District Heating: Economic Assessment and Evaluation of Evidence

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1. Empirical evidence supports and informs policy design. As such, given the potential importance of District Heating to achieving objectives for heat and energy saving, it is considered appropriate to supplement the Consultation Document with relevant information on our evidence base regarding the potential for District Heating in the UK and on our evaluation of this evidence to date.

2. The following paper aims to give an overview of those aspects of our evidence gathering that will provide the basis for policy designed to overcome barriers to District Heating. This paper does not aim to amplify the argumentation developed in the respective chapter of the Consultation Document; rather its focus is on those particulars of the District Heating sector that would inform an economic assessment of the impact of prospective measures.

3. The paper proceeds as follows. The first section provides a background to the UK's experience with District Heating. The second section describes the market failures that prevent expansion of District Heating. The third section sets out the potential scope for District Heating. The fourth section sets out the concept of heat density on which our projections are predicated. The fifth section discusses efficiency gains from District Heating. Annexes tabulate quantitative information.

Table of Contents

District Heating in the UK

4. District Heating coverage of the UK's heating demand is estimated at 4%. Proportionally the largest share is in communally operated installations, such as universities, hospitals, and industrial sites. District Heating has not established itself as a heat delivery method of choice.

5. Many District Heating schemes were built in the 1960s and 1970s. The justification then was an economic one – the central plant could use lower cost fuel such as coal or heavy fuel oil which could not be used so easily in individual dwellings especially in blocks of flats. Stagnation of District Heating as a means of heat delivery in the UK built environment has been in keeping with consumers' preference since the 1970s for a retreat from provision of services at municipal level.

6. Today, in the UK decisions on choice of heat delivery are usually made at the level of individual dwellings. The predominant model of UK domestic heat provision to individual domestic and non-domestic dwellings is gas-fuelled heating supplied off a central grid.

7. Most of the dwellings heat demand is supplied from individual gas boilers (81%), individual electrical heating systems (9%) and oil (8%) the latter mainly in off-gas grid areas.

8. The UK's minor reliance on District Heating is at variance with heating markets in countries across Scandinavia and Eastern Europe, where the share of housing served by District Heating can be as high as 90% (in Iceland) and 60% (in Sweden) and in eleven Balkan and Nordic countries exceeds 30%. The viability of District Heating is location specific. In Helsinki and Vienna, for example, District Heating covers 90% and 30% of the building stock, respectively. Whilst there are plausible explanations for this variance from the UK – many of these countries have a markedly different institutional heritage and all of them have a much colder climate – there remains the question whether in the UK the materially lower percentage share of District Heating in the

heat sector could not be higher. This prompts the need for evidence gathering.

Market Failure

9. The comparatively low take up of District Heating is one particular manifestation of a market failure of concern across climate change policies, namely the social cost of CO_2 emissions and its materialisation in the discrepancy between private and social cost of carbon.

10. In the particular circumstances of the District Heating sector, market failures that prevent market actors from raising welfare lie in the absence of co-ordination of information and of established norms for consumer protection. These are discussed in turn.

11. The viability of District Heating depends on a shared awareness of benefits across a diverse group of stakeholders – investors, operators, consumers, and public authorities. Individual actors seeking to aggregate information lack incentive to bear search costs where benefits disperse across different sections of the market. Whilst in such cases it is conceivable that public authorities would address this shortcoming, District Heating by its nature is contingent on locational particulars and it is unlikely an individual Local Authority would undertake the necessary research for lack of assurance these efforts are rewarded.

12. A further market failure is the lack of established norms to ensure consumer protection. The transition to District Heating would entail significant initial installation costs and consumers would understandably be reluctant to expose themselves to the risk of contractual lock-in.

13. Given the UK's commitment to reaching CO_2 reduction targets there is a need for proactive examination of options to realise the potential for improved carbon savings and more efficient use of energy from District Heating. Substantial work was carried out in the late 1970's (e.g. Energy Paper 35, 1979), and a more recent update was commissioned by the then DETR in 1998. This work was updated in 2002 for the Carbon Trust and has since been published by the BRE[1].

14. Previous studies of District Heating potential have taken into account the heat demand of individual dwellings, and extrapolated the maximum potential reach of District Heating using as a variable threshold Internal Rates of Return ("IRR"). Key sources surveyed have been work done by BRE (Client Report 211-533, The UK Potential for Community Heating with Combined Heat and Power, 2006), by PB

[1] BRE Client Report 211-533, The UK Potential for Community Heating with Combined Heat and Power, BRE 2006

Power (Community Heating Development Study for London, 2006), and by the IEA (A comparison of large-scale and small-scale CHP/DH, 2005).

15. Previous work has shown the importance of assumptions on the required rate of return on investment. The following table shows that the imputed requirement for reaching specified IRR has a material impact on the expansion of District Heating. For example, DEFRA (2007) concluded that an increase in IRR from 6% to 9% collapses the volume of supply from 150 TWh to 0.6 TWh.

Source	16. TWh heat at >6% IRR	17. Nos of dwellings at >6% IRR	18. TWh heat at >9% IRR
DETR (1998-2002), published by BRE	19. 114	20. 5.5m	21. 19.4
Defra October 2007	22. 150	23. 6.5m	24. 0.63
Oxford Energy Institute	25.	26. 4.4m by 2050	27.

28. Dwellings account for some 70% of the UK's heat demand and an evaluation of potential carbon savings from heat provision therefore merits examination, in order to ensure all possible carbon reduction measures are considered.

UK Potential for District Heating

29. The cost of fuels supplied to individual dwellings is determined by both the fuel production cost and the distribution cost of this fuel. If the heat production cost is lower than the heat selling price, District Heating capital cost can be recovered over time.

30. This section describes the scope for expanding District Heating in the UK's built environment. The relative merit of efficiency gains of different fuel sources is discussed in the subsequent section.

31. For the purposes of scoping scenarios our research[2] disaggregates the built environment into five 'tranches' (city centre, urban, suburban high/low density, rural) and six building types (pre-1919 small/large terrace, semi-detached, flats pre-1919 flats/1919-1975/post-1975).

32. Additionally, our research has considered the potential in the non-domestic market. The wider diversity of building types (which are

[2] Research has been commissioned and is scheduled to conclude during the consultation period.

purpose-built for particular uses) in the non-domestic sector makes assessment of potential connection to District Heating more difficult.

33. Non-domestic heat demand ranked by size features in the following table

Key sector	34. Potential for District Heating connection	35. Assumptions
Factories and warehouses	36. 0 TWh	37. Assumes that District Heating connection not viable due to locations.
Hotels and catering	38. 5.2 TWh	39. Assumes that 50% of sites are in higher density city centre and urban areas.
Commercial offices	40. 5.1 TWh	41. Assumes that 50% of sites are in higher density city centre and urban areas.
Hospitals	42. 0 TWh	43. Assumes that site schemes are preferable or currently in existence.
Retail	44. 3.9 TWh	45. Assumes that 80% of fossil heated retail is located in city centre and urban areas with District Heating connection potential.
Education	46. 1.6 TWh	47. Assumes that 50% of education floor space is schools located in residential areas.
Total	48. 15.8 TWh	49.

50. The value of 15.8 TWh corresponds to 1.7% of UK heating demand (this figure covers all non-domestic properties regardless of locational barriers). Work continues to scope the impact of including non-domestic buildings in District Heating, particularly in the context of anchors for base load heat demand on which to construct District Heating infrastructure.

51. Given the size of the heat demand, it appears that a significant amount of the potential for viable District Heating will be located in the domestic dwelling sector.

Heat Density

52. Research commissioned for this Consultation applied as methodology an analysis of heat density. “Heat density” is a conceptual tool which allows inferences regarding the scale of potential District Heating.

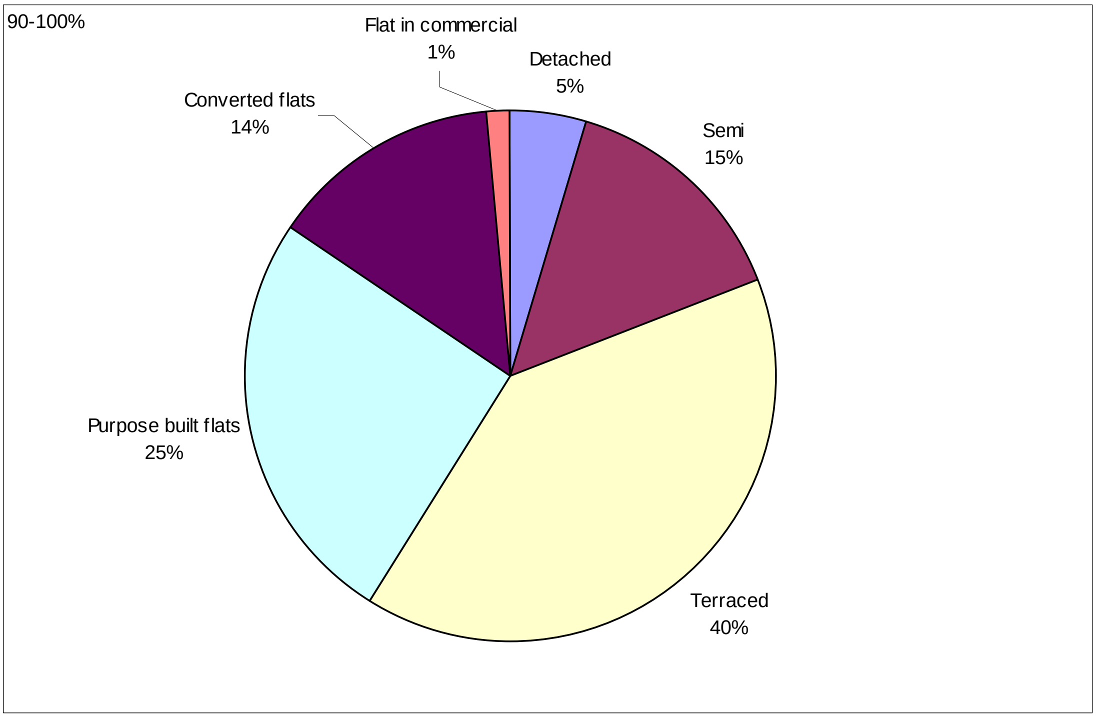
53. Heat density is defined as the annual heat demand divided by 8760 (the number of hours in a year), divided by the area in km^2. Higher density urban areas would have a higher heat demand per km^2 and hence would be expected to have lower District Heating costs and greater potential for a cost-effective scheme.

54. The heat density of an area can be estimated using census data of house types and the physical area of the census unit used. Higher density regions are defined in our research as those areas where heat density exceeds 3000 kW/km2.

55. The characteristics of a conurbation most likely to suit the requirements of an economically viable District Heating would feature a high proportion of flats rather than houses:

56. Pre-1919 flats have large thermal demands, due to poor energy efficiency and high density
57. Low rise 1919-1975 flats have lower efficiency than modern flats and high density (typically found in town centres)
58. High rise 1919-1975 flats, often in the social sector and heated electrically

59. By way of example, the following chart shows the breakdown of housing types in the 10% of areas with highest heat density



60. Heat load was estimated for the UK's 8000 postcode sectors. The proportion of heat demand for dwellings in the higher density region (defined as above) is 20%. This could equate to about 90% of the flats and about 20% of the terraces in these census output areas.

Efficiency Gains

61. Two factors determine the benefits of District Heating: the scale and characteristics of the network in service, and the carbon efficiency of fuel. Our research examines alternative sources of heat delivered. Energy technologies under review include a range of gas engines and boilers, as well as biomass-fuelled energy, anaerobic digestion, waste incineration, heat pumps (air and ground source) and solar thermal.

62. Furthermore, an important contributor to the efficiency of District Heating is the application of the joint production of heat and power via CHP where the dual utilisation of heat first to generate electricity and then to be 'recycled' to raise heat incurs relatively less CO_2 than producing electricity and heat singly. The cost of heat at a CHP plant is low as the heat can be seen as 'waste heat' that would otherwise be dissipated to the atmosphere.

63. There are natural synergies between the expansion of CHP and of District Heating. However, there are economic obstacles affecting expansion of CHP, in particular the differential prices paid for heat and electricity that create incentives to favour production of electricity rather than heat. The absence of subsidies for heat generation may be regarded as a further hindrance.

64. Key results from annexed tables are

65. Community boilers are predicted to increase emissions – this is due to District Heating network thermal losses outweighing any efficiency gains which may be obtained at the centralised plant.
66. Air source heat pumps are also predicted to increase emissions compared with individual gas boilers– this is due to the CO_2intensity of grid electricity combined with relatively low COPs from air source heat pumps.

For systems which save CO_2:

67. The least cost effective technology are ground source heat pumps – these provide little or no CO_2 savings compared to individual gas boilers and are sensitive to assumptions of emissions for electricity from the grid.
68. Small gas CHP (0.5 MW) is less efficient than larger systems – maximising the engine size improves electrical efficiency and therefore increases CO_2 reductions.
69. Individual biomass boilers are the most cost effective counterfactual, although air quality concerns may make a material impact depending on location (rural v. urban)
70. Anaerobic digestion can provide the largest CO_2 reduction but at a high cost (comparable to Energy from Waste). (These technologies rely heavily on increased electricity revenue through ROCS, and high gate fees). This assessment assumed that these plants are built solely for the purpose of generating energy.
71. One of the most cost effective District Heating technologies is the use of waste heat from existing sources. Here, the only costs incurred are the cost of the District Heating network and an electricity revenue loss due to the lower efficiency of plant with heat extract.
72. The results indicate that at a discount rate of 3.5%, a number of District Heating technologies are on average cost effective against the baseline for the medium District Heating penetration scenario. These include waste heat, large natural gas engine CHP, medium CCGT, and community biomass boilers.

73. The installation of District Heating would be most likely to succeed on a commercial basis in densely populated urban centres. Social housing is likely to comprise an important portion of relevant housing stock. Thus, where heat can be supplied at a lower cost than conventional gas condensing boilers or electric heating, there are likely to be benefits for households threatened by fuel poverty. This will be relevant to consider in future design of District Heating regulatory regime.

Annexes

74. Economic constraints impeding the application of technically viable District Heating include issues of high upfront costs of installing heat networks, producer and consumer uncertainty over long term viability of District Heating scheme, and risks for investors of stranded assets if the network ceases to operate.

75. Estimates of market size vary considerably with discount factor. Choosing the Green Book's societal discount rate of 3.5% instead of a private sector discount rate (in this case, 7% to ensure consistency of approach with other research on energy market investment) inevitably provides a higher net present value (or: a lower level of costs) of benefits than would be required to attract external investors.

76. The full data sets are available in the accompanying spreadsheet providing the full set of output parameters.

77. Four scenarios for modelling alternatives for heat provision are tabulated in this Annex. Scenarios 1 and 2 feature the impact of District Heating provision on individual dwellings, scenarios 3 and 4 aggregate the impact to a UK wide level.

78. Given the importance of Internal Rates of Return to the viability of District Heating, two discount rates are applied. A discount rate of 7% applies to scenarios 1 and 3, a discount rate of 3.5% applies to scenarios 2 and 4. Costs for technologies and fuels include projections over the period 2008 –2050 allowing operational costs modelled over a 30 year discounted period.

Annex 1: District Heating Technical Parameters

Type	**Indicative size range**	**Data source**

Baseline		
Baseline individual gas boilers and electric heating[3]	Individual dwelling	BERR and Faber Maunsell
DISTRICT HEATING Technologies		
Small gas engine CHP	0.6 MWe	BERR
Large gas engine CHP	3.7 MWe	BERR
Small CCGT	50 MWe	BERR
Large CCGT	90 MWe	BERR
District gas boiler	0.5 MWth	BERR
Small biomass air turbine CHP	0.1 MWe	Talbotts
Large biomass steam turbine CHP	8 MWe	Ernst & Young[4]
District biomass boiler	0.5 MWth	BERR
Anaerobic digestion CHP	1 MWe	Ernst & Young
Waste incineration CHP	24 MWe	Ernst & Young
Waste Heat	40 MWe	Faber Maunsell
Counterfactuals		
Individual biomass boilers	Individual building	BERR
Ground source heat pumps	Individual building	BERR and Faber Maunsell
Air source heat pumps	Individual building	BERR and Faber Maunsell
Solar thermal	Individual building	BERR

[3] This report only examines gas heated dwellings, i.e. those with wet central heating systems. The baseline used for a full UK assessment included both gas heating and electric heating.
[4] Renewable Heat Initial Business Case. 2007. Report for DEFRA and BERR.

Annex 2: Potential Saving: Average of Building Types, Discount Rate 7%

2a: Against Counterfactuals

Parameter		Baseline (gas boilers and electric heating)	Individual Biomass Boilers	Ground Source Heat Pumps	Air Source Heat Pumps	Solar Thermal
Annual net CO_2savings	kg p.a.	na	2,899	544	-135	393
Annual cost per building	£ / p.a.	979	£1,572	£1,558	£1,405	£1,132
Cost of heat	£ / MWh	72	£116.103	£115.110	£103.820	£83.636
Annual CO_2 emissions	kg p.a.	3,288	389	2,744	3,422	2,895
NPC / tonne CO_2 saved	£ / tonne	na	£90	£471	CO2 increase	£172
NPC (including shadow CO_2 price)	£	14,421	£21,031	£21,849	£20,108	£16,279
Annual gas demand	kWh p.a.	16,954	na	7,678	9,575	8,081
CO_2 saved per kWh fuel used	kg / kWh	na	0.01	na	na	na
NPC	£	13,003	£20,866	£20,687	£18,658	£15,031
% CO_2 saving from baseline	%	0%	88%	17%	-4%	12%

2b:Small Scale

Parameter		Small Biomass Air turbine CHP	Small Engine Natural Gas	Community Boiler Natural Gas	Community Boiler Biomass	Anaerobic digestion CHP
Annual net CO_2 savings	kg p.a.	4,038	992	-10	2,873	5,941
Annual cost per building	£ / p.a.	£1,726	£1,312	£1,044	£1,198	£3,087
Cost of heat	£ / MWh	£127.514	£96.960	£77.147	£88.539	£228.100
Annual CO_2 emissions	kg p.a.	-751	2,295	3,297	415	-2,654
NPC / tonne CO_2 saved	£ / tonne	£82	£149	CO2 increase	£34	£157
NPC (including shadow CO_2 price)	£	£21,182	£16,980	£13,843	£14,671	£38,453
Annual gas demand	kWh p.a.	-3,721	6,386	9,201	-	-7,429

CO_2 saved per kWh fuel used	kg / kWh	0.17	na	na	0.17	na
NPC	£	£22,917	£17,426	£13,865	£15,912	£40,994
% CO_2 saving from baseline	%	123%	30%	0%	87%	181%

2c: Medium Scale

Parameter		Large Engine Natural Gas	Large Biomass Steam turbine CHP
Annual net CO_2 savings	kg p.a.	1,786	3,511
Annual cost per building	£ / p.a.	£1,250	£1,452
Cost of heat	£ / MWh	£92.318	£107.243
Annual CO_2 emissions	kg p.a.	1,501	-223
NPC / tonne CO_2 saved	£ / tonne	£67	£60
NPC (including shadow CO_2 price)	£	£15,810	£17,762
Annual gas demand	kWh p.a.	4,158	-1,912
CO_2 saved per kWh fuel used	kg / kWh	na	0.19
NPC	£	£16,591	£19,274
% CO_2 saving from baseline	%	54%	107%

2d: Large Scale

Parameter		Small CCGT Natural Gas	Medium CCGT Natural Gas	EFW Incineration CHP	Waste heat
Annual net CO_2 savings	kg p.a.	2,221	2,612	3,299	2,076
Annual cost per building	£ / p.a.	£1,305	£1,284	£2,472	£1,045
Cost of heat	£ / MWh	£96.402	£94.882	£182.649	£77.199
Annual CO_2 emissions	kg p.a.	1,067	676	-11	1,212
NPC / tonne CO2 saved	£ / tonne	£65	£52	£200	£14
NPC (including shadow CO_2 price)	£	£16,360	£15,921	£31,404	£12,970
Annual gas demand	kWh p.a.	2,938	1,840	-6,502	1,840
CO_2 saved per kWh fuel	kg /	na	na	na	na

used	kWh				
NPC	£	£17,325	£17,052	£32,826	£13,874
% CO_2 saving from baseline	%	68%	79%	100%	63%

Annex 3: Potential Saving: Average of Building Types, Discount Rate of 3.5%

3a: Against Counterfactuals

Parameter		Baseline (gas boilers and electric heating)	Individual Biomass Boilers	Ground Source Heat Pumps	Air Source Heat Pumps	Solar Thermal
Annual net CO_2 savings	kg p.a.	na	2,899	544	-135	393
Annual cost per building	£ / p.a.	992	1,430	1,375	1,320	1,104
Cost of heat	£ / MWh	73	106	102	97	82
Annual CO_2 emissions	kg p.a.	3,288	389	2,744	3,422	2,895
NPC / tonne CO_2 saved	£ / tonne	na	96	447	CO2 increase	180
NPC (including shadow CO_2 price)	£	20,993	27,475	27,918	27,294	22,864
Annual gas demand	kWh p.a.	16,954	na	7,678	9,575	8,081
CO_2 saved per kWh fuel used	kg / kWh	na	0	na	na	na
NPC	£	18,893	27,228	26,175	25,120	21,015
% CO_2 saving from baseline	%	0%	88%	17%	-4%	12%

3b: Small Scale

Parameter		Small Biomass Air turbine CHP	Small Engine Natural Gas	Community Boiler Natural Gas	Community Boiler Biomass	Anaerobic digestion CHP
Annual net CO_2 savings	kg p.a.	4,038	992	-10	2,873	6,494
Annual cost per building	£ / p.a.	1,473	1,131	881	965	2,205
Cost of heat	£ / MWh	109	84	65	71	163
Annual CO_2	kg	-751	2,295	3,297	415	-3,206

emissions	p.a.					
NPC / tonne CO_2 saved	£ / tonne	76	89	CO2 increase	-6	118
NPC (including shadow CO_2 price)	£	25,463	20,893	16,769	16,542	37,833
Annual gas demand	kWh p.a.	-3,721	6,386	9,201	0	-8,974
CO_2 saved per kWh fuel used	kg / kWh	0	na	na	0	na
NPC	£	28,040	21,535	16,775	18,378	41,969
% CO_2 saving from baseline	%	123%	30%	0%	87%	198%

3c: Medium Scale

Parameter		Large Engine Natural Gas	Large Biomass Steam turbine CHP
Annual net CO_2 savings	kg p.a.	1,786	3,511
Annual cost per building	£ / p.a.	987	1,171
Cost of heat	£ / MWh	73	87
Annual CO_2 emissions	kg p.a.	1,501	-223
NPC / tonne CO_2 saved	£ / tonne	-2	32
NPC (including shadow CO_2 price)	£	17,633	20,051
Annual gas demand	kWh p.a.	4,158	-1,912
CO_2 saved per kWh fuel used	kg / kWh	na	0
NPC	£	18,779	22,293
% CO_2 saving from baseline	%	54%	107%

3d:Large Scale

Parameter		Small CCGT Natural Gas	Medium CCGT Natural Gas	EFW Incineration CHP	Waste heat
Annual net CO_2 savings	kg p.a.	2,221	2,612	3,299	2,076
Annual cost per building	£ / p.a.	1,009	985	1,848	786
Cost of heat	£ /	75	73	137	58

	MWh				
Annual CO_2 emissions	kg p.a.	1,067	676	-11	1,212
NPC / tonne CO_2 saved	£ / tonne	5	-2	165	-63
NPC (including shadow CO_2 price)	£	17,782	17,073	33,076	13,632
Annual gas demand	kWh p.a.	2,938	1,840	-6,502	1,840
CO_2 saved per kWh fuel used	kg / kWh	na	na	na	na
NPC	£	19,204	18,744	35,182	14,963
% CO_2 saving from baseline	%	68%	79%	100%	63%

Annex 4: Potential Saving Total, Discount Rate 7%

The following data shows the above two scenarios using the data aggregated across the UK. These totals are shown at discount rates of 7% discount rate (Scenario 3) and 3.5 % (Scenario 4).

4a: Against Counterfactuals

Parameter		Baseline (gas boilers and electric heating)	Individual Biomass Boilers	Ground Source Heat Pumps	Air Source Heat Pumps	Solar Thermal
Annual net CO_2 savings	kt p.a.	na	15,968	2,994	-743	2,166
Annual cost	£million / p.a.	5,395	8,657	8,583	7,741	6,236
Cost of heat	£ / MWh	72	£116.103	£115.110	£103.820	£83.636
Annual CO_2 emissions	kt p.a.	18,110	2,143	15,116	18,853	15,944
NPC / tonne CO_2 saved	£ / tonne	na	£90	£471	CO2 increase	£172
NPC (including shadow CO_2 price)	£million	79,437	115,848	120,358	110,763	89,673
Annual gas demand	GWh p.a.	93,394	0	78,121	97,431	82,225
CO_2 saved per kWh fuel used	kg / kWh	na	0.01	na	na	na
NPC	£million	71,629	114,941	113,958	102,781	82,799
% CO_2 saving from baseline	%	0%	88%	17%	-4%	12%

4b: Small Scale

Parameter		Small Biomass Air turbine CHP	Small Engine Natural Gas	Community Boiler Natural Gas	Community Boiler Biomass	Anaerobic digestion CHP
Annual net CO_2 savings	kt p.a.	22,245	5,467	-53	15,824	32,728
Annual cost	£million / p.a.	9,508	7,229	5,752	6,602	17,007
Cost of heat	£ / MWh	£127.514	£96.960	£77.147	£88.539	£228.100
Annual CO_2 emissions	kt p.a.	-4,134	12,643	18,163	2,287	-14,618
NPC / tonne CO_2 saved	£ / tonne	£82	£149	CO2 increase	£34	£157
NPC (including shadow CO_2 price)	£million	116,679	93,535	76,257	80,813	211,820
Annual gas demand	GWh p.a.	-37,865	64,976	93,623	0	-75,592
CO_2 saved per kWh fuel used	kg / kWh	0.17	na	na	0.17	na
NPC	£million	126,238	95,989	76,375	87,653	225,818
% CO_2 saving from baseline	%	123%	30%	0%	87%	181%

4c: Medium Scale

Parameter		Large Engine Natural Gas	Large Biomass Steam turbine CHP
Annual net CO_2 savings	kt p.a.	9,839	19,338
Annual cost	£million / p.a.	6,883	7,996
Cost of heat	£ / MWh	£92.318	£107.243
Annual CO_2 emissions	kt p.a.	8,271	-1,228
NPC / tonne CO_2 saved	£ / tonne	£67	£60
NPC (including shadow CO_2 price)	£million	87,088	97,842
Annual gas demand	GWh p.a.	42,304	-19,451
CO_2 saved per kWh fuel used	kg / kWh	na	0.19

NPC	£million	91,394	106,170
% CO_2 saving from baseline	%	54%	107%

4d: Large Scale

Parameter		Small CCGT Natural Gas	Medium CCGT Natural Gas	EFW Incineration CHP	Waste heat
Annual net CO_2 savings	kt p.a.	12,233	14,387	18,170	11,436
Annual cost	£million / p.a.	7,188	7,074	13,618	5,756
Cost of heat	£ / MWh	£96.402	£94.882	£182.649	£77.199
Annual CO_2 emissions	kt p.a.	5,878	3,724	-60	6,674
NPC / tonne CO_2 saved	£ / tonne	£65	£52	£200	£14
NPC (including shadow CO_2 price)	£million	90,118	87,702	172,988	71,445
Annual gas demand	GWh p.a.	29,894	18,725	-66,161	18,725
CO_2 saved per kWh fuel used	kg / kWh	na	na	na	na
NPC	£million	95,437	93,933	180,821	76,427
% CO_2 saving from baseline	%	68%	79%	100%	63%

Annex 5: Potential Saving Total, Discount Rate 3.5%

5a: Against Counterfactuals

Parameter		Baseline (gas boilers and electric heating)	Individual Biomass Boilers	Ground Source Heat Pumps	Air Source Heat Pumps	Solar Thermal
Annual net CO_2 savings	kt p.a.	na	15,968	2,994	-743	2,166
Annual cost	£million / p.a.	5,467	7,879	7,574	7,269	6,081
Cost of heat	£ / MWh	73	106	102	97	82
Annual CO_2 emissions	kt p.a.	18,110	2,143	15,116	18,853	15,944
NPC / tonne CO_2 saved	£ / tonne	na	96	447	CO2 increase	180

NPC (including shadow CO_2 price)	£million	115,640	151,346	153,789	150,350	125,947
Annual gas demand	GWh p.a.	93,394	0	78,121	97,431	82,225
CO_2 saved per kWh fuel used	kg / kWh	na	0	na	na	na
NPC	£million	104,072	149,985	144,185	138,372	115,762
% CO_2 saving from baseline	%	0%	88%	17%	-4%	12%

5b: Small Scale

Parameter		Small Biomass Air turbine CHP	Small Engine Natural Gas	Community Boiler Natural Gas	Community Boiler Biomass	Anaerobic digestion CHP
Annual net CO_2 savings	kt p.a.	22,245	5,467	-53	15,824	35,770
Annual cost	£million / p.a.	8,114	6,232	4,854	5,318	12,145
Cost of heat	£ / MWh	109	84	65	71	163
Annual CO_2 emissions	kt p.a.	-4,134	12,643	18,163	2,287	-17,659
NPC / tonne CO_2 saved	£ / tonne	76	89	CO2 increase	-6	118
NPC (including shadow CO_2 price)	£million	140,264	115,091	92,375	91,122	208,403
Annual gas demand	GWh p.a.	-37,865	64,976	93,623	0	-91,312
CO_2 saved per kWh fuel used	kg / kWh	0	na	na	0	na
NPC	£million	154,458	118,626	92,403	101,237	231,190
% CO_2 saving from baseline	%	123%	30%	0%	87%	198%

5c: Medium Scale

Parameter		Large Engine Natural Gas	Large Biomass Steam turbine CHP

Annual net CO_2 savings	kt p.a.	9,839	19,338
Annual cost	£million / p.a.	5,434	6,451
Cost of heat	£ / MWh	73	87
Annual CO_2 emissions	kt p.a.	8,271	-1,228
NPC / tonne CO_2 saved	£ / tonne	-2	32
NPC (including shadow CO_2 price)	£million	97,131	110,454
Annual gas demand	GWh p.a.	42,304	-19,451
CO_2 saved per kWh fuel used	kg / kWh	na	0
NPC	£million	103,444	122,802
% CO_2 saving from baseline	%	54%	107%

5d: Large Scale

Parameter		Small CCGT Natural Gas	Medium CCGT Natural Gas	EFW Incineration CHP	Waste heat
Annual net CO_2 savings	kt p.a.	12,233	14,387	18,170	11,436
Annual cost	£million / p.a.	5,557	5,424	10,181	4,330
Cost of heat	£ / MWh	75	73	137	58
Annual CO_2 emissions	kt p.a.	5,878	3,724	-60	6,674
NPC / tonne CO_2 saved	£ / tonne	5	-2	165	-63
NPC (including shadow CO_2 price)	£million	97,955	94,049	182,198	75,095
Annual gas demand	GWh p.a.	29,894	18,725	-66,161	18,725
CO_2 saved per kWh fuel used	kg / kWh	na	na	na	na
NPC	£million	105,789	103,251	193,803	82,422
% CO_2 saving from baseline	%	68%	79%	100%	63%

Annex 6: CO_2 Saving

The following tables show CO_2 emissions reductions for each of the technologies. Data is provided for an average dwelling and the total potential based on the median 3,000 kW / km^2 scenario. The following values are presented:

1. Total net CO_2 reduction. This is the total reduction in CO_2 calculated by taking the difference between baseline emissions and the scenario emissions.
2. Traded CO_2 savings. These are the savings due to displacement or reduction in grid electricity consumption. For example a reduction may take place through the generation of electricity by a CHP system. Alternatively, traded emissions may increase if more electricity is used, for example by heat pumps displacing gas heating.
3. Non-traded CO_2 emissions. This data includes savings from all non grid electricity uses.

Counterfactuals		Individual Biomass Boilers	Ground Source Heat Pumps	Air Source Heat Pumps	Solar Thermal
Average per house @ 3000 kW / km2					
Net CO_2 savings	kg	2,899	544	-135	393
Traded CO_2 savings	kg	0	-2,172	-2,850	0
Non traded CO_2 savings	kg	2,899	2,715	2,715	393
Total UK (3000 kW / km2 District Heating penetration scenario)					
Net CO_2 savings	Mt	15,968	2,994	-743	2,166
Traded CO_2 savings	Mt	0	-11,964	-15,700	0
Non traded CO_2 savings	Mt	15,968	14,957	14,957	2,166

District Heating Small scale		Small Biomass Air turbine CHP	Small Engine Natural Gas	Community Boiler Natural Gas	Community Boiler Biomass	Anaerobic digestion CHP
Average per house @ (3000 kW / km2						
Net CO_2savings	kg	4,038	992	-10	2,873	5,941
Traded CO_2savings	kg	1,988	2,676	0	0	3,313
Non traded CO_2savings	kg	2,050	-1,684	-10	2,873	2,628
Total UK (3000 kW / km2 District Heating penetration scenario)						
Net CO_2savings	Mt	22,245	5,467	-53	15,824	32,728
Traded CO_2savings	Mt	10,950	14,741	0	0	18,250

Non traded CO_2savings	Mt	11,295	-9,274	-53	15,824	14,478

District Heating Medium Scale		Large Engine Natural Gas	Medium Biomass Steam turbine CHP
Average per house @ 3000 kW / km2			
Net CO_2savings	kg	1,786	3,511
Traded CO_2savings	kg	4,496	1,341
Non traded CO_2savings	kg	-2,710	2,170
Total UK (3000 kW / km2 District Heating penetration scenario)			
Net CO_2savings	Mt	9,839	19,338
Traded CO_2savings	Mt	24,768	7,387
Non traded CO_2savings	Mt	-14,929	11,951

District Heating Large Scale		Small CCGT Natural Gas	Medium CCGT Natural Gas	EFW Incineratio n CHP	Waste heat
Average per house @ 3000 kW / km2					
Net CO_2 savings	kg	2,221	2,612	3,299	2,076
Traded CO_2 savings	kg	5,493	6,390	2,982	0
Non traded CO_2 savings	kg	-3,272	-3,778	317	2,076
Total UK (3000 kW / km2 District Heating penetration scenario)					
Net CO_2 savings	Mt	12,233	14,387	18,170	11,436
Traded CO_2 savings	Mt	30,257	35,197	16,425	0
Non traded CO_2 savings	Mt	-18,024	-20,810	1,745	11,436