5 Opportunities for Renewable and Low Carbon Technologies

This chapter outlines the opportunities for decentralised renewable and low carbon energy installations in Hertfordshire, at a range of scales.

The methodology used in this section closely follows (where possible) the methodology set in Renewable and Low-carbon Energy Capacity Methodology commissioned by the Department for Energy and Climate Change (DECC) and the Department for Communities and Local Government (CLG). Where there is an absence of guidance, assumptions were made. These are all listed in Appendix B.

A large part of Hertfordshire is land designated as greenbelt. Government policy on development in the greenbelt is set out in PPG2. The opportunity areas identified in this study highlight the greenbelt areas and show the impact that this may have on development of renewable and low carbon energy schemes. However, PPS22 is clear that whilst elements of many renewable energy projects will comprise inappropriate development, this does not preclude them from taking place should “very special” circumstances be demonstrated. Very special circumstances for example could include the wider environmental benefits associated with increased production of energy from renewable sources. The location of opportunity areas and therefore energy generation of the study area is potentially greater if greenbelt designation is viewed within the context of PPS22. The constraints maps are presented in a way which shows the opportunity areas without greenbelt constraints and with the greenbelt shown as an overlay to allow the reduction in available opportunity areas to be highlighted.

5.1 Large Scale Wind Resource

Wind turbines convert the energy contained in the wind into electricity. Large scale, free standing turbines have the potential to generate significant amounts of renewable energy.

5.1.1 Existing Large Scale Wind Energy

Large scale wind turbines are those with the capacity of around 1MW or above and are typically used in the UK in commercial wind farms, with sizes now commonly being 2.5MW. There are currently no large-scale wind developments in Hertfordshire. Two applications for large scale wind farms have been made in the County but neither has been permitted.

Another application of 3 wind turbines each rated at 2 MW has also been rejected. The turbines were planned to be located at Weston Hills in North Hertfordshire.

5.1.2 Local Potential for Large Scale Wind Energy

The wind resource in Hertfordshire is potentially suitable for large scale wind energy with average wind speeds of 5.5 m/s at 45m height throughout the County, according to the UK Wind Speed Database (Figure 5.1).At lower heights, and especially in urban areas, it is likely that the UK Wind Speed Database is not representative due to localised turbulence effects. However in the more rural areas and at the heights of large scale turbines, modelled in this study (typically 80m hub height); this data is likely to be accurate, with higher speeds above the 45m baseline. We therefore believe that a minimum average windspeed of 6m/s can be used across the County – this can be suitable for economic operation of large scale wind turbines.

Physical constraint geographical information systems (GIS) mapping has been carried out to identify areas where large scale wind energy may be feasible, based on a wind turbine with an 80m rotor diameter and 120m tip height. There are no official guidelines for the constraints on locating wind turbines and a detailed case-by-case study is required in all cases. For this reason, this study uses two separate constraints analyses. The first set of constraints is based on engineering constraints (areas where it is physically impossible to develop turbines and therefore represent the absolute constraints) and comprises:

- Roads
- Railways
- Inland Waters – rivers, canals, lakes, reservoirs
- Built up areas – houses, buildings
- Airports
- Buffer around roads and rail lines of 132 m (110% of turbine height)

The second analysis encompasses additional constraints[18] where wind turbine development may possibly conflict with land uses and includes all of the following (including the engineering constraints above). This could results in a significant reduction in available land area for large scale turbines:

- AONB
- SSSI
- Wildlife Sites
- Conservation Areas
- Ancient Woodlands
- Woodlands
- Greenbelt
- Local Nature Reserve
- Area of Archaeological Significance
- Scheduled monuments
- RSPB Reserves
- Ramsar Sites
- Waterside Green Chains
- 500 m buffer zone from urban – built up areas.
- 5 km from airports (Luton, Stansted, any major airfields)

[18] *The North Hertfordshire Core Strategy Preferred Options (2007) proposed that the green belt should be extended to cover the area bounded by the Metropolitan Green Belt to the south, the Luton Green Belt to the west and the A505 Offley Bypass to the north. This has not been included in the wind maps.*

It should be noted that some land designated as a 'soft' constraint will not physically prevent the installation of wind turbines. These areas may have constraints which <u>will</u> need careful examination on a case by case basis to ensure that wind turbine development is appropriate to the area, but should not be considered a blanket constraint'

Government policy on development in the green belt is set out in PPG2. The opportunity areas identified in the study area treat Green Belt as if development of renewable or low carbon energy generation automatically conflicts with that designation and is therefore not acceptable. However, PPS22 is clear that whilst elements of many renewable energy projects will comprise inappropriate development, this does not preclude them from taking place should very special circumstances be demonstrated. Very special circumstances for example could include the wider environmental benefits associated with increased production of energy from renewable sources. The location of opportunity areas and therefore energy generation of the study area is potentially greater if GB designation is viewed within the context of PPS22.

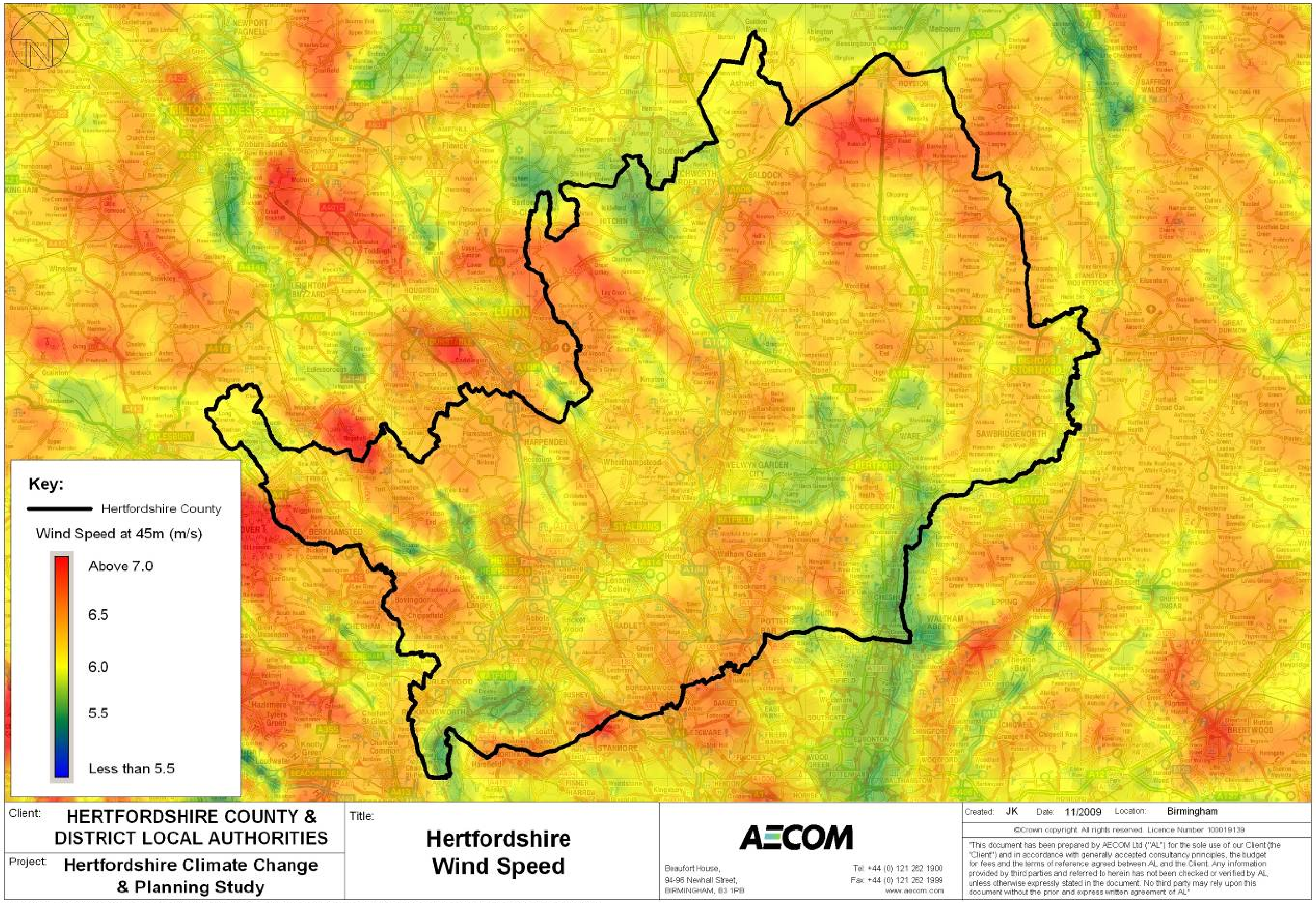
Further information and guidance on green belts is provided within this report.

Figure 5.2 and Figure 5.3 on the following pages represent the GIS maps of engineering and further constraints.

Users of the latter map (Figure 5.3 Further constraints) should take into consideration the previous comment regarding soft constraints, particularly greenbelt, when determining suitable sites for wind energy applications.

The total area of land in Hertfordshire that is potentially suitable for large scale wind turbines is approximately 1,084 km^2 according to the engineering constraints analysis and 82.75 km^2 according to the further constraints analysis. This excludes land currently designated as greenbelt. Greenbelt constitutes an additional 521 km^2 area[19] available for large wind turbine installations. Therefore if greenbelt is included in the total area available for wind development this amounts to a total land area of 604 km^2. In general, around 9MW of large scale wind capacity can be installed per square kilometre of available land – this is roughly three to four large turbines. Thus 5,436 MW of installed wind capacity could be achieved if all of the 604 km^2 land area was made available. On greenbelt land alone this equates to 4,689 MW of capacity (or roughly 2,300 large scale wind turbines). This could provide the total electricity consumption for approximately1.5 million homes and offset the total CO_2 emissions related to that consumption.

[19] This area takes into account the constraints in greenbelt. For example roads, railways and rivers are subtracted from this area as these project constraints to large wind turbines.



F:\TP\Map_Data\Project_areas\Hertfordshire Project\GIS data\Wind data\Wind Speed\Hertfordshire Windspeed.WOR

Figure 5.1: Hertfordshire Wind Speed Map The majority of areas at a 45 m height exhibit windspeeds of 5.5 m/s or more. At the height of large scale turbines (typically around 80m hub height) these speeds will be higher.

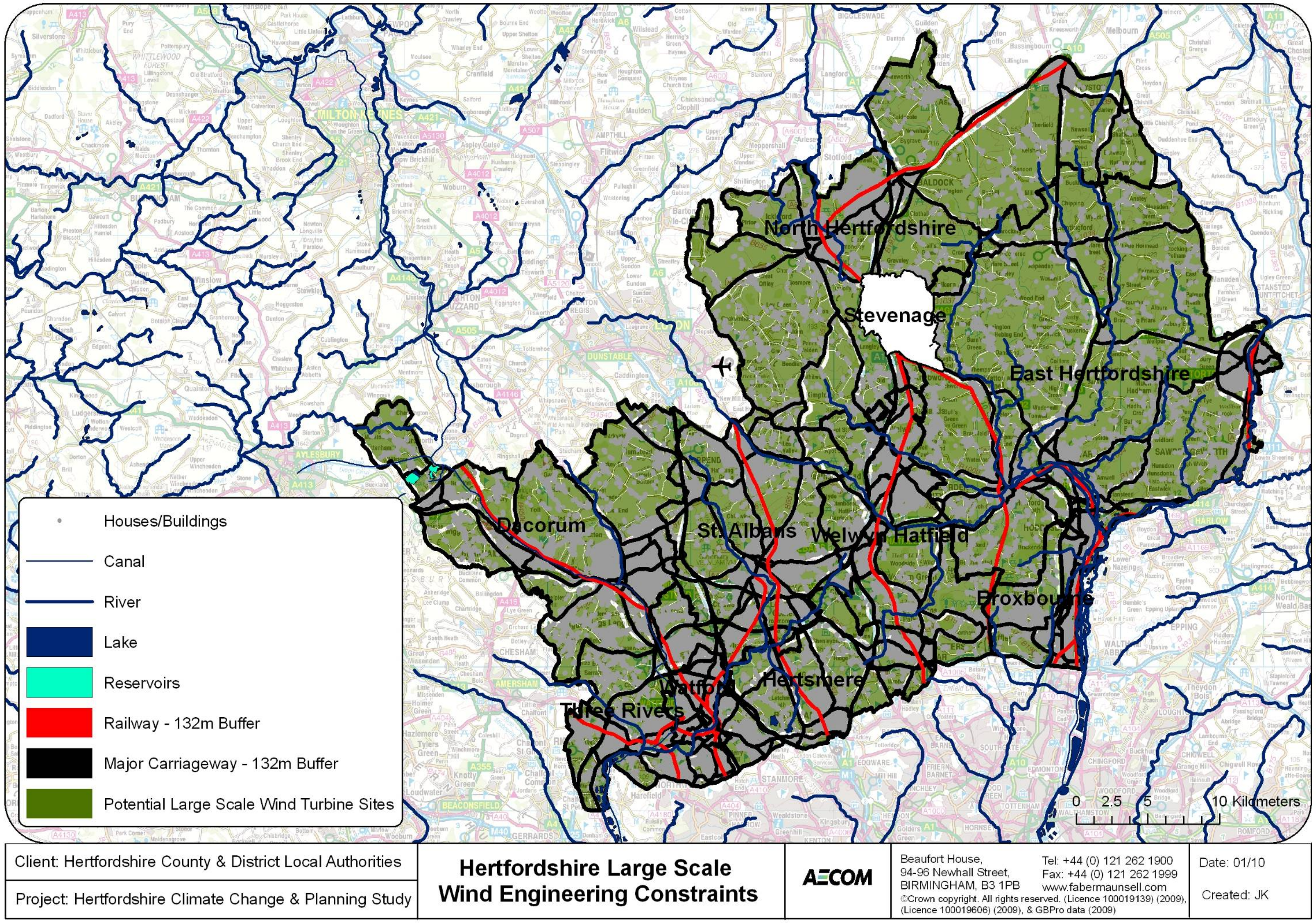


Figure 5.2: Hertfordshire Large Scale Wind Constraints Analysis - Engineering Constraints. There is 1,084 km^2 of land identified as suitable for large scale wind assuming no further constraints.

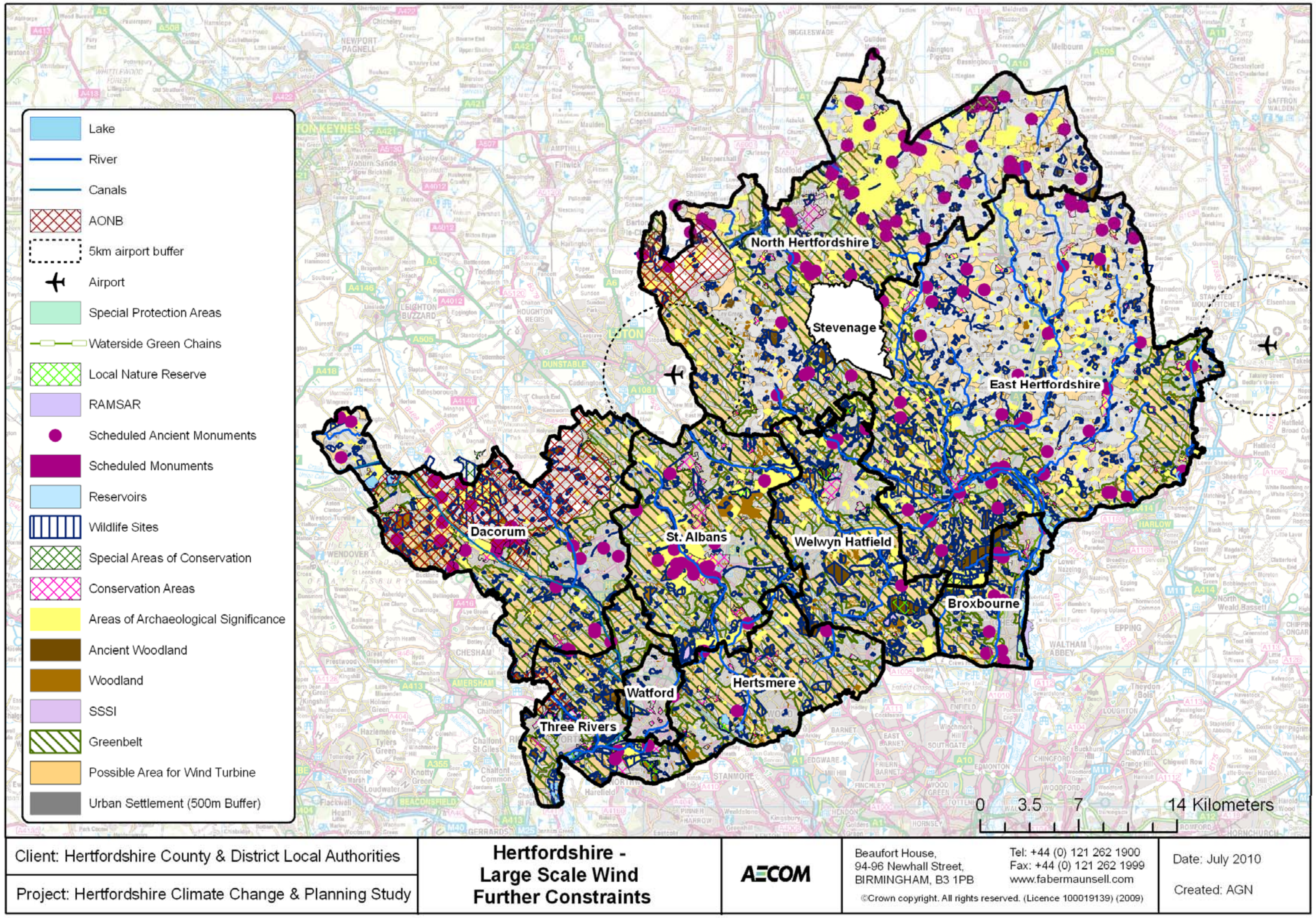


Figure 5.3: Hertfordshire Large Scale Wind Constraints Analysis - Further Constraints. The introduction of the further constraints results in a land area of 82.75 km^2 being identified as suitable for large scale wind.

5.2 Large Wind Capacity in Hertfordshire according to further constraints analysis

It should be noted that this analysis is indicative and that considerably more land could be available for wind development if constraints labelled as 'soft' are not viewed as absolute constraints by the LPA. Please refer to the comment made in section 5.1.1 regarding the need for a positive approach.

The 1,084 km^2 land availability assessed with the engineering constraints only represents a very optimistic view, and almost certainly, the land area which is actually suitable for large wind will be further constrained. If the further constraints are applied, the land area reduces to 83 km^2. This represents a relatively pessimistic view and in reality, large scale wind turbine development will be viable within many of the areas defined as "further constraints". For example, the 500m buffer zone around urban areas could be significantly reduced if visual impact and noise mitigation can be improved, or if the wind turbines are community owned resulting in a higher level of acceptance with local residents. One important constraint in determining the capacity is the greenbelt area. greenbelt in Hertfordshire constitutes 521 m^2 of land and therefore the available area for wind development would be 604 km^2 if greenbelt were included.

It should be noted that a Whole Region Wind Assessment [20]has been carried out for the East of England. A conclusion from this report is that the south of the region (including Hertfordshire) is less windy when compared to Cambridgeshire, Norfolk and Suffolk and therefore less viable for large scale wind. Although this statement is correct (Norfolk, Suffolk and Cambridgeshire will certainly offer more potential for large scale wind due to a better wind resource) this does not mean there is no wind potential at all in Hertfordshire. Indeed, due to this lesser large scale potential, there is an argument for Hertfordshire LPAs to be looking favourably upon smaller viable proposals (such as community scale wind) in the County due to the significant CO_2 savings that can be realised by wind energy at this smaller scale, and the opportunity it presents for helping to tackle climate change.

Further Constraints

If 10% of all of the land identified under "further constraints (with greenbelt area included) is made available for large scale wind, then 540 MW capacity could be achieved – this is roughly 270 large scale turbines. Assuming a capacity factor of 23%, this would have an annual generation of more than 1 million MWh a year, which is equivalent to the electricity requirements of roughly 192,250 typical detached homes, or 618 ktonnes of CO_2 per year. These results are summarised in Table 5.1. Detailed feasibility studies should always be carried out to confirm the suitability of these areas and precise locations for turbines on a case by case basis. This analysis should always challenge the further constraints identified in line with PPS 22 to assess whether developing wind turbines in these areas will have an adverse impact, potentially opening up further areas to the development of large wind.

Large Scale Wind Turbines	
Number of turbines	270
Rated power of turbines	2 MW
Hub Height	80 metres
Rotor Diameter	80 metres
Installed capacity	540 MW
Annual generation	1,088,610 MWh
Potential for CO_2 savings	618,330 tonnes
Number of homes equivalent (energy)	192,250

Table 5.1: Large scale wind energy resource in Hertfordshire according to further constraints analysis

5.2.1 Financial Implications of Large Scale Wind

Wind turbines, when located appropriately in areas of high wind speeds, are one of the most cost effective renewable energy technologies currently available in the UK. Generally the capital cost per unit output reduces as the size of the turbine increases. Large scale wind power is projected to cost around £800,000 per megawatt installed[21]. A typical cost breakdown is provided in Figure 5.4 below.

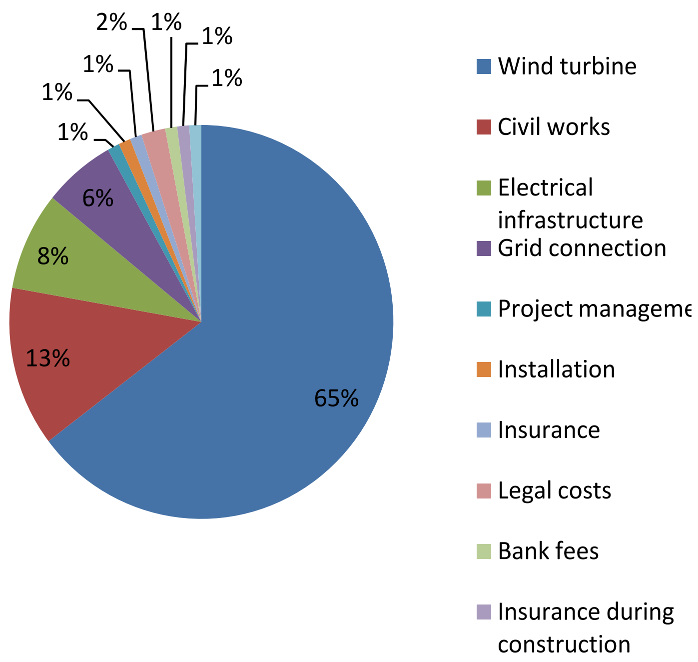


Figure 5.4: Capital cost breakdown for a large scale wind turbine. (Source: The economics of onshore wind energy; wind energy fact sheet 3, DTI) [22]

5.3 Medium and Small Scale Wind Energy Resource

Suitability of wind speeds in the district mean that smaller scale turbines of the order of 15m in tip height could be a significant opportunity, including in some areas that are not suitable for large scale wind. Smaller wind turbines have a significantly reduced visual impact and would be particularly suitable for farms and industrial sites, but also for municipal buildings such as community centres or schools. There are many examples of these turbines installed in schools, industrial estates and farms throughout the country some within very close proximity to the buildings and the residential areas.

5.3.1 Existing Installations

There are a number of small scale turbines installed in Hertfordshire. The largest is installed at the Renewable Energy Systems (RES) office near Kings Langley. This is a Vestas 225 kW turbine with a hub height of 36m and a rotor diameter of 29m. The turbine has been in operation since 2004 and produced so far just under 1000 MWh electricity. There are also a number of smaller turbines installed in Hertfordshire. These are;

- 2 x 6 kW turbines at Leventhorpe School in Sawbridgeworth. It is the first school in Hertfordshire to have planning permission granted for two 6kW wind turbines. (Figure 5.5)
- 20 kW Turbine at Howe Dell School in Hatfield
- 2 x 20 kW Gazelle Turbines with 20 m hub height and 26 m tip height in Welwyn Garden City at Tesco Headquarters
- 6KW turbine at the Council offices in Cupid Green Depot, Redbourn Road in Hemel Hempstead,
- 15KW wind turbine at Astley Cooper School in Grovehill, Hemel Hempstead

Figure 5.5: 2 x 6 kW Turbines at Leventhorpe school

[20] [20] Hertfordshire Renewable Energy Study, Renewable Energy Options for Hertfordshire, July 2005 Entec UK Limited

[21] BWEA Small Wind Turbine FAQ (BWEA website, accessed September 2009)

[22] The economics of onshore wind energy; wind energy fact sheet 3 (DTI, June 2001)

Based on the information provided to inform this study, there are a limited number of planned / proposed turbines in the County:

- 1kW turbine, with a rotor diameter of 1.75m, at Abbot Hill School, Bunkers Lane Hemel Hempstead
- 6kW Turbine, with a rotor diameter of 5.5 m, at Hemel Hempstead School, Heath Lane, Hemel Hempstead.

Figure 5.6 on page 37 shows the locations of the existing, planned and rejected wind turbines. The siting constraints on smaller scale turbines are dependent on a case by case basis – due to their smaller size the restrictions which may apply to large turbines covering visual appearance and noise do not apply to smaller scale systems, and in general, they can be located in most areas providing sufficient wind resource is available, including residential and urban areas, close to roads, and in areas of environmental sensitivity.

Due to their low height, the performance of small turbines is heavily dependent on localised wind conditions which in turn is influenced by the local topography and built environment. It is therefore important that the whole of Hertfordshire should be considered as suitable for small scale wind, but with suitable wind analysis carried out on a site basis.

For the purpose of estimating the potential resource, it has been assumed that 100 small scale turbines could be accommodated, on farms, in parks, near municipal buildings, community centres, schools or industrial estates, although there could be the potential to install significantly more. Installation of 100, 15 kW turbines would add 1.5MW to the district's renewable energy capacity and assuming a capacity factor of 10% would generate approximately 1,314 MWh annually. The contribution from 100 small scale turbines is around 26% of the energy generated by one large scale turbine, demonstrating the efficiencies of scale that can be achieved with large scale wind.

We have obtained costs from a manufacturer of small scale wind turbines. These costs are based on an installed cost of £50,000 for one 15 kW turbine and include civil works for an average site. Therefore the total cost would be around £5 Million. These results are summarised in Table 5.2.

Small Scale Wind Turbines	
Number of turbines	100
Hub Height	15 metres
Rotor Diameter	9 metres
Installed capacity	1.5 MW
Annual generation	1,314 MWh
Potential for CO_2 savings	746 tonnesCO_2
Number of homes equivalent (energy)	231

Table 5.2: Small Scale Wind Turbine potential of Hertfordshire

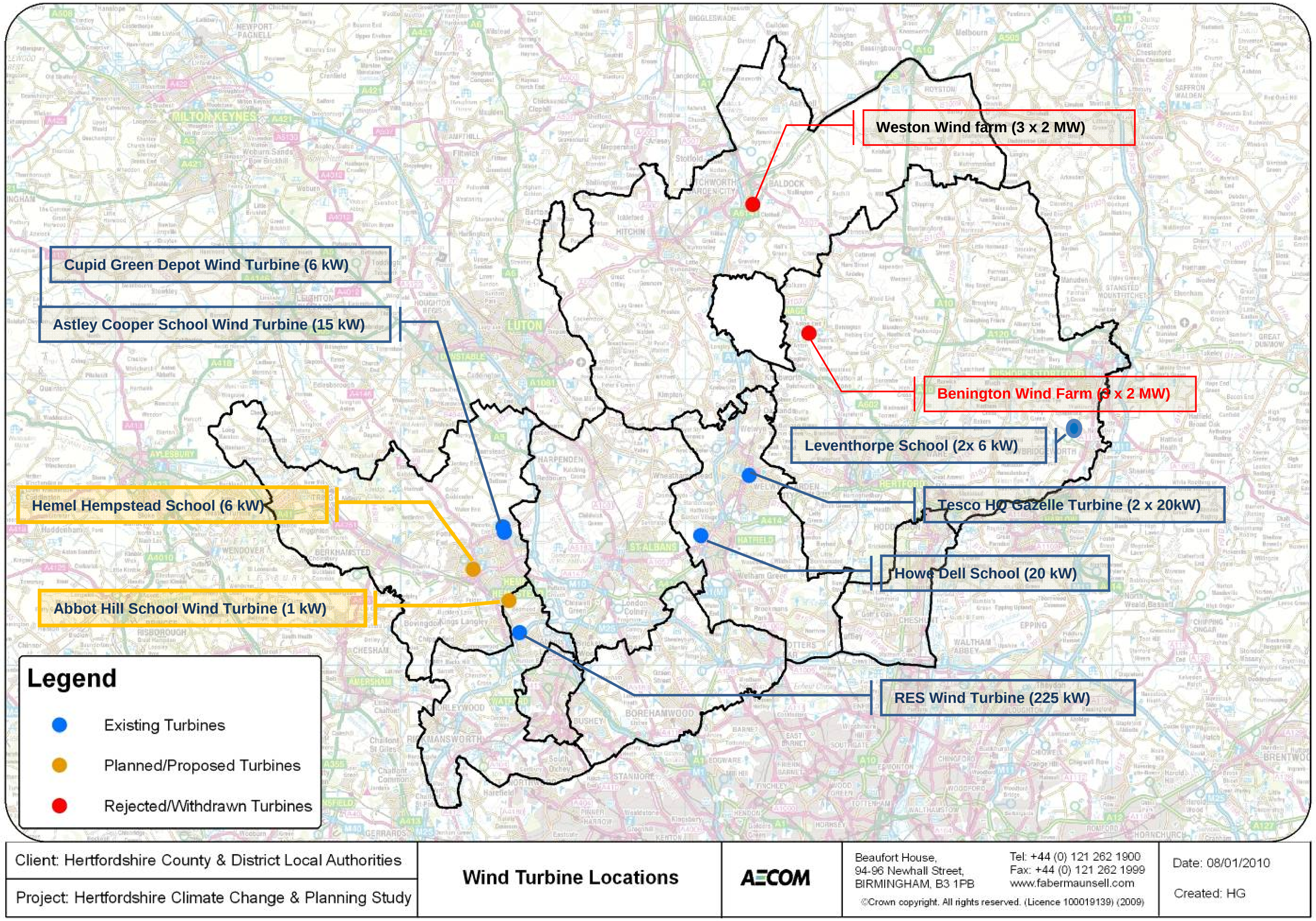


Figure 5.6: Wind turbine locations in Hertfordshire

5.4 Biomass Energy

Biomass is a collective term for all plant and animal material. It is normally considered to be a renewable fuel, as the CO_2 emitted during combustion has been (relatively) recently absorbed from the atmosphere by photosynthesis. Most CO_2 associated with the use of biomass fuels is due to the processing and transportation stages, which typically rely on grid electricity and fossil fuels. Liquid biomass fuels are not considered in this study. They are more applicable to transport sector in the form of bio-diesel and bio-ethanol and outside of the scope of this study.

5.4.1 Existing Biomass Energy Generation Sites

There are no medium to large scale existing biomass plants in Hertfordshire. A planning application has been made by Navitas Environmental for biomass plant to produce electricity. The proposed scheme will utilise 60,000 tonnes of waste wood with a production capacity of 6 MWe. The location of the proposed scheme is Appspond Lane, Potter's Crouch, St Albans.

A green waste digester in Much Hadham was permitted in June 2005 to produce bio-gas.

5.4.2 Biomass Resource

The assessment is based on the regionally available feedstock. GIS mapping exercise has been carried out to estimate the biomass resource in Hertfordshire. Natural England's agricultural land classifications have been used to assess the potential for energy crops and datasets from the Forestry Commission and Natural England have been used for wood biomass arisings. Four sources of biomass have been explored:

- Potential contribution of dedicated energy crops
- Arisings from arboriculture management
- Arisings from management of parks, highways, open spaces, green waste and waste wood. Currently these arisings are not collected in a coordinated manner.
- Contribution through wet biomass
- Industrial and municipal timber waste
- Agricultural Waste

The following areas of biomass resource have been estimated. The units are in square km. Each type of biomass brings its own set of constraints and these should be explored in detail before finalising locations.

Areas of biomass (km^2)	
Ancient Woodlands:	57
Woodland:	53
Parks:	59
Urban Areas:	234
Grade 2:	307
Grade 3:	953
Grade 4:	23
Grade 5:	0.41

Table 5.3: Biomass Resource of Hertfordshire

HCC has a large estate; The County Council controls over 10,380 acres of rural land and it is one of the largest landowners in Hertfordshire.

5.4.3 Energy Crops

The potential for energy crops has been assessed according to the availability of suitable arable land, taking into account competing land uses and typical yields. Agricultural land use classification maps[23] have been used to delineate appropriate soil types (Figure 5.7 on page 40).

The following criteria have been used to assess capacity:

- Grades 1 and 2 land have been omitted as being reserved for food production. These areas are prime quality land.
- The total energy crop potential includes use of 75% of grade 3 land and 20% of grade 4 land. These are of poorer quality and less suited to food production.
- Short rotation coppice (SRC) willow as the main energy crop. It has been assumed that 8 oven dried tonnes of willow SRC could be derived per hectare of grade 3 and 4 land.[24]

The area available for Grade 3 land was estimated to be 953 km^2 and for Grade 4 land 23 km^2. The assessment suggests that the County can generate around 1,330,000 MWh per year from energy crops enough to heat 88,000 homes and equivalent to 225,000 tonnes of CO_2 savings.

If the biomass resource was used for electricity then 95 MW electrical plant can be installed based on the available energy crops resource. With the electrical efficiency of 35% and 80% availability this would mean 233,000 MWh electrical supply (sufficient to provide electricity to 40,000 homes) and 126,500 tonnes of CO_2 savings.

[23] Dataset downloaded from MAGIC website. www.magic.gov.uk
[24] DECC Regional Renewable Energy Targets Methodology

5.4.4 Arboriculture

Locations of woodland have been mapped (Figure 5.7) and their areas were calculated. The assessment included areas of Woodlands and Forestry Commission Management areas in Hertfordshire. A realistic figure for biomass yield has been derived from these areas, using assumptions from the DECC methodology.

The total area of woodlands was found to be 57 km^2 and Forestry commission woodlands were found to be 53 km^2. In addition a new forest in North of St Albans that is being planted with the total area of 3.4 km^2 was also added to the calculation.

If all potential arisings were collected, around 22,500 oven dried tonnes would be available annually for energy generation equating to 50,111 MWh sufficient to heat approximately 3,300 homes and displacing 8,500 tonnes CO_2.

5.4.5 Parks and Highways Waste

The maintenance of parks, gardens, road and rail corridors and other green spaces gives rise to plant cuttings that can be used as fuel. Hertfordshire Council is responsible for the management of over 5,900 hectares of amenity land including parks and gardens.

To estimate the potential resource from pruning and cuttings we have used GIS mapping, and parks and gardens information from the local authorities. It was assumed that cuttings from 20% of the total area could be gathered for biomass fuel. This would provide 2,360 oven dried tonnes for annual energy generation equating to 6,600 MWh, reducing CO_2 emissions by 1,100 tonnes.

5.4.6 Wet Biomass Resource

Other sources of biomass include animal waste, such as poultry litter and manures. Potential energy generation from animal waste is based on number of animals in the County and standard energy conversion figures for anaerobic digestion [25, 26]. We have used Defra Agricultural and Horticultural Survey - England (June 2008) datasets to estimate the number of animals and the wet biomass resource in the County. According to the databases there are roughly around 407,000 poultry, 15,500 cattle and 8,000 pigs in the County.

Cattle and Pig manure is typically converted to energy through anaerobic digestion (AD) that produces bio-gas. It has been assumed that small scale AD plants can be installed within farms throughout Hertfordshire. This is because a centralised large scale plant taking manure from a number of sources would not be economically viable due to high haulage costs. In addition the energy yield from animal wastes is relatively low (due to the feedstock already being largely digested) and these schemes should be seen as a waste treatment process as

[25] Opportunities for anaerobic digester CHP systems to treat municipal and farm wastes (The Agricultural Research Institute of Northern Ireland, Science Service, DARD, 2005)
[26] Biomass Task Force Report to Government (DEFRA, October 2005)

much as an energy generation process. The relatively poor economics mean that smaller simple local schemes at farm scale are probably preferable.

Assuming all of the resource (pig and cattle manure) can be utilised to AD plants, this would be expected to generate around 21,270 MWh per year of heat (saving 3,600 tonnes of CO_2, equivalent to that emitted by 1,000 homes). On a typical farm AD plant processes 5,000cu.m of pig slurry and 10,000 tonnes of maize silage and the electrical output would be in the region of 500 kW electrical. Of this amount approximately 5% of the output would come from the manure due to the low calorific value.

Poultry litter is generally converted to electricity by way of direct combustion. There are in total more than 407,000 poultry in the County (380,000 of these are chicken - broilers and 26,000 chicken – layers). The litter would provide enough energy for a plant of around 1MW electrical capacity and around 2,700MWh of electrical generation with 1,500 tonnes of CO_2 savings (equivalent of a1,000 dwellings).

5.4.7 Agricultural Waste

According to June 2008 Agricultural and Horticultural Survey of England, Hertfordshire has 38,559 hectares of wheat and 8,647 hectares of oil seed rape fields. This resource provides a significant opportunity for energy production from agricultural biomass waste. Half of this resource is used as bedding for cattle farming. The remaining could be used for electricity production (as heat generation is not seen as a viable use of straw). The output would be 32,340 MWh electrical and the CO_2 emission savings would be approximately 18,350 tonnes.

5.4.8 Industrial and Municipal Timber Waste

Industrial waste consists of packaging waste and construction wood waste. It has been estimated that the construction and packaging waste in Hertfordshire is 46,000 tonnes and timber waste by households is about 7,150 tonnes. Assuming 50% of this is available then 108,000 MWh heating with 18,000 tonnes of CO_2 savings could be provided. If the resource is used for power generation only (not CHP) then a circa 4 MW electrical plant (based on 6,000 tonnes waste wood per MW capacity) could be installed to produce approximately 27,000 MWh electricity (assuming 20% electrical efficiency) per year (enough for around 4,700 detached homes per year).[1]

5.4.9 Transporting Biomass

It is generally accepted that sourcing biomass locally is the best environmental option as the emissions associated with biomass fuels are those of processing and transport.

However a recent technical paper which investigates biomass fuel emissions estimates that energy use due to 200 km return journey is less than 2% of the energy in biomass fuel27. Therefore energy use in transport shouldn't be a concern. However it would still be most appropriate to source locally and effects on air quality (NOx emissions), traffic and noise would need to be considered carefully together with the implications on air quality and the other effects to the neighbourhood. This is especially important for air quality management areas.

5.4.10 Financial Implications of Biomass

Forest residues, whilst abundant, are produced at a cost which varies significantly depending upon market conditions, type of plantation, size, and location. Typical production costs for a range of products is £30 - £45 per tonne, this includes £5 per tonne for transport costs for local supply. Establishment of energy crops is estimated to cost approximately £2,000/hectare (Table 5.4).

Activity	Cost Per Hectare
Ground preparation (herbicides, labour, ploughing and power harrowing)	£133
Planting (15,000 cuttings, hire of planter and team)	£1,068
Pre-emergence spraying (herbicide and labour)	£107
Year 1 management costs (cut back, herbicides, labour)	£112
Harvesting	£170
Local use (production, bale shredder, tractor and trailer)	£378
Total	£1,968

Table 5.4: Indicative costs of establishing willow SRC energy crops, exclusive of payments from grants or growing on set aside land. Costs for miscanthus SRC are expected to be broadly comparable (Source: Energy Crops, CALU and Economics of Short Rotation Coppice, Willow for Wales[28], [29])

A recent analysis of the potential income from both willow SRC and miscanthus suggested that for medium yield land (i.e. Grade 3) the average annual income would be £187 to £360 per hectare[29]. Energy crops are relatively expensive compared to some other biomass fuels but do have the potential to provide very significant volumes of fuel (Figure 5.8).

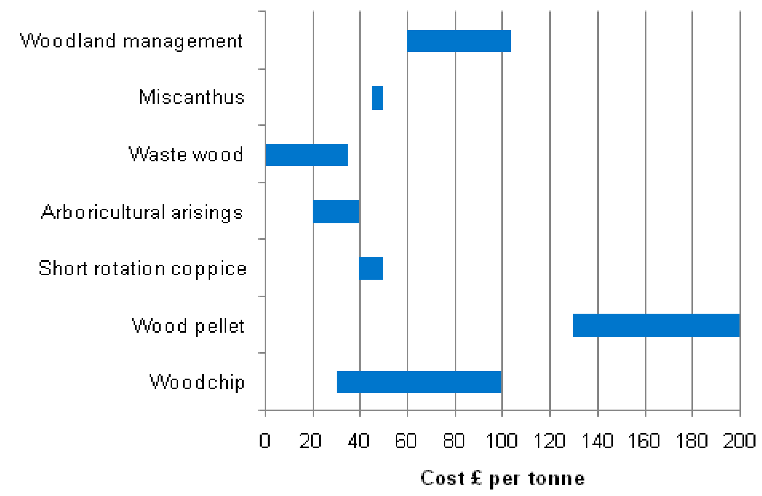


Figure 5.8: Guideline costs for different biomass fuels. (Source: Biomass heating: A practical guide for potential users)

The biomass fuel supply chain is currently in its infancy and the market conditions are extremely variable. This makes the long-term forecasting of biomass system costs extremely difficult. For example, biomass fuel, particularly waste wood, has in the past been either free of charge or attracted a gate fee (where the supplier pays the user a fee which is lower than the alternative disposal cost). However as the market for biomass increases with additional biomass electricity, heat, and CHP capacity being installed, the demand will increase and the fuel will command a higher premium. It is important for LPAs to consider the longer term potential market conditions around biomass for new developments. There is also a potential role for local authorities and Counties to assist with establishing a robust biomass supply chain to provide some degree of long term stability.

5.4.11 Summary of Biomass Resource

The total biomass resource in the County, based on this assessment, is summarised in Table 5.5 on page 41.

However this analysis is based on the data available from official – national sources and the data provided by local authorities constitutes a relatively small proportion of this resource. In general, local authority derived data is likely to be more up-to-date and accurate and so these figures should only be taken as approximate.

27 Freight Transport and Deployment of Bioenergy in the UK, Dr. David Bonilla Transport Studies Unit University of Oxford, December 2009

[28] Economics of short rotation coppice (Willow for Wales, July 2007)
[29] Energy Crops, Economics of miscanthus and SRC production (CALU, November 2006)

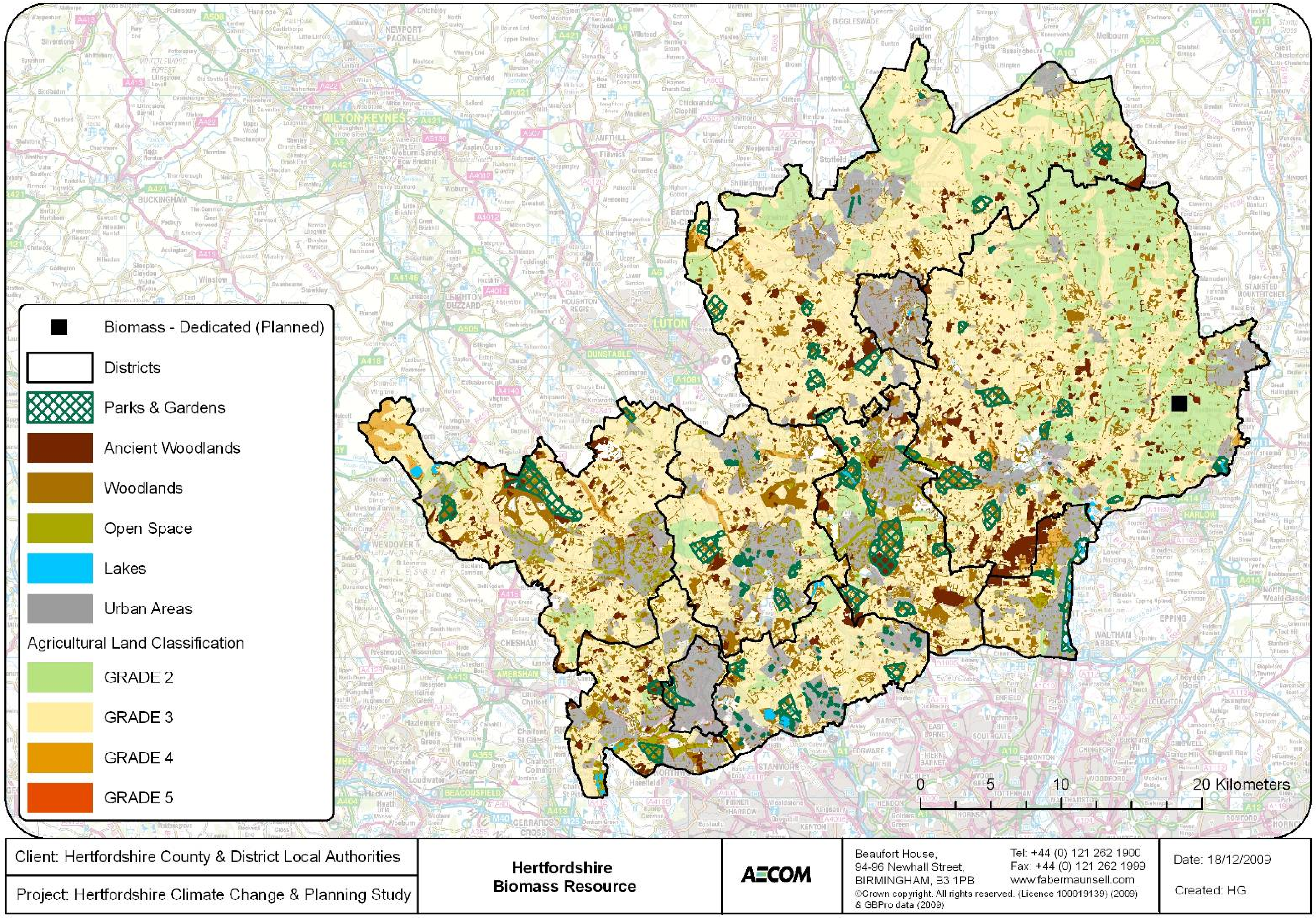


Figure 5.7: Biomass resource in Hertfordshire

Source	Recoverable Biomass	Area/Number in Hertfordshire	Useful Proportion	Useful amount	Moisture Content	Calorific Value	Annual generation	CO_2 savings	Number of homes equivalent (energy)	Number of homes equivalent (CO2)
	odt/hectare	hectares or number of animals	%	odt/tonnes	%	GJ/odt	MWh	tonnes	detached	detached
Agricultural Land Grade 3 (SRC)	8	95,300	75%	571,800	30%	13.00	1,321,599	223,350	88,106.6	62,916
Agricultural Land Grade 4 (SRC)	8	2,300	20%	3,680	30%	13.00	8,506	1,437	567.0	405
Ancient Woodland	2	5,700	100%	11,400	45%	12.50	25,335	4,281	1,689	1,206
Forestry Commission Woodland	2	5,316	100%	10,632	45%	12.50	23,629	3,993	1,575	1,125
Woodland creation - Hertfordshire Forest	2	344	75%	516	45%	12.50	1,147	193	76	55
Country Parks, Historic Parks and Gardens	2	5,900	20%	2,360	n/a	15.76	6,613	1,117		315
Household and Commercial wood waste	-	-	-	26,651	n/a	18.30	108,391	18,318	9,033	6,450
Waste from agriculture	4	23,947	100%	88,604	20%	-	32,340	18,369	2,156	5,174
Poultry (Broilers)	-	381,375	-	11,144	40%	22.00	2,485	1,411		398
Poultry (Layers)	-	25,906	-	1,113	70%	25.00	248	141		40
Cattle	0	15,506	-	188,786	88%		20,137	3,403	1,342	959
Pigs	0	8,024	-	10,657	91%		1,133	191	76	54

Table 5.5: Overview of potential biomass resource in Hertfordshire

5.5 Geothermal Energy

Geothermal energy is derived from the very high temperatures at the Earth's core and requires extraction of heat from deep wells (geothermal energy should not be confused with the extraction of low grade heat using ground source heat pumps at the earth's surface). The exploitation of geothermal resources in the UK continues to be minimal since there are only a few places where hot dry rocks are sufficiently close to the surface to make exploitation cost effective. Most of the hot dry rocks resource is concentrated in Cornwall; studies have concluded that *"generation of electrical power from hot dry rock was unlikely to be technically or commercially viable…in the UK, in the short or medium term."*[30] This technology has therefore not been considered further.

5.6 Marine Energy

There is no coastline in the County and so marine wave and tidal technologies have not been considered further.

5.7 Hydro Energy

Hydropower generates electricity from passing water (from rivers or stored in reservoirs) through turbines. The energy extracted from the water depends on the flow rate and on the vertical drop through which the water falls at the site (the head). Existing and potential hydro energy capacity in Hertfordshire was reviewed in 2005[31] . According to this study Hertfordshire does not have a significant hydro electric potential and all of potential is located at small, low-head, relatively modest flow sites. The 'Salford Study[32]' identified 12 sites within Hertfordshire for consideration. However all 12 were concluded to be uneconomical. The total maximum potential capacity of the above sites amounts to some 330kW installed capacity. In addition to these sites a map review of the County identified a number of other former mill sites, weirs and canal locks all of which will have some, all be it very small potential. It is estimated that there may be a further 100 sites or so with a capacity of between 10 and 20kW. Hence if every site with any potential was to be developed the total resource is unlikely to be significantly more than 2MW.

Although the potential is small refurbishment of the existing but currently unused weirs present a very good opportunity to explore this available resource – a good example is the small hydro electric scheme at Lemsford Mill in Welwyn Hatfield. The only proposed hydro installation is in East Hertfordshire. The Council is proposing to install a small hydro facility at the weir on the river Lea next to Castle Hall in Hertford.

Since producing the Energy Opportunities Plan, the Environment Agency has published a study of hydro power in England and Wales – *Mapping Hydropower Opportunities and Sensitivities in England and Wales – Technical Report, February 2010*[33].

[30] Sustainable Energy — without the hot air (Mackay, D.J.C, November 2008)

[31] Hertfordshire Renewable Energy Study, Renewable Energy Options for Hertfordshire, July 2005 Entec UK Limited

[32] Small Scale Hydroelectric Generation Potential in the UK, Salford University, 1989

[33] Mapping Hydopower Opportunities and Sensitivities in England and Wales, The Environment Agency, February 2010 http://www.environment-agency.gov.uk/shell/hydropowerswf.html

5.8 Waste Heat and Electricity

Heat and electricity from waste has the benefits of both reducing the waste going into landfill and producing energy from low carbon source. Existing waste to energy sites were investigated and shown in the table on the following page[34].

5.8.1 Waste Potential in Hertfordshire

Hertfordshire needs to manage all the waste produced in the County and some of London's waste. This consists of 3m tonnes of waste in total (2m of this is generated by Hertfordshire[35]) and includes municipal waste (0.5m tonnes), construction and demolition waste (1.5 m tonnes), commercial and industrial waste (1m tonnes). Measures are already in place and about 60% of the County's municipal, commercial and industrial waste is currently recovered, recycled or composted. Currently the County Council's existing contracts comprise six landfill sites of which only two are in Hertfordshire. (The other ones are in Essex; Cambridgeshire; Bedfordshire and Buckinghamshire). A small amount of the waste is disposed of in the Westmill landfill site in the County and the rest is sent to other landfill sites outside of the county. Existing waste management facilities in the County (Figure 5.8) do not have enough capacity to recover the maximum amount of waste so a number of new facilities are needed to ensure a sustainable approach to waste management. In addition there is a significant shortage of landfill sites in the County and limited potential for new sites. The main landfill site in the County (Westmill) has limited capacity and is expected to be full by 2015[36].

Latest figures suggest that approximately 44% of the municipal waste in Hertfordshire has been recycled and composted last year, (which is close to the target of recycling a minimum of 50% by 2012). The remaining municipal waste is approximately 210,000 tonnes that cannot be reused or recycled due to the absence of alternative disposal methods in Hertfordshire. A municipal solid waste treatment facility has been proposed to recover most of this waste efficiently and turn into energy; however at the time of writing this proposal is still in discussion. Hertfordshire has recently been awarded funding by Defra for this scheme. It hasn't been designed yet however technologies considered for the facility are likely to be direct combustion for electricity production. The final decision of the site has not been made yet. The site is expected to be in operation by 2015.

Based on the available municipal waste resource an analysis has been carried out to estimate the output of this scheme. It has been estimated that a 27 MW electrical steam turbine / system can be installed supplying up to 47,300 MWh electricity with the CO_2 savings of 27,000 tonnes[37]. If a CHP system is considered then the electrical output would be circa 66,000 MWh and heat output would be circa 85,000 MWh and the CO_2 savings from heat and electricity supply would be around 37,500 tonnes. The plant would be enough to supply 11,600 homes with power and 5,600 homes with heat.

If a CHP system is installed the electricity produced by the scheme can be connected to the national grid, supply demand match is unlikely to be an issue (hence distribution or storage costs are not necessary). However the viability of using waste heat depends in part on the proximity and suitability of buildings in the area for district heating. Hertfordshire should consider the plant location with a view to maximising the use of waste heat for distribution in areas of high heat density as illustrated in the heat maps. Alternatively new housing developments could be considered where excess heat supply exist to make use of this otherwise wasted resource. Therefore proximity of the aforementioned system could be examined as a potential new housing development site.

In addition to meet the targets of different types of waste, Hertfordshire's requirements include new recycling, recovery and treatment sites to handle between 230,000 and 600,000 tonnes a year of commercial and industrial wastes.

Based on a number of sources, the remaining waste resource in the County is estimated to be between 280,000 – 650,000 tonnes. Assuming most of this resource is solid waste (less and less organic waste is envisaged to be sent to landfills) and utilised as energy from waste, the electricity output would be 49,000 to 114,000 MWh and the emission savings would be 28,000 to 65,000 tonnes.

Energy from waste has a number of discharges including ash and emissions to the atmosphere. Therefore it should be tightly regulated as flue gases may contain significant amounts of particulate matter, heavy metals, dioxins, sulphur dioxide, and hydrochloric acid. However a study found that energy from waste plants emitted fewer particles, hydrocarbons and less SO2, HCl, CO and NOx than coal-fired power plants, but more than natural gas fired power plants[38]

[34] Ref: Ofgem database

[35] http://enquire.hertscc.gov.uk/qol/2008/waste08.pdf, accessed Jan 2010

[36] Hertfordshire Minerals and Waste Development Framework Consultation on Waste Development Plan Documents Summary http://www.hertsdirect.org/docs/pdf/s/wasteconsum09.pdf, accessed on December 2009

37 Assumptions are from Renewable and Low-carbon Energy Capacity Methodology, Draft Final November 2009 10 kilo tonnes of SMW required for 1 MW capacity per annum.25% plant efficiency and 80% availability

[38] Waste-to-Energy Compared to Fossil Fuels for Equal Amounts of Energy". Delaware Solid Waste Authority. Archived from the original on 26 January 2008.

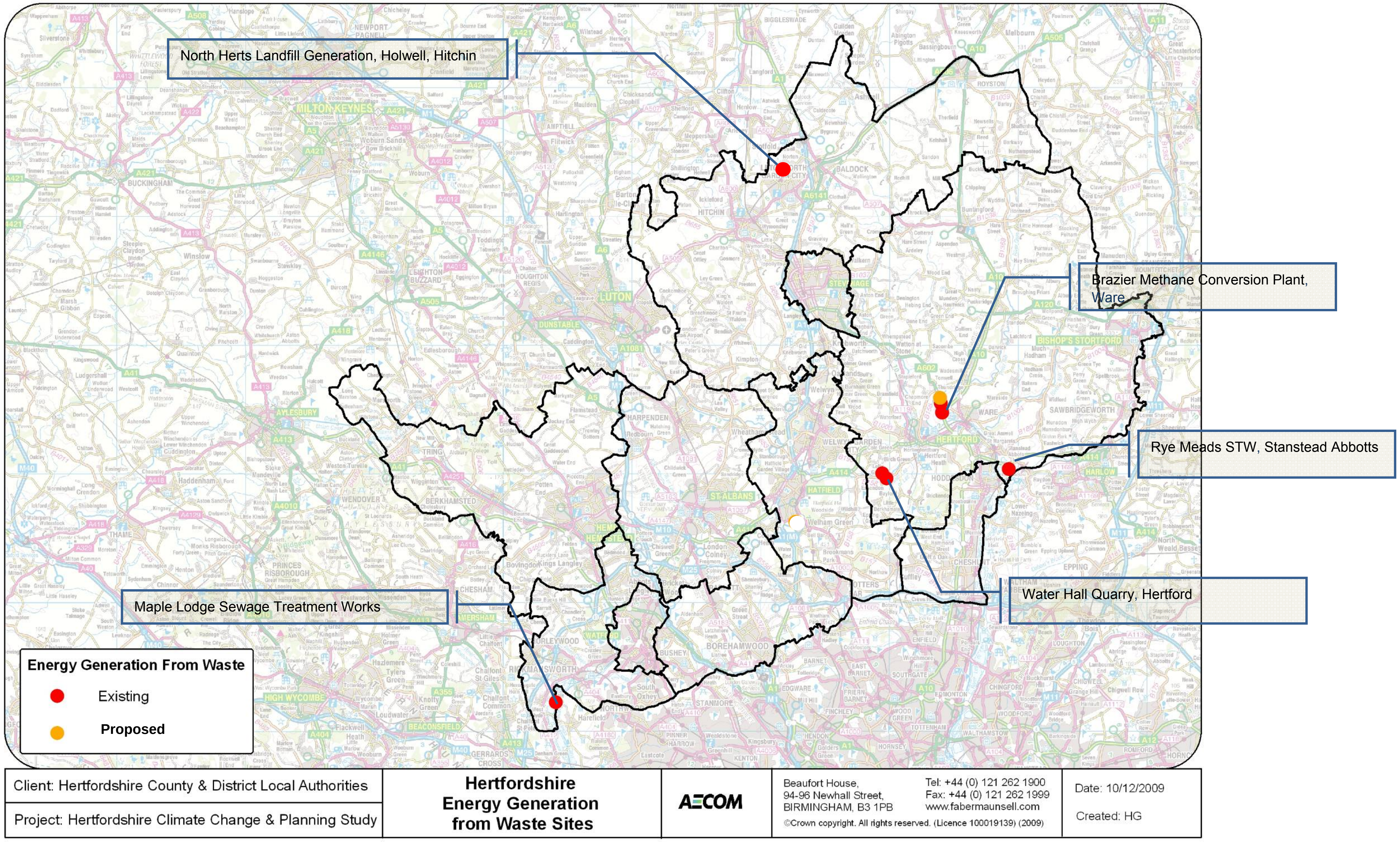


Figure 5.8: Existing and proposed energy generation from waste sites in Hertfordshire

5.9 Microgeneration Technologies

The term "microgeneration" is used to describe the array of small scale technologies, typically less than 50 kW electricity generation and 100 kW heat generation, that can be integrated as part of the development of individual sites, or retrofitted to existing buildings. These technologies tend to be less location specific and therefore have little influence on the spatial arrangement of sites.

Combinations of technologies can be applied but it is important to note that some combinations can lead to competition between systems and therefore sub-optimal performance, which will affect both output and maintenance. Generally, conflict occurs where multiple technologies are competing to provide heat, as opposed to electricity which can be exported if excess is generated.

The impact of competition can be avoided through appropriate sizing and design of the systems. For example, two heat supplying technologies could work effectively together if one is sized to meet the annual hot water demand while the other is sized and operated to meet only the winter space heating demands. Figure 5.9 shows potential combinations of high conflict (red), no conflict (green) and conflicts that can be avoided through appropriate design (yellow).

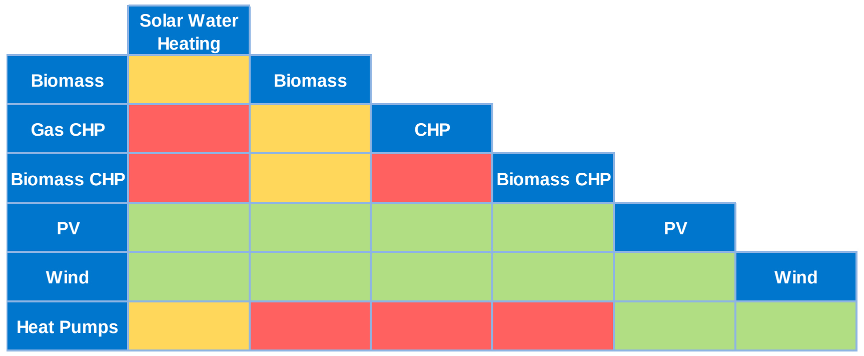


Figure 5.9 Potential conflicts between microgeneration technologies

Feed-in-tariff's (FIT) in the UK came into force in April 2010[39] for installations not exceeding 5 MW[40]. The following low-carbon technologies are eligible:

- Anaerobic Digestion
- Hydro
- Micro CHP (pilot trails)
- PV
- Wind

For further information on FITs please refer to Appendix D.

[39] Green feed-in tariff needs to maximise solar power (Guardian website http://www.guardian.co.uk/environment/2009/may/14/feed-in-tariff-solar-power, accessed August 2009)
[40] Energy Act 2008 Section 41.4.b

5.10 Solar Energy

The two main solar microgeneration technologies currently in use are solar photovoltaics (PV) and solar water heating. The solar resource, in terms of annual irradiation per year, is similar across much of the UK, with Hertfordshire in southern part of the country at the higher end of the solar spectrum (Figure 5.10). Table 5.5 shows the potential for CO_2 savings from solar energy technologies.

Figure 5.11 shows how the output of solar systems varies by orientation and tilt of the installation. Panels should be mounted in a south-east to south-west facing location. The optimum angle for mounting panels is between 30º and 40º, although this is often dictated by the angle of the roof. Careful consideration should be given to placing the systems so that they are not over shaded by adjacent buildings, structures, trees or roof furniture such as chimneys.

Solar PV panels use semi-conducting cells to convert sunlight into electricity. The output is determined by the brightness of natural light available (although panels will still produce electricity even in cloudy conditions) and by the area and efficiency of the panels. PV is expensive in comparison to other renewable energy options, but is one of the few options available for renewable electricity production and is often one of the only on-site solutions to mitigate CO_2 reductions associated with electricity use. In addition initiation of feed in tariff is estimated to make this technology significantly more attractive solution financially. A feed-in tariff is a mechanism for encouraging investment in renewable generation. It is essentially a premium rate paid for clean generation, e.g. from solar panels or small wind turbines, and guaranteed for a long time period. Currently the tariff for PV is between 29 – 41 pence per kWh electricity production depending on the size of the system. Initial analyses suggest that this would have a significant impact on the finances of PV reducing the payback period to 12-15 years down from 60 years. Therefore it is anticipated that the deployment of this technology may be accelerated in the near future.

Solar water heating panels are used primarily to provide hot water. Output is constrained by the amount of sunlight available, panel efficiency and panel area. Devices are most cost effective when sized to meet 50-70% of average hot water requirements, which avoids wasting heat in the summer. It should be noted that solar water heating supplements and does not replace existing heating systems.

There are two standard types of solar water heating collectors: flat plate and evacuated tube collectors. Historically, flat plate collectors have dominated due to their lower cost per unit of energy saved. However, recent advances in evacuated tube collector design have achieved near parity in terms of cost per kgCO_2 saved. Generally, evacuated tubes are more expensive to manufacture and therefore purchase, but achieve higher efficiencies and are more flexible in terms of the locations they can be used (Table 5.5).

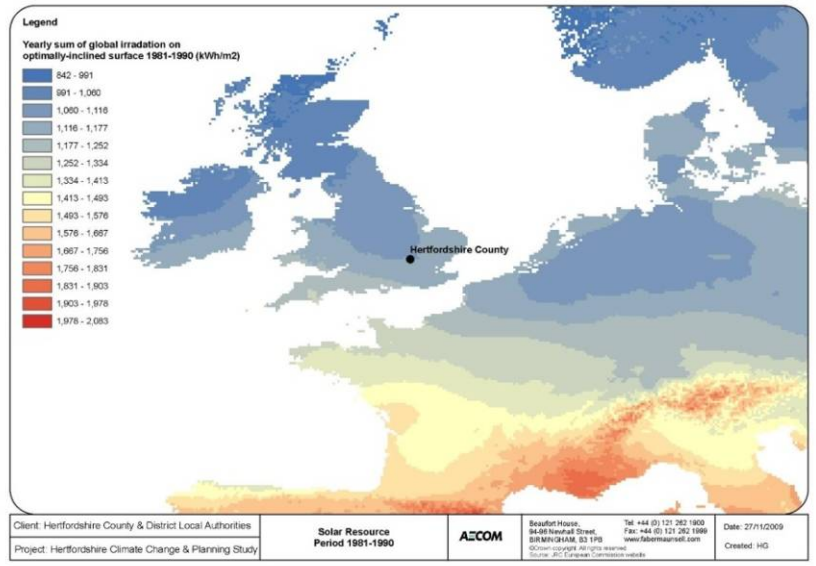


Figure 5.10: Solar Resource in Hertfordshire (Source: Photovoltaic Geographical Information System (PVGIS), JRC European Commission)[41]

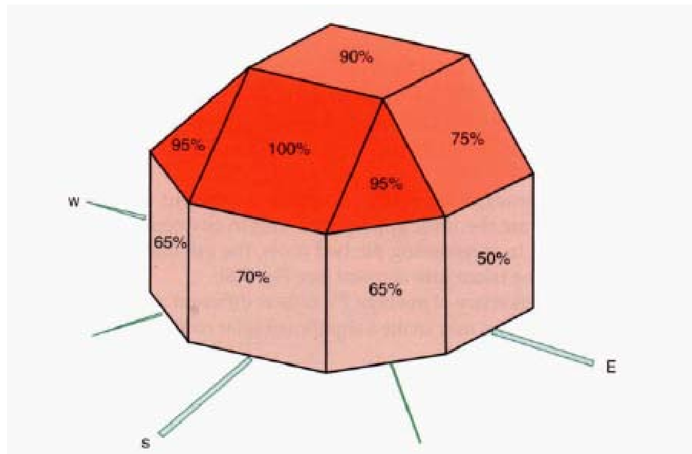


Figure 5.11: Optimum orientation for solar panels in the UK (Source: Sustainability at the Cutting Edge) [42]

[41] Photovoltaic Geographical Information System (PVGIS) (JRC Commission website, accessed October 2009)
[42] Sustainability at the Cutting Edge (Smith , F, 2007)

Technology	Solar Hot Water	Solar Photovoltaics (PV)
Approximate size required	~4 m^2 per dwelling	~8 m^2 per dwelling
Total cost of system	£2,500 for new build homes (2 kW system) £5,000 for existing homes (2.8 kW system) £1,000/kW for new build non-domestic £1,600/kW for existing non-domestic	£5,500 for new build homes (1 kWp system) £6,000 for existing homes (1 kWp system) £4,500/kW for new build non-domestic £5,000/kW for existing non-domestic
Annual Generation Potential	396 kWh/m^2 for flat plates 520 kWh/m^2 for evacuated tubes	850 kWh/m^2 for high performing systems
Potential for CO_2 savings	13% of total emissions for existing homes 23% of total emissions for new build homes	26% of total emissions for existing homes 38% of total emissions for new build homes

Table 5.5: Potential CO_2 savings for solar energy technologies. Buildings are assumed to have good practice energy efficiency (Hertfordshire Energy Model, AECOM)

5.11 Heat Pumps

Heat pumps are low carbon rather than renewable devices since they require electricity to run which is partially derived from fossil fuels. They can provide significant CO_2 savings in comparison to standard electrical heating systems, since they require around a third less electricity. However, due to the carbon intensity of the grid, CO_2 emissions from heat pumps are similar to those of an efficient gas heating system. As electricity is currently around four times more expensive than gas, running costs are also comparable with, and often higher than an equivalent gas system.

Heat pumps are primarily space-heating devices and the best efficiencies are achieved by running systems at low temperatures. For this reason, they are ideally suited for use in conjunction with under floor or air-based heating systems.

This creates a significant challenge for heat pumps installed in future homes, where hot water demands are likely to be comparable to the (reduced) space heating requirements. Due to the higher temperature requirements of hot water, the coefficient of performance (CoP – effectively the efficiency) of heat pumps reduces and so where the hot water is a significant fraction of the overall heating demand, the overall efficiency can be relatively poor. In such cases, heat pumps might be well be complemented by other microgeneration systems that are sized in relation to domestic hot water requirements, for instance, solar hot water systems.

The performance of ground source heat pumps is linked to the average ground temperature, while air source heat pump performance is influenced by the average air temperature. Table 5.6 shows the potential carbon savings from installing a heat pump to a new or existing building. The high cost of ground works for ground source heat pumps means that air source heat pumps are around half the installed cost, albeit with a lower efficiency. For air source heat pumps, retrofit costs are slightly higher than new build to allow for increases in plumbing and electrical work. For ground source heat pumps, the cost for retrofit is higher to allow for modifications to existing plumbing and removal of existing heating system, plus ground works costs when digging up an established garden.

There is a wide variation in costs for ground source heat pumps at the 20-100kW scale, principally due to differences in the cost of the ground works. The cost of the heat pumps themselves is also dependent on size as commercial systems are usually made up of multiple smaller units rather than a single heat pump. Due to these variations, heat pumps in the 20-100kW range are shown with an indicative cost of £1,000 per kW installed.

Technology	Air Source Heat Pump	Ground Source Heat Pump
Approximate size required	5 kW	5kW trench system for new build 11kW trench system for existing
Total cost of system	£5,000 for new build £7,000 for existing £500/kW for non domestic	£8,000 for new build £12,000 for existing £1,000/kW for non domestic
Potential for CO_2 savings	5% of total emissions for existing homes 0.25% of total emissions for new build homes	12% of total emissions for existing homes 8% of total emissions for new build homes

Table 5.6: CO_2 saving potential of heat pumps (based on 2007 costs) a borehole ground source heat pump system is more costly due to a high drilling cost of £30 per metre. A typical 70m borehole provides 3-5kW of heat output, giving a drilling cost of £4200 for an 8kW system (Source: The Growth Potential for Microgeneration in England, Wales and Scotland (Element Energy for BERR) [43]

5.12 Biomass Heating

Biomass heating is generally more suited to areas which are less urban, where land is available for fuel storage, and there is adequate access for fuel delivery vehicles. The most common application is as one or more boilers in a sequenced (multi-boiler) installation where there is a communal i.e. a block of flats or district heating system.

There is significant potential for small scale biomass heating in the district. Most of the local authorities have the potential of Grade 3 Agricultural resource, and woodlands (both ancient and forestry commission woodlands) are spread out across the County. There would be particular benefit in encouraging biomass in areas where district heating is feasible or where off –gas grid houses occur in rural areas. The rural areas are also likely to have better access to local biomass fuel. There are some Air Quality Management Areas designated in Hertfordshire, therefore care needs to be taken if biomass heat to be introduced in near the Air Quality Management Areas (although these do not necessarily preclude the use of biomass boilers).

Table 5.7 shows the CO_2 savings potential of biomass boilers. Existing building costs are considerably higher than new build costs due to the extra building and plumbing work. Costs are generally installation based and not size variable; this is because the actual boiler makes up a small proportion of the overall cost (Figure 5.12).

Technology	Small Scale Biomass Boiler
Approximate size required	8.8 kW for homes
Capital cost of system	£9,000 for new build homes £11,000 for existing homes
Potential for CO_2 savings	34% of total emissions for existing homes 33% of total emissions for new build homes

Table 5.7 CO_2 savings from biomass technologies

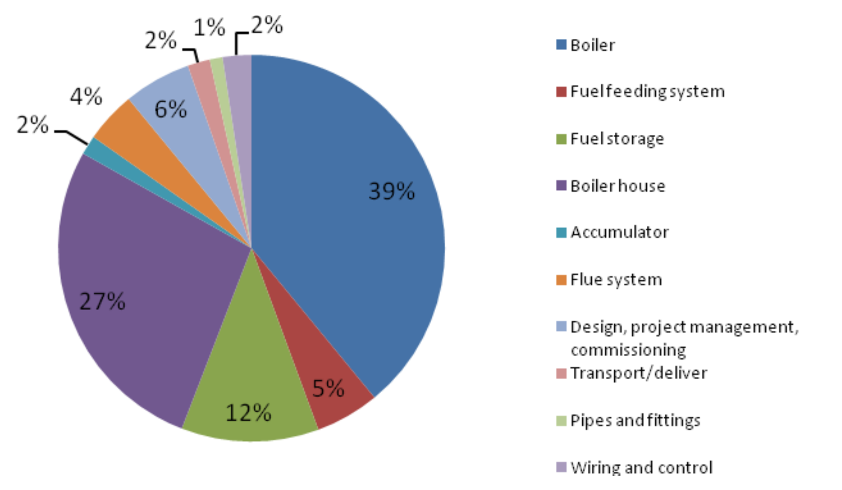


Figure 5.12: Capital cost/kW breakdown for example biomass heating project, based on a recently designed project of 500 kW capacity. The total system cost was £187,000. (Source: Biomass heating: A practical guide for potential users) [44]

[43] The Growth Potential for Microgeneration in England, Wales and Scotland (Element Energy for BERR, June 2008)

[44] Biomass heating A practical guide for potential users (Carbon Trust, January 2009)

5.13 Building Mounted Wind turbines

Over the last few years, a number of companies have started to market wind turbines designed specifically for building mounted applications. However, early feedback suggests that building mounted turbines located in urban areas suffer from lower and much more disrupted wind speeds (due to turbulence around buildings) than larger turbines mounted in open sites and this has a significant impact on their energy generation potential.[45] There is limited data on energy generation from building mounted wind turbines in urban locations but early examples appear to have generated significantly less than was predicted by manufacturers (in many cases only around 10% of the predicted output or even less). Even with reductions in turbine costs which may happen in the future, this level of operation is not economic or desirable and micro-wind turbines should only be located in areas where there is likely to be a suitable wind resource. Due to low costs associated with small capacities, a detailed resource / viability study will not be economic for each application, and so rules of thumb will need to be employed based on best practice.

AECOM are following the progress of monitoring studies and intend to include small scale wind turbines in their renewable feasibility assessments when performance data is available to make accurate estimates of likely performance. An assessment of their potential for CO_2 reduction has been excluded from this study.

5.14 Fuel Cells

Fuel cells CHP is an emerging technology and currently at a pre-commercial stage. Fuel cells are similar to batteries in that they produce electricity from a chemical reaction. However, whereas a battery delivers power from a finite amount of stored energy, fuel cells can operate indefinitely provided that a fuel source is continuously supplied; for current fuel cell CHP systems, this is currently natural gas, although the end aim is to operate fuel cells from renewably generated hydrogen.

There is debate as to whether electricity generation from fuel cells via hydrogen is better than generating electricity directly from renewable sources such as PV and wind. This is due to the inefficiencies in producing hydrogen, and then converting back into electricity, versus direct electricity generation. However a key advantage is the opportunity to store renewable electricity in the form of hydrogen, which can then be used to provide electricity on demands.

The capital cost of fuel cells is currently much higher than most other competing micro-generation technologies. Commercial large scale CHP fuel cells currently available cost approximately £3,000/kW. Fuel cell prices are expected to drop to £500-£1500/kW in the next decade with further advancements and increased manufacturing volumes.

[45] Micro-wind turbines in urban environments: an assessment (BRE, 2007)

5.15 Key Considerations Emerging from this Chapter

Key considerations emerging from the assessment of renewable and low carbon energy resources are:

- Hertfordshire has resource potential for large scale wind turbines across 83 km^2. If less than 10% of this were used, it could provide 74MW of installed capacity, comprising around 37 large turbines. This would generate 150,000 MWh annually, saving nearly 85,000 tonnes CO_2. This is equivalent to that emitted by over 26,000 typical detached homes, well over the total number of dwellings in the County including new development. If areas classed as constrained are available to additional capacity based on site analysis, then this potential could be greatly increased.
- Smaller scale turbines of around 15m to 45m tip height could be an opportunity in most areas of the County. Smaller turbines have a significantly reduced visual impact and would be particularly suited to farms, industrial sites and municipal buildings such as community centres or schools. Installation of 100, 15 kW turbines would add 1.5MW to the County's capacity and assuming a capacity factor of 10% would generate around 1,314 MWh annually.
- The County can generate around 1,330,000 MWh per year from energy crops on grade 3 and 4 land. This is equivalent to 225,000 tonnes CO_2, or carbon emitted from around 88,000 typical detached homes
- Potential annual arboriculture arisings are around 22,500 oven dried tonnes, equating to 50,000 MWh and displacing 8,500 tonnesCO_2 annually (equivalent to that emitted by 5,500 typical detached homes).
- Parks and highways waste from 20% of the total area would provide 2,360 oven dried tonnes annually, equating to 6,600 MWh and reducing CO_2 emissions by 1,100 tonnes.
- Cattle and Pig manure could be converted to energy through anaerobic digestion (AD) that produces bio-gas. This would be expected to generate around 21,270 MWh per year of heat (saving 3,600 tonnes of CO_2, equivalent to that emitted by 1,000 homes).
- Poultry litter could provide around 1MW electrical capacity and around 2,700MWh of electrical generation with 1,500 tonnes of CO_2 savings (equivalent of a 1,000 dwellings).
- Packaging waste and construction wood waste has been estimated to provide 135,000 MWh heating with 23,000 tonnes of CO_2 savings.
- Municipal solid waste has been estimated to feed into a 27 MW electrical steam turbine / system supplying up to 47,300 MWh electricity with the CO_2 savings of 27,000 tonnes. If a CHP system is considered then the electrical output would be 66,000 and heat output would be 85,000 MWh and the CO_2 savings from heat and electricity supply would be around 37,500 tonnes. The plant would be enough to supply 11,600 homes with power and 5,600 homes with heat.
- Energy crops are relatively expensive compared to some other biomass fuels but do have the potential to provide very significant volumes of fuel.
- No resource for geothermal, marine wave and tidal and very little resource for large-scale hydro have been identified.
- Hertfordshire has potential to exploit a range of microgeneration technologies, including:
    - solar thermal and PV
    - Heat pumps (air and ground sourced) may be suited to areas not served by gas and where under floor heating is possible
    - Biomass heaters are ideal in lower density areas for individual buildings and where district heating is feasible in higher density areas.
    - There is limited data on energy generation from building mounted wind turbines in urban locations but early examples appear to have generated significantly less than was predicted by manufacturers and installations should carefully consider local topography.
    - Fuel cells can be used as CHP systems in buildings but are considered to be an emerging technology and currently the costs are high.