSUMPTIONS	JUSTIFICATION/RATIONALE
STAGE 6	INCORPORATE ADDITIONAL PLANNING RISKS ASSOCIATED WITH WIND PROJECTS AND ADJUST THE TECHNICAL POTENTIAL	Include green belt, local nature reserves, county parks as further constraints and incorporate a wider buffer around dwellings.	
	INCORPORATE DEPLOYMENT RISK BASED ON PLANNING PERMISSION RATES	Set deployment coefficients such that they reflect the probable planning permission rates for each scenario. **Scenario 1:** 25% **Scenario 2:** 25% **Scenario 3:** 50% **Scenario 4:** 70% **Scenario 5:** 50%	Based on the figure of 25% of wind applications (by MW) achieving planning permission in England. A further 62% gets approved at the appeal stage which would bring up the average permission rates to be between those set out for Scenario 3 and 4. Source: The British Wind Energy Association (2009) State of the industry report.
	MULTIPLY TECHNICAL POTENTIAL BY ECONOMIC COEFFICIENT AND DEPLOYMENT COEFFICIENT TO DETERMINE 2020 DEPLOYMENT RATE	**RESULTS FOR COEFFICIENTS** (Stage 5 economic coefficient x Stage 6 deployment coefficient = 2020 deployment rate) **Scenario 1** 46.8% x 25% = 11.7% **Scenario 2** 53.0% x 25% = 13.3% **Scenario 3** 56.9% x 50% = 28.4% **Scenario 4** 56.9% x 70% = 39.8% **Scenario 5** 53.0% x 50% = 26.5%	
	CALCULATE THE INTERIM AND 2031 DEPLOYMENT POTENTIAL BY USING A SIGMOID FUNCTION		The S-curve is used to describe the market deployment of many technologies where initial slow market growth is followed by a fast growth rate through to a final slow down as the market reaches saturation or support mechanisms decrease. The shape of the curve is callibrated to the German PV market as an example of renewables market growth patterns under support mechanisms. Source: German Solar Industry Association (2010) Development of the German PV Market

Appendix F: Decentralised energy methodology

METHODOLOGY FOR ASSESSING THE DEPLOYMENT POTENTIAL OF DECENTRALISED ENERGY (STAGE 5)



CALCULATE THE COST OF HEAT FOR DIFFERENT HEAT GENERATION TECHNOLOGIES AND DIFFERENT HEAT NETWORKS

FOR EACH MSOA COMPARE THE COST OF DECENTRALISED HEAT GENERATION AND THE COST OF HEAT DISTRIBUTION WITH THE COST OF LOCALISED HEAT DISTRIBUTION

CARRY OUT A SIMPLIFIED ANALYSIS ON NEW BUILD DEVELOPMENTS AND COMBINE RESULTS ENSURING NO OVERLAPS

CAPEX, OPEX and fuel costs form the basis of the calculations

To be viable: Cost of generation + cost of distribution must be less than the baseline cost of heat

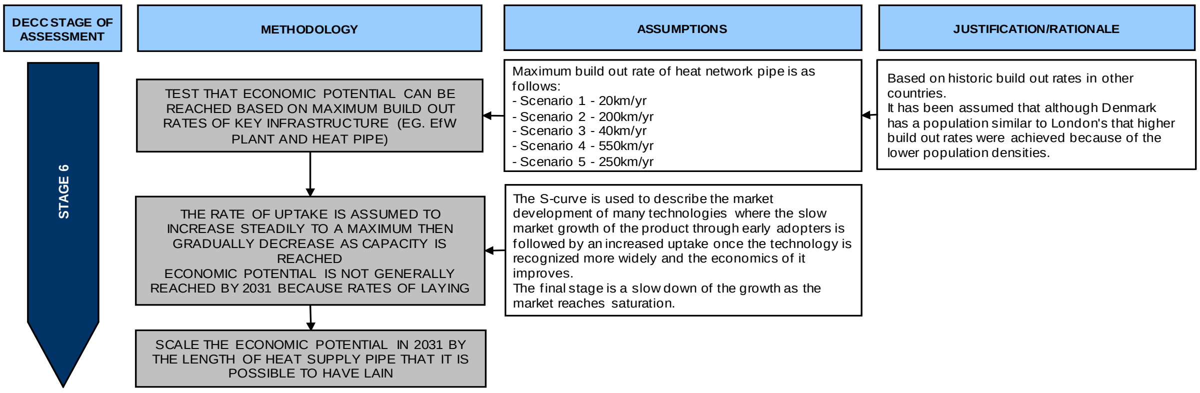
$NPV_{gen}+NPV_{dist} < NPV_{baseline}$

Baseline cost is the cost of local heat production using a gas boiler using the lowest form of alternative heat provision, usually a gas boiler.

Figures for different technologies and heat supply infrastructure are taken from various sources, see Appendix H and I

Investment in DE infrastructure will be by public and private organisations taking decisions based on the best use of available capital
They will not invest in DE if its whole life cost is not less than the whole life cost of the current heat supply

METHODOLOGY FOR ASSESSING THE DEPLOYMENT POTENTIAL OF DECENTRALISED ENERGY (STAGE 6)



TEST THAT ECONOMIC POTENTIAL CAN BE REACHED BASED ON MAXIMUM BUILD OUT RATES OF KEY INFRASTRUCTURE (EG. EfW PLANT AND HEAT PIPE)

THE RATE OF UPTAKE IS ASSUMED TO INCREASE STEADILY TO A MAXIMUM THEN GRADUALLY DECREASE AS CAPACITY IS REACHED
ECONOMIC POTENTIAL IS NOT GENERALLY REACHED BY 2031 BECAUSE RATES OF LAYING

SCALE THE ECONOMIC POTENTIAL IN 2031 BY THE LENGTH OF HEAT SUPPLY PIPE THAT IT IS POSSIBLE TO HAVE LAIN

Maximum build out rate of heat network pipe is as follows:
- Scenario 1 - 20km/yr
- Scenario 2 - 200km/yr
- Scenario 3 - 40km/yr
- Scenario 4 - 550km/yr
- Scenario 5 - 250km/yr

The S-curve is used to describe the market development of many technologies where the slow market growth of the product through early adopters is followed by an increased uptake once the technology is recognized more widely and the economics of it improves.
The final stage is a slow down of the growth as the market reaches saturation.

Based on historic build out rates in other countries.
It has been assumed that although Denmark has a population similar to London's that higher build out rates were achieved because of the lower population densities.

Appendix G: Deployment potential results by scenario

This appendix sets out the results for each scenario, including the deployment potential over the periods to 2015, 2020, 2025 and 2031. For each scenario two tables and two graphs are presented, one each for RE and DE.

For RE not connected to heat networks, the 2009 installed capacity is included within the deployment curves, as a detailed breakdown of technologies is available (see Section 2.5.6 in the Phase 1 report). For DE plant connected to heat networks, no detailed breakdown of installed capacity by technology type is available, therefore the 2009 installed capacity (which generates 3,160 GWh of heat and electricity – see Section 12.3 in the Phase 1 report) is not included in the 2015 and 2020 figures, but assumed to have been accounted for within the final deployment figures.

BAU scenario

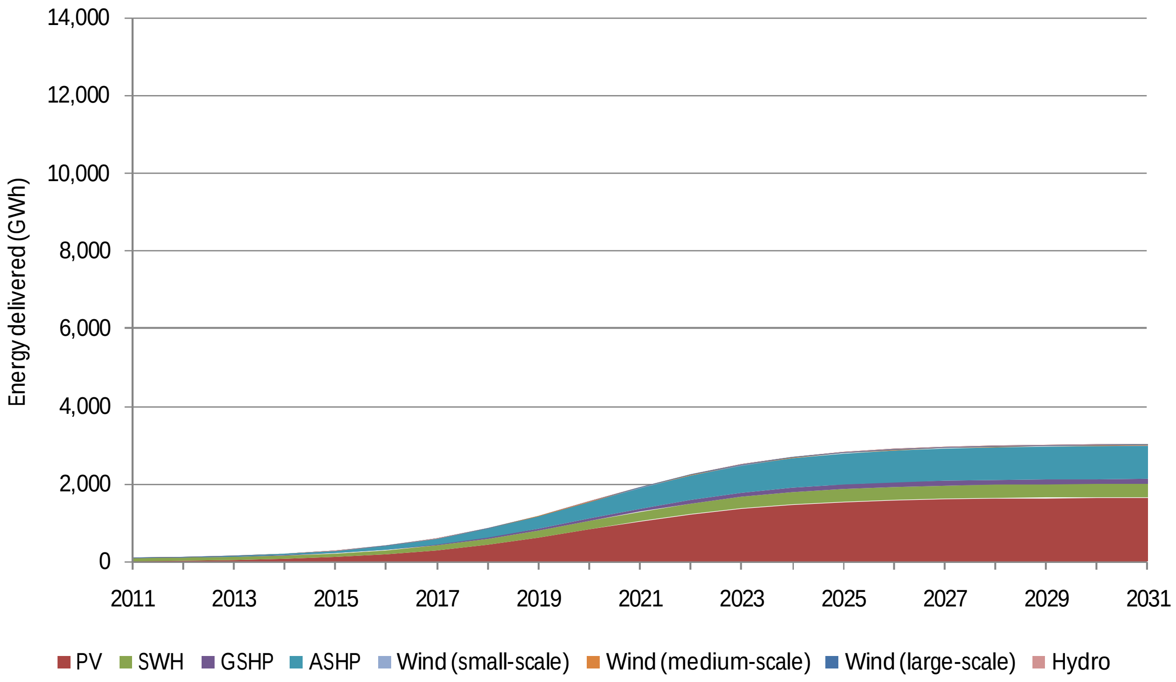


Figure 5-1: Deployment potential for renewable energy in BAU scenario

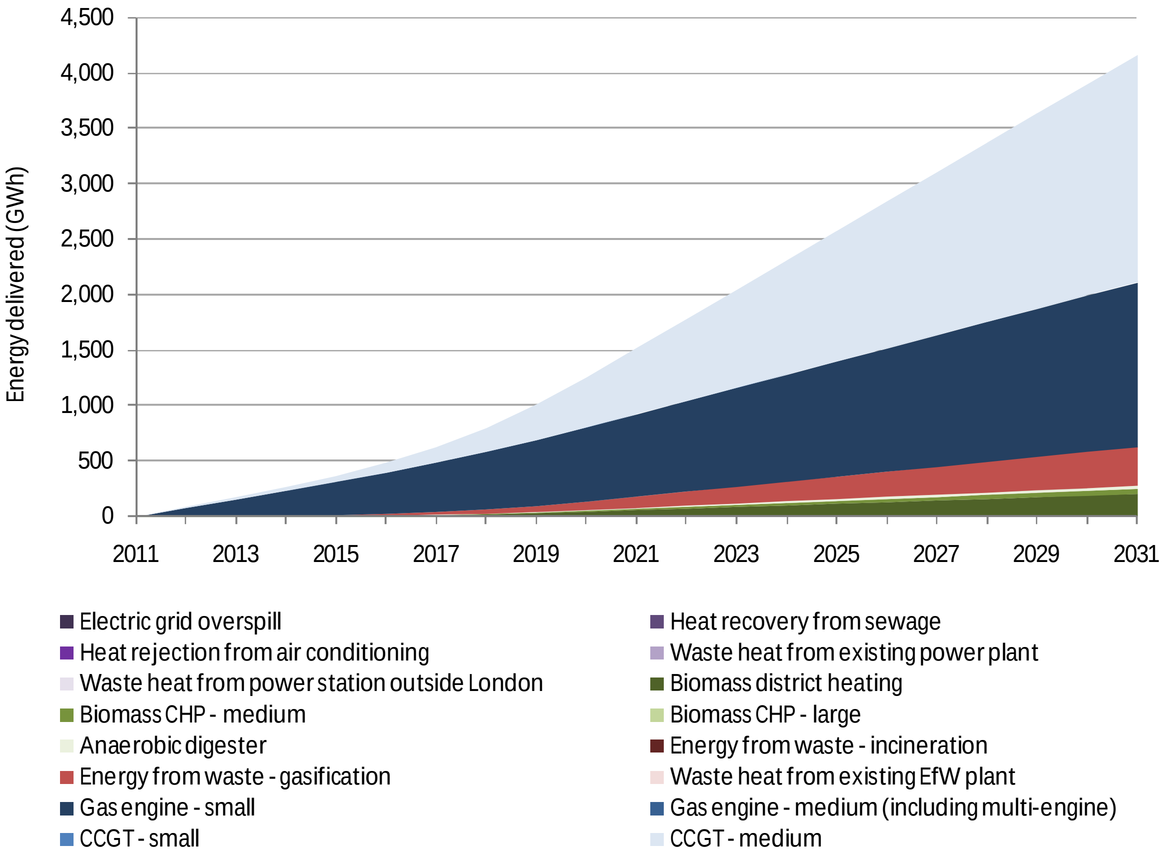


Figure 5-2: Deployment potential for decentralised energy in BAU scenario

	Total energy delivered (GWh)				% of London's electricity demand by 2031	% of London's heat demand by 2031	% of London's energy demand by 2031
	2015	2020	2025	2031			
PV	107	819	1,532	1,646	3.8%	1.8%	1.2%
SWH	93.0	211	329	348	0.8%	0.4%	0.3%
GSHP	16.3	66.2	116	124	0.3%	0.1%	0.09%
ASHP	62.6	430	797	856	2.0%	0.9%	0.6%
Wind – small-scale	0.1	1.0	1.8	1.9	0.004%	0.002%	0.001%
Wind – medium-scale	7.9	21.0	34.1	36.2	0.08%	0.04%	0.03%
Wind – large-scale	8.4	15.0	21.6	22.6	0.05%	0.02%	0.02%
Hydro	0.4	2.9	5.5	5.9	0.01%	0.007%	0.004%
Total	**296**	**1,566**	**2,837**	**3,041**	**7.1%**	**3.4%**	**2.3%**

Table 5-1: Deployment potential for renewable energy in BAU scenario

	Total energy delivered (GWh)				% of London's electricity demand by 2031	% of London's heat demand by 2031	% of London's energy demand by 2031
	2015	2020	2025	2031			
Anaerobic digester	0.8	6.5	16.9	29.5	0.03%	0.02%	0.02%
Biomass CHP – large	-	-	-	-	-	-	-
Biomass CHP – medium	1.3	10.3	27.0	47.0	0.03%	0.04%	0.04%
Biomass district heating	5.3	42.3	111.0	193.4	-	0.2%	0.1%
CCGT – medium	56.4	449	1177	2050	2.8%	0.9%	1.5%
CCGT – small	0.2	1.6	4.2	7.3	0.01%	0.004%	0.01%
Electric grid overspill	-	-	-	-	-	-	-
Energy from waste – gasification	9.7	77.0	202	352	0.3%	0.3%	0.3%
Energy from waste – incineration	-	-	-	-	-	-	-
Gas engine – medium (including multi-engine)	-	-	-	-	-	-	-
Gas engine – small	296	667	1037	1482	1.2%	1.1%	1.1%
Heat recovery from sewage	-	-	-	-	-	-	-
Heat rejection from air conditioning	-	-	-	-	-	-	-
Waste heat from existing EfW plant	-	-	-	-	-	-	-
Waste heat from existing power plant	0.2	1.6	4.2	7.3	0.009%	0.004%	0.005%
Waste heat from power station outside London	-	-	-	-	-	-	-
Total	**370**	**1,255**	**2,579**	**4,168**	**4.4%**	**2.5%**	**3.1%**

Table 5-2: Deployment potential for decentralised energy in BAU scenario

National action scenario

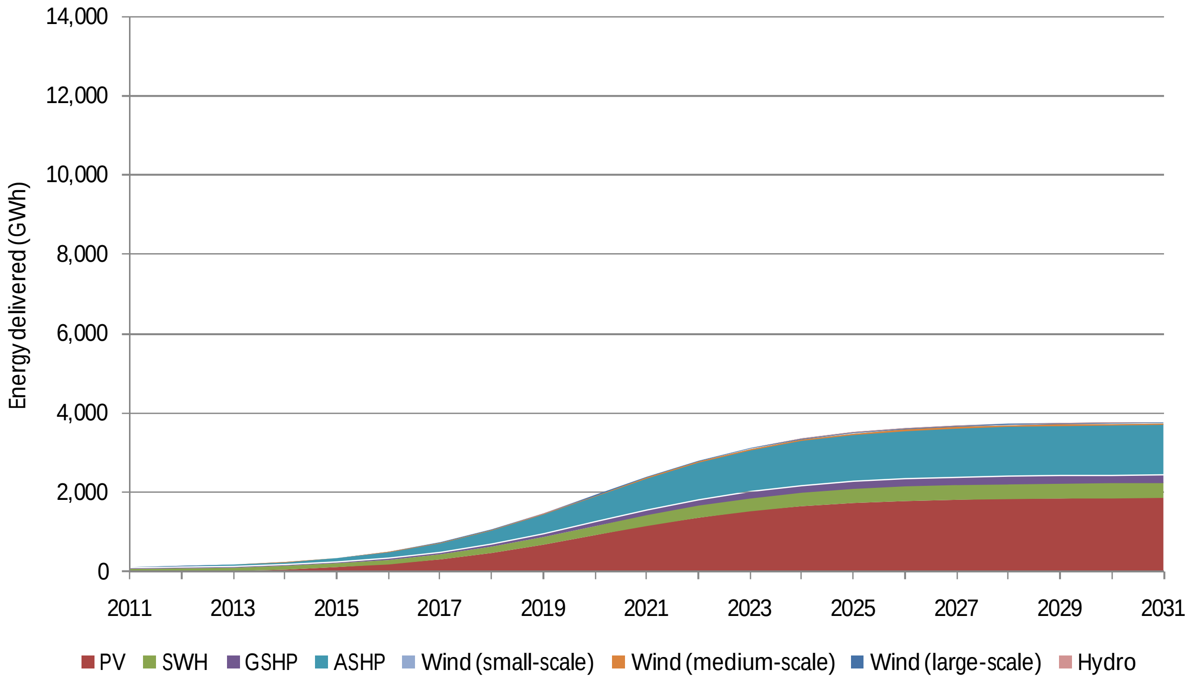


Figure 5-3: Deployment potential for renewable energy in national action scenario

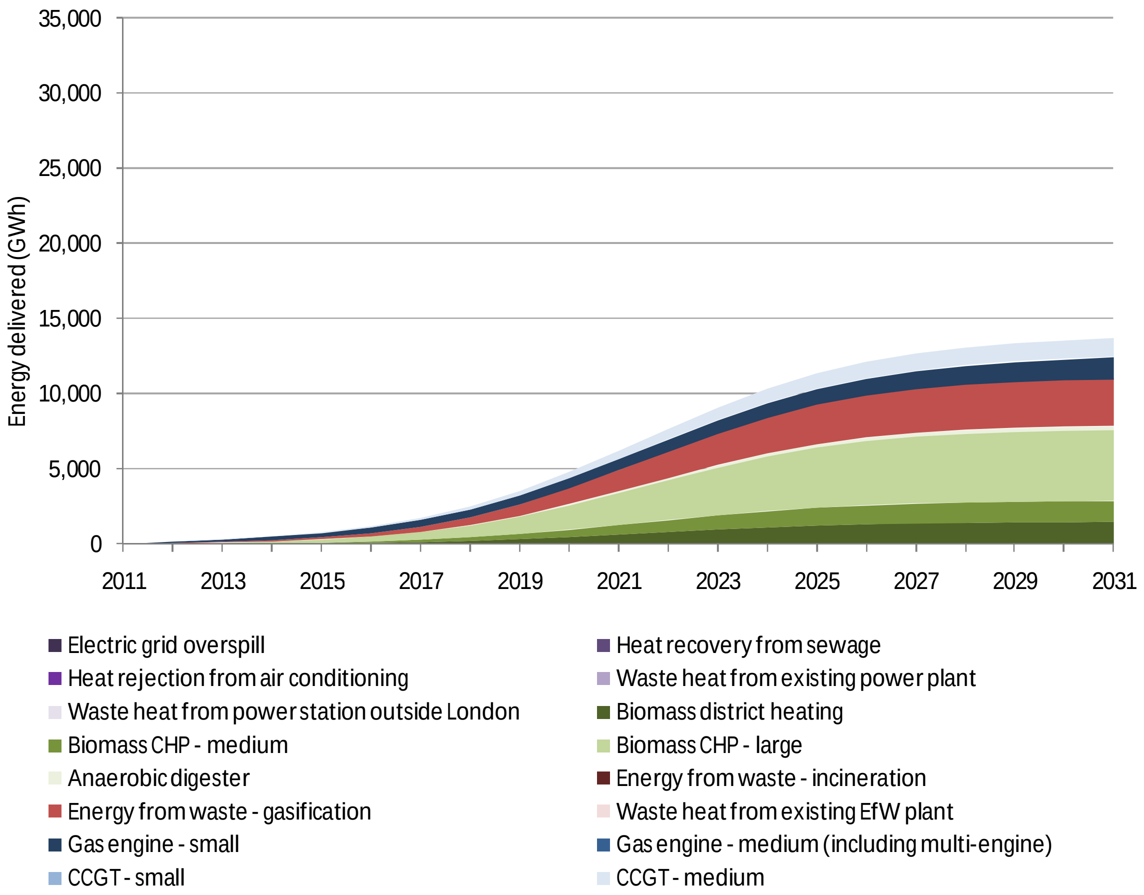


Figure 5-4: Deployment potential for decentralised energy in national action scenario

	Total energy delivered (GWh)				% of London's electricity demand by 2031	% of London's heat demand by 2031	% of London's energy demand by 2031
	2015	2020	2025	2031			
PV	119	917	1,715	1,844	4.7%	2.7%	1.7%
SWH	96.4	238	379	402	1.0%	0.6%	0.4%
GSHP	20.3	97.2	174	186	0.5%	0.3%	0.2%
ASHP	89.4	640	1,191	1,279	3.3%	1.8%	1.2%
Wind – small-scale	0.1	1.1	2.0	2.1	0.005%	0.003%	0.002%
Wind – medium-scale	7.9	21.3	34.7	36.9	0.09%	0.05%	0.03%
Wind – large-scale	8.8	17.7	26.6	28.1	0.07%	0.04%	0.03%
Hydro	0.8	6.0	11.2	12.0	0.03%	0.02%	0.01%
Total	**343**	**1,938**	**3,533**	**3,790**	**9.6%**	**5.5%**	**3.5%**

Table 5-3: Deployment potential for renewable energy in national action scenario

	Total energy delivered (GWh)				% of London's electricity demand by 2031	% of London's heat demand by 2031	% of London's energy demand by 2031
	2015	2020	2025	2031			
Anaerobic digester	11.2	89.5	223	263	0.3%	0.2%	0.2%
Biomass CHP – large	202	1,607	4,001	4,730	4.0%	4.6%	4.4%
Biomass CHP – medium	59.1	470.3	1,171.0	1,385	0.81%	1.5%	1.3%
Biomass district heating	64	506	1,261	1,491	-	2%	1%
CCGT – medium	51.5	410	1,020	1,206	1.8%	0.7%	1.1%
CCGT – small	-	-	-	-	-	-	-
Electric grid overspill	-	-	-	-	-	-	-
Energy from waste – gasification	134	1,069	2,661	3,146	2.7%	3.0%	2.9%
Energy from waste – incineration	-	-	-	-	-	-	-
Gas engine – medium (including multi-engine)	-	-	-	-	-	-	-
Gas engine – small	294	662	1,030	1,472	1.3%	1.4%	1.4%
Heat recovery from sewage	-	-	-	-	-	-	-
Heat rejection from air conditioning	-	-	-	-	-	-	-
Waste heat from existing EfW plant	-	-	-	-	-	-	-
Waste heat from existing power plant	-	-	-	-	-	-	-
Waste heat from power station outside London	-	-	-	-	-	-	-
Total	816	4,814	11,366	13,693	10.9%	13.6%	12.6%

Table 5-4: Deployment potential for decentralised energy in national action scenario

Regional action scenario

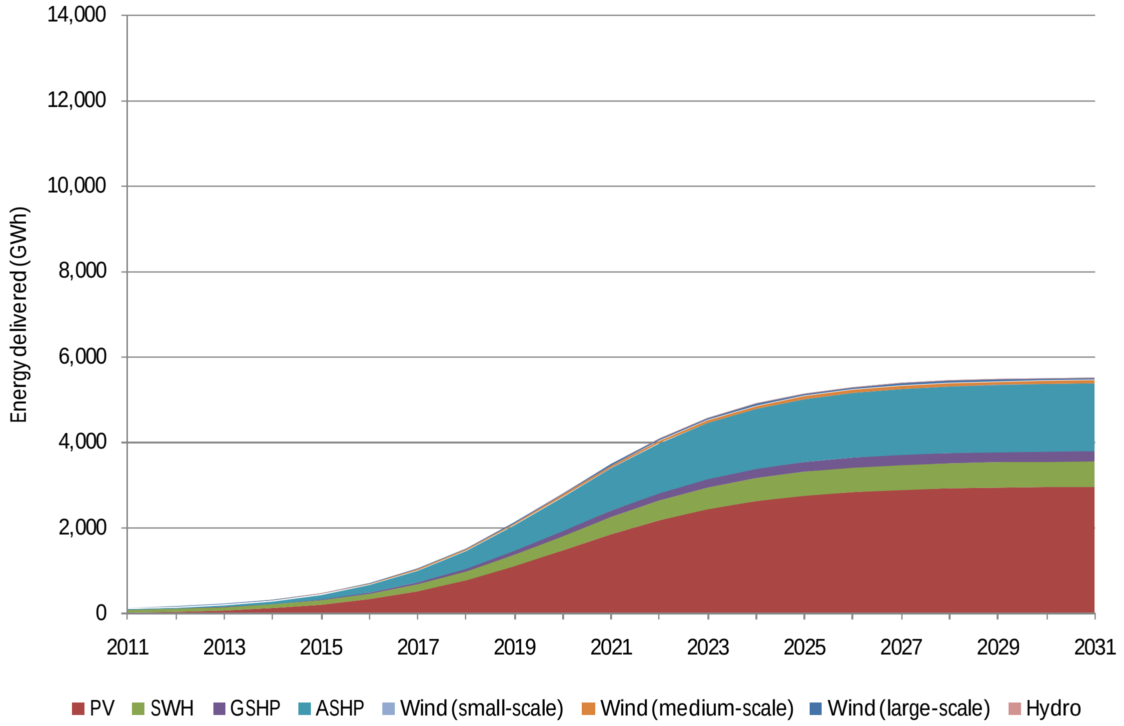


Figure 5-5: Deployment potential for renewable energy in regional action scenario

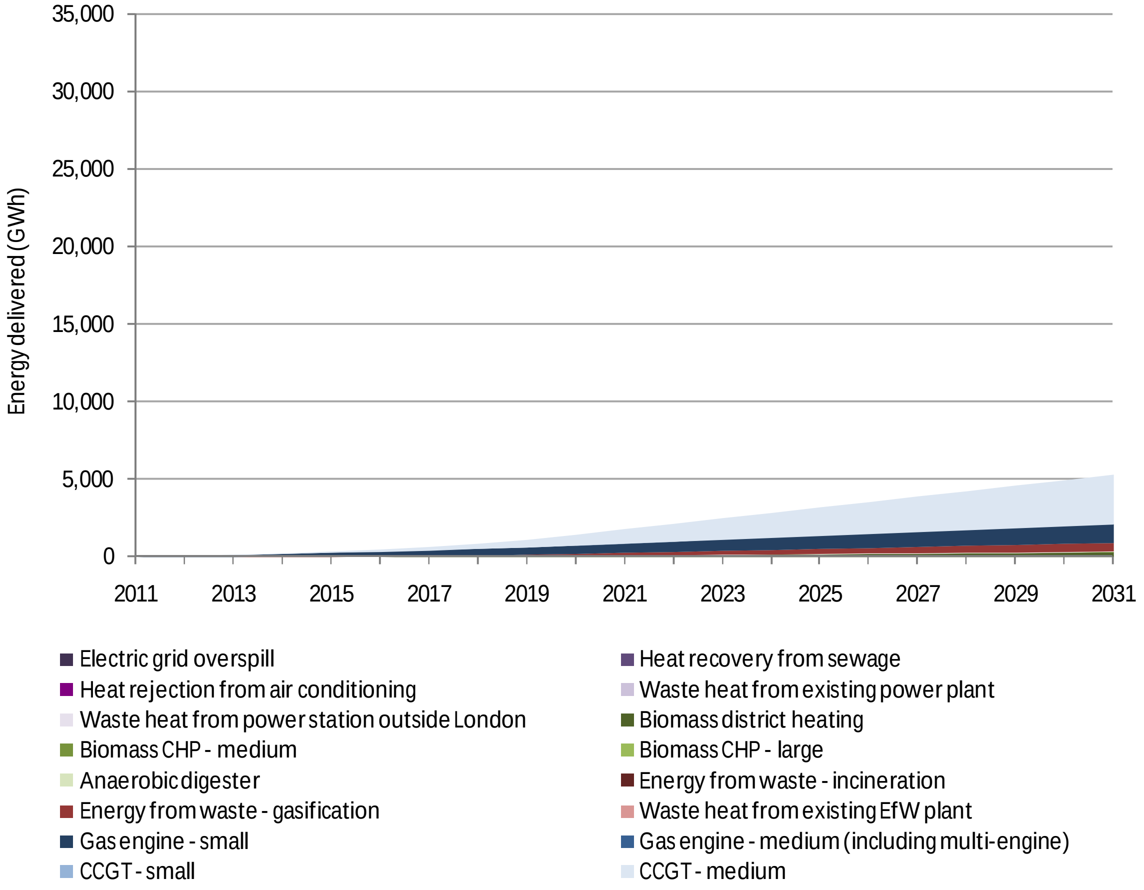


Figure 5-6: Deployment potential for decentralised energy in regional action scenario

	Total energy delivered (GWh)				% of London's electricity demand by 2031	% of London's heat demand by 2031	% of London's energy demand by 2031
	2015	2020	2025	2031			
PV	189	1,462	2,735	2,940	7.5%	4.2%	2.7%
SWH	109	336	563	599	1.5%	0.9%	0.6%
GSHP	24.1	127	230	246	0.6%	0.4%	0.2%
ASHP	109	791	1,473	1,583	4.0%	2.3%	1.5%
Wind – small-scale	0.3	2.3	4.2	4.5	0.012%	0.007%	0.004%
Wind – medium-scale	10.2	38.9	67.5	72.2	0.18%	0.10%	0.07%
Wind – large-scale	10.3	29.9	49.5	52.6	0.13%	0.08%	0.05%
Hydro	0.9	7.1	13.3	14.3	0.04%	0.02%	0.01%
Total	**452**	**2,794**	**5,135**	**5,512**	**14.0%**	**7.9%**	**5.1%**

Table 5-5: Deployment potential for renewable energy in regional action scenario

	Total energy delivered (GWh)				% of London's electricity demand by 2031	% of London's heat demand by 2031	% of London's energy demand by 2031
	2015	2020	2025	2031			
Anaerobic digester	1.3	10.2	26.6	46.4	0.05%	0.04%	0.04%
Biomass CHP – large	-	-	-	-	-	-	-
Biomass CHP – medium	0.07	0.5	1.4	2.4	0.002%	0.003%	0.002%
Biomass district heating	8	65	170	296	-	0%	0%
CCGT – medium	88	697	1,827	3,183	4.9%	1.8%	2.9%
CCGT – small	0.02	0.2	0.5	0.9	0.001%	0.0005%	0.0008%
Electric grid overspill	-	-	-	-	-	-	-
Energy from waste – gasification	15.2	121	317	552	0.5%	0.5%	0.5%
Energy from waste – incineration	-	-	-	-	-	-	-
Gas engine – medium (including multi-engine)	-	-	-	-	-	-	-
Gas engine – small	242	545	847	1,210	1.1%	1.1%	1.1%
Heat recovery from sewage	-	-	-	-	-	-	-
Heat rejection from air conditioning	-	-	-	-	-	-	-
Waste heat from existing EfW plant	-	-	-	-	-	-	-
Waste heat from existing power plant	0.0	0.2	0.5	0.8	0.001%	0.0005%	0.0007%
Waste heat from power station outside London	-	-	-	-	-	-	-
Total	354	1,438	3,189	5,291	6.5%	4.0%	4.9%

Table 5-6: Deployment potential for decentralised energy in regional action scenario

Ambitious action scenario

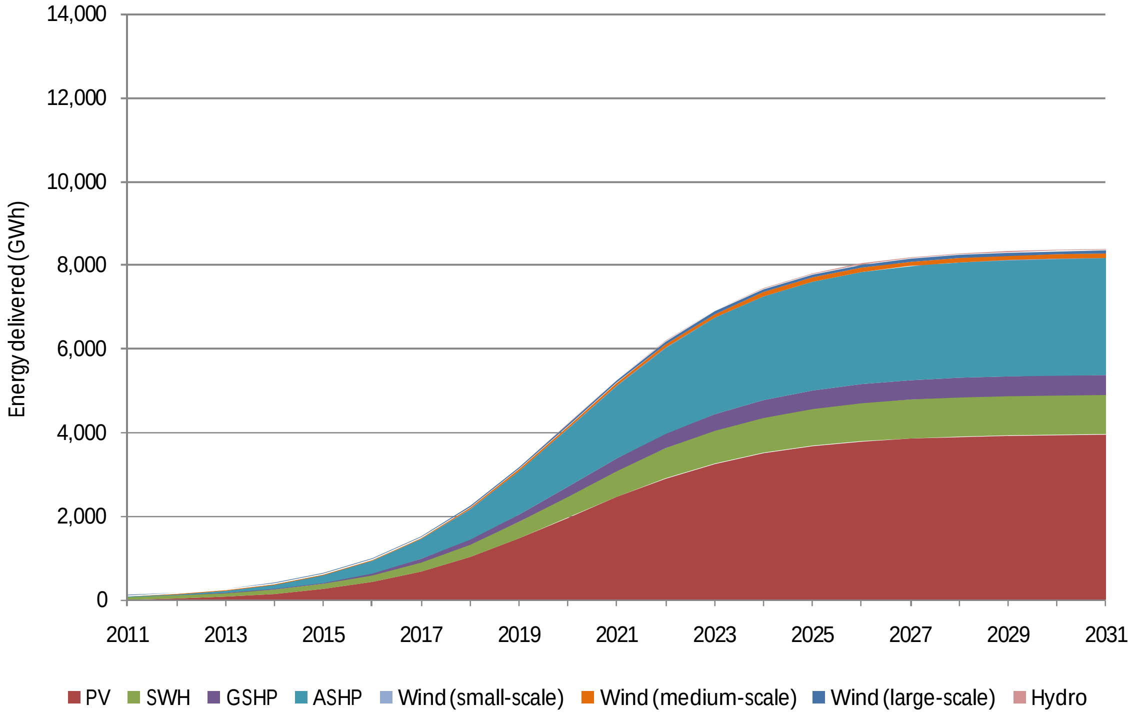


Figure 5-7: Deployment potential for renewable energy in ambitious action scenario

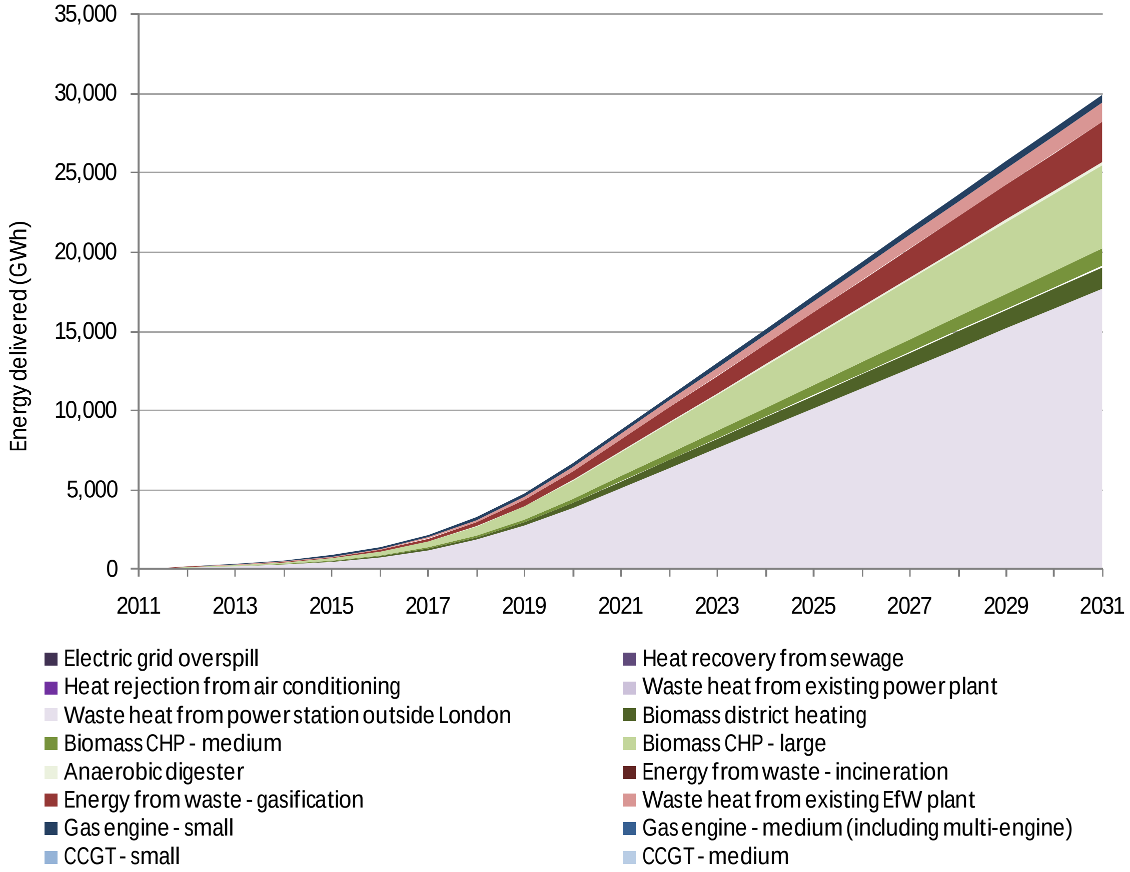


Figure 5-8: Deployment potential for decentralised energy in ambitious action scenario

	Total energy delivered (GWh)				**% of London's electricity demand by 2031**	**% of London's heat demand by 2031**	**% of London's energy demand by 2031**
	2015	**2020**	**2025**	**2031**			
PV	253	1,967	3,681	3,957	10.1%	5.7%	3.6%
SWH	131	511	891	952	2.4%	1.4%	0.9%
GSHP	38.8	243	447	480	1.2%	0.7%	0.4%
ASHP	185	1,395	2,604	2,799	7.1%	4.0%	2.6%
Wind – small-scale	0.4	3.2	5.9	6.4	0.02%	0.009%	0.006%
Wind – medium-scale	12.2	55.1	97.9	105	0.3%	0.2%	0.1%
Wind – large-scale	11.8	41.5	71.1	75.9	0.2%	0.1%	0.07%
Hydro	1.1	8.9	16.7	17.9	0.05%	0.03%	0.02%
Total	**634**	**4,224**	**7,815**	**8,392**	**21.3%**	**12.1%**	**7.7%**

Table 5-7: Deployment potential for renewable energy in ambitious action scenario

	Total energy delivered (GWh)				**% of London's electricity demand by 2031**	**% of London's heat demand by 2031**	**% of London's energy demand by 2031**
	2015	**2020**	**2025**	**2031**			
Anaerobic digester	5.8	46.6	122	213	0.2%	0.2%	0.2%
Biomass CHP – large	145	1,154	3,025	5,270	4.5%	5.1%	4.8%
Biomass CHP – medium	30.7	244.3	640.4	1,115.7	0.65%	1.24%	1.03%
Biomass district heating	37	298	781	1,361	-	2.0%	1.3%
CCGT – medium	-	-	-	-	-	-	-
CCGT – small	-	-	-	-	-	-	-
Electric grid overspill	-	-	-	-	-	-	-
Energy from waste – gasification	69.6	554	1,453	2,531	2.2%	2.4%	2.3%
Energy from waste – incineration	-	-	-	-	-	-	-
Gas engine – medium (including multi-engine)	-	-	-	-	-	-	-
Gas engine – small	101	228	354	506	0.5%	0.5%	0.5%
Heat recovery from sewage	-	-	-	-	-	-	-
Heat rejection from air conditioning	-	-	-	-	-	-	-
Waste heat from existing EfW plant	32.6	260	681	1,186	1.6%	0.8%	1.1%
Waste heat from existing power plant	-	-	-	-	-	-	-
Waste heat from power station outside London	487	3,879	10,171	17,720	25.6%	11.0%	16.3%
Total	**910**	**6,663**	**17,227**	**29,903**	**35.2%**	**23.1%**	**27.5%**

Table 5-8: Deployment potential for decentralised energy in ambitious action scenario

Coordinated action scenario

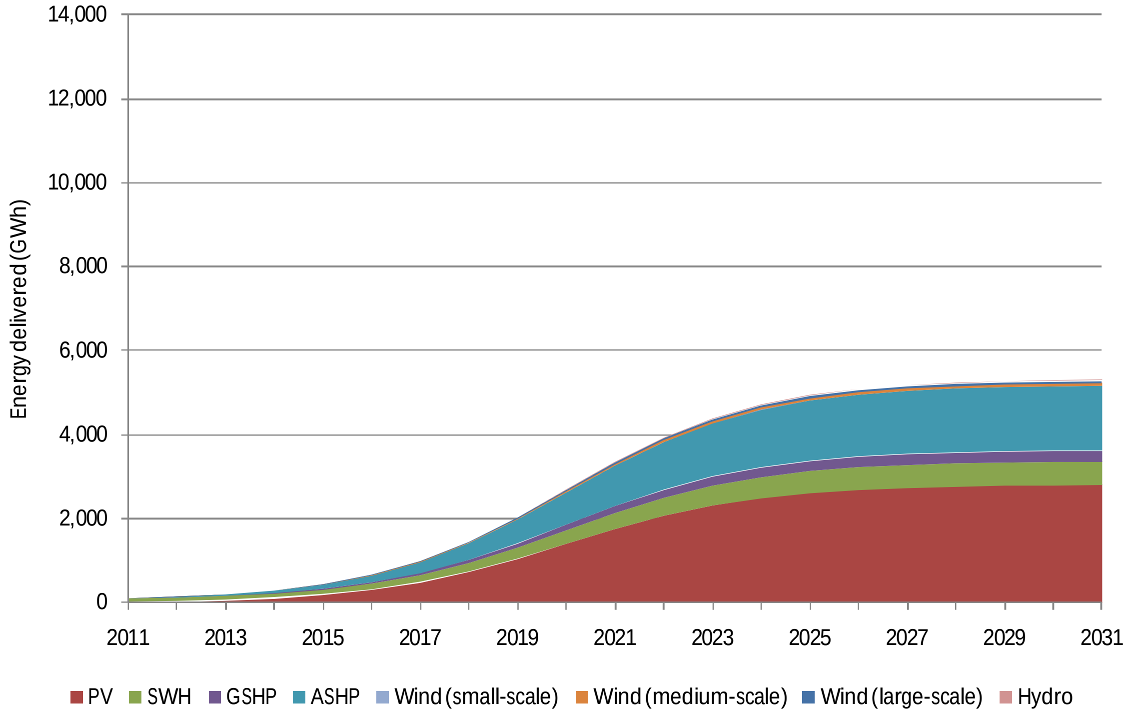


Figure 5-9: Deployment potential for renewable energy in coordinated action scenario

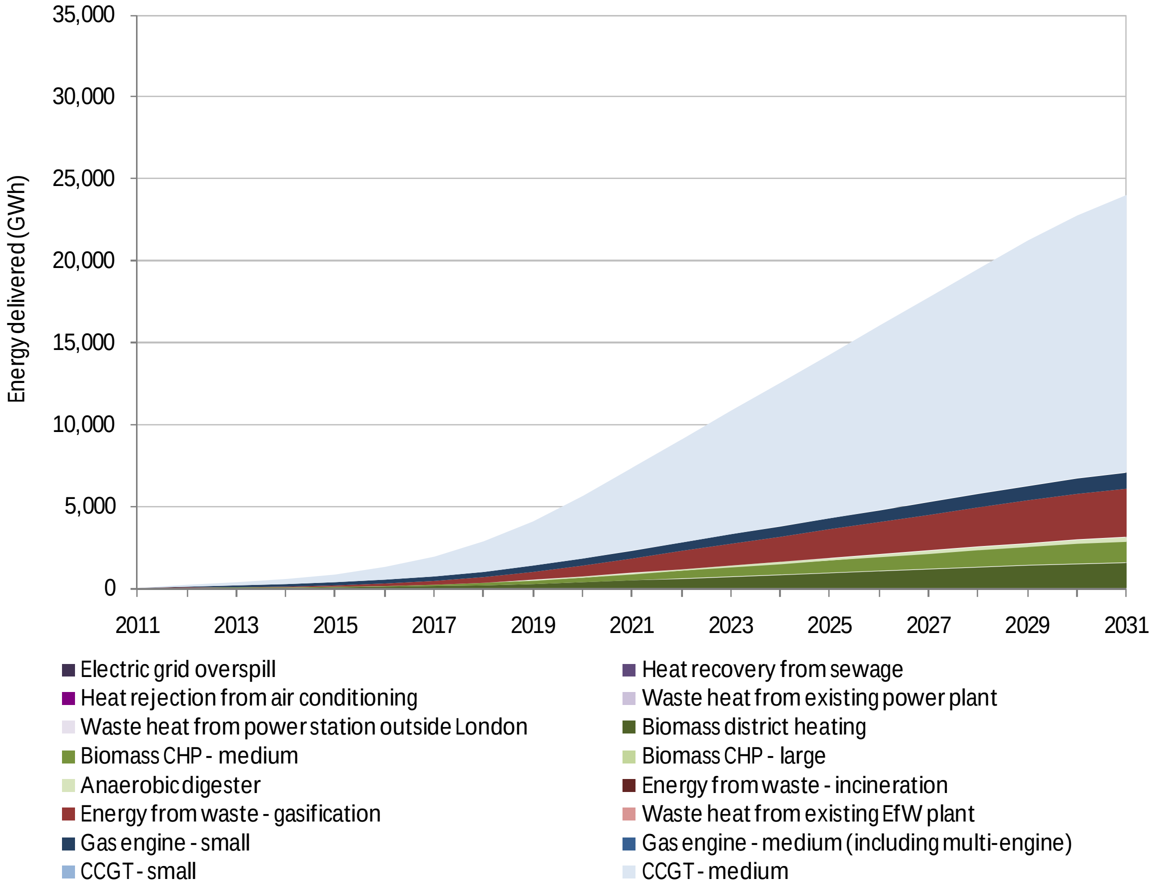


Figure 5-10: Deployment potential for decentralised energy in coordinated action scenario

	Total energy delivered (GWh)				% of London's electricity demand by 2031	% of London's heat demand by 2031	% of London's energy demand by 2031
	2015	2020	2025	2031			
PV	179	1,389	2,599	2,793	7.1%	4.0%	2.6%
SWH	107	319	531	565	1.4%	0.8%	0.5%
GSHP	24.7	132	239	256	0.7%	0.4%	0.2%
ASHP	105	766	1,427	1,533	3.9%	2.2%	1.4%
Wind – small-scale	0.3	2.1	4.0	4.3	0.01%	0.006%	0.004%
Wind – medium-scale	10.2	39.0	67.9	72.5	0.2%	0.1%	0.07%
Wind – large-scale	10.4	30.4	50.3	53.5	0.1%	0.08%	0.05%
Hydro	0.9	7.1	13.3	14.3	0.04%	0.02%	0.01%
Total	**438**	**2,684**	**4,930**	**5,292**	**13.5%**	**7.6%**	**4.9%**

Table 5-9: Deployment potential for renewable energy in coordinated action scenario

	Total energy delivered (GWh)				% of London's electricity demand by 2031	% of London's heat demand by 2031	% of London's energy demand by 2031
	2015	2020	2025	2031			
Anaerobic digester	7.1	56.1	147	249	0.3%	0.2%	0.2%
Biomass CHP – large	-	-	-	-	-	-	-
Biomass CHP – medium	37.0	294.9	773.2	1308.3	0.76%	1.45%	1.2%
Biomass district heating	45.2	359.7	943.2	1595.8	-	2.3%	1.5%
CCGT – medium	480	3,822	10,020	16,954	26.0%	9.7%	15.6%
CCGT – small	-	-	-	-	-	-	-
Electric grid overspill	-	-	-	-	-	-	-
Energy from waste – gasification	84.2	670	1,757	2,972	2.6%	2.8%	2.7%
Energy from waste – incineration	-	-	-	-	-	-	-
Gas engine – medium (including multi-engine)	-	-	-	-	-	-	-
Gas engine – small	193	434	675	964	0.9%	0.9%	0.9%
Heat recovery from sewage	-	-	-	-	-	-	-
Heat rejection from air conditioning	-	-	-	-	-	-	-
Waste heat from existing EfW plant	-	-	-	-	-	-	-
Waste heat from existing power plant	-	-	-	-	-	-	-
Waste heat from power station outside London	-	-	-	-	-	-	-
Total	**846**	**5,637**	**14,315**	**24,044**	**30.5%**	**17.4%**	**22.1%**

Table 5-10: Deployment potential for decentralised energy in coordinated action scenario

Appendix H: Carbon factor calculations

The carbon factors are calculated to apportion all the carbon savings to the heat produced by a technology. This allows the carbon savings to be calculated based on the heat produced which simplifies the model. First the carbon emissions for a technology are calculated by working out the emissions from fuel consumption, auxiliary energy use (such as DE pumps) and finally a credit for the electricity produced. The credit for the electricity produced is calculated with reference to the marginal grid electricity carbon intensity. The marginal grid factor is used because local electricity production is inherently unpredictable therefore when it is imported into the grid it displaces electricity produced by standby generation (also called the spinning reserve).

Technology carbon emissions = carbon emissions from fuel consumption + carbon emissions from auxiliary energy - credit for generating electricity

Carbon factor for heat use = technology carbon emissions / heat supplied

Carbon emissions from waste combustion (biomass fraction) = 0

*Carbon emissions from waste combustion = (fossil fuel fraction) * (heat produced * gas boiler carbon factors + electricity produced * grid carbon factor)*

The carbon emissions from the fossil fuel fraction of waste combustion are assumed to be equal to the production of energy through conventional means.