Appendix C: Renewable & Low Carbon Energy Technology Descriptions

This section introduces a range of decentralised, renewable and low carbon energy technologies. It focuses only on those that the evidence base study identifies as being feasible in the district.

Combined Heat and Power (CHP)
A CHP plant is an installation where there is simultaneous generation of useful heat and power in a single process. The heat generated in the process is utilised via suitable heat recovery equipment for a variety of purposes including industrial processes, district heating and space heating.

Because the heat from electricity generation is used rather than disposed of and the avoidance of transmission losses by generating electricity on site, CHP typically achieves a 35 per cent reduction in fuel usage compared with power stations and heat only boilers. This can allow economic savings where there is a suitable balance between the heat and power loads.

Wind Energy
The UK has a large wind resource which remains largely untapped. Wind turbines come in a variety of sizes and shapes but they all work in a similar way; the turbine blades are moved by the wind and this movement is captured by a generator to produce electricity.

The large scale, free standing wind turbines that are now produced commercially have been optimised over a number of decades to result in highly efficient, reliable machines that have the potential to generate large amounts of energy. However, there are significant time implications and costs involved in locating them appropriately in order to achieve optimum energy yields.

Free standing turbines are traditionally larger and more cost effective in terms of their electricity production, however they are very rarely suitable for urban locations as they require free stream, non turbulent wind to be effective.


Figure C1: Freestanding wind turbines, Vestas V29 225kW wind turbine at Beaufort Court, RES Ltd in Hertfordshire (left) and Proven 15kw wind turbine (right)

The following issues should be assessed when considering the installation of large scale wind turbines:

Landscape and visual impact - A large free standing wind turbine is highly visible in the landscape. The specific sites of the turbines should be carefully considered to ensure that they do not detrimentally impact key view corridors and that they are well integrated into the surrounding landscape.

Wind resource - Wind speeds of 5.5m/s or above at turbine hub height are typically needed to operate a large scale wind turbine efficiently. The energy output of wind turbines is extremely sensitive to the wind speed therefore before making this kind of investment it would be prudent to carry out accurate wind speed measurements (preferably at hub height) over a period of at least 12 months, to ensure that the correct wind turbine is selected for the site wind climate.

Site location - For optimum output, turbines should be located in areas with high wind speeds, with few obstacles to create turbulence, i.e. with limited trees and buildings. Turbines should also be spaced to avoid turbulence affecting each other.

Noise implications - There are currently no statutory requirements regarding distances that must be maintained between wind turbines and residences, but 400m is a guide that is used in London[54]. A separation distance of 5-10 rotor diameters from turbines to the nearest dwelling is usually sufficient to satisfy the recommendations set out in the Noise Working Group report ETSU-R-97 on “The Assessment and Rating of Noise from Wind Farms.”[55]

Flora and fauna - It is important at the time of site assessment to identify any particular areas or species of nature conversation interest existing within the area under consideration. The presence of breeding birds on the site may affect the times of construction of the wind farm.

Shadow flicker - Rotating wind turbine blades can cast moving shadows that cause a flickering effect and can affect residents living nearby. This can be an issue at certain times of day when the wind is blowing, but effects can usually be mitigated.

Local infrastructure - It is advantageous if turbine sites have good access to roads, railway lines, rivers and canals, to enable delivery of components during construction and access for maintenance. An exclusion distance is observed to reduce the risks to property and human health in the unlikely event of a turbine failure. “Consideration should be given to reducing the minimum layback of wind turbines from overhead lines to three rotor diameters”[56]. Turbines should be at least 200m from blade tip to bridle paths; the British Horse Society recommends “a separation distance of four times the overall height should be the target for National Trails and Ride UK routes…and a distance of three times overall height from all other routes.” [57] A distance of 3 rotor diameters should be maintained from power transmission lines.[58]

Aeronautical and defence impacts - Turbines above a certain height may interfere with the operation of local air traffic control or radar systems used for military purposes. Consultation with organisations such as the National Air Traffic Service (NATS) and the Ministry of Defence may result in constraints on potential turbine locations.

Telecommunication impacts – large wind turbines can interfere with radio signals, television reception and telecommunications systems including fixed radio links and scanning telemetry links, which are a vital component of UK telecommunications infrastructure. Wind turbines may also affect local television reception, although the pending switch from analogue to digital terrestrial transmission will make networks less vulnerable.

Impact upon land use and land management - The actual footprint of wind turbines is relatively small and adjacent land can still be used for grazing, farming, etc. Crane hard standings and access tracks are usually required at each turbine location

Grid connection and substation requirements - Large scale turbines will be connected to the National Grid by arrangement with the local electricity network operator. It is ideal to locate turbines close to a 10-30 kV power line. The electrical grid near the wind turbine should be able to receive the incoming electricity; if there are already many turbines connected to the grid, then the grid may need reinforcement.

Flood risk - Development of wind turbines on areas of high flood risk is currently restricted by PPS 25. Proposed revisions to the PPS suggest wind turbines be reclassified as essential infrastructure[59]. This would largely permit turbine development in flood zones and as such flood zones have not been considered a constraint in the above analysis.

Gas pipelines and other sub terrain analysis - The feasibility of the construction of a large turbine should be supported by geotechnical investigations.

Archaeological constraints - Any impacts on archaeology in the area will have to be assessed in more detailed studies.

Listed building and conservation areas – a detailed impact assessment has not been conducted at this stage and would be required for any further study.

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54 Guidance Notes for Wind Turbine Site Suitability (London Energy Partnership, London Renewables, October 2006)
55 The Assessment and Rating of Noise from Wind Farms (Noise Working Group report EtSU-R-97, 2007)
56 NGET Technical Report TR(E) 453 A Review Of The Potential Effects Of Wind Turbine Wakes On National Grid’s Overhead Transmission Lines (NGET, 2009)
57 Advisory Statement on Wind Farms AROW20s08/1 (The British Horse Society)
58 Review of the Potential Effects of Wind Turbine Wakes on Overhead Transmission Lines, TR (E) 453 Issue 1 (National Grid – internal use only, May 2009)
59 Planning Policy Consultation – Consultation on proposed amendments to Planning Policy Statement 25: Development and flood risk, paragraphs 3.31-3.38 (DCLG, August 2009)

There are benefits to choosing a turbine in the small to medium size range. This size of turbine is particularly well suited to direct connection to a development electrical network rather than to the National Grid. The electricity generated can then be used on site thus sparing costly distribution network development and avoiding distribution losses.

Transport access - Construction costs will be considerably less, since it is not necessary to use cranes or build a road strong enough to carry large-scale turbine components.

Landscape and visual impact - Aesthetical landscape considerations may also dictate the use of smaller machines. Large machines, however, will usually have a much lower rotational speed, which means that one large machine does not attract as much attention as many small, fast moving rotors.

Building mounted turbines tend to be cheaper, but despite considerable interest from developers and the media in recent years, they are still relatively unproven in urban locations. There is much debate about what can realistically be assumed in terms of their annual electrical output in turbulent, urban wind flows.

Building mounted turbines can be mounted either to a gable wall or on the ridge of the roof. If mounted to a gable wall, the mounting is relatively simple. If mounted to the ridge, the mast of the turbine can be bolted to the timber roof trusses. The mast would pass through a gland in a modified roof tile, to prevent water penetration around the mast.

So far, the turbines mounted on buildings have tended to be those with a horizontal axis (HAWTs) i.e. the familiar rotor on a tower, where the rotor needs to be positioned into the wind direction by means of a tail or active yawing by a yaw. HAWTs are very sensitive to sudden changes in wind direction and turbulence, which have a negative effect on the performance of the turbine. In an urban environment, vertical axis wind turbines (VAWTs) are perhaps a more suitable option, since they are less responsive to the variability of the wind and turbulence. These types of turbine can also often utilise the upward wind flows that are present around large buildings.

Biomass Energy

Biomass is a collective term for all plant and animal material. A number of different forms of biomass can be burned or digested to produce energy. Examples include wood, straw, poultry litter, putrescibles (kitchen and garden waste) and energy crops such as willow and poplar, grown on short rotation coppice, and miscanthus. Biomass is a virtually carbon neutral fuel, as the CO_2 emitted during energy generation has been recently absorbed from the atmosphere. A very low carbon emissions factor for biomass reflects the emissions related to production and transport.

Wood from forests, urban tree pruning, farmed coppices or farm and factory waste can be burnt directly to provide heat in buildings, although nowadays most of these wood sources are commercially available in the form of wood chips or pellets, which makes transport and handling on site easier. Pellets are produced from the compression of saw dust and, because they are drier and denser than wood chip, have a higher energy yield per tonne.

Biomass heating has seen a large increase in the public sector, especially in schools and colleges. The technology is potentially the lowest capital cost method of achieving planning targets for CO_2 reductions from low carbon or renewable energy on new developments.

A major factor that determines the energy content of a biomass material is its moisture content. The moisture content of material can vary greatly, from around 5-8% for wood pellets to 65% for freshly felled timber. The greater the moisture content the less energy is contained within the fuel, consequently the majority of raw biomass materials require some form of processing before they become biomass fuels. Processes can range from simple cutting and drying to more involved processes like producing pellets.

Modern systems can be fed automatically by screw drives from fuel hoppers. This typically involves daily addition of bagged fuel to the hopper, although this process can also be automated with use of augers or conveyors. Electric firing and automatic de-ashing are also available and systems are designed to burn without smoke to comply with the Clean Air Act.

The most common application of biomass heating is as one or more boilers in a sequenced (multi-boiler) installation where there is a communal block or district heating system.

Plant size (kW)	Footprint (m²)	Length (m)	Width (m)	Height (m)
250	22	5.5	4	2.1
320	33	8.2	4	2.5
400	33	8.2	4	2.5
500	42.5	8.5	5	2.7
700	42.5	8.5	5	2.9
900	45	9	5	3.6
1500	47.5	9.5	5	4.3
2500	55	10	5.5	4.7
3500	60.5	11	5.5	5.6
4500	69	12.5	5.5	5.9

Source: B&V market data

Table C1 Indicative biomass plant sizes

Biomass systems generally need more physical space than fossil fuel systems of the same rated output. The spatial requirements of parts of biomass heating systems are described further below:

Size of plant - A biomass plant will also need a degree of clearance around certain areas to enable cleaning and such tasks as ash removal. Table C1 contains a range of typical biomass plant sizes.

Fuel storage – as biomass is a solid fuel, careful consideration needs to be given to the storage so as to enable straightforward delivery to the combustion chamber.

Vehicle access for fuel delivery – biomass plants need regular deliveries of a solid fuel and consideration needs to be given to the space available for delivery vehicles.

Issues which can prevent uptake of biomass boiler technology are:

On-site access for large lorries delivering wood chip, especially for urban locations;

Availability of space for a large fuel storage area adjacent to the plant area (the smaller the storage area the more frequent fuel deliveries);

Concerns over sustainable, reliable fuel supply chains being in place.

A move towards greater use of biomass will inevitably increase emissions in urban areas. The design of a biomass plant has a large impact on its combustion efficiency and emissions. A modern biomass plant should, with careful design, be able to meet all air pollution control standards at reasonable costs. Even so, siting of the plant must be carried out with care, and in particular it is important that biomass plants should not be located in areas where they would exacerbate existing poor air quality.

Energy crops

The suitability of a site for the cultivation of energy crops depends on factors including local landscape, environmental and social issues.

Different varieties of energy crops are suited to different soil types and have specific climatic and hydrological requirements. Agricultural land is divided into land classifications which provide a measure of the lands productivity and versatility. Grades 1 and 2 should be retained entirely for food crops.

	% of agricultural land	Description
Grade 1	3%	Excellent quality agricultural land. Land that produces consistently high yields from a wide range of crops such as fruit, salad crops and winter vegetables.
Grade 2	16%	Very good quality agricultural land. Yields may have some variability but are generally high, some factors may affect yield, cultivation or harvesting.
Grade 3	55%	Good to moderate quality land. Limitations of the land will restrict the choice of crops, timing and type of cultivation, harvesting. Yields are generally lower and fairly variable.
Grade 4	16%	Poor quality agricultural land. Severe growing limitations restrict the use of this land to grass and occasional arable crops.
Grade 5	10%	Very poor quality land. Land that is generally suitable only for rough grazing or permanent pasture.

Table C2 Agricultural land classifications in England and Wales. [Source: Biomass as a renewable energy source, Royal Commission on Environmental Pollution, 2004)

Arboriculture (woodland and forestry residues)

Forests under management can produce a sustainable yield of biomass and have the potential to supply a large volume of wood without compromising existing land uses. Reduced cover and cleared grounds can also bring ancillary environmental benefits. However, long term trends in timber prices have rendered forest management uneconomic[60]. A strengthened market for locally sourced biomass would encourage greater exploitation of the existing resource.

Parks, waste wood and highways waste

Local authorities produce large quantities of green waste, through management of parks, trees and community land. It is commonly composed of wood, trimmings, cuttings and grasses and biodegradable waste which is usually high in nitrogen.

Traditionally this green waste has been sent to landfill or used in composting. Instead green waste can be used as a fuel, creating a valuable resource.

Waste wood has been a largely overlooked resource to date, partly part due to it often arising as part of a mixed waste stream, with limited facilities for its segregation, and also a result of its predominantly contaminated nature, which often makes recycling impractical. Waste wood has a relatively low moisture content (18-25%), potentially making it preferable to forestry and biomass crops (approximately 40%)[61], although waste wood from arboriculture management usually has higher moisture content and requires drying before use.

Solar Energy

The sun's energy arrives at the earth's surface either as 'direct', from the sun's beam, or 'diffuse' from clouds and sky. The total or 'global' irradiation is the sum of these two components and, across the UK, the daily annual mean varies between 2.2kWh/m^2 to 3.0kWh/m^2 as measured on the horizontal plane. There is a very significant variation around this average value due to both seasonal and daily weather patterns.

There are two main technologies that can directly exploit the solar resource:

- Solar water heating - direct conversion of solar energy into stored heat;
- Photovoltaics (PV) - direct conversion of solar energy into electricity.

Solar water heating

Solar water heating systems use the energy from the sun to heat water, most commonly for hot water needs. Ideally the collectors should be mounted in a south-facing location, although south-east/south-west will also function successfully. The panels can be bolted onto the roof or walls or integrated into the roof.

The systems use a heat collector, generally mounted on the roof or façade in which a fluid is heated by the sun. This fluid is used to heat up water that is stored in either a separate hot water cylinder or more commonly a twin coil hot water cylinder with the second coil providing top up to heating from a conventional boiler.

The heat collector can be in the form of a flat plate array or evacuated tubes. Flat plate panels are cheaper but less efficient , while evacuated tubes have the advantage that they can be adjusted individually to achieve optimum pitch and have lower heat losses.

A conventional heat source is necessary because a standard solar system in the UK cannot provide sufficient heat to supply hot water at the desired temperature, throughout the year.

Apart from providing hot water, the other major use for the technology in the UK is for swimming pool heating, where it is particularly suited to pools used only between spring and autumn. These may be outdoor pools or enclosed pools where the air over the water is not conditioned.

Figure C2 Solar hot water installation. Schuco flat plate system providing domestic hot water (photo courtesy of Ecolution Renewables)

Solar photovoltaics

Solar photovoltaic panels (PV) use semi-conducting cells to convert sunlight into electricity. The panel produces electricity even in cloudy conditions, but power output increases with the intensity of the sun.

Modules are connected to an inverter to turn the direct current (DC) generated into alternating current (AC), which is usable in buildings. PV can supply electricity either to the buildings it is attached to, or, when the building demand is insufficient, electricity can be exported to the electricity grid.

PV is available in a number of forms, including mono-crystalline, poly-crystalline, amorphous silicon (thin film) or hybrid panels that can be mounted on or integrated into the roof or facades of buildings. Different types have different outputs per metre squared of panel, with hybrid and mono-crystalline producing the most and amorphous the least. PV system size is measured in kilowatt peak (kWp).

A flexible option for a variety of roof orientations is the Kalzip AluPlusSolar system, which involves a PV laminate (PVL) adhered to the surface of a specific Kalzip profiled standing seam roof, constructed in the normal manner and still retaining the full choice of structural decking, liner deck or tray. The system can be installed on roofs from 3.5º and 60º.

Figure C3 Solar PV panels. PV panels angled at 10º on flat roofs

For PV to work effectively, it should ideally face south and at an incline of 30º to the horizontal, although orientations within 45º of south are acceptable. It is essential that the system is not shaded, as even a small shadow may significantly reduce output.

Heat Pumps

Air source heat pumps use the refrigeration cycle to extract low grade heat from the outside air and deliver it as higher grade heat to a building. Ground source heat pump systems operate in a similar way by taking low grade heat from the ground and delivering it as higher grade heat to a building.

The measure of efficiency of a heat pump is given by the Coefficient of Performance (CoP). For example, if a heat pump has a CoP of 3 then for every three units of heat delivered, two units are from the renewable heat source and one from the electrical power supply.

Air source heat pumps

The ability of an air source heat pump to transfer heat from the outside air to the house depends on the outdoor temperature. If the air temperature falls below zero, moisture in the air may condense and form ice on the external heat exchanger. This will reduce the heat transfer coefficient, and must be melted periodically using a ‘defrost cycle’ which warms up the external heat exchanger using energy to no useful gain inside the building.

Below the outdoor ambient temperature, the heat pump can supply only part of the heat required to keep the living space comfortable, and supplementary heat is required (e.g. back up electric immersion heater). Unfortunately, the CoP is lowest when air temperatures are low – this coincides with the times when the heat pump is most used.

60 Biomass for London: wood fuel demand and supply chains (BioRegional Development Group, SE Wood Fuels and Creative Environmental Networks, December 2008)
61 Waste wood as a biomass fuel, market Information report (DEFRA, April 2008)

Ground source heat pumps

Ground source heat pumps make use of the constant temperature that the earth in the UK keeps throughout the year. This is related to the annual average air temperature for the site ±2°C; for the UK this is generally around 10^{o}C. Since the ground stays at a fairly constant temperature, annual seasonal COPs of 3.5 or more are achievable, giving good energy and running cost savings.

Ground source heat pumps can be used for both heating and cooling purposes. The water that circulates through the loop is cooled by the ground in the summer and heated in the winter. For cooling systems, water can be introduced directly in the building or if the capacity of the soil is inadequate, a refrigerator unit or a reversible heat pump can be used. When the system is used both for heating and cooling the building, the investment and running costs are particularly economical.

Detailed geological and geotechnical assessment is required on a site by site basis to ensure that sufficient energy can be extracted from the ground on each site. The yield of the open boreholes or limitations on space or number of piles can limit the amount of energy that can be extracted from the ground.

Assumptions used in Section 5 Opportunities for Renewable and Low Carbon Technologies

Biomass

Type of Biomass	Source	Recoverable Biomass	Area/Number in Hertfordshire	Useful Proportion	Useful amount	Moisture Content	Calorific Value
		odt/hectare	hectares or number of animals	%	odt/tonnes	%	GJ/odt
Energy Crops	Agricultural Land Grade 1 (SRC)	8		0%	-	30%	13.00
Energy Crops	Agricultural Land Grade 2 (SRC)	8		0%	-	30%	13.00
Energy Crops	Agricultural Land Grade 3 (SRC)	8	95,300	75%	571,800	9. 30%	10. 13.00
Energy Crops	Agricultural Land Grade 4 (SRC)	8	2,300	20%	3,680	30%	13.00
Energy Crops	Agricultural Land Grade 5 (SRC)	8	41	0%	-	30%	13.00
Arboriculture	Ancient Woodland	2	5,700	100%	11,400	45%	12.50
Arboriculture	Forestry Commission Woodland	2	5,316	100%	10,632	45%	12.50
Arboriculture	Park	2		100%	-	45%	9.28
Arboriculture	Woodland creation - Hertfordshire Forest	2	344	75%	516	45%	12.50
Park and Highways Waste	Country Parks, Historic Parks and Gardens	2	5,900	20%	2,360	n/a	15.76
Waste Wood	Household and Commercial waste	-	-	-	26,651	n/a	18.30
Waste Wood	Waste from agriculture	4	23,947	100%	88,604	20%	-
Wet Biomass	Poultry (Broilers)	-	381,375	-	11,144	40%	22.00
Wet Biomass	Poultry (Layers)	-	25,906	-	1,113	70%	25.00
Wet Biomass	Cattle	0	15,506	-	188,786	88%	
Wet Biomass	Pigs	0	8,024	-	10,657	91%	

Waste

Timber Waste

For construction wood waste - use national level data and disaggregate on the basis of new housing allocations.

timber waste by households - UK total	420,000	tonnes	
No of households in Hertfordshire	420,650		(UK government statistics)
no of households in the UK	24,700,000		(UK government statistics)
Total timber waste in Hertfordshire	7,153	tonnes	
total packaging + construction waste in the UK	1,420,000	tonnes	
total packaging + construction waste in Hertfordshire	46,150	tonnes	

Waste - Animal farming (manure, beddings etc)

Biogas Yield

cattle	25	m3/t
pigs	26	m3/t
food and drinks	46	m3/t

Wind

		Large Scale Turbine	Small Scale
Cost per turbine			39,000
Typical cost per installed MW		800,000	2,600,000
1 kmsq	9	MW wind turbine	
Wind Energy Resource			
area available - further constraints	m2	604	
turbine capacity in total	MW	5436	
turbine capacity 10%	MW	543.6	100
Rating	MW	2	0.02
no of turbines		271.8	
Capacity Factor	%	23%	10%
Manufacturer	-	Vestas	Proven
Model	-	V90	Proven 15
Approximate Cost	£	434,880,000	3,900,000
Rated wind speed	m/s	14.5	12.0
Cut-in wind speed	m/s	3.8	2.5
Hub Height	m	80	15.0
Rotor diameter	m	80	9.0
Recommended exclusion zone	m	800	54.0
Annual energy output	MWh/year	1,095,870	1,314
CO2 emissions saved	tonnesCO2/year	622,454.40	746.35
Homes equivalent (3bed detached)		177,844.11	210.24
Cost/tonne CO2 saved	£	£699	£5,225
Homes equivalent (3bed detached)	energy	192,258	231