MAYOR OF LONDON

GREENPEACE

POWERING LONDON INTO THE 21ST CENTURY

MARCH 2006

This report was written by PBPower Energy Services Division for the Mayor of London and Greenpeace.

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FOREWORD

Powering London in the 21st Century

Until very recently the concept of decentralised energy attracted almost no attention outside the ranks of a small number of enlightened engineers and climate change campaigners. Yet of all the policies I have introduced as Mayor, I am certain that the recent steps we have taken to introduce decentralised energy in London will turn out to be among the most crucial to London's long-term well-being.

The reason is straight-forward - tackling climate change is now humanity's single most important struggle.

It is not an issue that can be resolved at the level of municipal government, but a major world city like London can play a decisive role in setting an example for the rest of the world to follow. And in the process we can become a key player in the new technologies and services that will drive the 'sustainable economy' of the next decades.

There is no need to wait for technological solutions that might never be realised to start this. Or to dust off old, failed ideas like nuclear energy. The beauty of the decentralised energy solution is that at its core it is simply about using energy more efficiently and we can start implementing it straight away.

Large-scale out of town power stations squander two thirds of the energy sources they consume either as waste heat or in the process of transmitting energy around the country. In contrast, decentralised energy systems cut out most of the transmission losses by producing energy close to the homes and offices they heat and power, and by re-using heat produced in the energy generation process rather than wasting it.

As this report demonstrates, London with its high density of housing and commercial buildings is the perfect place to pioneer decentralised energy on a large scale. That is why I have established the London Climate Change Agency – to deliver decentralised energy across the capital. But if it works here there is no reason why it should not be copied in cities around the UK.

This report doesn't argue that decentralised energy is the only answer to the questions posed by the government's energy review. But it demonstrates that it is one solution and comprehensively nails the lie propagated by the nuclear lobby that only nuclear energy, and all the tremendous unquantifiable risks that go with it – can both meet our energy needs and tackle climate change.

Ken Livingstone

Ken Livingstone, Mayor of London

PREFACE

The Government believes that nuclear power is the solution to climate change, and the rest of us are lectured about the need for 'hard choices' – which basically means we are being given no choice but to accept the nuclear agenda. Support for nuclear power is being turned into a question of political machismo: we need big power stations to produce big amounts of power. This view is reflected in the Government's current Energy Review consultation, which is clearly attuned to the thinking of big business involved in centralised fossil-fuel and nuclear generation, and is fixated with the technologies and infrastructure of the past.

What this worldview completely misses is the potential of a decentralised energy system to deliver greater security of supply, reduced CO_2 emissions and better value for money.

Our current, centralised energy system wastes a staggering two-thirds of primary energy input, mostly in the form of waste heat going up the cooling towers of large power stations. A decentralised future would rely on more, but smaller power stations close to the point of use. This approach reduces electricity transmission losses, and allows the waste heat from the generation process to be piped to nearby homes so that a much greater proportion of input energy is used, resulting in far higher overall efficiency.

This report – which follows two previous Greenpeace reports on decentralised energy ('*Decentralising Power: An energy revolution for the 21st century'* and '*Decentralising UK Energy: Cleaner, cheaper, more secure energy for the 21st Century'*) – destroys the myth that we need big power stations to supply big demand.
It shows that the largest city in Europe could slash its CO_2 emissions by adopting a dynamic decentralised energy policy, at the same time as saving gas and vastly reducing its reliance on centralised fossil fuel generation – all without any need to rely on new nuclear power.
If the largest city in Europe doesn't need new nuclear power, then who does?

Stephen Tindale, Executive Director, Greenpeace UK

EXECUTIVE SUMMARY

This report is a response to the Government's Energy Review. It does not seek to provide all the answers to the many questions that this review poses, but it does demonstrate that there is at least one viable set of options for achieving the Government's key goals of CO_2 emission reductions, a secure energy supply, economic growth, and alleviation of fuel poverty – without the need for a new generation of nuclear power stations.

The cornerstone of this approach is decentralised energy (DE). This entails generating locally a significant proportion of the energy consumed in homes, offices and shops. The DE options modelled in this report do not require dramatic breakthroughs in technology: they rely wholly on the use of existing, technically proven solutions largely based on conventional energy sources, topped up by small-scale renewable energy generation.

The study which forms the basis for this report, carried out by the international energy consultancy PB Power, predicts and compares the CO_2 emissions which result from meeting the heating and electricity needs of all the buildings in London in 2025, for four different energy supply scenarios. Two of these scenarios assume the continuation of a wholly centralised approach to energy supply, while the other two posit different levels of DE take-up. Briefly, these scenarios are as follows:

1. **Centralised low nuclear scenario** – existing nuclear power stations (apart from Sizewell B) are allowed to close when they reach the end of their current lifespan and are replaced by gas-fired generation rather than new nuclear plant.

2. **Centralised high nuclear scenario** – new nuclear plant is installed at the rate of one 1.6GW station in 2015 and two further 1.6 GW stations by 2025.

3. **Low DE scenario** – existing nuclear power stations (apart from Sizewell B) are allowed to close when they reach the end of their current projected life span and a mix of conventional energy generation and technically proven DE sources – mostly gas-engine combined heat and power (CHP) generation supplying community heating (CH) networks – is added to the national energy supply.

4. **High DE scenario** – as above, but with a higher proportion of DE sources closer to the limits of current technical constraints, the use of domestic scale micro-CHP and a higher percentage of small-scale renewable energy sources fitted to buildings.

In accordance with the Government's consultation document,[1] all scenarios assume that large-scale renewable energy developments (mostly wind farms) will contribute 20% of national grid generation and that centralised coal-fired power stations will provide 16%.

The study estimates potential growth of energy demand on the basis of increases in population, numbers of households and non-domestic floorspace, as projected in the Mayor's London Plan. Increased use of appliances is also allowed for. Limited improvements in gas boiler efficiency and in building energy efficiency (for both existing and new buildings) are assumed for all scenarios. Predicted demand (both overall and separately in the domestic and non-domestic sectors) is matched with the four different energy supply scenarios using an energy model developed by PB Power.

The assumptions used are conservative with respect to the possible benefits of DE sources:

- All scenarios assume the same demand growth and savings in energy efficiency.
- Only proven DE technologies have been assumed to be used in both DE scenarios.
- All electricity generated within London is assumed to displace output from centralised gas-fired power stations. In reality it is likely that some of the plant displaced will also be coal plant, which produces more CO_2 emissions than gas plant, giving rise to larger emission savings than those envisaged in the scenarios.
- A larger percentage of new housing is assumed to be electrically heated than is actually expected to be the case under the DE scenarios.

On the basis of these inputs and assumptions, the study concludes that:

- By 2025, on a conservative estimate, CO_2 emissions from London could be reduced from current levels by **27.6%** through the adoption of the low DE approach and without new nuclear power stations being built. This reduction would put London on track to achieve the Government's target of a 60% reduction in emissions by 2050.
- Of the four scenarios considered only the two DE scenarios could reach this target, by a considerable margin in the case of the high DE scenario.
- DE would enable London's projected heat and electricity demand to be met, without assuming exceptional energy efficiency improvements, while using far less primary energy than the centralised high nuclear scenario – **23.6%** less under the low DE scenario, and **35.5%** less under the high DE scenario.
- Despite the use of natural gas for CHP and the increased use of gas in power stations (to compensate for the falling nuclear contribution) London's overall gas consumption would fall under the low DE scenario to a figure **7.0%** lower than that for the centralised high nuclear scenario. Gas consumption under the high DE scenario would be almost 15% lower than under the high nuclear scenario.
- The installation of CHP plants and of CH networks capable of distributing heat from different fuel sources (including renewables) would offer flexibility in meeting heat demand in the coming decades.
- Locally generated electricity and heat can provide a more secure energy supply.
- DE would reduce the level of electricity imports into London, with significant potential benefits to the National Grid.
- A major component of London's energy demand, particularly in the domestic sector, is for heat, and DE solutions such as CHP offer the most efficient means to satisfy that demand.

DE solutions are highly suited to meeting the energy requirements of densely populated urban areas such as London. The Mayor of London has already set out his intention to move London towards a DE future and has set up the London Climate Change Agency to achieve this. As the majority of the UK population live in urban areas this approach has a potentially much wider application.

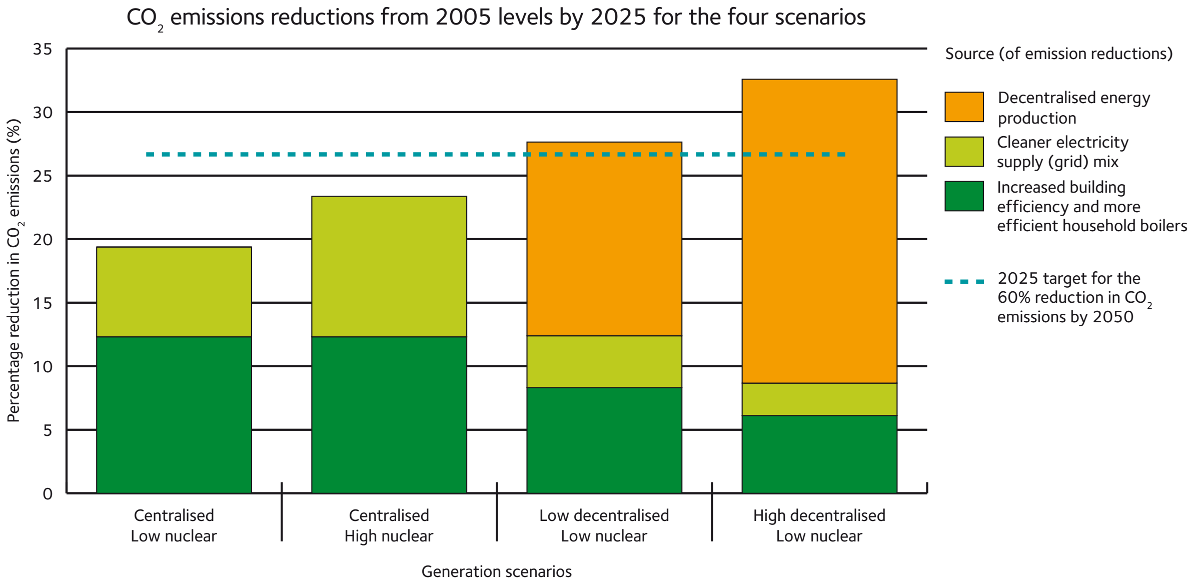


Figure 2: Sources of annual CO_2 emission reductions for all buildings by 2025
Only a decentralised energy pathway enables sufficient CO_2 savings to put the capital on a trajectory to meet the UK CO_2 emission reduction target of 60% by 2050.

1. INTRODUCTION

1.1 THE CONTEXT OF THIS REPORT

The Government has recently announced an Energy Review to re-examine energy strategies with a view to delivering the four energy policy goals set out in the Energy White Paper (EWP) issued in 2003 (DTI, 2003). These are:

- to put the country on a path to cut the UK's CO_2 emissions by 60% by 2050
- to maintain reliability of energy supplies
- to promote competitive markets
- to ensure that every home is adequately and affordably heated.

A consultation document for the Energy Review was issued in January 2006 (DTI, 2006) with a response invited by 14 April 2006. Greenpeace and the Mayor of London have commissioned the present report from PB Power in order to inform this policy debate.

The objectives of the report are:

1. to show that London has a choice as to how it meets its future energy demand
2. to illustrate how a decentralised energy (DE) strategy for London could be developed
3. to estimate the reduction in London's CO_2 emissions that would result from such a strategy
4. to assess the implications for wider energy supply issues such as the demand for natural gas.

The report investigates the impact by 2025 of four scenarios on the key areas of CO_2 emissions and energy security for London. The first two scenarios assume a centralised approach to future energy supply and look at the impacts of choosing either a low nuclear approach (in which there is no new build of reactors) or a high nuclear approach (with some new build of reactors). The second two scenarios are based on adopting a decentralised approach to future energy supply. Both assume a low nuclear future to allow the contrast with the nuclear new build approach to be analysed. One is a low DE scenario, that assumes a relatively low uptake of DE consistent with moderate policy support for the technologies, and a high DE scenario, which assumes a higher uptake limited only by technological constraints.

London is defined in this report as the area within the Greater London Authority (GLA) political boundary and therefore encompasses the 32 London Boroughs and the City of London.

The report only considers the CO_2 emissions associated with energy use in buildings (representing 73% of energy consumed in London – GLA 2004b) and does not consider emissions arising from transport or industrial processes.

1.2 STRUCTURE OF THE REPORT

The report firstly forecasts the 2025 energy demand of London's buildings (both domestic and non-domestic) on the basis of existing published data. Making some assumptions about the future centralised power station mix that will supply electricity to London, it then considers ways in which the forecast level of demand could be met and proposes four different energy supply scenarios.

1. **Centralised low nuclear scenario** – The current schedule of nuclear reactor closures is assumed with no extensions to plant life and no new reactors being built. Lost nuclear generation is displaced by gas. By 2025 only Sizewell B is scheduled to remain in operation.

2. **Centralised high nuclear scenario** – New nuclear plant is installed at the rate of one 1.6GWe station in 2015 and two further 1.6GWe stations by 2025.

3. **Low DE scenario** – Comprises a mix of technically proven decentralised energy sources and conventional centralised energy generation, mostly using gas-engine combined heat and power (CHP) plant supplying community heating (CH) networks. Centralised electricity supply is as per the low nuclear scenario.

4. **High DE scenario** – Includes a higher proportion of decentralised energy sources, closer to the technical limits of CHP capacity, the use of domestic 'micro'-CHP; and a higher percentage of building-integrated renewables. Centralised electricity supply is as per the low nuclear scenario.

The approach to delivering the two DE scenarios is explained in relation to the known distribution of heat demand for London. The workings of the model – which brings together the single projected energy demand figure and the four supply scenarios – are briefly explained before its results are illustrated and discussed. Finally, a series of conclusions is drawn out from these results.

1.3 TECHNOLOGIES SUITED TO A DECENTRALISED ENERGY SYSTEM

The following provides a brief overview of the technologies assumed to be employed within the DE scenarios. Further information is available from the relevant trade associations. The recent report by Greenpeace, *Decentralising Power: An Energy Revolution for the 21st Century* (Greenpeace, 2005), also provides descriptions of the technologies involved.

Combined heat and power

The benefits offered by CHP make a major contribution to the CO_2 savings estimated for the DE scenarios and some explanation of the principles of CHP is therefore included here.

Generation of electricity in conventional thermal power stations requires the combustion of fuel sources in order to generate heat. This heat is then used to raise steam at a high pressure, which in turn drives a turbine that generates electricity. Some of the heat energy is lost in this process and is no longer hot enough to generate electricity. In conventional power stations, this waste heat is emitted either to the air via cooling towers or to the sea or rivers in discharged cooling water. All thermal power stations discharge substantial quantities of this waste heat to the environment. This fundamental constraint limits the efficiency[2] of the electricity generation process to about 50% even for the most efficient gas-fired stations.

CHP is a technology which captures this waste heat rather than allowing it to be lost. The available waste steam is extracted at a higher pressure than in conventional power stations, maintaining a higher temperature, enabling the waste heat to be used either for industrial processes or supplied to CH (often called district heating) networks which in turn supply the buildings. There is a small drop in electricity production as a result, but the overall efficiency of CHP plants can reach in excess of 90% compared to the 50% of centralised electricity-only thermal power plants. For the purposes of this model, however, we have assumed a typical CHP efficiency of 80%.

Nuons gas engine CHP plant sits discreetly alongside the European headquarters of international businesses at de Omval in the heart of Amsterdam. ©Greenpeace/Reynaers

The technology is well proven, but in the UK the main application has been on industrial sites. Elsewhere however, especially in Scandinavia, it is normal practice to build power stations using CHP technology and in locations where the heat generated can be used to supply large-scale CH networks. The cities of Copenhagen and Helsinki are heated in this way. Any major thermal power station, whether coal, oil, gas or biomass-fired, can operate as a CHP plant, as only a small modification to the steam turbine system is required. However, since the UK's major power stations have historically been built remote from population centres, it has not been practicable to use their waste heat for buildings. Now, though, it is possible to generate electricity from thermal combustion at a range of scales, making it more suited to sites located much nearer to centres of demand, or even to location within buildings as part of their heating system.

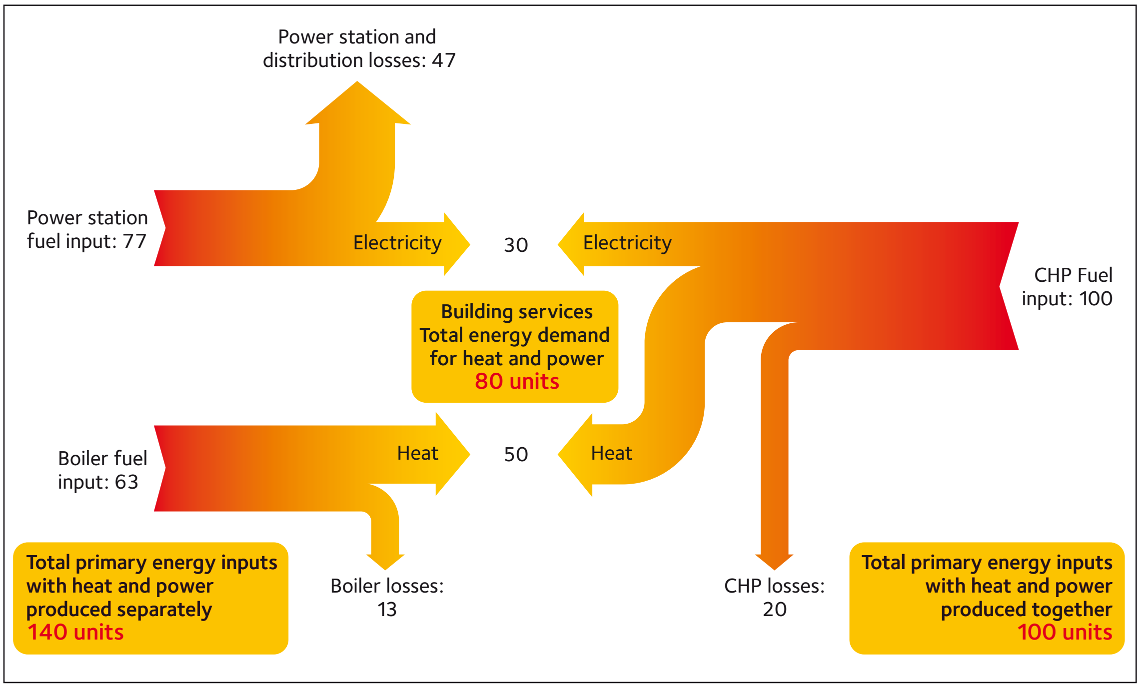


Figure 1.1: Principles of CHP energy efficiency

Figure 1.1 illustrates the energy saving that can result from a CHP system. The building's demand is for 80 units of energy (30 for electricity and 50 for heat). The conventional centralised method of delivering this requires 140 units of primary energy. However, to deliver it via a CHP unit takes just 100 units, representing a 28.6% saving of input energy.

Community heating networks

To obtain the greatest benefit from CHP it is at present necessary to distribute the heat either from a conventional power station or a more local CHP system by means of a CH network. The heat is transported in the form of hot water through well-insulated pipes, buried in the ground like those for other utility services. The circuit forms a closed loop with a flow pipe and a return pipe and typically transfers heat to a building's heating system through a heat exchanger. This technology has been well proven for more than 30 years, particularly in northern, eastern and central Europe, but UK examples also exist, including the Sheffield city centre scheme and the system supplying the Pimlico estate in Westminster, which has operated continuosly since 1950. Recently, new housing developments in London such as Greenwich Millennium Village have also adopted this technology.

District cooling

CHP systems can also supply a cooling demand by using absorption chillers. This technology uses heat as the driving energy for the cooling process and can reduce CO_2 emissions if the heat is produced by a sufficiently low-emission source, such as high-efficiency CHP or renewable energy. The present model has not however considered cooling, and there are therefore no CO_2 emissions reductions included for this type of system.

Decentralised energy generation technologies

The generation technologies that are suitable for DE include:

1. Combined cycle gas turbine (CCGT) CHP feeding into CH networks
2. Gas-engine CHP supplying CH networks
3. Building-based CHP - (only applicable to the non-domestic sector)
4. Biomass CHP and biomass boilers
5. Energy from waste
6. Fuel cells[3]
7. Building-integrated low and zero-emission technologies, including:
   a. Domestic CHP
   b. Renewable heat – solar thermal
   c. Renewable electricity – micro-wind turbines and photovoltaics.

These technologies (with the exception of fuel cells) are described in more detail in Appendix C. It can be seen that an important characteristic of DE is the ability to use of a range of different energy sources and systems, including renewables. CH networks in particular permit much greater flexibility in terms of energy source than the present use of individual heating boilers, with their high dependency on natural gas. The potential fuel diversity, coupled with the ease with which energy sources can be changed, in turn offers improved security of supply.

1.4 HOW DECENTRALISED ENERGY TECHNOLOGIES CAN BE USED IN LONDON

The energy London demands for its buildings is required in two forms – heat and electricity. Understanding heat demand is essential to planning an energy supply strategy. Heat transport is possible over an entire city (as can be seen in Copenhagen) but is more easily achieved across districts, and so far in the UK has been implemented at this level. The cost of heat distribution with CH networks depends on the distance between the supply and the customer and heat density, which is the heat demand divided by the area of the zone in question. If the demand is great enough, then heat can be transported over significant distances, as is the case in Copenhagen. However the main costs are in the local distribution pipes and lower costs will be incurred in areas of highest heat demand density.

Map 1 below is a heat map produced by The Community Heating Development Study for London (GLA 2005) showing the density of the heat demand within the city. From the map it can be seen that it is areas of high-density property associated with the City, the West End and the outlying centres which demand the most heat. This demand pattern informs and guides the allocation of CHP in the two DE strategies proposed in this report.

Within both DE scenarios two strategies for applying DE are used:

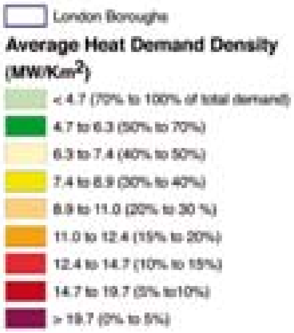
- In areas of high-density heat demand the scenarios propose the establishment of CH networks and the installation of (principally gas-fired) CHP technologies.
- In areas of lower-density heat demand where CH networks would be less practicable, a range of building-integrated low- and zero-emission energy generation technologies is envisaged.

These twinned strategies are applied in the two DE scenarios in the following manner:

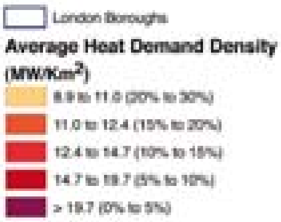
- **The low DE scenario** is illustrated in Map 2. It draws a tight line around the highest-density heat demand areas. The relatively small areas of high-density heat demand highlighted amount to 30% of London's total heat demand. The low DE scenario suggests that this level of demand can be met by simply installing CH networks and adopting existing decentralised technologies such as CHP on a moderate scale. Outside the highest-density heat demand areas a moderate level of building-integrated low- and zero-emission energy generation technologies is envisaged. It is anticipated that this level of DE penetration would be possible within the current regulatory framework

- **The high DE scenario** is illustrated in Map 3. It identifies a broader area to be considered for DE, albeit still one with relatively high-density heat demand. At the same time it assumes a much more extensive application of existing DE technologies, and anticipates that around 50% of the heat demand for the whole of London can be met through this approach. Outside the core zone for CH networks it also assumes a more extensive deployment of building-integrated low and zero-emission generation technologies. Such a level of DE penetration would likely require a degree of legislative support from Government.

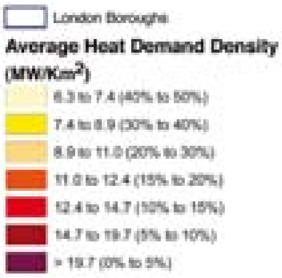
Map 1

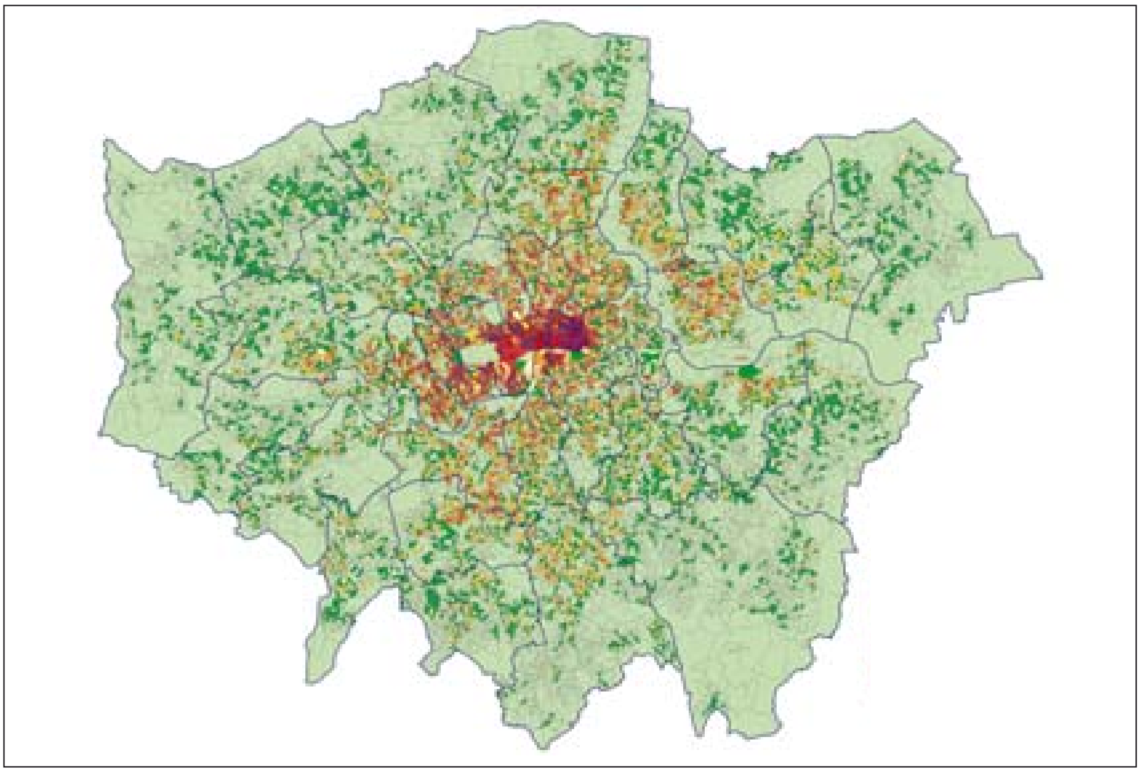


Map 2



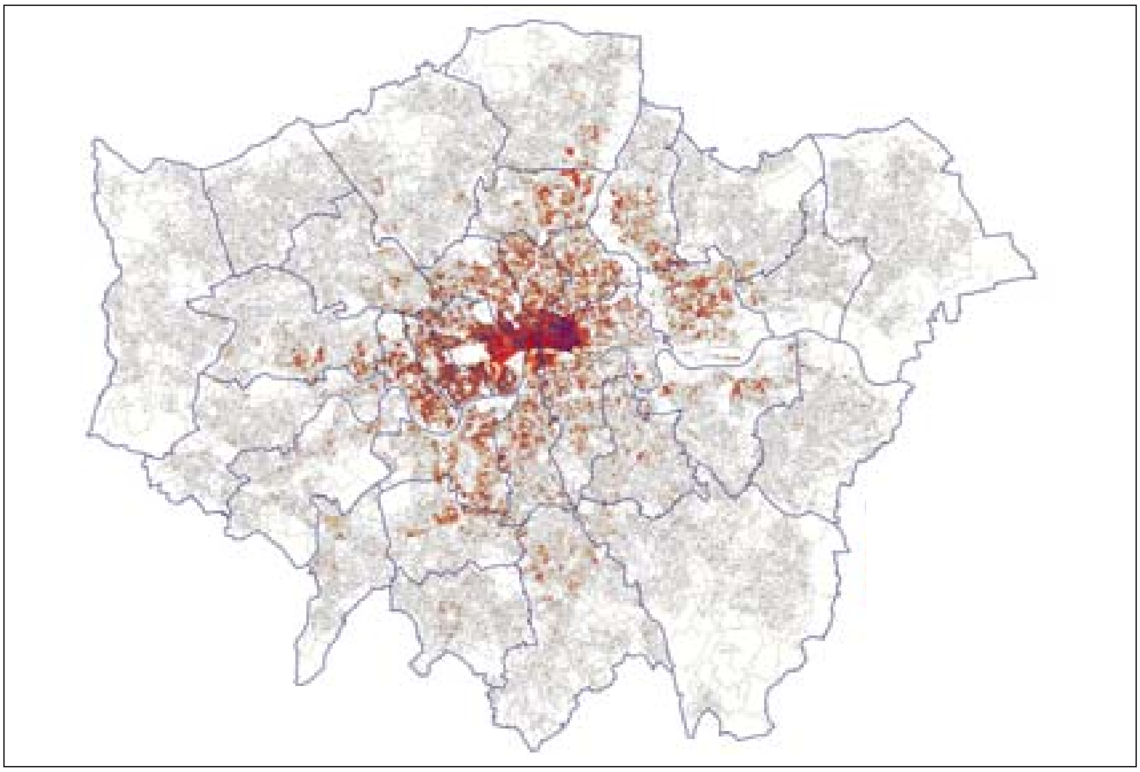
Map 3



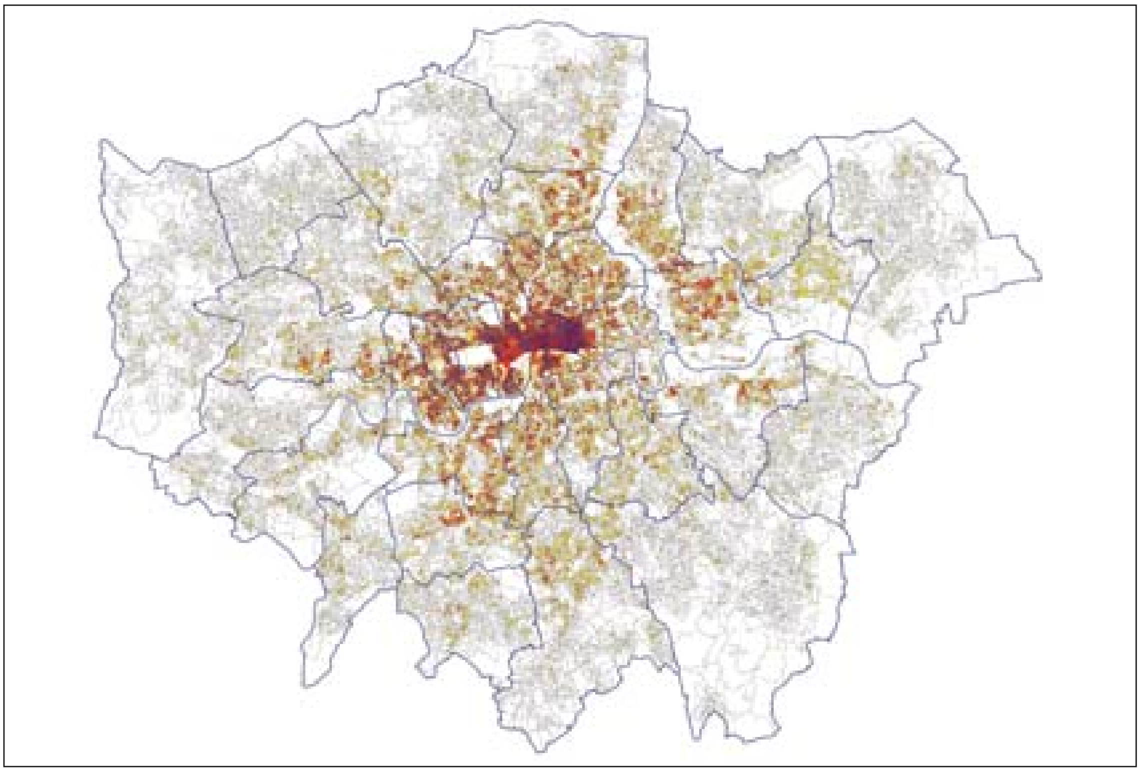


Map 1:

The heat map for London as mapped by The Community Heating Development Study for London (GLA 2005). It shows the density of the heat loads within the city.



Map 2:
The relatively small areas of high-density heat demand in London are highlighted here: they amount to 30% of the city's total heat demand.



Map 3:
A more extensive application of CH networks and the associated CHP technologies would meet around 50% of London's total heat demand.

2. METHODOLOGY

The methodology is firstly to establish the energy demand for heat and electricity from all buildings (both domestic and non-domestic) in London, and the associated CO_2 emissions, for the baseline year of 2005. The corresponding heat and electricity demand for 2025 is then predicted (see Section 2.3). Finally, this predicted demand is balanced against each of the four alternative energy supply scenarios, and the resulting primary energy requirements and CO_2 emissions are calculated. A brief description of the method and the principal assumptions used in the study follows below. A full discussion of the assumptions is included in Appendix B.

2.1 TIME HORIZON AND CO_2 REDUCTION TARGET

The study aims to show that over the next 20 years London can meet the energy demands of its increasing population and continued economic growth, while making substantial cuts in the emission of CO_2, all without the need for new nuclear power stations. The timescale of 20 years from 2005 has been taken as the basis for the study, since by the end of this period most of the existing generation of nuclear power stations, with the exception of Sizewell B, will have been retired. Moreover, in the 2003 EWP, the Government established a target of a 60% reduction of CO_2 levels by 2050 (compared to 1990 levels), and the Energy Review asks for substantial progress towards this target to be demonstrated by 2020, well within the timescale of the present study.

In this study it is assumed that there will be a linear reduction in CO_2 emissions between now and 2050, which requires a reduction of 26.7% from 2005 levels by 2025. It is also assumed that the target for building-related emissions is the same as the target for overall emissions, including those from transport and industry. Therefore a 26.7% reduction in CO_2 emissions from the 2005 base level has been used as the standard against which the four scenarios modelled are compared

The estimates of the technical and economic limits of the DE scenarios are based on the Community Heating Development Study for London by PB Power for the GLA (GLA 2005). This developed a map of heat demand in London, using GIS mapping techniques and Census 2001 data together with business rates.

2.2 ESTABLISHING BASE DEMAND IN 2005

The model divides building energy demand into four sectors: existing dwellings (as of 2005), new dwellings (built 2005 to 2025), existing non-domestic buildings (as of 2005) and new non-domestic buildings (again, built 2005 to 2025). For each of these sectors energy demands as heat and electricity are estimated. Further details can be found in Appendix A.

Base 2005 domestic energy demand is estimated using Census 2001 data and the Community Heating Development Study for London (GLA, 2005). The average annual heat demand per dwelling is estimated at 14,171kWh and electricity for lights and appliances at 3,300kWh (BREDEM 12). The proportion of electrically heated houses is assumed to be the national average of 9.5% (ODPM 2001). Average boiler efficiency of 70% (BRE 2005) is assumed.

Base 2005 demand for the non-domestic sector is based on floorspace data used in the Building Research Establishment's UK CH/CHP potential study (BRE, 2003). Existing floor space of 56.9 million m^2 is taken to have a heat demand of $128kWh/m^2$ and electricity demand of $154kWh/m^2$, assuming 50% of floorspace is air-conditioned and 20% is electrically heated. Boiler efficiency of 80% is assumed.

2.3 PREDICTED GROWTH IN ENERGY DEMAND TO 2025

Domestic demand

According to the London Plan (GLA, 2004a), London is expected to undergo a significant increase in population and a larger increase in new dwellings as the average number of people per dwelling continues to fall. An estimated additional 457,950 new dwellings will be needed by 2016, from which a figure of 659,550 homes for 2025 has been extrapolated. In addition, demolitions have been assumed at around 8,000 per annum – which equates to 160,000 over the next 20 years – an estimate based on the *40% House* report (ECI, 2005). This results in a net number of 499,550 new dwellings in 2025.

In this period it is assumed that for existing dwellings there will be a modest 10% reduction in heat demand due to improved insulation and that the proportion which are electrically heated will remain the same. Average domestic boiler efficiency is assumed to increase to 86% as this is the minimum requirement in the Building Regulations Part L. Electricity demand per dwelling for lights and appliances is assumed to remain the same. For new dwellings it has been assumed that heat demand per unit will be considerably lower at 3,000kWh per annum, in line with the revised requirements of the 2006 Part L1 Building Regulations, and that electricity demand for lights and appliances will be 20% less than for existing dwellings at 2,700kWh per annum. Average domestic boiler efficiency for new dwellings is assumed to be 92% in accordance with A grade appliance ratings. No further reduction has been assumed.

Non-domestic demand

On the basis of the London Plan (GLA, 2004a) an increase in employment of 845,000 and a 24% increase in required non-domestic floorspace together with replacement of 5% demolitions has been assumed, resulting in nearly 16.4 million m^2 of new-build floor space.

It is assumed that there will be a 25% reduction in annual heat demand compared to the current level for 'Good Practice' offices as given in the CIBSE Guide F (CIBSE, 2004), giving heat demand of 57kWh/m^2. It is also assumed that there will be a 30% reduction in electricity use, excluding electricity used for heating compared to 'Typical Practice' benchmarks also given in CIBSE guide F, giving 108kWh/m^2.

It is assumed that the proportion of electrically heated floorspace will fall to 10% in new buildings and that the proportion of new air-conditioned offices will remain at 50%. Boiler efficiencies of 86% for existing buildings and 92% for new buildings are assumed on the basis of the 2006 Building Regulations.

Energy efficiency assumptions

In the last EWP the role of energy efficiency was identified as central to the UK's chances of meeting our long-term CO_2 emission reduction targets.

Although there is anecdotal evidence that implementation of DE technologies may incentivise significant demand-side energy savings (for example through the use of smart metering within domestic households, the more widespread installation of domestic generation technologies, and the establishment of Energy Service Companies), no concrete evidence has yet been found to conclude that the implementation of DE technologies necessarily reduces demand.

It is however reasonable to assume that in planning a new infrastructure such as CH networks or private wire electrical networks there would be an added incentive to reduce peak demands prior to designing and installing such networks as well as the ongoing energy savings. It is therefore likely that a DE approach would provide impetus towards demand side energy efficiency, but as it difficult to quantify its effect and to maintain a conservative approach we have not taken this into account.

For this reason, the impact of demand-side energy efficiency improvements in 2025 has been assumed to be the same for all scenarios.

A summary of the assumptions made regarding annual energy demands is given in Table 2.1 below.

Table 2.1: Energy demand assumptions

Domestic buildings			
	units	**2005**	**2025**
Existing dwellings in 2005		3,109,424	—
Dwellings demolished 2005–25		—	160,000
Existing dwellings remaining in 2025		—	2,949,424
New dwellings constructed 2005–25		—	659,550
TOTAL DWELLINGS		3,109,424	3,608,974
Existing dwellings			
Proportion of electric heating	%	9.5	9.5
Individual gas boiler efficiency	%	70	86
Heat energy efficiency improvement 2005–25	%	—	10
Electricity energy efficiency improvement 2005–25	%	—	0
Heat demand per dwelling (space and water heating)	kWh	14,171	12,754
Electricity demand per dwelling (excluding heating)	kWh	3,300	3,300
New dwellings post-2005			
Proportion of electric heating	%	—	25
Individual gas boiler efficiency	%	92	92
Heat demand per dwelling (space and water heating)	kWh	3,000	3,000
Electricity demand per dwelling (excluding heating)	kWh	2,700	2,700
Total domestic energy demand for heat	**GWh**	44,063	39,594
Total domestic energy demand for electricity (excluding heating)	**GWh**	10,261	11,514
Non-domestic buildings			
	Units	**2005**	**2025**
Floor area of existing buildings in 2005	m^2	56,899,320	—
Floor area demolished 2005–25	m^2	—	2,844,966
Floor area of existing buildings remaining in 2025	m^2	—	54,054,354
Floor area of new buildings constructed 2005–25	m^2	—	16,364,966
TOTAL FLOOR AREA	m^2	56,899,320	70,419,320
Existing buildings			
Proportion of electric heating (as percentage of floorspace)	%	20	20
Gas boiler efficiency	%	80	86
Heat energy efficiency improvement 2005 to 2025	%	—	10
Electrical energy efficiency improvement 2005 to 2025	%	—	0
Heat demand (space and water heating)	GWh	7,262	6,209
Electricity demand (excluding heating)	GWh	8,785	8,346
New buildings post-2005			
Proportion of electric heating (as percentage of floorspace)	%	—	10
Gas boiler efficiency average	%	—	92
Heat demand (space and water heating)	GWh	—	939
Electricity demand (excluding heating)	GWh	—	1,768
Total non-domestic energy demand for heat	**GWh**	7,262	7,147
Total non-domestic energy demand for electricity (excluding heating)	**GWh**	8,785	10,115
Total London property energy demands for heat	**GWh**	51,325	46,741
Total London property energy demands for electricity (excluding heating)	**GWh**	19,046	21,629

2.4 THE FOUR ENERGY SUPPLY SCENARIOS

As already mentioned, the above predictions in the growth of heat and electricity demand are used as inputs to the model and balanced against supply according to four possible different energy supply scenarios:

1. **Centralised low nuclear scenario** – The current schedule of nuclear reactor closure is assumed with no extensions to plant life and no new reactors being built. Lost nuclear generation is replaced by centralised gas-fired generation. By 2025 only Sizewell B is scheduled to remain in operation.
2. **Centralised high nuclear scenario** – New nuclear plant is installed at the rate of one 1.6GW station in 2015 and two further 1.6GW stations at five-year intervals to 2025.
3. **Low DE scenario** – Existing nuclear power stations (apart from Sizewell B) are allowed to run down as in the centralised low nuclear scenario. A mix of technically proven DE sources (mostly gas-engine CHP generation supplying CH networks and some building integrated renewables) and conventional energy generation is added to the energy supply. 30% of the total heat demand, as shown in Map 2 above, is met using DE sources.
4. **High DE scenario** – As above but with a higher proportion of DE sources, closer to the technical limits of CHP capacity, the use of domestic 'micro'-CHP, and a higher percentage of building-integrated renewables.

All scenarios assume that large-scale renewables will contribute 20% of centralised generation by 2025 and that centralised coal-fired power stations will provide 16%, in accordance with the DTI's consultation document 'Our Energy Challenge' (DTI 2006a).

2.5 CO_2 EMISSIONS, ELECTRICITY AND HEAT BALANCE CALCULATION METHODOLOGY

All the scenarios are assumed to have the level of energy demand and efficiency savings set out in 2.3 above. For the two centralised energy scenarios (low nuclear and high nuclear), the assumptions on gas boiler efficiency and the proportion of electric heating enable the overall demands for electricity and gas for London to be established. CO_2 emission factors from table 2.3 are then applied to the electricity imported to London and the emission factor of 190g/kWh is applied to the gas imported to London, for the centralised scenarios. This enables the total CO_2 emissions for London in 2005 and in 2025 to be calculated for the centralised scenarios.

The CO_2 emissions for the DE scenarios are calculated by taking the centralised low nuclear total emissions figure and subtracting the reduction in CO_2 emissions arising from each DE technology. Detailed assumptions for each technology are given in Appendix C.

In addition to the CO_2 emissions, the model calculates:

- the consumption of primary energy (ie the ultimate fuel or energy source)
- the contribution from the technologies employed to satisfy the heat demand (the heat balance)
- the contribution from the technologies employed to satisfy electricity demand (the electricity balance).

Table 2.2a: Proportion of electricity supplied to the national grid from different sources, and associated CO_2 emissions factors, 2005

Electricity source	CO_2 emissions factor	Share of supply	Contribution to emissions factor
	g/kWh	%	g/kWh
Nuclear	0	19.47	0
Renewables	0	1.93	0
Hydro	0	1.30	0
Coal	954	33.27	317.40
Oil	838	1.15	9.64
Gas	462	40.38	186.56
Other	527*	2.51	13.23
Average CO_2 emissions factor for total grid mix (g/kWh)			526.83

*The calculation is derived from DUKES (2004), which does not provide details of the emissions factor for the generation component termed 'Other'. This has therefore been taken as the average of all sources for the purposes of deriving the average CO_2 emissions factor.

Table 2.2b: Proportion of electricity projected to be supplied to the national grid from different sources, and associated CO_2 emissions factors, 2025

	CO_2 emissions factor	Share of supply: low nuclear scenario	Share of supply: high nuclear scenario
	g/kWh	%	%
Nuclear	0	2	11
Renewables	0	20	20
Coal	990	16	16
Gas (CCGT)	414	62	53
Average CO_2 emissions factor for total grid mix (g/kWh)		415	378

2.6 SOURCES OF DATA

This study draws on a wide range of different data sources. The database of energy demands estimated in the Community Heating Development study for London (GLA, 2005) has been used as the basis for assessing the current heat demands.

The report also draws on information from the Building Research Establishment study *The UK Potential for Community Heating with CHP* (BRE, 2003). Other documents providing key data include: *The London Plan* (GLA, 2004a); *Green Light to Clean Power*, the Mayor's Energy Strategy (GLA, 2004b); and *The potential in London for biomass and wind energy* (LEP/GLA, 2006).

The report therefore meets the requirement of the Energy Review consultation, which asks for 'evidence-based' contributions.

E2's Avedor power station close to Copenhagen produces 20% of the electricity required by the region of eastern Denmark, and 40% of the heat demand for the city. Two major transmission pipes carry heat to 200,000 homes.
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3. DECENTRALISED ENERGY TECHNOLOGIES AND THEIR LONDON POTENTIAL

Tables 3.1 and 3.2 below summarise the projected market penetration of the various DE technologies that are assumed to be employed for the low DE and high DE scenarios.

These technologies include:

1. CCGT CHP feeding in to CH networks
2. Gas-engine CHP supplying CH networks
3. Building-based CHP (considered for the non-domestic sector only)
4. Biomass CHP and biomass boilers
5. Energy from waste
6. Building-integrated low- and zero-emission technologies, including:
    a. Domestic CHP
    b. Renewable heat – solar thermal
    c. Renewable electricity – micro-wind turbines and photovoltaics.

A fuller discussion of these technologies and their London potential appears in Appendix C. This includes a description of each technology, an assessment of the likely opportunities for employment of each technology in London, and an estimate of each technology's market share under both the low and high DE scenarios.

The straw barn at Avedor in Copenhagen. Supplied by 400 farmers, the plant uses 10% of the nation's surplus straw in combined heat and power production. Able to use four different fuels (straw, wood pellets, gas and oil), it blends world beating efficiencies of 95% with maximum fuel flexibility.

©Greenpeace/Reynaers

Solar thermal units used for heating domestic hot water to individual properties are becoming a common sight. But these units at Western Harbour in Malmö, Sweden, are connected together and supply 20% of the Community Heating network.

©Greenpeace/Reynaers

Gas engine CHP plants sit well within the urban environment providing the heat, power and cooling required keeping a city in business.

©Greenpeace/Christelis

Table 3.1: Low DE projections by energy contribution to building type, 2025

DE TYPE	EXISTING DOMESTIC				NEW DOMESTIC				EXISTING NON-DOMESTIC				NEW NON-DOMESTIC			
	Electrical output		Thermal output		Electrical output		Thermal output		Electrical output		Thermal output		Electrical output		Thermal output	
	MW	GWh/yr	MW	GWh/yr	MW	GWh/yr	MW	GWh/yr	MW	GWh/yr	MW	GWh/yr	MW	GWh/yr	MW	GWh/yr
CCGT CHP - Barking	n/a	n/a	100	237	n/a	n/a	100	237	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CCGT CHP – (Eg Tilfen Land)	n/a	n/a	50	118	n/a	n/a	50	118	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Gas-engine CHP	1,700	8,500	1,900	8,740	100	500	112	514	448	1,120	501	1,152	100	250	112	257
Building-based CHP	0	0	0	0	0	0	0	0	100	200	170	340	15	30	26	51
Domestic CHP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Large-scale biomass CHP	40	280	60	213	0	0	0	0	0	0	0	0	0	0	0	0
Waste to energy CHP (existing)	n/a	n/a	40	184	n/a	n/a	0	0	0	0	0	0	0	0	0	0
Waste to energy CHP (new)	n/a	n/a	78	282	n/a	n/a	0	0	0	0	0	0	0	0	0	0
Solar thermal	n/a	n/a	105	60	n/a	n/a	105	60	0	0	0	0	0	0	0	0
Biomass boilers	n/a	n/a	0	0	n/a	n/a	75	164	n/a	n/a	0	0	n/a	n/a	50	88
Micro-wind turbines	20	40	n/a	n/a	33	66	n/a	n/a	0	0	n/a	n/a	45	90	n/a	n/a
Photovoltaics	20	20	n/a	n/a	33	33	n/a	n/a	0	0	n/a	n/a	90	90	n/a	n/a
TOTAL	1,780	8,840	2,228	9,833	166	599	337	1,093	548	1,320	671	1,492	250	460	187	396

Table 3.2: High DE projections by energy contribution to building type, 2025

DE TYPE	EXISTING DOMESTIC				NEW DOMESTIC				EXISTING NON-DOMESTIC				NEW NON-DOMESTIC			
	Electrical output		Thermal output		Electrical output		Thermal output		Electrical output		Thermal output		Electrical output		Thermal output	
	MW	GWh/yr	MW	GWh/yr	MW	GWh/yr	MW	GWh/yr	MW	GWh/yr	MW	GWh/yr	MW	GWh/yr	MW	GWh/yr
CCGT CHP - Barking	n/a	n/a	300	710	n/a	n/a	100	237	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CCGT CHP – (Eg Tilfen Land)	n/a	n/a	60	142	n/a	n/a	60	142	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Gas-engine CHP	2,500	12,500	2,794	12,853	100	500	112	514	750	1,875	838	1,928	100	250	112	257
Building-based CHP	0	0	0	0	0	0	0	0	150	300	255	510	15	30	26	51
Domestic CHP	135	270	630	1,260	0	0	0	0	0	0	0	0	0	0	0	0
Large-scale biomass CHP	60	420	90	319	0	0	0	0	0	0	0	0	0	0	0	0
Waste to energy CHP (existing)	n/a	n/a	40	184	n/a	n/a	0	0	0	0	0	0	0	0	0	0
Waste to energy CHP (new)	n/a	n/a	155	563	n/a	n/a	0	0	0	0	0	0	0	0	0	0
Solar thermal	n/a	n/a	210	120	n/a	n/a	210	120	0	0	0	0	0	0	0	0
Biomass boilers	n/a	n/a	0	0	n/a	n/a	150	329	n/a	n/a	0	0	n/a	n/a	100	175
Micro-wind turbines	40	80	n/a	n/a	66	132	n/a	n/a	0	0	n/a	n/a	90	180	n/a	n/a
Photovoltaics	40	40	n/a	n/a	66	66	n/a	n/a	0	0	n/a	n/a	180	180	n/a	n/a
TOTAL	2,775	13,310	4,069	16,151	232	698	422	1,341	900	2,175	1,093	2,438	385	640	237	483

4. DISCUSSION OF RESULTS

4.1 CO_2 EMISSIONS

The reductions in CO_2 emissions for all buildings are shown in Figures 4.1 and 4.2 in absolute terms and percentage terms for each scenario.

Results

- As a result of improved efficiency of buildings, higher efficiency boilers and the changes in the grid mix of power stations, the Centralised Low Nuclear scenario results in a 19% reduction in CO_2 emissions compared to 2005 levels.
- The adoption of a Centralised High Nuclear scenario results in a further four-percentage-point reduction in CO_2 emissions on 2005 levels – giving a total CO_2 saving of 23%
- Implementation of the Low DE scenario provides an additional eight-percentage-point reduction in CO_2 emissions on 2005 levels – giving a total CO_2 saving of 27%. The level of savings required in order to be on track for the 2050 target of 60% reduction in CO_2.
- Implementation of the High DE scenario results in a total reduction of CO_2 emissions of nearly 33% on 2005 levels, compared to the target of 27%. It is fourteen-percentage-points more than the Centralised Low Nuclear scenario and ten-percentage-points more than the Centralised High Nuclear scenario.

Assumptions behind the results

CO_2 emissions fall in all four scenarios for two reasons: firstly because of an improvement in individual gas boiler efficiencies as a result of Building Regulations Part L requiring the use of condensing boilers (by 2025 it is assumed that all existing boilers will have been replaced); and secondly because of a continuation of the trend of fuel switching from coal to gas in centralised energy generation and the anticipated parallel increase in centralised renewable energy. The centralised scenarios include a greater contribution to London's energy needs from centralised renewables than do the DE scenarios, due to the fact that the bulk of electricity in the centralised scenarios is imported from outside London. This factor reduces the differential in emissions between the centralised and decentralised scenarios

Analysis of results

Overall, the DE scenarios achieve CO_2 emission savings mainly by using CHP systems which are more efficient than CCGT power stations. The centralised high nuclear scenario achieves emission savings compared to the low nuclear scenario as a result of generating a proportion of its energy from nuclear power stations instead of CCGT. However, as Figures 4.1 and 4.2 demonstrate, despite the increased contribution in the centralised scenarios

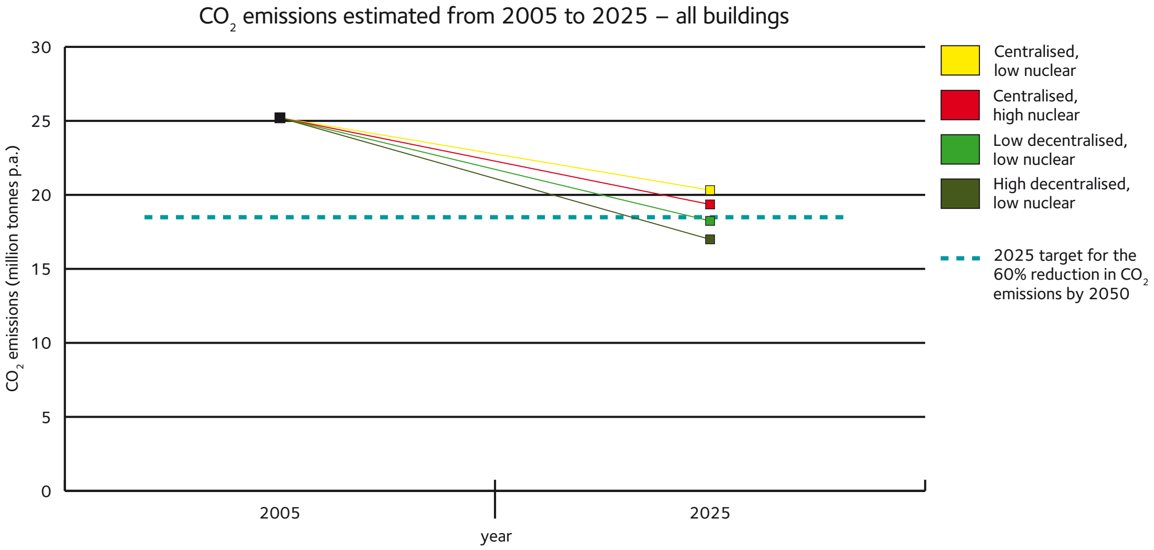

CO_2 emissions estimated from 2005 to 2025 – all buildings

Figure 4.1: Total CO_2 emissions from all buildings in London
Only the decentralised energy pathway can put the capital on a trajectory to meet the UK CO_2 emission reduction target of 60% by 2050.

from zero-emission centralised renewable electricity, only the two DE scenarios would enable London to exceed the interim CO_2 reduction target and keep it on track for a reduction of 60% by 2050. This is largely due to the greater efficiency of CHP compared not just to CCGT but to any centralised generation source.

A further crucial point is the degree to which each scenario offers potential to make further cuts in CO_2 emissions in order to meet the Government's long-term target of 60% reductions by 2050.

The DE pathway not only offers the means by which London can meet the assumed 2025 CO_2 reduction target, it also promises to put London in a good position to meet the 2050 target. This is because the DE scenarios entail the installation of infrastructure in order to exploit renewable energy sources within the boundaries of London and to distribute heat to dwellings and other buildings. The installation of this infrastructure is not technology-specific, meaning that as technologies slowly mature or the economics of different fuel sources improve, the infrastructure already in place can easily be adapted to respond to these changes. An example is the South East London CHP (SELCHP) incineration plant. When the lifespan of the current incinerator comes to an end, a plant using a different CHP technology (such as biomass-fired CHP or alternative waste-to-energy technology) could be constructed in its place.

A further point to note in Figure 4.2 is the reduction in the role of the 'energy efficiency and more efficient boilers' component in the DE scenarios compared to the centralised scenarios. The emission savings in this sector result partly from improvements in the energy efficiency of buildings, which are assumed to be the same across all scenarios, and partly from the increased efficiency of individual boilers. One consequence of the DE scenarios is that the number of buildings generating heat from individual boilers decreases as buildings are gradually connected to CH grids. It is this reduction in the number of buildings generating heat from individual boilers that causes the diminishing role of this component in the DE scenarios.

Similarly, as can also be seen in Figure 4.2, the impact of a cleaner grid mix also decreases as we move towards a DE future for London. This is caused not by any change in the grid mix (as the proportions of the mix are assumed to be the same for both DE scenarios and the centralised low nuclear scenario) but by the fact that the amount of electricity that has to be imported to London decreases as higher levels of local electricity generation are exploited.

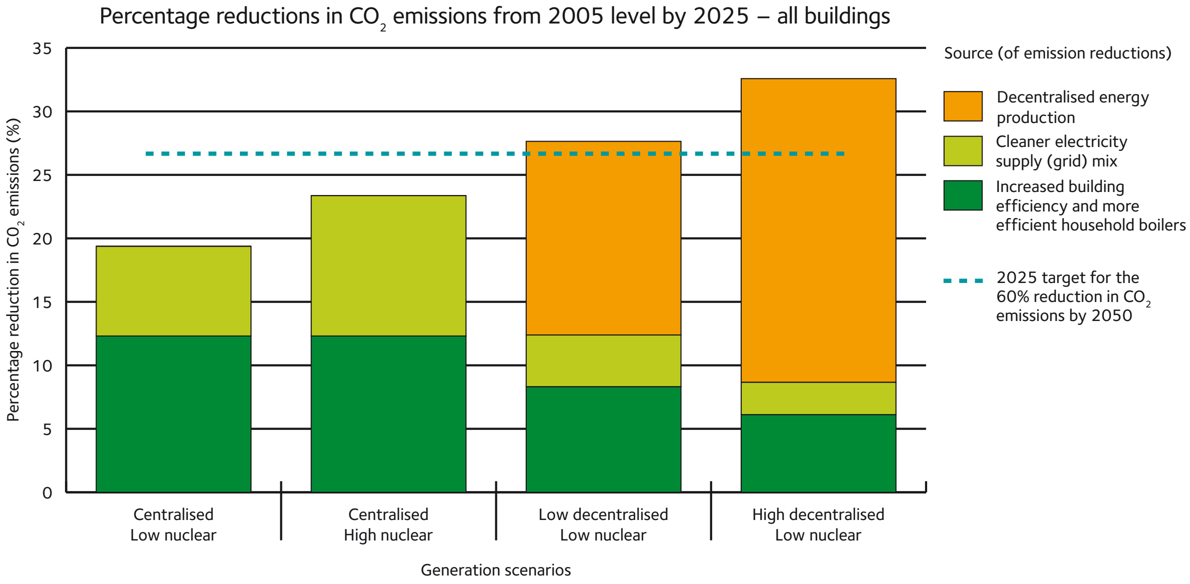


Figure 4.2: Sources of annual CO_2 emission reductions for all buildings by 2025
Only a decentralised energy pathway enables sufficient CO_2 savings to put the capital on a trajectory to meet the UK CO_2 emission reduction target of 60% by 2050.

The difference between the domestic and non-domestic sectors

Figures 4.3 and 4.4 compare the reduction in CO_2 emissions from buildings in the domestic and non-domestic sectors. The bar charts reveal a marked difference in terms of performance against the overall target. The primary reason for this difference is the proportionally much greater demand for heat than electricity in the domestic sector compared to the non-domestic sector. Non-domestic buildings are typically occupied only in the daytime (thus requiring relatively little heating), often have higher electrical demand (due to the many appliances normally found in offices), and are increasingly fitted with electrically powered air conditioning. This combination of factors results in a high electricity demand and a low heat demand.

The bar charts show that the key sector in reducing overall building-related emissions is the domestic sector, and illustrate the fact that in this sector the key requirement that needs to be addressed is the provision of heat. Taking this into account, it is worth reiterating both how effective CH and CHP could be in addressing domestic heat demand, and that changes in the supply of electricity from centralised power stations cannot make a significant impact on the emissions associated with this energy demand.

As a result of following a DE approach in Denmark, GDP has risen, energy demand has remained stable, and CO_2 emissions have fallen. In individual households, living standards remain high and people have confidence in the security of their supply of heat and power, now and in the future. ©Greenpeace/Reynaers

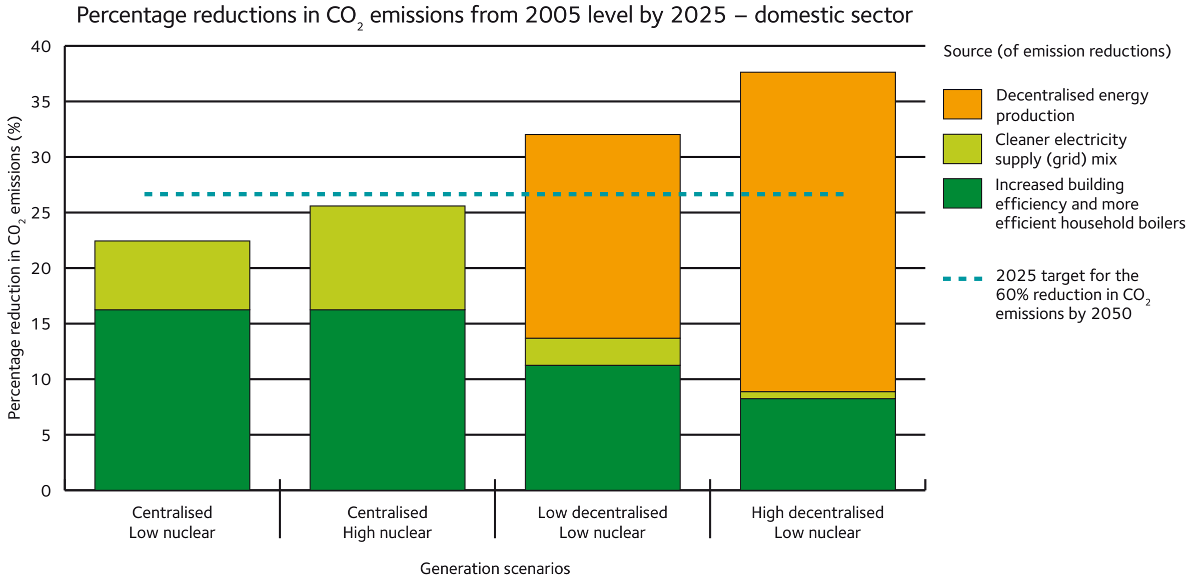


Figure 4.3: Sources of annual CO_2 emission reductions for domestic dwellings by 2025

Tackling the domestic sector's high heat demand is crucial to achieving the CO_2 reductions. The DE scenarios meet the 2025 emissions reduction target because they offer the best option for tackling heat demand in the domestic sector.

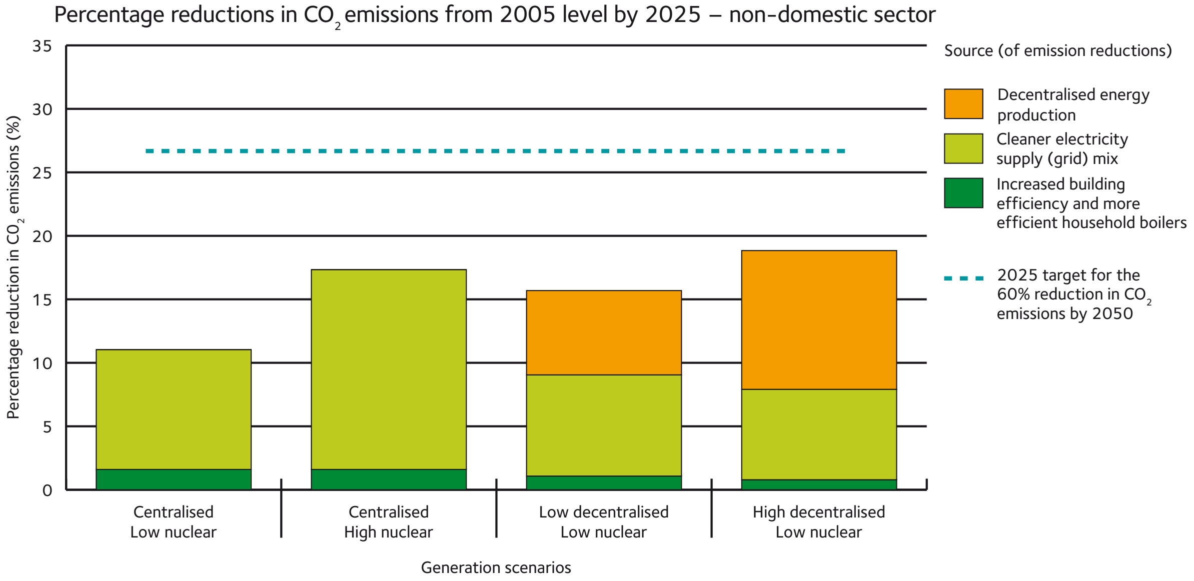


Figure 4.4: Sources of annual CO_2 emission reductions for non domestic dwellings by 2025

The greater reliance on electricity for buildings in the non domestic sector means that CO_2 savings are less easy to achieve. In all scenarios the 2025 emissions reduction target is not met.

Figure 4.5: Reductions in CO_2 emissions from 2005 level by 2025 – by energy source
How the different decentralised energy technologies contribute to the CO_2 savings

Technology type

🟩	CCGT CHP - Barking	🟩	Building CHP	🟩	Waste to energy (existing)	🟫	Biomass boilers
🟥	CCGT CHP - Tilfen Land	⬜	Domestic CHP	🟥	Waste to energy (new)	🟨	BIWT
🟧	Gas-engine CHP	🟧	Biomass CHP	🟦	Solar thermal	🟧	PV

CO_2 savings under the Low DE scenario (%)

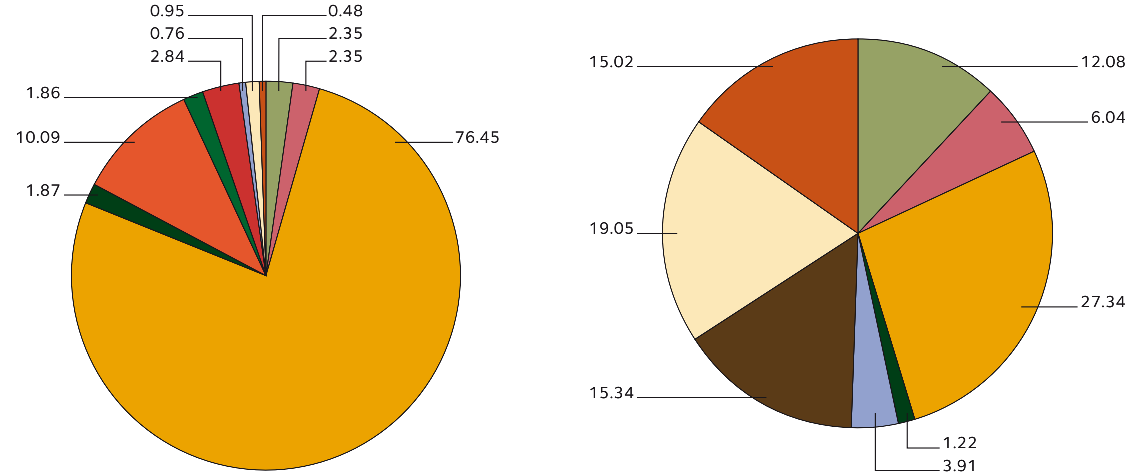


Figure A. For the existing building stock
Efficient use of gas through widespread use of gas-engine CHP (and associated Community Heat networks) dominates the CO_2 savings from existing properties. Biomass as a fuel becomes significant with building integrated low and zero carbon technologies making a marginal contribution.

Figure B. For the new build properties
Renewable technologies account for over half of the CO_2 savings when they incorporated in to new buildings.

CO_2 savings under the High DE scenario (%)

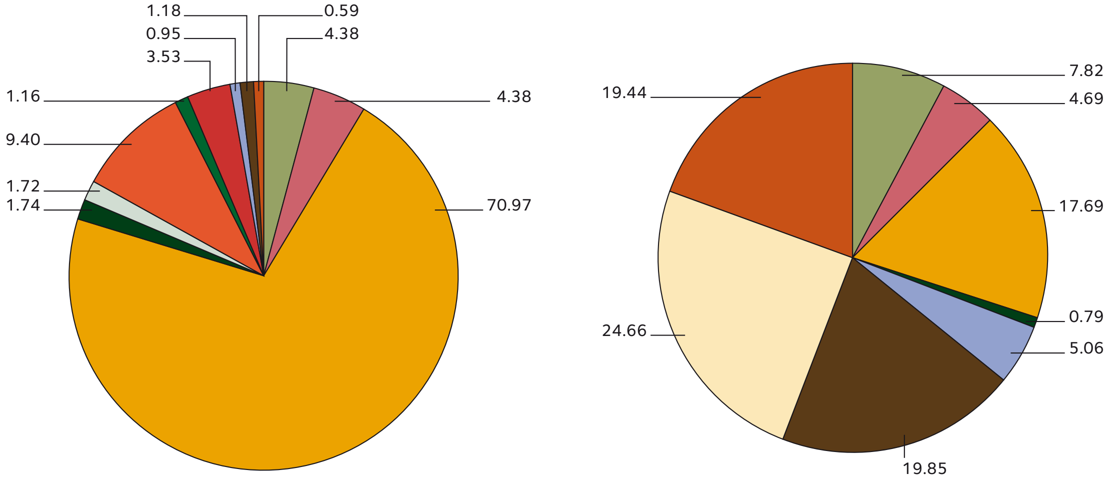


Figure C. For the existing building stock
Gas-engine CHP remains the principle way to save CO_2 in existing buildings but building integrated low and zero carbon technologies begin to make a marked contribution.

Figure D. For the new build properties
with two thirds of the CO_2 savings being delivered through renewable energy technologies the future role of gas (even used in CHP) is reduced.

The difference between existing and new-build dwellings

The contributions made by the various DE technologies to the overall CO_2 emission savings in each DE scenario are shown in Figure 4.5 for both existing and new buildings. The pie charts show that gas-engine CHP with CH will be the most important single contributor for existing buildings, whereas for new buildings the opportunities to save CO_2 are much more diverse. This is partly because in the non-domestic sector we have included no capacity for retrofitting new renewable energy into existing buildings.

With new building projects, there is ample opportunity to design in high energy performance through a diversity of efficient energy sources. Here at Western Harbour in Malmö, Sweden they use wind and photovoltaics for the electricity and ground source heat pumps and solar thermal for the heating. ©Greenpeace/Reynaers

4.2 PRIMARY ENERGY ANALYSIS

The primary energy requirements for London as calculated by the model are shown for all scenarios in Figure 4.6 in absolute terms and in Figure 4.7 in percentage terms. Primary energy means the input energy consumed as fuel whether in boilers or in power stations. Nuclear power stations are assumed to have a primary fuel input based on an efficiency of 35% (DTI 2005).

Imported electricity within all 2025 scenarios is assumed to have basically the same mix of primary energy sources regardless of its overall volume. Under the DE scenarios, less centralised electricity is used in London and hence the total consumption of primary energy associated with centralised electricity also falls. If the DE approach were extended across the UK, however, the renewable energy contribution could be higher in percentage terms.

Figure 4.6 shows that the high DE scenario uses over one-third less primary energy in meeting the heat and electricity demands of London than the centralised low nuclear scenario. This level of primary energy saving assumes, as has been the case throughout the report, that there are no additional savings through demand-side energy efficiency measures as a result of pursuing a DE pathway – in practice the saving might therefore be expected to be even greater. Such a large reduction in primary energy should in turn greatly reduce London's dependence on imported energy.

Indeed, it can be seen from Figure 4.6 that the total gas consumption for the low DE scenario is significantly lower than the current level and that for the centralised low nuclear scenario. It is even a clear 7% lower than that for the high nuclear scenario. The high DE scenario reduces gas use by around 15% compared to the high nuclear scenario. The primary reason for this reduced gas consumption is once again the high efficiency of CHP systems, which reduces the use of gas in boilers and allows much more usable energy to be generated per unit of gas burned.[4]

Thus, even though in percentage terms both DE scenarios are more reliant on gas, they offer a reduced dependence on gas in absolute terms compared both to current consumption levels and to either of the centralised scenarios envisaged. The extent to which this reduced consumption promises to reduce London's vulnerability to gas price fluctuations will moreover increase in the long term as the DE fuel mix diversifies away from a reliance on gas towards a variety of different renewable sources for both electricity and heating. It is also worth noting that even within the centralised scenarios, gas will still be the dominant fuel, providing over 60% of the total primary energy – mainly because it remains the main fuel for space and water heating, by means of condensing boilers.
The fuel mix in the heat sector for the centralised scenarios will be less diverse than under the DE scenarios and without the scope for flexibility in changing to new fuel sources provided by the DE scenarios. In addition, whereas rises in fossil fuel prices including gas will tend to result in higher heating and electricity prices under the centralised scenarios, a larger proportion of the cost of heat from CH systems is related to the capital investment in the networks and is thus less influenced by fuel price changes.

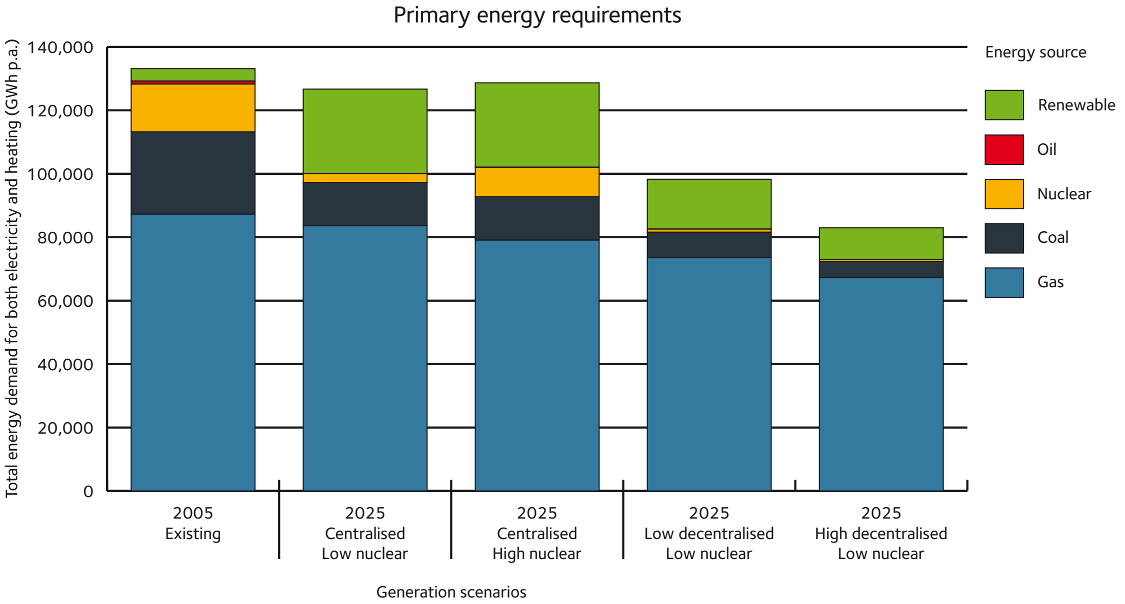


Figure 4.6: Total primary energy demand

By 2025, energy demand will have fallen, under both centralised scenarios, as a result of increased energy efficiencies in buildings and boilers. Adoption of a DE pathway enables demand to be actively reduced where primary energy is used for both heat and power production together. The quantity of gas consumed falls under the DE scenarios, as compared to both the centralised scenarios.

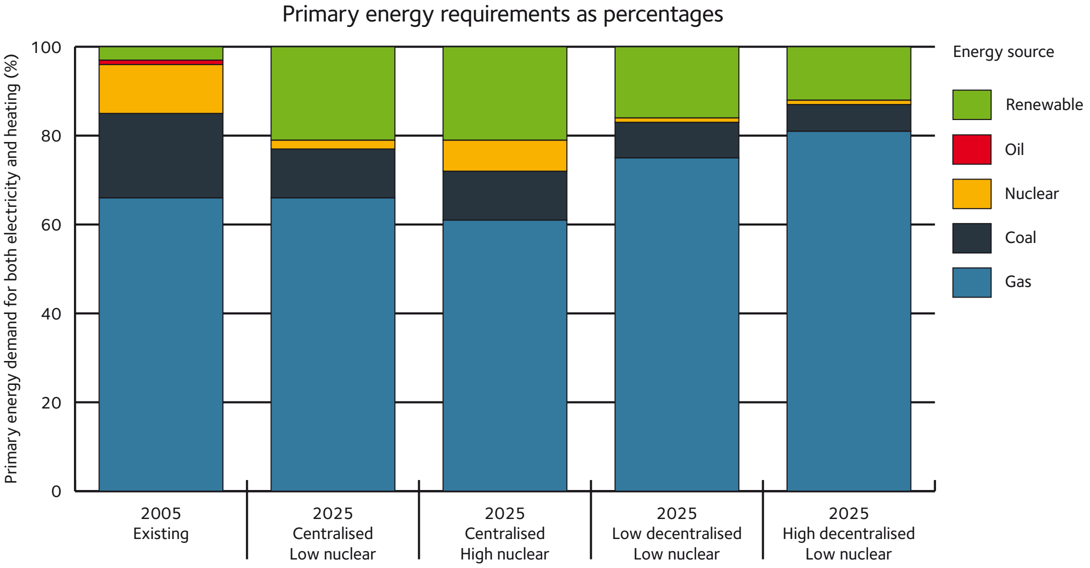


Figure 4.7: Proportion of total primary energy by fuel type

Use of gas is proportionately higher under the two DE scenarios, but the absolute quantity consumed (as shown in Figure 5 above) is reduced.

4.3 HEAT BALANCE

The heat balance calculation shows how the heat demand for London would be supplied under the various scenarios. The totals shown in Figures 4.8 and 4.9 represent heat delivered.

The overall share of electric heating is assumed to be 11% for all scenarios because of the potential difficulties and/or cost of converting electrically heated buildings to either CH or gas-fired individual boiler systems. In practice, a CH network developer would be likely to prioritise the conversion of electrically heated buildings, as this is where the greatest CO_2 emission and cost savings would be obtained. However, this variable has been kept constant in each scenario in order to remain consistent with our conservative approach, even though this once again underplays the potential CO_2 emission savings of DE.

For both centralised scenarios the heating supply is dominated by gas-fired boilers. For the low DE scenario, the various DE technologies supply 27.4% of the total heat demand. The majority of this supply is through gas-fired CHP and CH, but with some contribution from renewable energy (through biomass and solar thermal systems) and from waste-to-energy plants.

For the high DE scenario, the contribution from DE is 43.7% – a considerable contribution, but still well under half of the overall heat demand. Even discounting the 11% share of electric heating, it is clear from Figures 4.8 and 4.9 that there is potential for further expansion of DE heating capacity into the share of the heat market that is still envisaged to be occupied by individual boilers. As this expansion would be in areas of lower-density heat demand, the DE solutions required would include micro-CHP and solar thermal systems.

The areas covered by the levels of CH envisaged in both the high and low DE scenarios are shown on Maps 2 and 3 on page 11.

Efficient use of heat is key to DE systems. While engineering precision is required to achieve great efficiencies, the critical decision is to locate and design power plants for heat production and distribution.©Greenpeace/Reynaers

Both DE scenarios offer a realistic way of ultimately meeting the heat demand of London through provision of a number of different types of CHP and solar thermal systems. The variations in the centralised electricity fuel mix do not translate significantly into the heat market and the more immediate requirement is to develop a more efficient way to utilise our limited gas supplies – which CHP and CH can deliver.

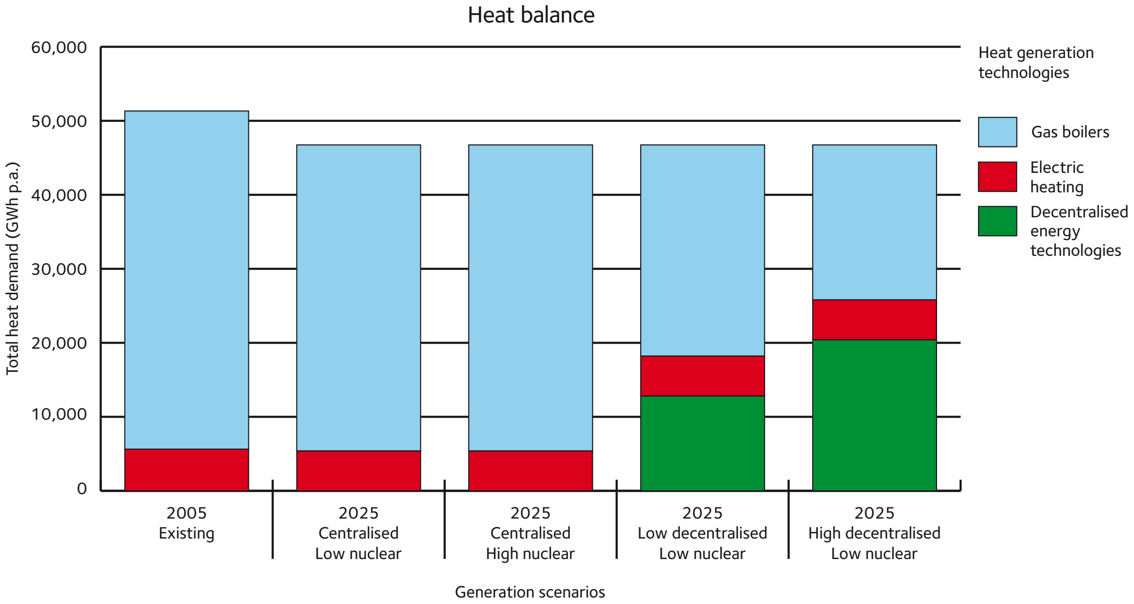


Figure 4.8: Total demand for heat and associated primary fuel

Overall demand for gas for heating remains the same under each scenario. However, gas demand is divided between use in individual gas boilers producing only heat and gas that is used in DE technologies, such as CHP, that produces both heat and electricity. Much of the gas use shown in this Figure for heat is also shown in Figure 4.10 for electricity.

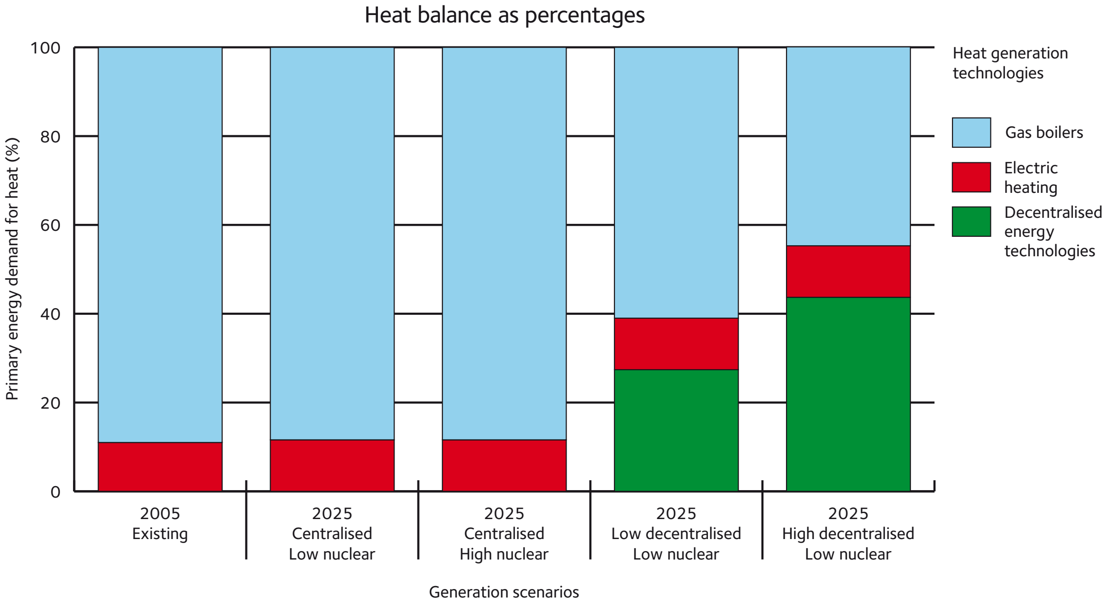
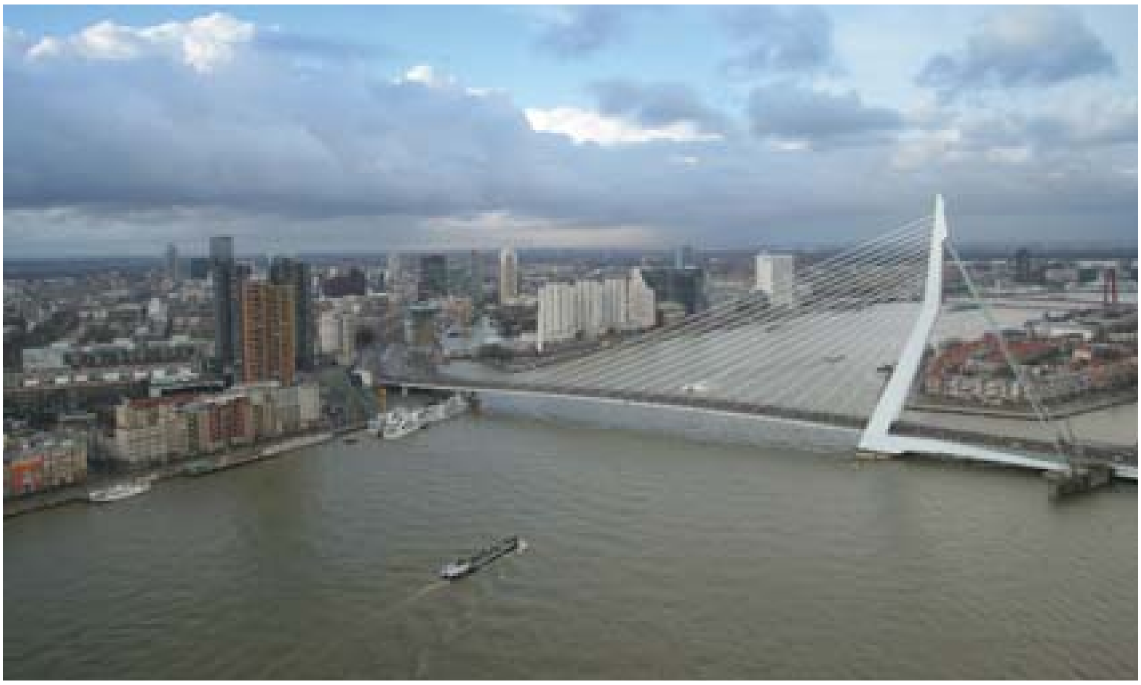


Figure 4.9: Proportion of total heat demand by fuel type

Provision of heat can be diversified under the DE scenarios with the gas used in decentralised systems also yielding electricity (as indicated in Figure 4.11).



As a nation. The Netherlands produces 50% of its electricity from CHP. Cities like Rotterdam are outlining plans to increase the use of their surplus industrial heat and can foresee a future where they achieve maximum efficiencies and maximum competitiveness. ©Greenpeace/Reynaers

4.4 ELECTRICITY BALANCE

The electricity balance calculation estimates how London's electricity demand will be supplied under the various scenarios. The totals shown in Figures 4.10 and 4.11 represent electricity delivered.

Total electricity demand is projected to increase by 2025 principally as a result of the expansion of London and the assumption that gains in energy efficiency are offset by increased use of appliances.

It can be seen that in the low DE scenario somewhat less than half of London's electricity is generated within London, with nearly two-thirds of the centralised electricity provided by gas-fired power stations. In the high DE scenario over 60% of total demand is generated within London. The proportion contributed by nuclear power in the DE scenarios is much reduced as a result compared to the high nuclear scenario. Some of the electricity generated in London under both DE scenarios (3% in the low DE scenario and 6% in the high DE scenario) is from renewable energy sources (biomass, wind and solar). The implications of the generation of over 60% of London's electricity demand locally under the high DE scenario are as follows:

- The large number of smaller generators will mean a more reliable and flexible generating mix, which will reduce the total generating capacity needed to supply London and enable a greater proportion of intermittent renewable energy to be accommodated on the distribution network, as experienced in Denmark.
- The reduction in London's peak demand for centralised energy will cut the need for investment in additional national grid capacity to meet London's growing demand, and may also reduce the cost of maintaining the current system.
- Some buildings may enjoy greater security of supply as a result of decentralised generation, depending how this is introduced.
- Generating electricity from both gas-fired CHP and building-integrated renewables is likely to require modifications to the distribution system within London, to ensure energy balancing within the city and to enable surplus energy to be exported onto the national grid. Such an updated distribution network will be able to incorporate further local renewable generating capacity as micro-renewable technologies mature.

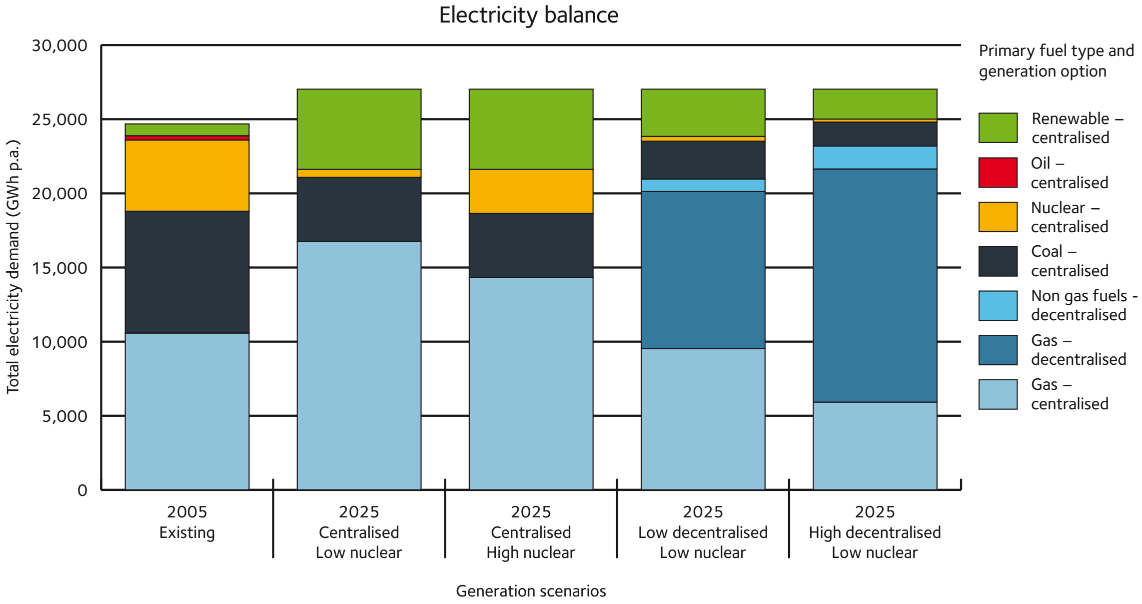


Figure 4.10: Total demand for electricity and associated primary fuel

London can produce an increasing amount of its own electricity under the DE options. While an increased dependence on gas is indicated, this same gas is also yielding heat (as indicated in Figure 4.8).

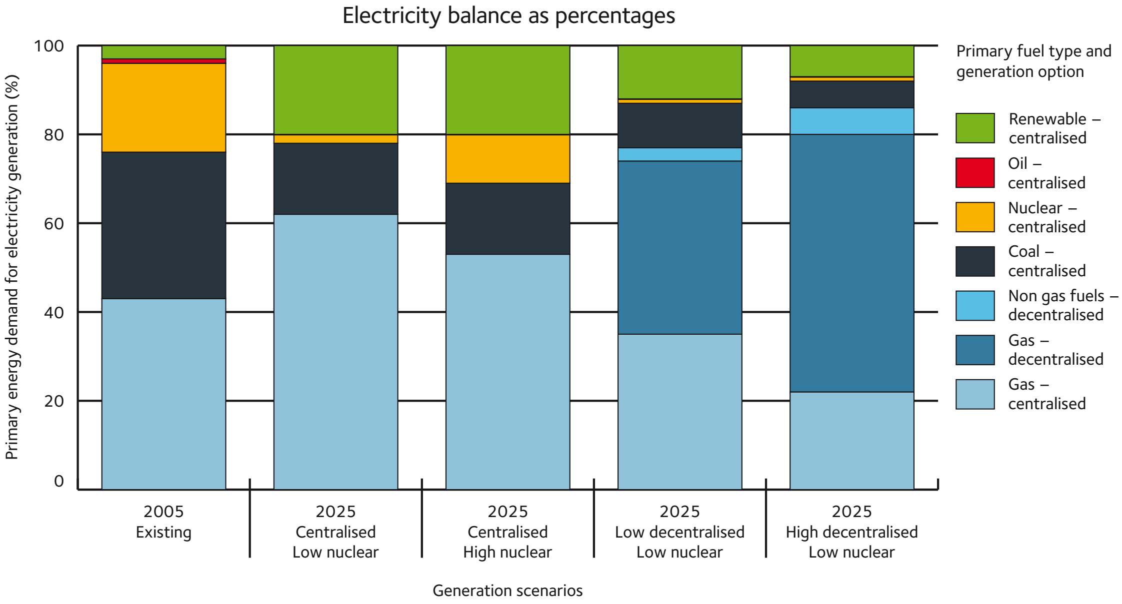


Figure 4.11: Proportion of total electricity demand by fuel type

Under both DE scenarios, gas becomes the dominant fuel for electricity production, but the electricity produced via gas-fired DE is effectively the by-product of heat generation.

5. CONCLUSIONS

The model which forms the basis of this report has been developed to estimate the contribution that DE systems could make by 2025 to supplying London's energy needs, enhancing energy security, ensuring adequate heating in every home and reducing CO_2 emissions from buildings. The model has been used to consider two scenarios for the development of DE:

- a low DE scenario assuming a modest degree of regulatory support which is based on existing technologies and assumptions broadly consistent with current regulations and economic conditions
- a high DE scenario using more advanced technologies and in which the regulatory background is assumed to be more favourable to DE.

These have been compared with two scenarios reliant on conventional centralised generation – a low nuclear scenario involving no new nuclear power stations to replace retired plant, and a high nuclear scenario in which several new stations are built.

The low DE scenario has shown that by 2025:

1. CO_2 emissions from London could be reduced by over **27.6%** from current levels by using a range of existing DE technologies and without new nuclear power stations being built. This reduction is in line with the Government's target of a 60% reduction by 2050, even though it uses a number of conservative assumptions.
2. London's projected heat and electricity demand could be met without assuming any exceptional demand-side energy efficiency gains while using **23.6%** less primary energy than the high nuclear scenario.
3. The majority of the CO_2 savings would arise from a major investment in gas-fired CHP and CH systems, although a range of other technologies could also be used, particularly in the new-build sector, offering further scope for exploitation of previously untapped renewable resources and providing greater security through diversity.
4. Despite the use of natural gas for CHP and the increased use of gas in power stations (without the nuclear contribution) London's overall gas consumption would fall and would be **7%** lower than for the centralised high nuclear scenario.
5. The proportion of the London heat market supplied through DE would be **27.4%**. Electricity generated from DE systems within London would provide **42.3%** of total consumption. Both of these parameters show that there would be scope for still further expansion of DE.
6. The installation of CH networks capable of distributing heat from different fuel sources and CHP plants would offer flexibility in meeting heat demand in subsequent decades.

The high DE model has similarly shown that by 2025:

7. CO_2 emissions from London could be reduced by nearly **33.0%** by using a higher deployment of DE technologies and assuming some newer technologies become commercially established, once again without new nuclear power stations being built.
8. London's projected heat and electricity demand could be met without assuming any exceptional demand-side energy efficiency gains while using **35.5%** less primary energy than the high nuclear scenario.
9. The majority of the CO_2 savings would still be obtained from gas-fired CHP and CH systems, but there would be a greater contribution from renewable energy sources.
10. Despite the use of natural gas for CHP and the increased use of gas in power stations, London's overall gas consumption would be **14.9%** lower than under the centralised high nuclear scenario.
11. The proportion of the London heat market supplied through DE would be **43.7%.** Electricity generated from DE systems within London would provide **63.9%** of total consumption**.**

The primary goals set out in the EWP of CO_2 emission reductions and increased security of supply could thus easily be met by adopting the DE approach. It has been shown that CO_2 emission reductions in line with the target of a 60% reduction by 2050 can be achieved, and in fact exceeded, whereas with the centralised scenarios (including the high nuclear scenario) this target cannot even be met. It has also been shown that the high efficiency of DE will result in a lower consumption of natural gas and that there will be a wider variety of energy sources, many of which are based on local supplies, thus enhancing energy security. These findings suggest that the most effective way for London to reduce its CO_2 emissions and increase its energy security is by adopting a DE pathway.

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ABBREVIATIONS

CCGT	combined cycle gas turbine
CH	community heating (also known as district heating)
CHP	combined heat and power
CO_2	carbon dioxide
DE	decentralised energy
DTI	Department of Trade and Industry
EWP	Energy White Paper
GLA	Greater London Authority
ODPM	Office of the Deputy Prime Minister
SEDBUK	Seasonal Efficiency for Boilers in the UK

UNITS

°C	degrees Celsius
bar	bar (unit of pressure)
hr	hour
GW	gigawatt (1,000,000kW)
GWh	gigawatt hour
kW	kilowatt (1,000 watts)
kWh	kilowatt hour
MW	megawatt (1,000 kilowatts)
MWe	megawatt(s) of electrical power
MWh	megawatt hour
MWth	megawatt(s) of thermal power
p.a.	per annum

ENDNOTES

1 *Our Energy Challenge: Securing Clean Affordable Energy for the Long-term* – DTI January 2006

2 Efficiency is defined for the purposes of this report as the amount of energy extracted from the primary fuel source expressed as a percentage

3 Fuel cells are not included in the model discussed due the relatively early stage of their development and our intention to only include existing, proven technologies

4 see section 5 for a discussion on CHP efficiency

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APPENDIX A – ASSUMPTIONS ABOUT ENERGY DEMANDS IN LONDON

1. The domestic sector

Existing dwellings

The total number of existing dwellings in London is a little over 3.1 million, according to *The Community Heating Development Study for London* (GLA, 2005) which uses data from Census 2001. The average annual heat demand per London dwelling is estimated in the same study as 14,171kWh.

The proportion of electrically heated dwellings nationally is about 9.5% (ODPM, 2001). It has therefore been assumed that 9.5% of the existing dwellings in London are electrically heated and the remaining 90.5% heated by individual gas boilers. The average efficiency of existing domestic gas boilers is taken to be 70% (BRE, 2005). More recent systems will have a higher efficiency and older systems a lower efficiency.

Some properties in London are heated by CH systems predominantly supplied by gas-fired heat-only boilers. The proportion of dwellings thus supplied is probably less than 5% (based on PB Power's experience of the sector) and the CH systems are assumed to have similar efficiencies overall (although boiler efficiency will be higher there will be distribution losses). There are a few systems supplied by CHP or run on renewables but the numbers are too small to be statistically significant.

Annual electricity demand for an average dwelling in the UK is 3,300kWh for lights and appliances (ie excluding electricity for space and water heating). This is the figure that is used by the supply companies in comparing annual costs (BRE, 2005). Although London probably has a higher proportion of smaller dwellings than the national average, disposable incomes are also higher on average which may give rise to higher electricity use. Hence we have cautiously assumed that the average demand for London is 3,300kWh a year in accordance with the national average.

By 2025 we would expect existing dwellings to show some reduction in space heating demand as a result of energy efficiency improvements such as cavity wall insulation, increased loft insulation and more flexible and responsive temperature controls. The potential for this is limited, however, by the age and type of the buildings, as a large proportion of residential properties in London date from the 19th or early 20th century and do not have cavity wall construction, making cavity wall insulation impossible. A 10% reduction in average heat demand from existing dwellings by 2025 has therefore been estimated, resulting in an average heat demand per dwelling of 12,754kWh a year.

Individual gas boiler efficiencies will rise as a result of the new Building Regulations which require the use of a condensing boiler whenever a boiler is replaced. By 2025 it is assumed that most boilers in existence now will have been replaced with a condensing model, so that the average efficiency should rise to at least 86% (the SEDBUK B rating).

The proportion of dwellings heated electrically has been assumed to remain the same at 9.5%, as either gas supply installation will not be feasible for structural reasons or specific reasons for retaining electric heating (such as low installation costs) will exist.

Non-heating electricity demand per existing dwelling is also assumed to remain the same, as it is likely that improvements in the efficiency of appliances will be offset by a growth in their number and use. There is also the possibility that there will be a growth in air-conditioning in the existing domestic sector if climate change trends continue; however, this has not been taken into account.

Demolitions will have occurred by 2025. The *40% House* report (ECI, 2005) estimates current national demolition rates at 160,000 dwellings annually, which equates to about 8,000 a year for London, giving a total over 20 years of 160,000 dwellings demolished. This may be an overestimate for London, where property values are high and there is high demand for housing; however, the national rate has been assumed in the absence of more local data. The number of existing properties remaining in 2025 has therefore been assumed to be 2,949,424.

New dwellings

London is expected to undergo significant expansion in the period to 2025. Information provided by the LDA for *The Community Heating Development Study for London* (GLA, 2005) indicates that 226,000 dwellings are projected to be built in the Thames Gateway region lying within the GLA boundary alone. The London Plan (GLA, 2004a) refers to 457,950 new dwellings being constructed by 2016. There is also a forecast of an additional population of 800,000, (GLA, 2004a) with the average number of persons per dwelling continuing to fall. The number of new dwellings built by 2025 is assumed to be 659,550 (GLA, 2004a).

The energy use in these new dwellings will be determined in the most part by the Building Regulations then in force, as well as by lifestyle choices. We have based our energy assessment on a typical two-bedroom apartment in a six-storey block, as new dwellings in London are likely to be at a high density of development. On the basis of the Building Regulations coming in to force in April 2006, we have estimated an average heat demand for space heating and hot water of 3,000kWh a year per dwelling. Over the period 2006 to 2025 it is expected that Building Regulations will be further tightened, and so on average a further reduction in heat demand may be seen for the dwellings built up to 2025; however, this has not been taken into account as it cannot be quantified

Average boiler efficiency has been assumed to be 92%, the SEDBUK A level, which future Building Regulations are likely to make compulsory.

Electric heating is currently estimated to have a share of around 50% of the new-build market, although no firm data is available; but with the new Building Regulations we would expect this to fall to 25% of new dwellings built to 2025. Under the DE scenarios the percentage of new dwellings with electric heating would be expected to be lower; nevertheless we have taken the conservative approach of retaining the 25% electric heating share under all the scenarios, even though this favours the centralised energy scenarios.

Average electricity demand for new dwellings has been assumed to fall by 2025 to about 18% less than for existing dwellings, or 2,700kWh a year, as new, more efficient appliances are acquired and low-energy lighting installed as a Building Regulations requirement. As with heating, the smaller average size of new dwellings will also be a factor.

It can be seen that the heat demand for new dwellings is much reduced compared to that for existing dwellings, to the point where it is only 11% higher than the electricity demand.

2. THE NON-DOMESTIC SECTOR

Existing non-domestic buildings

The buildings database developed for *The Community Heating Development Study for London* (GLA, 2005) is based on floorspace data taken from a business rates database as previously used for *The UK Potential for Community Heating with CHP* (BRE, 2003). This classifies buildings into a number of categories, to each of which we assigned heat and electricity demands. As with the domestic sector, a 10% average improvement in heat energy efficiency in existing properties by 2025 has been estimated on the basis of these categories.

The total existing non-domestic floorspace has been estimated at 56,899,000m^2 with an annual heat demand of 128kWh/m^2 and an electricity demand of 154kWh/m^2. Offices and retail floor space predominate in London, with the office floorspace about twice that for retail. The amount of air conditioning installed is a major determinant in the electricity demand of such non-domestic floorspace, but detailed information on the extent of air conditioning is not available, so we have assumed 50% air conditioned and 50% naturally ventilated floorspace in determining the above figures. It is also likely that there will be a growth in air conditioning in the future if climate change trends continue; the impact of this has not been included in the current model.

It is assumed that 20% of existing non-domestic floorspace utilises electric heating and that this level of electric heating will continue through to 2025. Gas boiler efficiencies are assumed to rise from the current figure of 80% to 86% (SEBDUK B).

New non-domestic buildings

The GLA is predicting an increase in employment in London of 845,000 (GLA 2005) and the London Plan (GLA, 2004a) assumes that each employee occupies 16m^2 of floorspace. This results in a requirement for a net increase in non-domestic floorspace of 13,520,000m^2 (GLA, 2005b) or a nearly 24% increase over the current estimated floorspace. We have assumed the demolition of 5% of existing floor space so the total new floorspace to be built is just under 16,365,000m^2.

Energy use in new non-domestic buildings will vary considerably with the type of building, the use pattern and whether air conditioning is employed. The Building Regulations to come into force from April 2006 will require a reduction in energy use of between 23% and 28% compared to current standards.

Average heat demand has been estimated assuming a 25% reduction from 'Good Practice' levels for offices: these represent a significantly higher level of performance than the 'Typical' levels assumed in estimating the demand for existing buildings (both benchmarks are taken from CIBSE Guide F (CIBSE, 2004). On the basis of this calculation, average annual heat demand has been taken as 57kWh/m^2.

Boiler efficiencies in new non-domestic buildings are assumed to be 92%, as it is likely that future revisions to the new Building Regulations will make such a level of efficiency compulsory.

It is assumed that the proportion of electrically heated floorspace in new buildings will fall to 10% as a result of the new Building Regulations.

Electricity demand is taken to be 30% below 'Typical' levels, as the scope for improvement is not as great as for heating, and Building Regulations do not cover the use of electrical equipment (such as computers), which is currently producing a rising energy demand trend. The average annual electricity demand has therefore been taken as 108kWh/m^2.

As with new dwellings, the ratio between electricity and heat is predicted to change, with heat demand becoming a less significant (but still important) proportion of the total energy demand of new non-domestic buildings.

There is significant effort in the construction industry to design naturally ventilated buildings and this is encouraged in the London Plan. However we have assumed that 50% of new non-domestic floor space will be air-conditioned in the future. The use of DE would potentially enable lower-emission cooling sources such as absorption chillers to be used. However, no account has been taken in the DE scenarios of the further emission savings that might result from implementation of this approach.

APPENDIX B – ASSUMPTIONS ON FUTURE POWER STATION MIX

To determine the overall CO_2 emissions for London, account needs to be taken of the amount of centrally generated electricity used in London and the emissions from the power stations that supply it. The approach taken is to assume that electricity supplied from outside London has a CO_2 emissions factor equivalent to the average of the emissions from the total UK national grid.

The proportion of electricity supplied to the national grid by each power source is given in the tables 2.2a and 2.2b below, together with the CO_2 emissions factor associated with each. From this data the average CO_2 emissions per unit of electricity delivered by the grid can be calculated.

Table 2.2a: Proportion of electricity supplied to the national grid from different sources, and associated CO_2 emissions factors, 2005

Electricity source	CO_2 emissions factor	Share of supply	Contribution to emissions factor
	g/kWh	%	g/kWh
Nuclear	0	19.47	0
Renewables	0	1.93	0
Hydro	0	1.30	0
Coal	954	33.27	317.40
Oil	838	1.15	9.64
Gas	462	40.38	186.56
Other	527*	2.51	13.23
Average CO_2 emissions factor for total grid mix (g/kWh)			526.83

*The calculation is derived from DUKES (2004), which does not provide details of the emissions factor for the generation component termed ‘Other’. This has therefore been taken as the average of all sources for the purposes of deriving the average CO_2 emissions factor.

Table 2.2b: Proportion of electricity projected to be supplied to the national grid from different sources, and associated CO_2 emissions factors, 2025

	CO_2 emissions factor	Share of supply: low nuclear scenario	Share of supply: high nuclear scenario
	g/kWh	%	%
Nuclear	0	2	11
Renewables	0	20	20
Coal	990	16	16
Gas (CCGT)	414	62	53
Average CO_2 emissions factor for total grid mix (g/kWh)		415	378

Notes:
a) Imports and oil use have been ignored as these are small quantities.
b) Although nuclear and renewables have a CO_2 emissions factor of zero it is recognised that, as for all energy technologies, there are emissions associated with the construction of generation facilities and, in the case of nuclear, with the fuel processing cycle. These emissions have been ignored.

The proportion of electricity from renewable sources is expected to rise to 15% in accordance with the government projections for 2015 in the Renewables Obligation Order 2006 (DTI 2006b). A further rise beyond 15% may occur, as envisaged in the Energy Review consultation. We have assumed a 20% renewables contribution by 2025 in the model in accordance with the Government's aspirational 2020 renewable energy target announced in the EWP (DTI 2003).

The proportion of electricity from coal-fired stations is expected to fall in the future due to the introduction in 2008 of the EU Large Combustion Plant Directive (EU LCPD) and the impact of the EU Emissions Trading Scheme (EU ETS). The Energy Review consultation (DTI, 2006a) predicts that 16% of electricity will be generated from coal in 2020. We have assumed that the same proportion will be in place in 2025, partly due to the advantages of maintaining a diversity of fuel sources, although it is recognised that coal-fired electricity may be increasingly uncompetitive as a result of the constraints of the EU LCPD and EU ETS.

The balance of electricity production is assumed to be made up by gas-fired stations of the CCGT type. The electrical efficiency of the existing gas-fired stations is typically 45%, with the next generation typically achieving 50% (IPPC Bureau, 2005). This may rise to 55% over time. We have assumed 50% average efficiency when calculating the fuel displaced by DE generation (see below).

The DE options which generate electricity will displace electricity imported to London. In order to calculate the resultant CO_2 emission savings an assumption has to be made as to which centralised power source would be displaced. It is clear that it would not be nuclear or renewables, as these stations have low operating costs and will therefore generate at maximum output whenever available. It has therefore been assumed that it is the gas-fired stations whose output will fall. If instead the coal-fired plant were to be taken as the marginal plant to be displaced by DE, the resultant CO_2 emission savings would be significantly higher. **The emission reductions estimated for the DE scenarios are consequently likely to be lower than would occur in practice, and the approach taken is therefore robust.**

In the centralised electricity system, energy is lost not only at the point of generation but also from the transporting of electricity through the transmission and distribution networks to where it is needed. Average electricity losses are taken as 3% for the main transmission system and 6% for the distribution system (IEA, 2005). In calculating the impact of decentralised electricity production we have assumed a saving of the full 9% for both DE scenarios. In practice the smaller domestic-scale systems will save a higher proportion of the losses associated with centralised production and the larger district- or community-scale ones will save less.

APPENDIX C – DECENTRALISED ENERGY TECHNOLOGIES AND THEIR LONDON POTENTIAL

The potential for CHP and CH is closely related to the density of heat demand. *The Community Heating Development Study for London* (GLA, 2005) developed GIS maps of the potential heat demand density of London, based on the Census 2001 enumeration districts. These are reproduced as Maps 1, 2 and 3. These show the heat demand density grouped into ranges of total heat demand. The areas of highest heat demand, representing 30% of total demand, were analysed together with data on social deprivation to identify 32 Priority Areas where community heating was most likely to be economic and contribute most to the alleviation of fuel poverty. Detailed feasibility studies, including economic assessments based on a test discount rate of 3.5 %, were carried out for three large projects: Barking CCGT CHP, SELCHP and Tower Hamlets biomass CHP.
The various technologies are considered in turn below.

1. CCGT CHP supplying CH networks

Historically, major power stations in the UK were located near to coalfields or port facilities, as it was generally more cost-effective to transmit electricity on the national grid than to transport coal or oil to where the energy demand was.

The more recent gas-fired power stations are less influenced by fuel transportation costs, and a number of stations have been built closer to cities. Despite this, the opportunity has not yet been taken in the UK to integrate these stations into large-scale CHP schemes, as has happened elsewhere in Europe. The recent Helsinki gas-fired power station Vuosaari B has been designed to produce 463MW of electricity and 416MW of heat at an overall efficiency of 83%, while Avedore B multi-fuelled power station in Copenhagen achieves efficiencies of 94%.

Description of technology

CCGT power stations are the preferred gas-fired power station type today, due to their higher efficiency. A gas-turbine generating set produces electricity and releases high-temperature exhaust gases. These exhaust gases are used to raise steam in a boiler and the steam is used in a steam turbine to produce further electricity. The steam is then condensed and returned to the boiler. The residual heat is lost to the environment through this steam condenser and there is also some loss of energy from the exhaust gases after they leave the boiler.

A CCGT plant can be modified to provide heat for a CH network. Most of the existing CCGT power stations in the UK are too remote from centres of population for this to be practicable; however, London is fortunate in having the large (1,000MWe) Barking power station close enough to centres of high heat demand density to allow the heat to be utilised. Its location is also ideal for supplying new buildings in the Thames Gateway area.

London opportunities

Barking power station is the key opportunity. The concept of taking heat from this power station has been investigated in *The Community Heating Development Study for London* (GLA, 2005) and found to be technically feasible. About 230MW of waste heat is estimated to be available from one of the two existing steam turbine systems and a further 100MW will be available if the 400MWe extension of the power station goes ahead. This additional capacity could be increased to 350MW if the extension was specifically designed as a CHP plant. (The second existing turbine is not considered technically suitable for the purpose as the waste steam is not emitted at a high enough pressure to maintain a useful temperature.) It is therefore reasonable to assume that around 230MW of heat would be available at a minimum, with up to 580MW available if a CHP design for the new extension were chosen at an early stage.

If a sufficiently large heat load can be established, it is possible to transport heat economically over significant distances. For example, the Copenhagen transmission system extends 40km across the conurbation, linking a number of local district heating systems with the major power stations. The location of the Barking power station is ideal for the supply of heat to the new developments in the Thames Gateway north of the river, and a feasible route has been identified through to Tower Hamlets.

A second major opportunity in London is presented by a gas-fired power station proposed by Tilfen Land, the main property developer in Greenwich. This will produce 140MWe and about 120MW of heat, with the target heat customers being the new developments proposed in the Thames Gateway south of the river. A planning application has been made for this project.

There are a number of other possible locations where smaller CCGT CHP plants could be constructed.

Expected market share

Barking power station

Under the low DE scenario the Barking power station would be expected to supply 100MW of heat (out of the 230MW available from existing plant) to 50,000 new dwellings. It is known that there are 12,000 dwellings planned immediately to the west of the plant and a further 38,000 dwellings to the north, including the Barking Town Centre redevelopment which will contain 7,500 new dwellings. In addition, 100MW would be supplied to 20,000 existing dwellings via a CH network. New non-domestic buildings in the area are likely to be few, and have not been considered. The initial studies carried out in the Community Heating Development Study for London (GLA 2005) show that this level of heat supply could readily be achieved within our low DE scenario.

Under the high DE scenario an output of the plant of 400MW (of the 580MW available) is expected to be used. This would enable 710,000MWh of heat to be delivered annually to around 70,000 existing dwellings (including the 20,000 existing dwellings mentioned above); in addition to the 237,000MWh supplied to the 50,000 new dwellings already accounted for under the low DE scenario.

Tilfen Land

Under the low DE scenario the new CCGT is expected to supply 50MW of heat to around 25,000 new dwellings as well as 50MW to around 10,000 existing dwellings in the area.

Under the high DE scenario the new CCGT is expected to reach its maximum output by supplying 60MW to around 30,000 new dwellings as well as 60MW to around 12,000 existing dwellings in the area.

2. GAS-ENGINE CHP SUPPLYING CH NETWORKS

An alternative approach to CHP using large CCGT power stations is to produce smaller CHP stations which can be located closer to the heat customers thereby saving heat transport costs. Gas-engine CHP technology supplying CH networks is well established, particularly in Jutland, Denmark and in the Netherlands. In London examples exist at the Barkantine Estate in Tower Hamlets and in new-build residential schemes at Greenwich Millennium Village. Examples of the conversion of existing housing to CHP/CH can be found across Europe, where significant heating networks were installed during the 1970s and 1980s; here in the UK the CHP/CH system at the Dickens Estate in Portsmouth provides a good example.

Description of technology

Over the last 15 years developments in reciprocating engine technology have been significant. A number of European diesel engine suppliers are now offering spark-ignition gas engines designed for use as base-load CHP generators.

Efficiencies have improved and emissions have reduced. Engines are available in the size range from 1MWe to 8MWe, with the highest efficiencies obtained for engines greater than 3MWe. We have assumed a 5MWe engine size as being typical.

London opportunities

Gas-engine CHP schemes are currently being developed for existing buildings by the London Boroughs of Islington, Croydon, Westminster and Merton. New-build gas–engine CHP schemes are being developed at New Wembley and for the Elephant and Castle redevelopment.

Expected market share

The primary market for this technology is the existing housing stock reached through newly-built CH networks. The predominance of social housing at high density in inner London was identified in The Community Heating Development Study for London (GLA, 2005), and these areas of high-density social housing would become the starting points for CH networks supplied by gas-engine CHP. A number of these social housing areas already have existing CH schemes, including in Southwark, Tower Hamlets, Islington, Camden and Lambeth.

The CHP potential identified in these high-density social housing areas, defined as Priority Areas in the GLA study, was estimated at 1,426MW of heat. An earlier study, *The UK Potential for Community Heating with CHP* (BRE, 2003), estimated that the potential for CHP for existing buildings in London is a total of 2,448MWe of gas-engine CHP.

Under the low DE scenario the potential capacity of 2,448MWe estimated by the BRE study has been assumed, but this has been reduced by 300MWe to take account of the supply of heat by the other technologies that also supply heat via CH, which reduces the amount of potential heat available for gas engine CHP. This results in a total of 2,148MWe CHP capacity supplying existing buildings across both the domestic and non-domestic sectors, with about 80% supplying the domestic sector. A further 100MWe is also projected for each of new domestic and non-domestic buildings.

Under the high DE scenario we have considered a further expansion of gas-engine CHP for existing buildings close to a limit determined by the heat density map, to a total of 3,250MWe. The 100MWe projected capacities for each of new domestic and non-domestic buildings remain the same.

3. BUILDING-BASED CHP

In some non-domestic buildings connection to a local CH scheme is likely to be less suitable than having a dedicated CHP system on site. On-site systems will also be suitable for such buildings not within the reach of CH networks, particularly where the occupants also wanted to secure their electricity supply in case of grid failure. Candidate buildings include:

- hospitals
- prisons
- university campuses
- hotels
- leisure centres
- large retail or office complexes where cooling is required.

Description of technology

The technology normally involves smaller gas engines within the range of 100kWe to 1MWe, although small-scale gas turbines of around 100Kwe are also available. In the future fuel cells may become commercially available for this application. Recent technological developments have led to smaller CHP units down to 5kWe, which would be suitable for quite small buildings.

London opportunities

A number of building CHP systems already exist in universities and hospitals: for example, Imperial College, University College and Royal Free Hospital all have large CHP installations. In the office sector there is the Whitehall CHP scheme. There is the potential for a further expansion of this type of CHP to all similar sites.

Expected market share

The main applications are expected to be in new build non-domestic buildings and in the larger existing buildings.

Under the low DE scenario we envisage 100MWe of CHP capacity in existing buildings, comprising 20 major sites of 3MWe and 80 minor sites of 500kWe. Most of these will be located in outer London, outside the CH network areas. In the new-build sector we have assumed 15MWe of CHP capacity, principally located in large commercial developments.

Under the high DE scenario the capacity is developed further in existing buildings to 150MWe, with no increase in the new-build sector.

4. BIOMASS CHP AND BIOMASS BOILERS

Biomass is a renewable energy source that has been underdeveloped in the UK. Although the resource available from forestry is more limited than in some other European countries, there is still a significant amount of clean wood waste that is sent to landfill, including that generated within London itself. In the future energy crops such as wood, straw or miscanthus grass may be able to contribute. The most efficient way of using biomass fuel is in CHP, and yet very few biomass-fuelled CHP plants have been built or are proposed for the UK compared to other countries such as Austria, Denmark, Sweden and Finland.

Description of technology

The technology of biomass CHP using steam turbines in the range 10MWe to 50MWe is well established in countries such as Scandinavia, Germany, the Netherlands and Austria. However, most UK experience has been with heat-only boilers or electricity-only production (eg the straw-burning plant at Ely). Slough Heat and Power has however been using a biomass fluidised bed boiler for CHP production for some years.

We have based the analysis on the large-scale CHP systems proposed for Tower Hamlets as part of the GLA's CH study (GLA, 2005). This involves a 20MWe plant with a 30MW heat output capacity. In the longer term smaller schemes may become more viable.

The use of biomass boilers for heating is an established technology, the only constraints being availability of suitable fuel, storage space and increased labour costs for maintenance and operation compared to conventional gas boilers. As a result of these issues, biomass boilers are more likely to be used in new-build developments.

Expected market share

The use of biomass plants in London is limited by the fuel resource available: this has been estimated by the GLA at being around 973,000 tonnes p.a. (LEP/GLA, 2006).

Under the low DE scenario we have assumed two CHP plants equivalent to the 20MWe plants proposed for Tower Hamlets, together with 5.7% of new dwellings and 10% of new non-domestic floor space utilising biomass boilers. Total biomass utilisation would then represent 32% of available fuel.

Under the high DE scenario one further CHP plant is proposed, together with 11% of new dwellings and 20% of new non-domestic floorspace utilising biomass boilers. Total biomass utilisation would then represent 52% of available fuel.

5. Energy from waste

At present a significant proportion of London's municipal solid waste (MSW) is disposed of in landfill outside London. The GLA's *London waste strategy* (GLA, 2003) proposes a major increase in recycling of material to reduce the quantity sent to landfill. Extracting energy from the waste produced by the capital plays a relatively small part in how it meets its energy needs, but three broad opportunities are available.

Description of technology

Existing waste-to-energy plants

The waste-to-energy process involves the combustion of waste material in order to generate heat. This heat can then be used either for electricity generation or heating purposes.

Mechanical biological treatment

The mechanical biological treatment (MBT) process results in a solid recovered fuel (SRF) which has a high calorific value and consistent properties, and is suitable for a gasification process.

Anaerobic digestion

Anaerobic digestion (AD) is the digestion of organic wastes in the absence of air. The enclosed system results in the production of biogas. AD biogas production is very well established across Northern and Central Europe, with biogas used for both transport and electricity production. It can as readily be used for CHP as for electricity only. It is gaining a foothold in the UK with plants such as that at Ludlow, Shropshire processing source-segregated household waste into biogas ultimately for use in electricity generation.

London opportunities

Existing waste-to-energy plants

One of the most cost-effective opportunities identified in the GLA CH study (GLA, 2005) is to supply local housing with heat from an existing waste-to-energy plant, the South East London Combined Heat and Power Station (SELCHP), which was originally conceived as a CHP plant but which currently produces only electricity. This would involve minimal changes to the existing plant.

Greenpeace opposes the operation of SELCHP incineration plant. Whilst the GLA also opposes the construction of any new incinerators of this type, the capture of heat from existing facilities such as SELCHP is formally included in both its waste and energy strategies for London. The quantity of heat potentially supplied by SELCHP is 184GWh p.a., or 0.4% of London's total heat demand.

The location of SELCHP next to an identified heat demand and the proposed establishment of a CH network to distribute the heat makes the site an ideal candidate for long-term CHP production.

Mechanical biological treatment

The *London Waste Strategy* assumes that 1.2m tonnes of waste a year will be treated in this way, resulting in about 600,000 tonnes of SRF being produced per year. This would be capable of producing 200MW of heat and 53MW of electricity.

Expected market share

For the purposes of this model only the potential heat contribution from SELCHP has been taken into account along with the heat contribution from an SRF-fuelled CHP plant such as the Noverra plant. CO_2 emissions savings associated with electricity production from waste have not been included: electricity generation from CHP plant burning SRF is assumed to be part of the 20% renewable energy from the grid supply.

Under the low DE scenario we assume that the SELCHP scheme is developed to the full extent envisaged in the GLA CH study (GLA, 2005), supplying 184GWh of heat annually.

We have assumed that 50% (300,000 tonnes a year) of the potential annual output of SRF from the MBT process envisaged in the *London Waste Strategy* (GLA, 2003) is used for electricity generation in CHP plant, resulting in a maximum heat output of 78MW.

Under the high DE scenario the full amount of the annually available SRF (600,000 tonnes) is assumed to be utilised for electricity generation, resulting in a maximum heat output of 155MW. The heat supplied from SELCHP is as for the low DE scenario.

6. BUILDING-INTEGRATED LOW- AND ZERO-EMISSION TECHNOLOGIES

There are a wide range of low- and zero-emission technologies suited to being incorporated into properties. Zero-emission renewable energy sources include solar thermal and PV units and small-scale wind turbines. Low-emission technologies include gas-fired micro-CHP units.

Description of technology

Domestic CHP

The utilisation of larger-scale CHP to supply the residential sector requires CH networks to deliver the heat. This is cost-effective in areas of high population density, but less so in low-density suburban streets with semi-detached or detached dwellings. Significant research has been devoted to developing a domestic-scale CHP unit which would take the place of a conventional boiler and generate around 1kW of electricity and enough heat for space and water heating. At present the Stirling engine and the organic Rankine cycle are the most promising technologies for the coming decade, with an electrical efficiency of around 15% and heat efficiency of around 70%, but they are still far from commercial viability. In the longer term fuel-cell CHP, which offers higher efficiency, may become economically viable.

Renewable heat – solar thermal

Solar thermal systems, using panels fixed to a south-facing roof, are designed to provide heat only to a domestic hot-water heating system. They work in conjunction with a conventional heating system which provides top-up capacity, especially in winter. This technology is not normally compatible with CHP (because CHP systems usually have surplus heat available in the summer when solar thermal output is at its highest), although there are a few systems in existence in which larger solar thermal arrays provide heat to a CH network.

Renewable electricity – photovoltaic panels and wind turbines

Two technologies are considered under this head: photovoltaic panels (PV) and building-integrated wind turbines (BIWT). The advantages of these technologies include the avoidance of grid losses and the zero-emission energy sources used. The disadvantage of PV is that unshaded surfaces are needed; the disadvantage of BIWT is that the output is relatively low due to the lower wind velocities in built-up areas.

Expected market share

Domestic CHP

Under the low DE scenario we have assumed that the current technical barriers will not be overcome by 2025, and therefore there is *no capacity* included for domestic CHP.

Under the high DE scenario we have assumed that from 2010 domestic CHP will gain about a 10% share of the new boiler market, which is estimated to be 1.2 million units p.a. (CT, 2005) for the UK and approximately 120,000 units in London. This results in 12,000 units a year in London over 15 years (2010 to 2025) which means by 2025 there would be 180,000 units – covering about 5% of the total number of dwellings.

Renewable heat – solar thermal

The main market is considered to be in new dwellings, where the capital cost of the initial installation can be lower than for retrofit and where the planning regulations of the GLA and Boroughs will require consideration of solar thermal and other renewables. In addition, solar thermal systems will be appropriate for dwellings in outer London where CHP and CH are unlikely to be viable. Apart from specialist buildings such as hotels and leisure centres, the non-domestic sector is unlikely to have sufficient summer heat demand to justify solar thermal systems.

Under the low DE scenario 50,000 dwellings are assumed to have solar thermal systems, representing 7.5% of the new-build total, along with 50,000 existing dwellings, representing 5% of dwellings in the low heat density areas of outer London.

Under the high DE scenario these numbers are doubled to 100,000 dwellings in each sector.

Renewable electricity – photovoltaic panels and wind turbines
We expect the main market to be in the new-build non-domestic sector where the high cost of the PV can be offset by avoided costs for high-quality cladding materials and where concerns over noise from wind turbines will not be as relevant. Moreover, electricity demand for this sector is highest during the daytime, which is obviously compatible with PV.

Under the low DE scenario we have assumed that:
- 10% of the electricity demand of new non-domestic buildings is met from PV and BIWT
- 10% of new dwellings will have PV or BIWT installed
- 1.3% of existing dwellings will have PV or BIWT installed.

Total installed capacity for the entire new-build sector is assumed to be 78MWe of BIWT and 123MWe of PV. Total installed capacity (at a much lower density) for existing buildings is assumed to be 20MWe of BIWT and 20MWe of PV.

Under the high DE scenario we have assumed that:
- 20% of the electricity demand of new non-domestic buildings is met from PV and BIWT
- 20% of new dwellings will have PV or BIWT installed
- 2.6% of existing dwellings will have PV or BIWT installed

Total installed capacity for the entire new-build sector is assumed to be 156MWe of BIWT and 246MWe of PV. Total installed capacity for existing buildings is assumed to be 40MWe of BIWT and 40MWe of PV.

APPENDIX D – ASSUMPTIONS FOR CALCULATIONS RELATING TO HEAT, GAS AND ELECTRICITY BALANCE AND RESULTING CO_2 EMISSIONS

The following paragraphs describe the calculations carried out within the model and some of the key assumptions on which they were based.

1. CCGT CHP supplying CH networks (Barking and Tilfen Land)

CO_2 savings calculation

The CO_2 savings calculation has two parts. Firstly, the gas saved from not using domestic boilers is calculated, assuming a 92% boiler efficiency for new dwellings and 86% for existing dwellings.

Secondly, when heat is extracted from a steam turbine system there is a drop in the electricity output of the power station, which has to be made up by other power stations. The ratio of heat output to lost electricity was estimated in the GLA CH study (GLA, 2005) as 9:1. The electricity to make up this shortfall is assumed to come from centralised gas-fired power stations of average efficiency.

Gas balance calculation

The local gas demand will fall as a result of displacing local gas boilers with heat from the CHP power stations. In calculating the total gas demand for London, however, account has been taken of the increase in gas consumption that will be needed at other power stations to compensate for the lost electricity from the CHP power stations.

Electricity balance calculation

The electricity from Barking power station is assumed to be outside London as it will continue to feed the national grid, so there is no electricity balance calculation required.

Heat balance calculation

The heat supplied from Barking power station and the other CCGT is taken into account in calculating the total heat supplied by DE. The amount of heat delivered annually is estimated using a load factor of 30% of the maximum output possible over the course of a year, based on the GLA CH study (GLA,2005). Heat losses from the distribution system are taken at 10%.

2. Gas-engine CHP supplying CH networks

CO_2 savings calculation

The CO_2 saving calculation is based on large-scale gas-engine CHP plant displacing individual gas-fired boilers and electricity produced by centralised gas-fired power stations. The CHP efficiency has been obtained from suppliers of gas-engine CHP plant and is:

electrical 38%
thermal 42%
overall 80%

The amount of energy generated by the CHP units is governed by the annual running hours. This will depend on the heat demand profiles and the economic balance between investments in CHP capacity and saving in boiler fuel. The use of thermal storage, which enables demand profiles to be smoothed and running hours maximised, has also been assumed. For many schemes there will be a mix of domestic and non-domestic loads, but the calculations have been set up for each sector separately. The annual running time has been taken as 5,000 hours for domestic load and 2,500 hours for non-domestic load, as non-domestic buildings tend to have limited summer heat demand. If all schemes have a mix of domestic and non-domestic load then the average annual running time will be about 4,500 hours, which is consistent with the assumptions in the BRE study *The UK Potential for Community Heating with CHP* (BRE, 2003).

Gas balance calculation

The gas balance calculation takes account of the gas used by the CHP engine, and the gas consumption displaced from conventional heating boilers and centralised power stations (electricity generation displaced is assumed to be gas-fired CCGT).

Electricity balance calculation

The electricity balance is calculated on the basis of how much centrally generated electricity is displaced.

Heat balance calculation

The heat balance calculation is based on the total heat supplied by gas-engine CHP as a proportion of the total heat demand. Heat losses from the distribution system are taken at 8%, less than for the more extensive CCGT schemes.

3. Building-based CHP

CO_2 savings calculation

The CO_2 savings calculation is based on small-scale gas-engine CHP plant displacing individual gas-fired boilers and electricity produced by centralised gas-fired power stations. The CHP efficiency has been obtained from suppliers of gas-engine CHP plant and is:

electrical 30%
thermal 52%
overall 82%

The annual running time has been taken as 2,000 hours for the non-domestic sector. This is lower than for the gas-engine CHP/CH technology because the use of thermal storage is less likely and because building-based CHP does not benefit from the diversity of demand which occurs with multiple buildings on CH networks. In practice, however, some buildings that are well suited to CHP, such as hotels and leisure centres, will have much longer operating hours and consequently greater savings than those estimated here.

Gas balance calculation

The gas balance calculation takes account of the gas used by the CHP engine, and the gas consumption displaced from conventional heating boilers and centralised power stations (electricity generation displaced is assumed to be gas-fired CCGT).

Electricity balance calculation

The electricity balance is calculated on the basis of how much centrally generated electricity is displaced.

Heat balance calculation

The heat balance calculation is based on the total heat supplied by building-based CHP as a proportion of the total heat demand. There are no heat losses as the CHP units are within buildings.

4. Domestic CHP

CO_2 savings calculation

The CO_2 savings calculation is based on domestic-scale Stirling-engine CHP plant displacing individual gas-fired boilers and electricity produced by centralised gas-fired power stations. The efficiency assumed for domestic CHP units is:

electrical 15%
thermal 70%
overall 85%

The average annual running time has been taken as 2,000 hours. This relatively low figure again reflects the absence of demand diversity.

Gas balance calculation

The gas balance calculation takes account of the gas used by the CHP unit, and the gas consumption displaced from conventional heating boilers and centralised power stations (electricity generation displaced is assumed to be gas-fired CCGT).

Electricity balance calculation

The electricity balance is calculated on the basis of how much centrally generated electricity is displaced.

Heat balance calculation

The heat balance calculation is based on the total heat supplied by domestic CHP as a proportion of the total heat demand. There are no heat losses as the CHP units are within dwellings.

5. Biomass CHP

CO_2 savings calculation

The CO_2 saving is scaled up from the calculation for the 20MWe biomass CHP plant proposed to supply Tower Hamlets in the GLA CH study (GLA, 2005). This takes account of the CO_2 emitted in the course of fuel transportation, and assumes that electricity is displaced from CCGT plant.

Gas balance calculation

The gas balance calculation takes account of the gas consumption displaced from individual heating boilers and centralised power stations (electricity generation displaced is assumed to be gas-fired CCGT).

Electricity balance calculation

The electricity balance is calculated on the basis of how much centrally generated electricity is displaced. The electricity generated is based on an annual operating time of 7,000 hours, which reflects the availability level of this type of plant. Account is taken of reductions in nominal electricity output as heat is extracted.

Heat balance calculation

The heat balance calculation is based on the total heat supplied by biomass CHP as a proportion of the total heat demand. A load factor of 45% and heat distribution losses of 10% are assumed in assessing the annual heat delivered, in accordance with the GLA CH study (GLA, 2005).

6. Biomass boilers

CO_2 savings calculation

The CO_2 savings calculation is based on biomass boilers displacing gas-fired boilers, assuming a load factor of 25% for new domestic buildings and 20% for new non-domestic buildings, and a biomass boiler efficiency of 75%.

Gas balance calculation

The gas balance calculation takes account of the gas consumption displaced from individual heating boilers.

Electricity balance calculation

This is not required as no electricity is generated by this technology.

Heat balance calculation

The heat balance calculation is based on the total heat supplied by biomass boilers as a proportion of the total heat demand. No heat losses are included as the biomass boilers are assumed to be small-scale and local to the building or buildings supplied.

7. Energy from waste – existing

CO_2 savings calculation

The CO_2 savings calculation is based on the GLA CH study (GLA, 2005), and assumes a heat extraction to lost electricity ratio of 10:1, heat distribution losses of 7% and a load factor of 57%.

Gas balance calculation

The gas balance calculation is based on the gas consumption displaced from individual condensing boilers. The additional gas consumption in centralised power stations required to compensate for the lost electricity output of SELCHP when heat is extracted is also taken into account.

Electricity balance calculation

The electrical output of SELCHP is assumed to be part of the imported power to London and is not included in the DE electricity generation.

Heat balance calculation

The heat balance calculation is based on the heat supplied by SELCHP as a proportion of the total heat demand.

8. Energy from waste – new

CO_2 savings calculation

The calorific value of the SRF is taken to be 16MJ/kg and the electrical efficiency of the CHP plant where it is consumed (net of parasitic loads that are required to maintain the operation of the plant) is assumed to be 20% and the plant availability 85%. The heat to electricity ratio is taken as 3:1 and the heat extraction to lost electricity ratio at 10:1. Heat distribution losses are assumed at 8% and the load factor is taken as 45%. The CO_2 savings calculation is based on the heat supplied displacing individual boilers. The electricity output lost when heat is extracted is replaced by gas-fired CCGT. No CO_2 savings have been attributed to the electricity generated, as electricity generated from waste in this way is assumed to form part of the predicted centralised renewable electricity generation.

Gas balance calculation

The gas balance calculation takes account of the gas consumption displaced from individual heating boilers. The additional gas consumption in centralised power stations required to compensate for the lost electricity output of the new energy-from-waste plants when heat is extracted is also taken into account.

Electricity balance calculation

The electrical output of the new waste-to-energy plants is assumed to form part of the projected centralised renewable generation and so no electricity balance calculation is required.

Heat balance calculation

The heat balance calculation is based on the heat supplied by new energy-from-waste plants as a proportion of the total heat demand.

9. Building-integrated renewables – solar thermal

CO_2 savings calculation

Each domestic solar thermal system is assumed to supply 60% of the annual heat demand for domestic water heating, which is taken to be 2,000kWh p.a. We have assumed that the alternative heating system will be a gas-fired boiler and the CO_2 saving therefore arises from displaced gas consumption.

Gas balance calculation

The gas balance calculation takes account of the gas consumption displaced from individual heating boilers.

Electricity balance calculation

This is not required as no electricity is generated by this technology.

Heat balance calculation

The heat balance calculation is based on the heat supplied by solar thermal systems as a proportion of the total heat demand.

10. Building-integrated renewables – photovoltaics and micro wind turbines

CO_2 savings calculation

The Renewables Toolkit (GLA, 2004c) gives an annual output figure for PV systems of 854kWh per kW installed capacity, but over the next 20 years technical improvements are likely. We have assumed an annual output of 1MWh per kW installed capacity, which is a 17% improvement on current levels. BIWT is assumed to produce 2MWh annually per kW installed capacity, which is lower than *The Renewables Toolkit*'s estimate of 2,400kWh per kW installed: the latter was based on sites with a 4m/s average wind speed, but some sites may not be so favourable. The CO_2 savings calculation is based on building-integrated renewables displacing electricity generated by centralised gas-fired power stations.

Gas balance calculation

The electricity generated is assumed to displace electricity from centralised gas-fired power stations and therefore reduces the gas demand for London.

Electricity balance calculation

The electricity balance is calculated on the basis of how much centrally generated electricity is displaced.

Heat balance calculation

This is not required as no heat is generated by these technologies.

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Greenpeace's clean energy campaign is committed to halting climate change caused by burning oil, coal and gas.We champion a clean energy future in which the quality of life of all peoples is improved through the environmentally responsible and socially just provision of heating, light and transport.

We promote scientific and technical innovations that advance the goals of renewable energy, clean fuel, and energy efficiency.

We investigate and expose the corporate powers and governments that stand in the way of international action to halt global warming and who drive continued dependence on dirty, dangerous sources of energy, including nuclear power.

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