Appendix B: Energy Modelling

To test and monitor the effects of national, regional and local targets on the borough, we have developed Microsoft Excel® based model of the energy use and CO_2 emissions of buildings in the district covering the period of influence of the Core Strategy.
Integral to our model is an updateable input sheet which includes energy demands and CO_2 emissions for 76 different building types - both in the 'base case' (i.e. Part L 2006 compliant) and assuming a range of CO_2 reduction improvements (i.e. energy efficiency measures and Renewable and Low Carbon technologies). The outputs from the input sheet, although derived from only these 76 assumed building forms, are expressed in a form which can then be applied to the actual building stock.

It is recognised that there are a number of alternative approaches to sizing renewable and low carbon technologies and for calculating the likely energy and CO_2 savings. Technology costs also vary greatly between product and suppliers and are expected to fall in future at differing rates, as a result of technology 'learning'. For these reasons we felt it important to set out clearly what has been assumed at this stage, so that it will be possible to update the model input sheet as more robust data becomes available.

We have tended to use 'rules of thumb' to estimate installed technology capacities, annual energy generation, CO_2 savings and costs. Some, but not all, of these 'rules of thumbs' can be referenced to external and authoritative sources. Unreferenced assumptions are based on our experience of undertaking renewable and low carbon feasibility studies for a range of developer clients over the last 10 years.

It is recommended that the model input sheet' is updated in line with the future publications of:

- Part L of the Building Regulations – expected March 2010, and;
- Standard Assessment Procedure (SAP) – expected end 2009.

Drafts of these documents (for consultation) contain a number of changes which will need to be updated in the model input sheet.

CO_2 Emissions
Conversion factors used to calculate CO_2 emissions are shown below. These are based on the emissions factors included in the 2006 Building Regulations Part L, Conservation of Fuel and Power ADL2. It should be noted that revised emissions factors are expected to be published in the 2010 update to Building Regulations Part L. The revised factors could significantly affect the calculated emissions figures, however as they are not yet known it has not been possible to take this into account in this study.

Fuel	CO_2 emissions $kgCO_2$/kWh delivered
Gas	0.194
Grid Supplied Electricity	0.422
Grid Displaced Electricity	0.568
Biomass	0.025
Waste Heat	0.018

Table B1 Conversion factors for different fuels

Calculating Energy Demand of Development
As far as possible the model aims to use locally specific data for the district (e.g. Census data, Valuations Office Agency (VOA) data) on the number, types and size of buildings. Although building numbers and floor areas in the model are informed directly by local data, in order to develop the modelling, and specifically to make assumptions relating to the types and likely cost of appropriate renewable and low carbon technologies, the buildings have been split into a manageable number of categories.

Residential

Data on the number of existing residential buildings in the district was taken from the 2001 Census in England and Wales and information from the Council regarding post-2001 developments. Both the age and dwelling type was taken into account to characterise differences in building fabric, occupant density, and the likelihood of building fabric improvements having been made.

Projected figures for location of new development, number of homes and non-domestic floor area were taken from records of planning applications. It has not been possible to model future development other than those sites where planning applications have already been submitted, due to a lack of information on the location and phasing. Residential development was modelled using benchmarks which take into account proposed changes to Building Regulations Part L requirements expected in 2010, 2013 and 2016.

Non-residential

Data was collected from the Valuation Office Agency (VOA) for existing, non-residential buildings. This provided floor areas of non-residential building types. Each building type was assigned to one of the benchmark categories set out in CIBSE TM46[53], which defines energy benchmarks to allow assumptions to be made of CO_2 emissions from a range of building types.

CIBSE TM46 benchmarks were used to model energy demand of future non-domestic buildings. The benchmarks are based on data from the existing non-domestic building stock. A 25% reduction was applied to account for higher energy efficiency standards in new buildings.

Projected figures for location of new development, number of homes and non-domestic floor area were taken from data supplied by the participating LPAs.

Building Type Assumptions
The 76 building categories that were modelled comprise;

- 12 existing dwelling types, comprising;
  - 4 types – semi detached (dense), semi detached (less dense), small terrace and flat/apartment
  - Modelled in three different age bands - pre 1919, 1919-1975 and post 1975
- 6 new dwellings types (i.e. post 2006), comprising;
  - Detached, semi detached, end terrace, 1 bed flat, 2 bed flat and 3 bed flat.
- 29 commercial building types (existing)
- 29 commercial building types (new, post 2006)

The house types selected were considered representative for the County(existing and proposed housing development) based on the SHLAA studies, Census information and the review of proposed development in the area. Residential floor areas were taken from existing building energy models and were cross checked with housing floor area assumptions used in earlier similarly strategic studies. The housing types and floor areas used for modelling are shown in Table B2.

House Type	Age	Floor Area	Storeys	Sources
Semi Detached (Dense)	pre 1919	104.65	2	Census Data + English House Condition Survey
Semi Detached (Dense)	1919-1975	83.89	2	Census Data + English House Condition Survey
Semi Detached (Dense)	post 1975	72.13	2	Census Data + English House Condition Survey
Semi Detached (Less Dense)	pre 1919	104.65	2	Census Data + English House Condition Survey
Semi Detached (Less Dense)	1919-1975	83.89	2	Census Data + English House Condition Survey
Semi Detached (Less Dense)	post 1975	72.13	2	Census Data + English House Condition Survey
Small Terrace	pre 1919	58.27	2	Census Data + English House Condition Survey
Small Terrace	1919-1975	60.40	2	Census Data + English House Condition Survey
Small Terrace	post 1975	54.32	2	Census Data + English House Condition Survey
Flat; maisonette or apartment	pre 1919	96.44	4	Census Data + English House Condition Survey
Flat; maisonette or apartment	1919-1975	84.76	4	Census Data + English House Condition Survey
Flat; maisonette or apartment	post 1975	89.21	4	Census Data + English House Condition Survey
Detached	post 2006	101.61	2	CLG Zero C. RIA (Hurstwood)
Semi	post 2006	76.32	2	CLG Zero C. RIA (Wessex)
End	post 2006	76.32	2	CLG Zero C. RIA (Wessex)
1 bed flat	post 2006	43.4	5	EST NBO Sirocco
2 bed flat	post 2006	76.6	5	EST NBO Sirocco
3 bed flat	post 2006	100.9	5	EST NBO Sirocco

[53] CIBSE TM46:2008 Energy Benchmarks (CIBSE, 2009)

Table B2 Modelled house type basic assumptions

Information on public buildings and buildings not eligible for business rates was obtained from Hertfordshire County Council. Commercial building categories were selected to match the energy benchmarks published in CIBSE TM46. Floor areas were assumed as below and are representative of floor areas for real buildings of these types within the district (verified using VOA data).

Commercial building type	Floor Area	Storeys
General office	1000	4
High street agency	200	1
General retail	400	1
Large non-food shop	500	1
Small food store	500	1
Large food store	7000	1
Restaurant	250	1
Bar, pub or licensed club	500	1
Hotel	5000	6
Cultural activities	500	3
Entertainment halls	300	1
Swimming pool centre	1000	1
Fitness and health centre	500	2
Dry sports and leisure facility	150	1
Covered car park	500	5
Public buildings with light use	200	3
Schools and seasonal public buildings	6000	2
University campus	500	2
Clinic	200	2
Hospital; clinical and research	500	2
Long term residential	500	2
General accommodation	500	2
Emergency services	500	1
Laboratory or operating theatre	500	1
Public waiting or circulation, e.g. local station or mall	500	1
Transport terminal, e.g. airport	500	1
Workshop	1000	1
Storage facility	10000	1
Cold storage	500	1

Table B3 Commercial building types basic assumptions.

Roof areas

Assumptions relating to available roof areas are important with respect to potential energy generation from solar technologies.

For all building types, the available roof area for the installation of solar technologies has been assumed to be total floor area divided by the number of storeys, multiplied by 45%. Floor areas and assumed storey heights for each of the building types are shown in tables B2 and B3.

On pitched roofs, only half of the roof will face south, whereas on flat roofs, panels are mounted on frames which need to be spaced apart to limit over shading. Some area is also required for circulation, maintenance etc. Therefore, the maximum roof area that can be used for mounting solar panels, whether on flat or pitch roofs, has been considered to be 90% of half the available roof area i.e. 45% of the total roof area.

Energy Demand Assumptions

Dwelling energy demands were modelled in SAP, input assumptions where altered to take account of the likely fabric and plant performance in homes of varying age. The new dwellings have been modelled to comply with Buildings Regulations Part L 2006 or later. Unregulated energy demand (i.e. from non fixed building services - small power) has been calculated using a formula published within the Code for Sustainable Homes. This approach (for the unregulated emissions) has been used for existing and post 2006 dwellings.

For commercial buildings energy demands have been estimated by multiplying the floor areas above with energy benchmarks from CIBSE TM46. Energy use benchmarks have not been altered to differentiate between existing and new (post 2006) commercial uses, as there are no robust sources of information on which to base this.

We have had to assume how the energy benchmarks breakdown according to the energy demands which are regulated under Part L (i.e. for fixed building services such as heating, hot water and lighting) and which are unregulated (i.e. for small power). This is clearly essential where proposed policies being tested are framed in these terms. There is no recognised method for splitting energy benchmarks according to the emissions which are regulated or unregulated, but we have used assumptions that were made in the development of an the energy strategy for a major and high profile development in London.

	Benchmarks			Assumptions for splitting benchmarks			
	All Fossil	All Electric	ALL CO_2	a.) Assumed % 'All Electric' (Regulated)	b.) Assumed % 'All Electric' used for space heat (where no Gas)	c.) Assumed % 'All Fossil' used for DHW	d.) Assumed % 'All Electric' used for DHW (where no Gas)
	kWh/m^2	kWh/m^2	kgCO_2/m^2	%	%	%	%
General office	120	95	75.1	30%	-	20%	-
High street agency	0	140	77	60%	20%	15%	10%
General retail	0	165	90.8	60%	20%	20%	10%
Large non-food shop	170	70	70.8	30%	-	15%	-
Small food store	0	310	170.5	60%	20%	20%	10%
Large food store	105	400	240	30%	-	20%	-
Restaurant	370	90	119.8	30%	-	25%	-
Bar, pub or licensed club	350	130	138	30%	-	25%	-
Hotel	330	105	120.5	30%	-	20%	-
Cultural activities	200	70	76.5	30%	-	20%	-
Entertainment halls	420	150	162.3	30%	-	15%	-
Swimming pool centre	1130	245	349.5	30%	-	20%	-
Fitness and health centre	440	160	171.6	30%	-	20%	-
Dry sports and leisure facility	330	95	115	30%	-	20%	-
Covered car park	0	20	11	60%	20%	0%	10%
Public buildings with light use	105	20	31	30%	-	15%	-
Schools and seasonal public buildings	150	40	50.5	30%	-	20%	-
University campus	240	80	89.6	30%	-	20%	-
Clinic	200	70	76.5	30%	-	20%	-
Hospital; clinical and research	420	90	129.3	30%	-	20%	-
Long term residential	420	65	115.6	30%	-	20%	-
General accommodation	300	60	90	30%	-	20%	-
Emergency services	390	70	112.6	30%	-	20%	-
Laboratory or operating theatre	160	160	118.4	30%	-	20%	-
Public waiting or circulation, e.g. local station or mall	120	30	39.3	30%	-	15%	-
Transport terminal, e.g. airport	200	75	79.3	30%	-	15%	-
Workshop	180	35	53.5	30%	-	10%	-
Storage facility	160	35	49.7	30%	-	10%	-
Cold storage	80	145	95	30%	-	20%	-

Table B4 Commercial building energy demand splits – regulated and unregulated.

Heat Mapping

Heat mapping as been conducted using gas supply data and assuming an average boiler efficiency of 80%. Heat density is defined as the annual heat demand in kWh, divided by the number of hours per year to give an annual average demand. This was then divided by the area under consideration. Potential issues with this method are:

The use of gas data ignores the use of other heating fuels such as electricity and oil, which is expected to make up a small proportion of heat demand. Heat maps produced show the heat demand averaged across an 'output area' in line with the DECC (Department for Energy and Climate Change) heat map methodology. It should be noted that the heat mapping carried out for this study uses a higher resolution of data which provides more detail than the DECC approach. Due to 'averaging' of the heat demand across an output area, there is the potential for maps to show areas of high heat demand where in fact a lower heat demand may be present for much of that area. The results only provide an average of each Output Area and do not highlight point sources which may have a high heat demand. Feasibility of heat networks in any given location should therefore be based on further, more detailed opportunities studies.

Assumptions for Renewable and Low Carbon Energy Packages

The model has been constructed to test different policy options and select the least cost technology option to meet the different policy requirements.

▪ **Energy Efficiency Level 1 (EE1)**		
Buildings applied	**All residential buildings plus all commercial buildings**	*References*
Modelled or assumed savings	*Energy savings* *Modelled* Existing residential units: ▪ Pre 1919 – 20% saving on heat demand (regulated) ▪ 1919-1975 – 15% saving on heat demand (regulated) ▪ Post 1975 – 10% saving on heat demand (regulated) New residential units: ▪ Package of measures designed to deliver a 15% - 20% reduction in the DER relative to TER (Part L 2006). ▪ Savings are split across regulated heat and regulated power – as modelled. *Assumed* Commercial: ▪ Between 5 – 15% (depending on building type) reduction in fossil fuel demand where fossil fuel used for heating and hot water. ▪ Between 5 – 10% (depending on building type) reduction in electricity use where electricity is used for heating and hot water.	▪ SAP 2005 ▪ AECOM
Costing assumptions	£15/m^2 residential £20/m^2 commercial	▪ From unpublished work undertaken by AECOM for Energy Savings Trust

▪ **Energy Efficiency Level 2 (EE2)**		
Buildings applied	**All residential buildings plus all commercial buildings**	*References*
Modelled or assumed savings	*Energy savings* *Modelled* Existing residential units: ▪ Pre 1919 – 30% saving on heat demand (regulated) ▪ 1919-1975 – 25% saving on heat demand (regulated) ▪ Post 1975 – 20% saving on heat demand (regulated) New residential units: ▪ Package of measures designed to deliver around a 25% reduction in TER relative to TER (Part L 2006). ▪ Savings are split across regulated heat and regulated power – as modelled. *Assumed* Commercial: ▪ Between 7 – 21% (depending on building type) reduction in fossil fuel demand where fossil fuel used for heating and hot water. ▪ Between 7 – 14% (depending on building type) reduction in electricity use where electric used for heating and hot water.	▪ SAP 2005 ▪ AECOM
Costing assumptions	£30/m^2 residential £40/m^2 commercial	▪ From unpublished work undertaken by AECOM for Energy Savings Trust

▪ **PV – minimum installation**		
Buildings applied	**All residential buildings plus all commercial buildings**	*References*
Technology sizing assumptions	Assumed kWp taken to be ¼ of maximum possible panel based on the assumed roof areas Panel area assumed to be 7m^2/kWp Assumed output to be 800kWhkWp	▪ SAP 2005 ▪ Supplier data
Costing assumptions	Assumed to be £6000 per kWp **Note:** Full system cost including invertors etc	▪ Supplier quotes (2004 – 2008).

▪ **PV – medium installation**		
Buildings applied	**All residential buildings plus all commercial buildings**	*References*
1. Technology sizing assumptions	2. Assumed kWp taken to be ½ of maximum possible panel area based on the assumed roof areas 3. Panel area assumed to be 7m^2/kWp 4. Assumed output to be 800kWh/kWp	▪ SAP ▪ Supplier data
5. Costing assumptions	6. Assumed to be £5500 per kWp. 7. **Note:** Full system cost including invertors etc 8. **Note:** Costs fall as system size gets larger.	▪ Supplier quotes (2004 – 2008).

▪ PV – maximum installation		
Buildings applied	**All residential buildings plus all commercial buildings**	*References*
Technology sizing assumptions	Assumed kWp taken to be maximum possible panel area based on the assumed roof areas Panel area assumed to be 7m^2/kWp Assumed output to be 800kWh/kWp	▪ SAP ▪ Supplier data
Costing assumptions	Assumed to be £5000 per kWp. **Note:** Full system cost including invertors etc **Note:** Costs fall as system size gets larger.	▪ Supplier quotes (2004 – 2008).

▪ Biomass		
Buildings applied	New (post 2006) residential and post 2006 commercial buildings only. Different assumptions for new detached and semi detached homes.	*References*
Technology sizing assumptions	Biomass assumed to meet 80% of total heat demand, remainder met by gas. Biomass boiler efficiency assumed to be 76% Biomass demand based on energy generation of 3.85kWh/kg based on woodchips at 22% Moisture Content System size per unit assumed to be 50% of peak demand based on 60W/m^2 Detached and semi detached homes are assumed to be fitted with a 10kW individual boiler. Terraced houses and flats assumed to be part of a communal system	▪ AECOM ▪ BSRIA 'rules of thumb' ▪ Supplier data
Costing assumptions	▪ £1020 per kW accounting for boiler, civils and communal heating infrastructure ▪ For the detached and semi detached homes – cost assumed £10,000 per dwelling for an individual boiler. **Note:** Costs exclude civils work in connection with the biomass installation – i.e. plant room, fuel storage room etc	▪ Supplier quotes (2004 – 2008). ▪ Department for Children, Schools, Families

▪ Ground Source Heat Pumps		
Buildings applied	New (post 2006) residential and post 2006 commercial buildings only. Different assumptions for new detached and semi detached homes.	*References*
Technology sizing assumptions	Replacing 90% efficient gas boiler (expect for in the case of commercial buildings which have no gas demand in the basecase and are assumed all electric) COP of 3.2 assumed for space heating COP of 2.24 assumed for water heating System sized to meet peak heat demand - based on 60W/m^2 Detached and semi detached homes are assumed to be fitted with an individual heat pump of 10kW. Terraced houses and flats assumed to be part of a communal system	▪ SAP 2005 ▪ BSRIA 'rules of thumb'
Costing assumptions	▪ GSHP costs of £2000 per kW installed. **Notes:** Costs exclude costs for ground testing and for laying ground loops either horizontally or vertically. Heat pumps provide heating and hot water and therefore often negate the need for a gas connection to the building. Given the strategic nature of this study this is assumed to be covered within the cost benchmark above.	▪ Supplier quotes (2004 – 2008).

▪ Air Source Heat Pumps		
Buildings applied	All residential buildings and all commercial buildings	*References*
Technology sizing assumptions	Replacing 90% efficient gas boiler (expect for in the case of commercial buildings which have no gas demand in the base case and are assumed all electric) COP of 2.5 assumed for space heating COP of 1.75 assumed for water heating Assumed all individual systems for residential	▪ SAP 2005 ▪ BSRIA 'rules of thumb'
Costing assumptions	Residential – £6000 per system Commercial – £800 per kW	▪ Supplier quotes (2006 – 2008).

▪ Gas fired CHP		
Buildings applied	New residential and new commercial buildings only.	*References*
Technology sizing assumptions	60% heat from CHP, 40% from gas fired boilers Distribution loss factor: 5% CHP Electrical Generation Efficiency assumed to be 33% CHP Heat Generation Efficiency assumed to be 45% System sized to meet 50% peak thermal demand, assumed to be 60W/m^2.	▪ AECOM ▪ SAP 2005 ▪ Supplier system efficiencies ▪ BSRIA 'rule of thumb'
Costing assumptions	*Residential* £5000 per dwelling for fixed cost of district heating infrastructure plus £2000 per kWe. *Commercial* Fixed cost of £20/m^2 (floor area) for district heating infrastructure plus £2000 per kWe.	▪ Supplier quotes (2006 – 2008). ▪ The potential and costs of district heating networks (Faber Maunsell & Poyry, April 2009)

▪ Gas fired CHP plus Biomass top-up

Buildings applied	New residential and new commercial buildings only.	*References*
Technology sizing assumptions	60% of total heat requirements delivered by CHP Remaining heat from biomass (80%) and gas fired boilers (20%) Distribution loss factor: 5% CHP Electrical Generation Efficiency assumed to be 33% CHP Heat Generation Efficiency assumed to be 45% System sized to meet 50% peak thermal demand, assumed to be 60W/m^2.	▪ AECOM ▪ SAP 2005 ▪ Supplier system efficiencies ▪ BSRIA 'rule of thumb'
Costing assumptions	*Residential* £5000 per dwelling for fixed cost of district heating infrastructure plus £2000 per kWe. Biomass boiler cost assumed to be £200 per kW *Commercial* Fixed cost of £20/m^2 (floor area) for district heating infrastructure plus £2000 per kWe.	▪ Supplier quotes (2006 – 2008). ▪ The potential and costs of district heating networks (Faber Maunsell & Poyry, April 2009)

▪ **Biomass CHP**		
Buildings applied	New residential and new commercial buildings only.	*References*
Technology sizing assumptions	60% heat from CHP, 40% from gas fired boilers Distribution loss factor: 5% CHP Electrical Generation Efficiency assumed to be 25% CHP Heat Generation Efficiency assumed to be 50% Biomass demand based on energy generation of 3.85kWh/kg based on woodchips at 22% Moisture Content System sized to meet 50% peak thermal demand, assumed to be 60W/m^2.	▪ AECOM ▪ SAP 2005 ▪ Supplier system efficiencies ▪ BSRIA 'rule of thumb'
Costing assumptions	*Residential* £5000 per dwelling for fixed cost of district heating infrastructure, biomass fuel store etc plus £4000 per kWe. *Commercial* Fixed cost of £25/m^2 (floor area) for district heating infrastructure plus £4000 per kWe.	▪ Supplier quotes (2006 – 2008).

Technology Combination Options

In addition to the 12 basic technology options outlined above, our model input sheet also includes a further 20 technology options made up from various combinations of the above. Allowable solutions are also introduced as a proxy technology measure to provide a way of using the model to help quantify money that could be raised using this mechanism.

For simplicity and because of the high level nature of the study – CO_2 savings and costs from the options outlined above are simply summed in the combined options. For example, where energy efficiency is specified with biomass boilers and PV, savings and costs from options 1, 5 and 7 above would be summed together. In actual fact the savings achieved from a range of measures would not be the sum of savings from three separate measures, however this approach is considered sufficiently robust for the purposes of this study. Combination options have been set up to group together only compatible technologies.

It was assumed that a basic level of energy efficiency should always be taken up – as a first step of a CO_2 reduction hierarchy, where low carbon energy supply and the use of renewable technologies come later in the hierarchy. Therefore savings from renewable technologies in the RLC sheet were calculated against the buildings where EE1 was already applied. Costs for the basic energy efficiency improvements have been added together with the cost of the RLC technology for every option, except where the advanced energy efficiency standard is applied.

Modelling the Impact of Targets

For each year in the study period, an appropriate scenario is chosen by the model for new or improved buildings on each development site, based on the lowest cost solution that achieves the policy target that is also compatible with the site specific constraints.

- The split between regulated and unregulated CO_2 emissions for commercial building types is assumed based on experience – in reality the split is highly variable. This could have implications in terms of the ability of technology options to deliver on policy targets within the model
- The same energy use benchmarks have been used for existing and new non-domestic buildings. There are no robust sources of information on variations in non-domestic building energy use by age or design characteristics.
- The size and form of commercial building types in the model is assumed. As a result the model does not deal well with commercial buildings that are integrated as part of mixed use developments (i.e. where the commercial element is one floor of a multi floor development). In these cases the calculated roof area available for solar panels will be greater than would be expected in reality and the model may assume an over reliance on solar technologies to deliver on policy targets
- Costs in the model input sheet are capital cost only. Our model does not consider maintenance and replacement costs over technology lifetime and allows no benefit for revenue gained from feed in tariffs or renewable heat incentives. These lifecycle costs and benefits are hugely important for some developers (housing associations and commercial owner occupiers) and need to be considered alongside results from the model.

Not every low carbon or renewable technology has been considered within this study – it has been assumed that building mounted wind turbines, hydro and fuel cells are either not technically feasible or financially viable at this stage. Discrete uses for these technology types have been considered as a separate exercise.