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EXECUTIVE SUMMARY

This renewable energy study for Worcestershire examines the potential for large-scale renewables in Worcestershire. The report estimates the potential for large biomass, wind and hydro capacity in the County.

Three scenarios were developed, with each scenario becoming increasingly optimistic in terms of the potential for the resource to be utilised and sites to be developed. Table 1 below presents the results of the assessment for the three scenarios for each District in the County.

Scenario 1 (Low) is a business as usual approach assuming only some of the potential is developed.

Scenario 2 (Medium) assumes a realistic approach to development and suggests certain sites that might potentially be developed (however, this is no guarantee).

Scenario 3 (High) is the theoretical maximum and assumes all wind and hydro sites identified as potentials in the region are developed and the total biomass resource identified in the study is developed. In reality Scenario 3 is unlikely to be achievable as there are so many influencing factors that govern the viability of renewable energy projects.

Table 1 Total estimated large scale renewable generation from biomass, wind and hydro power (assuming 60% biomass resource is used for heat and 40% is used for electricity).

District	Scenario 1		Scenario 2		Scenario 3	
	MW	MWh	MW	MWh	MW	MWh
Bromsgrove	1	7006	14	40910	23	72336
Malvern Hills	8	41078	14	72031	27	150306
Redditch	0	0	0	0	0	0
Worcester	1	3369	1	3369	1	3369
Wychavon	47	130877	73	213592	80	302222
Wyre Forest	5	17820	7	25511	9	42700
Totals	**62**	**200149**	**109**	**355413**	**140**	**570932**
Approximate no. of houses that total energy could supply	**N/A**	**8693**	**N/A**	**15436**	**N/A**	**24796**

Worcestershire, relative to other UK Counties, is limited in its renewable energy resources. The most significant resource in terms of electrical generation is from wind power with 181 223 MWh potential generation. Compared to other counties in the UK, Worcestershire's wind resource is relatively low, although there are localised areas of reasonable wind resource.

Biomass as a potential resource is extremely complex and difficult to calculate due to an unlimited number of scenarios which can be considered, ranging from the estimation of areas used for cultivation, through to the effect of future crop prices and subsidies. Notwithstanding this, assumptions indicate that biomass is able to provide up to 78 582 MWh potential generation (Scenario 2) if solely used for electrical generation. In reality biomass will be used for both electrical and heat generation in a potential mix of large scale generation plant, smaller generation plant, CHP systems, through to providing just thermal energy in boilers.

As might be expected hydro power has the least potential with an estimate of only 14 909 MWh due to the limited potential resource in the County.

The overall potential for renewable generation (in the realistic Scenario 2) is estimated as 355 413 MWh. This equates to approximately 3.7% of current (2006) energy demand and 3.5% of an estimated energy demand in 2020.

Using the realistic resources identified, Worcestershire will be unable to achieve its share of the Government target of 15% of energy usage to come from renewable generation, simply because the resource is not available within Worcestershire. Even if a dramatic reduction in energy usage were possible, the target would remain unattainable. However, Worcestershire can contribute to the renewables targets and could realistically aim for 3.5% of total energy (electrical and thermal) usage for the County by 2026. Though this does not appear as bold as Government or Regional targets, this is still considerably challenging for Worcestershire and would require a strong supportive policy framework. Currently there are limited policies within Worcestershire to stimulate large scale renewable energy generation.

IT Power therefore recommends that the results for Scenario 2 be adopted as targets for renewable energy development by 2026. In order to achieve this potential and meet the targets, a series of recommendations have been made for encouraging appropriate large-scale renewable energy development

- Consider staged targets for renewable energy (and monitor progress)
- Training for development control planners
- Criteria for community involvement and/or ownership and benefits
- Exemplar projects

GLOSSARY

Anaerobic Digestion (AD): is the process whereby bacteria break down organic material in the absence of air, yielding a biogas containing methane.

Areas of Outstanding Natural Beauty (AONB): AONBs are fine landscapes, of great variety in character and extent. The criteria for designation is their outstanding natural beauty.

Biomass: is biological material derived from living or recently living organisms which can be converted into fuel for electricity, heating or transport.

Combined Heat and Power (CHP): Combined heat and power utilises the waste heat from thermal power generators for either heating or other process such as absorption chilling or industrial process. This improves the energy efficiency from around 37% to over 70%. Biomass CHP plants are typically in the region of 50 kW and above although micro systems for domestic use are possible. A CHP unit typically produces 40% electricity and 60% heat i.e. a 100 kW biomass system would refer to 40 kWe and 60 kWt.

Cut-in wind speed: The wind speed at which a turbine starts to generate electricity typically 2.5 – 3.5 m/s

Energy demand: Rate at which electricity is delivered averaged over a specified time.

Head (hydro-power): Hydropower harnesses the potential energy in water as it moves from a high to a low point. The distance from the high to low point is referred to, as the head and is typically measured in metres.

Miscanthus: A wood perennial that can be burned to generate energy. Originating from Asia, it has the potential for very high rates of growth. Miscanthus is planted in the spring and once planted can remain in the ground for at least 15 to 20 years reaching up to 3.5m in height.

MW (Megawatt): A unit of power, represents one million watts of power.

MWh (Megawatt hour): A megawatt hour, is a million watts (1 000 000 Watts) of power expended in 1 hour. The concept of watt-hour is a convenient unit for electrical bills because the energy usage of a typical electrical customer in one month is several hundred kilowatt hours. Megawatt hours are used for metering larger amounts of electrical energy. Average annual power production or consumption can be expressed in megawatt hours per year.

NOABL database: National Oceanic and Atmospheric Administration (NOAA) Boundary Layer wind speed database developed by ETSU for the DTI (Department of Trade and Industry) in 1997. The NOABL database provides an estimated wind speed for a 1 km square at 10 m, 25 m and 45 m above ground level.

Sites of Special Scientific Interest (SSSI): These are nationally-important sites which are important due to their flora, fauna or geology.

Special Areas of Conservation (SAC): SACs are areas which have been given special protection under the European Union's Habitats Directive. They provide increased protection to a variety of wild animals, plants and habitats and are a vital part of global efforts to conserve the world's biodiversity.

Short Rotation Coppice (SRC): Consists of densely planted, high yielding varieties of poplar or willow that can be harvested and burned to generate energy. SRC can be established on a wide variety of soil types from heavy clay to sand.

Triticale: A hybrid of wheat which has high yield potential as well as good disease and environmental tolerance which could be grown in rotation with other crops. Triticale is widely grown in Eastern Europe for energy purposes and can yield up to 18 tonnes per hectare.

TWh (Terrawatt Hour): Terawatt hour, is a 1 000 000 000 Watts of power expended in 1 hour.

ABBREVIATIONS

AD	Anaerobic Digestion
AONB	Area of Outstanding Natural Beauty
BWEA	British Wind Energy Association
CHP	Combined Heat and Power
DEFRA	Department for Agriculture Food and Rural Affairs
DNO	Distribution Network Operator
kWh	Kilowatt Hour
kWe	Kilowatt Electrical Energy
kWt	Kilowatt Thermal Energy
GWh	Giga Watt Hour
MW	Megawatt
MWe	Megawatt Electrical Energy
MWt	Megawatt Thermal Energy
odt	Oven Dried Tonnes
OFGEM	Office For Gas and Electricity Markets
PPG	Planning Policy Guidance note
PPS	Planning Policy Statement
ROC	Renewables Obligation Certificate
SAC	Special Areas of Conservation
SPA	Special Protection Areas
SRC	Short Rotation Coppice
SSSI	Sites of Special Scientific Interest
TWh	Terrawatt Hour

1 INTRODUCTION

Background

1.1. The purpose of this Renewable Energy Study is to provide evidence to inform Worcestershire County Council on the potential for large-scale renewable generation in Worcestershire.

1.2. The Planning Policy Statement: Planning and Climate Change[1] states that "Planning authorities should have an evidence based understanding of the local feasibility and potential for renewable and low carbon technologies". It is accepted that at present a detailed and up to date assessment of Worcestershire's resources and potential for renewable energy does not exist. This presents difficulties in being able to fully exploit the available natural resources and thus comply with regional and national targets.

1.3. The present study aims to fill this information gap by providing a rigorous, evidence-based assessment of the renewable energy potential in Worcestershire, as stated in the Draft Practice Guidance[2] which accompanies PPS1: Climate Change, which calls for the 'Collection of baseline data on capacity and constraints on energy supply and to review the capacity for large scale technologies'.

Policy Drivers

1.4. Alongside the above policy drivers, the Energy White Paper (2007)[3] provides national energy targets for the amount of CO_2 emissions reductions and electricity generation from renewable sources. A target of 60% reduction in CO_2 emissions by 2050 and 10% of UK electricity supplied by renewables by 2010 has been set.

1.5. Further to this an intermediate target of 15.4% has been set for 2015/16 at an estimated increase of 1% a year from 2010. The UK has also recently signed up to the EU target of achieving 20% of its total energy use from renewable means by 2020. This includes energy from electricity, heat and transport. The UK's own commitment under this agreement is 15% of total energy use. To achieve this target the UK will need an exponential increase in renewable electricity generation if the 2015 target is achieved. An indication of the commitment to renewable electricity is the reform of the Renewables Obligation, which is being extended and expanded to help facilitate the 2015 target.

1.6. At present the government has not indicated an action plan for achieving the total energy target of 15% by 2020[4]. It is likely there will be continuing and strong policy support for renewable energy to achieve 2020 targets, all of which fare well for investment and early planning for renewables.

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1 Department for Communities and Local Government (December 2007): Planning Policy Statement: Planning and Climate Change - Supplement to Planning Policy Statement http://www.communities.gov.uk/publications/planningandbuilding/ppsclimatechange

2 ERM (March 2008): Working Draft of Practice Guidance to Support Planning Policy Statement: Planning and Climate Change

3 Energy white paper: meeting the energy challenge available at http://www.berr.gov.uk/whatwedo/energy/whitepaper/page39534.html

4 Department for Business Enterprise and Regulatory Reform (BERR) (June 2008): UK Renewable Energy Strategy Consultation. http://renewableconsultation.berr.gov.uk/consultation/consultation_summary

1.7. Similarly, there will be impetus on increasing the amount of heat generated from renewable energy and increasing bio fuels for transport, both of which have been encouraged within Worcestershire.

1.8. The West Midlands Regional Energy Strategy[5] also includes a target across the West Midlands of 5% of electricity consumption from renewable generation, rising to 10% by 2020. At a County level, the Worcestershire Local Strategic Partnership has an agreed priority within both the Sustainable Community Strategy 2008-2013 and the Local Area Agreement 2008-2011, to 'Increase energy efficiency and increase the proportion of energy generated from renewable sources'.

1.9. The present study focuses on an assessment of which renewable energy options can be best exploited in Worcestershire, concentrating on wood fuel, energy crops, anaerobic digestion, wind and hydro.

Scope

1.10. The aim of the renewable energy resource assessment for Worcestershire County Council was to establish the realistic potential of large scale renewable generation in the County. The project focuses on wind, biomass and hydro in the County. 'Large-scale' for the purposes of this study is potential sites for wind turbines greater than 250 kW, biomass plants greater than 500kWe and 45kWt and hydro plants greater than 50 kWe. Micro-generation and generators below these capacities are not included as part of the study.

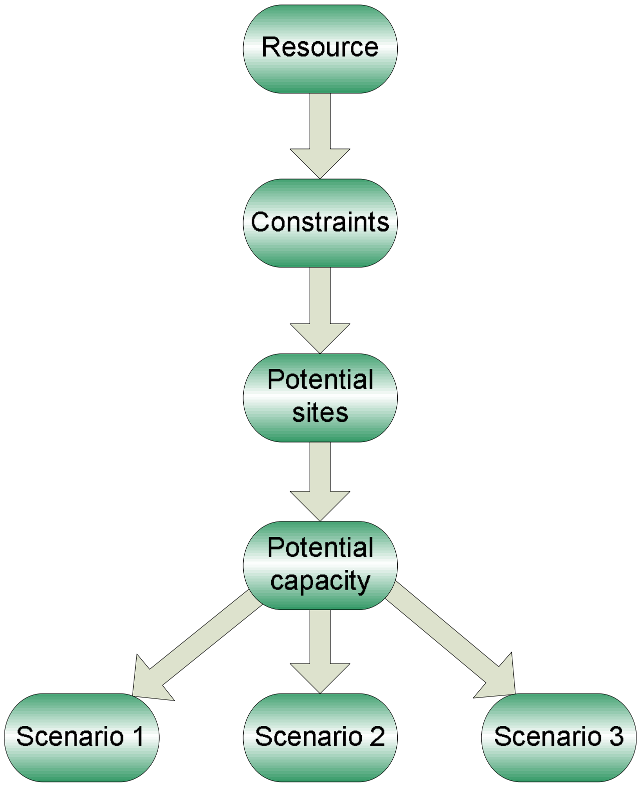
2 METHODOLOGY

2.1. The methodology undertaken by IT Power followed the following steps (Figure 1):

- Assessment of the total theoretical resource i.e. how much potential biomass is there in Worcestershire, are wind speeds sufficient and is there sufficient vertical drop and flow for hydro development.
- Identification and assessment of the constraints which prevent or hinder potential renewable energy development e.g. proximity to dwellings, transportation links etc.
- Identification of potential sites and areas that could be considered for development.
- Assessment of the economic renewable energy potential under the current and expected future commercial and regulatory regimes e.g. support provided by the Renewables Obligation, etc.
- Establishment of the potential capacity, taking into account the above issues PLUS local planning, environmental, and amenity issues.
- Presentation of the potential capacity in three scenarios.

[5] West Midlands Regional Assembly, et al (November 2004): West Midlands Regional Energy Strategy.

Figure 1 Methodology



2.2. The first step was to examine the potential resource for biomass, hydro and wind in Worcestershire. Each of these three sources were examined in-depth. The process involved consultation with interested parties and key organisations in the gathering of information on potential biomass, hydro and wind in the region. Having established the potential resource, potential constraints to site development were then identified.

2.3. The potential capacity of renewable energy generation in Worcestershire i.e. how much could potentially be installed was established and presented in megawatts (MW). This capacity considered both thermal and electrical capacity. There is significant potential for variation in identifying a potential renewable energy capacity for Worcestershire. This is due to a multitude of varying factors which can affect the potential development of renewable energy generators.

2.4. To assist in giving an indication of what is viable, a scenario-based approach has been adopted which reports varying potential capacity in Worcestershire. The aim of the scenario-based approach is to highlight the varying nature of such capacity values and give a capacity range in the region. The scenarios established are presented below:

Scenario 1 considers a conservative approach and assumes that only sites which present few substantial barriers to development will be constructed. There is assumed to be no change in current policy towards renewable energy development.

Scenario 2 offers a pragmatic approach to the development of renewables and assumes favourable planning and economic circumstances that would encourage development.

Scenario 3 is the most optimistic scenario and assumes that there are no barriers to the development of the sites identified and that all the resource will be utilised. The reality is that Scenario 3 is highly unlikely to be achieved as there are so many influencing factors as discussed under each technology.

It must be noted that identification of sites within this study does not suggest that they are being considered for development or that they will be developed. They have been identified using theoretical constraints. The methodology is not exhaustive and it is possible that developers may identify other potential sites not highlighted within this study.

3 BIOMASS

3.1. Biomass is derived from plant material and animal wastes and for the purposes of this study biomass excludes landfill and biofuels. It can be used to generate electricity, heat and fuel for transport. Biomass resources already represent just under 82% of UK renewable energy supply[6], and some predict that biomass will meet the majority of the 20% renewable energy target required by 2020. The UK Biomass Strategy estimates the potential future biomass resource in the UK to be approximately 96.2 TWh, if biomass supplies are expanded in the ways recommended in the strategy[7].

Fuel Sources

3.2. There are 5 basic categories of material suitable as biomass fuels:

i. **Energy Crops** are plants grown specifically for energy purposes; they typically have a short growing cycle and high calorific value. The most popular UK biomass crops are short rotation coppice (typically willow and poplar), miscanthus, reed canary grass and oil seed rape.

ii. **Wood** from forestry, arboriculture activities or wood processing. Wood from forestry typically includes the lesser quality wood residues which are discarded when high quality wood is used in the furniture and construction industries.

iii. **Agricultural residues** includes residues from agricultural harvesting such as straw as well as animal slurry and poultry litter.

iv. **Food waste** from food and drink manufacture, preparation and processing and also municipal waste from households and business where the food waste is collected separately.

v. **Landfill and sewage waste** are also suitable as biomass energy sources however they are not considered within the context of this study.

Conversion technologies

3.3. The conversion technologies are dependent on the type of fuel, application and project scale. The most common conversion technologies are;

- **Direct Combustion**: biomass is burnt to raise steam, or hot water, which is used for heat or to drive a steam turbine which generates electricity. The waste heat from biomass electricity generation can be used for combined heat and power. Direct combustion is the simplest, most common and most proven of the biomass technologies.

[6] Department for Business, Enterprise and Regulatory Reform/National Statistics (July 2008) UK Energy in Brief

[7] Defra (May 2007): UK Biomass Strategy http://www.defra.gov.uk/Environment/climatechange/uk/energy/renewablefuel/pdf/ukbiomassstrategy-0507.pdf

- **Gasification**: partial combustion of the biomass material in a restricted supply of air at high temperatures produces what is known as 'producer gas'. The producer gas is used in turbines and engines to produce electricity. This is a more complex process than direct combustion, but it can achieve much higher efficiencies.
- **Pyrolysis**: thermal decomposition of the biomass material, in the absence of oxygen, produces a liquid fuel, known as bio-oil or pyrolysis oil. This can be used as a fuel for heating or power generation. Pyrolysis technology is in the early stages of development and costs are therefore still high. However, this also means that there is considerable scope for cost reduction as the technology becomes better established.
- **Anaerobic Digestion**: is a biochemical process in which wet organic matter is broken down by bacteria and other microorganisms in an oxygen-free environment to produce biogas. The major constituent of biogas is methane, which can be used to produce heat and/or power. A nutrient-rich liquid 'digestate' is also produced, which can be used as a fertiliser and soil conditioner.

Uses

Electricity Generation

3.4. Generating electricity from biomass is usually done on a larger scale than biomass heating in order to obtain the economies of scale required for a turbine and generator or engine. New projects being built in the UK are in the size range of 2 MWe[8] to 45 MWe, with the small plants producing both electricity and heat (known as combined heat and power or CHP).

Heating

3.5. Biomass heating can be implemented on a much smaller scale than biomass power production using biomass boilers. A local fuel supply is very important so the transportation of fuel is minimised. Suitable materials for heat applications include woody biomass from local forestry and forestry residues or energy crops such as willow coppice. Residues from saw mills and other wood processes and pellets can also be used.

Combined Heat & Power (CHP)

3.6. Conventional electricity in the UK is generated in large centralised power stations. The average efficiency of these power stations is around 37%, with the rest of the energy being wasted as heat. Electricity is then transmitted across the country and is subject to around 3% transmission losses between the power station and the end user - such as a household. Combined Heat and Power (CHP) offers the opportunity for improved overall efficiency (70-90% overall combined efficiency) by delivering both heat and power. The ability to use CHP depends on there being a local heat demand. Buildings suitable for the application of CHP are those with a constant demand for heat throughout the year, such as hotels, leisure centres and hospitals or buildings linked

[8] MWe refers to the peak rated electricity output

to district heating networks. In tri-generation plants the by-product heat can be used in absorption chillers for cooling, in addition to the electricity and heat production.

Resource

3.7. Establishing the biomass resource in Worcestershire is fundamental to assessing the renewable energy capacity. The following section discusses the theoretical biomass, resource available in Worcestershire.

Methodology

3.8. This section reports on the assessment of the potential for both large biomass electricity power production and biomass heating in Worcestershire. The unconstrained biomass potential is considered by determining the amount of resource in the region (for example forestry land coverage, available land for energy crops, livestock and poultry numbers), and then applying a series of assumptions to determine how much of this resource is likely to be available for biomass energy production. The potential energy from these sources is then calculated using the energy potential of each type of fuel source. To help assess the resources and potential for biomass projects in the area a number of organisations were contacted. The list of those consulted is included in Appendix 1.

3.9. The results are presented in terms of the number of homes that could be supplied with power, heat or both power and heat dependent on how the fuel source is utilised. The size of power plant that the fuel source could support is also presented. To calculate these values a number of assumptions were made:

- A 'typical' home (three bedroom semi-detached) has an annual electricity consumption of 3300 kWh, heat consumption of 19,725 kWh and total energy consumption of 23,025 kWh[9]
- Conversion rates to convert the energy contained in the fuel sources to electricity, heat, or combined heat and power were as used in the UK Biomass Strategy[10] and are as follows:

	Electricity only	Heat Only	Combined Heat and Power (CHP)
Dry Materials Conversion rate	0.3	0.85	0.85
Wet Materials Conversion rate	0.4	0.85	0.8

- To calculate the potential installed capacity, operation was assumed as 365 days a year for 19.5 hours per day.

[9] Figures averaged from those supplied by the Energy Savings Trust, Personal Communication 10th October 2008

[10] Defra (May 2007) UK Biomass Strategy http://www.defra.gov.uk/Environment/climatechange/uk/energy/renewablefuel/pdf/ukbiomassstrategy-0507.pdf

3.10. In Worcester and Redditch there is only a limited amount of farmland and a small number of holdings for crops and livestock therefore Defra has withheld some of the data to prevent information being released about individual holdings. Capacities have not been calculated for these local authorities for some of the biomass fuel resources as the required data is not available. However the energy contribution in areas where data is not supplied would be extremely small and will be included in the total values for Worcestershire.

Current situation

3.11. There are a number of local and regional examples and initiatives underway to promote the sustainable use of bioenergy sources for heat and electricity generation. The greatest focus appears to be in the wood energy sector where there is already good potential and enthusiasm within the region to expand the wood fuel sector. Some of the initiatives and schemes already in place are detailed below:

- There are a number of woodchip boilers installed in Worcestershire. In May 2002 a 700kW woodchip boiler was installed at Worcestershire County Hall producing around 1 million kWh of renewable heat every year. This uses around 600 tonnes of woodfuel annually, sourced from local forestry operations. There is also a 90kW woodchip boiler at Defra's Worcester site canteen. The Forestry Commission have also been installing wood pellet boilers at FC estates and there are three boilers installed in Worcestershire which are used on a seasonal basis to provide heat.
- Across the West Midlands region small scale biomass installations have become relatively frequent, most commonly on country estates or farms where biomass is used to heat homes or businesses[11]. There are over 200 big bale burners[12] being used for farmhouse heating and grain drying. See for example Figure 2

[11] Marches Energy Agency (June 2005): An audit of existing and proposed 'bioenergy' installations and infrastructure in the West Midlands Region.
http://www.bioenergywm.co.uk/library.aspx?cat=2&linktitle=BioenergyWM

[12] Big bale burners are typically used on farms or country estates utilising straw bales as a fuel source.

Figure 2 Big bale burner / boiler[13]

- Marches Wood Energy Network (MWEN) was established in 2002 with the aim of identifying stakeholders in wood energy, raising awareness and developing opportunities in the area. Midlands Wood Fuel, set up by MWEN and in partnership with Econergy (biomass boiler suppliers and installers), has supplied fuel for a number of installations in the region.
- Heartwoods was established to support and develop the woodlands and timber industry of the West Midlands. During phase 1 of the project, which ran from 2002 to 2005, nearly £1 million was invested in the woodfuel sector, creating 28 new jobs, safeguarding 47 jobs, and training 100 business personnel[14]. Phase 2 of the programme, which commenced in 2006 is concentrating on the promotion of the use of woodfuel, supporting woodland businesses and encouraging management of neglected woodlands.
- The Wyre Woodfuel Pathfinder is one of 8 projects running across the country, funded by the Forestry Commission's Woodfuel Challenge Fund. The projects aim to establish the best methods for development of sustainable woodfuel supply chains in England.
- Biomass power projects are being considered at Tenbury and, in Shropshire, at Bishops Castle. The capacity of both of the proposed plants is 2.5MWe and the fuel source would be wood chip, energy crops and multi-functional crops sourced within the area.
- Some farmers are already growing energy crops including miscanthus (most popular), oil seed rape and SRC – willow coppice.[15]

[13] FARM 2000/Teisen Products Ltd

[14] Heartwoods Website http://www.heartwoods.co.uk/

[15] National Farmers Union West Midlands, Personal communication 1st August 2008

3.12. This is not an exhaustive list of the biomass initiatives within Worcestershire but demonstrates that there is already a localised supply chain for woodfuel in the County. The use of energy crops and animal manure as biomass feedstocks seem to be less established within Worcestershire and there is little information on schemes or installations available.

Woody Biomass

Woodland and Forestry

3.13. The total area of woodland of 0.1 hectares and over in Worcestershire is 13,445 ha, representing 7.5% of the total land area and consisting of 707 woods. The majority of the woods are small with an area less than 100 hectares. Only 13 woods have an area larger than 100 hectares and the largest of these, Wyre Forest, covers a total area of 2634 hectares, although most of this woodland lies in Shropshire, not Worcestershire. The use of woodland residues from larger areas of woodland is likely to be more viable due to the economies of scale of transport and processing.

3.14. The potential for dry biomass as a fuel for heating and power depends on the area of woodland and forest, its management and competition for this resource from other users. The amount of fuel available from woodland is highly dependent on the management of the woodland. Currently it is estimated that one third of the woodland in Worcestershire is actively managed, however there is significant potential to increase active management if the woodfuel market were established[16]. The Forestry Commission plans to increase the volume of woodfuel from forestry land under the Woodfuel Strategy. However only 8% (803) hectares of the woodland in Worcestershire is owned by or leased to the Forestry Commission. The majority of the woodland is under personal ownership (accounting for 62% of the total woodland) and business ownership (accounting for 15.5%). Personal/business owners' willingness to use woodland residues as a woodfuel source will be varied and the active management of the woodland will also vary. Forestry Commission data[17] shows that whilst 99% of Forestry Commission-owned land is actively managed for timber production only 74.2% of non Forestry Commission owned land is managed for timber production.

3.15. The Forestry Commission carries out woodland surveys and produces an inventory of woodlands and trees. The most recent inventory available for Worcestershire is based on survey work carried out in 1997 with updates relating to grant aided woodland and Forestry Commission land made in 2002. An estimation of the potential wood resource from woodland and forestry within Worcestershire has been made using data from the Woodland Inventory. Unfortunately the inventory does not segregate data below the County level, therefore the potential biomass energy from woodfuel sources cannot be disaggregated to individual District level. The Woodland opportunities map shows future potential sites for woodland planting. This has been taken into consideration when identifying sites/areas suitable for biomass plants, as the establishment of new woodland near a biomass power plant would increase the woodfuel resource within the proximity of the plant. Although it should be noted that Worcestershire's

[16] Forestry Commission West Midlands, Personal communication 25th July 2008

[17] Forestry Commission (2007) National Inventory of Woodland and Trees 1995-1999 Analysis of Management and Biodiversity
http://www.forestry.gov.uk/website/publications.nsf/WebPubsByISBN/5F126B76EB70F7DC80257401005323D3

Landscape Character Assessment may not necessarily support all of the proposed planting, and this could affect the final woodland area available. Designations such as Sites of Special Scientific Interest (SSSIs) may have an impact on the management of woodland and therefore amount of fuel available as biomass resource. However by analysing GIS data and geographical information on SSSIs it is estimated that only 6% of the total woodland in Worcestershire is within SSSI and therefore this will have a minimal impact on the total woodfuel resource calculated.

3.16. The assumptions that were made to estimate the wood fuel resource are as follows:

- Only areas greater than 0.1 hectare are considered as there is no data available on woodland smaller then this. Also smaller areas are likely to yield minimal quantities in comparison to the overall resource available.
- Only wood fuel available from conifer, broadleaf and mixed woodland areas was considered. The total woodland area for coppiced and felled woodland areas were not included in the calculations as the potential resource is minimal and the annual volume available would be dependant on the management of these areas.
- As a result of forest management wood residues will be available for use as wood energy. The yields assumed are: conifer 1.2m^3/ha/year, broadleaf 0.48m^3/ha/yr and mixed woodland 0.84m^3/ha/yr.
- A bulk density for wet wood of 400kg/m^3 with an assumed moisture content of 50%.
- A calorific value of 19MJ/kg dry wood was used.

Table 2 Potential Woodfuel Resource in Worcestershire

	Woodland Size (ha)	
	0.1 and over	**2.0 and over**
Conifer (ha)	1581	1518
Broadleaf (ha)	9255	6373
Mixed (ha)	1734	1703
Annual volume available (m3)	7796	6311
WET annual mass available (kg)	3118464	2524464
DRY annual mass available (kg)	1559232	1262232
Energy Content (MJ)	29625408	23982408
Energy Content (MWh)	8236	6667

Table 3 Energy available from woodfuel in Worcestershire

Energy Contained (MWh)	Potential energy output (MWh)						Potential Installed Capacity (MW)		
	Electricity only		Heat only		CHP		Electricity only	Heat only	CHP
	MWh	Homes	MWh	Homes	MWh	Homes			
8236	2471	749	7000	355	7000	304	0.3	1.0	1.0

3.17. As shown in Table 2, over 6000 MWh of energy is theoretically available annually from woodfuel from woodland areas of 2.0 hectares and over, which rises to over 8000MWh if smaller woodland areas over 0.1 hectares are included. Table 3 shows the potential energy output and installed capacity from the woodfuel resource in Worcestershire. This resource is not large, capable of supplying only the electricity to approximately 750 homes, heat to approximately 350 homes or total energy requirements of approximately 300 homes, dependent on the conversion technology used. However this could be supplemented with other forms of woody waste including waste wood.

Waste from wood manufacturing industries

3.18. There are around 10 million tonnes of waste wood being produced each year in the UK, most of which goes to landfill[18]. The Waste Strategy for England identifies waste wood as a priority material for action as its potential for recycling or energy is high. In addition, as landfill tax rises and the option to send waste wood to landfill becomes less attractive, the need to recycle waste wood or to use it as an energy source will become more important. There are a number of saw mills, fencing and pallet manufacturers in Worcestershire producing waste wood through these processes which could also be used as a fuel source. The furniture industry was identified as a regional priority industry in a 2007 report into employment land in Worcestershire[19], therefore expansion of this industry is likely, with a resultant expansion in wood waste. Pure unprocessed wood could be burnt in boilers in the same way as woodland residues. However, any processed wood would need to be treated differently and may be subject to waste regulations. Where waste wood is contaminated, Waste Incineration Directive (WID) compliant combustion facilities will be required to use the contaminated wood as a feed stock, and this type of material has not been included in this study.

3.19. Wood pellets can be made by compressing sawdust and wood shreds produced in saw milling and manufacturing. However, it should be noted that a lot of MDF (Medium Density Fibreboard) is cut at saw mills, and all of the excess wood and sawdust is combined. As MDF is glued together, it would (as with other contaminated waste wood), be necessary to separate out this wood or treat appropriately.

3.20. A feature of waste wood arisings is that both the tonnage and sources are unpredictable and materials are often mixed with other types of waste. Establishing precise volumes of 'clean' waste in Worcestershire was not possible due to these factors.

Waste from parks and highways

3.21. Forestry residues from landscape management can also be utilised as a biomass energy source. A mix of wood, leaves and stem products are produced during maintenance works along roads and waterways and in parks. In Worcestershire highway maintenance produced approximately 660m^3 of green waste in 2007 although this amount changes from year to year depending on the amount of work being done. This was recycled into woodchips and logs and used for heating.

3.22. The amount of woody waste from parks maintenance varies depending on land management and the type of work being done, therefore this cannot be relied upon as a constant fuel resource. In Worcester Woods Country Park approximately 15m^3 of woody waste is produced which is sold as firewood, used within the park to make furniture or bridges etc, made into woodchip which is used within the park or sold, or used within the park to form barriers and habitats. There is therefore no woody waste for energy production which is not utilised within the park or by the park. This is representative of other parks in the County, therefore waste from landscape maintenance could potentially be used alongside other fuel resources, but does not constitute a resource significantly large enough for a biomass installation in its own right.

[18] Defra (April 2008): Waste Wood as a Biomass Fuel, Market Information Report. http://www.defra.gov.uk/environment/waste/topics/pdf/wastewood-biomass.pdf

[19] GVA Grimley (November 2007) Worcestershire Employment Requirements Final Report

Energy crops

3.23. Energy crops are plants grown specifically for energy purposes which can typically be grown on set-aside land, arable land or in between the growing of other crops due to their short rotation times. Straw, which is a by-product from arable crops, is also suitable as a fuel source. The most common options are:

3.24. **Short Rotation Coppice (SRC)** consists of densely planted, high-yielding varieties of poplar or willow and can be established on a wide variety of soil types from heavy clay to sand. The crop can be harvested on a 2-5 year cycle, although it is commonly harvested every three years. The plants last 20-30 years after establishment, reaching up to 7 or 8 meters in height and producing 7-12 oven dry tonnes (odt) per hectare per year. SRC will produce good growth where there is sufficient soil moisture available within 1 metre of the soil surface and it can withstand seasonal flooding (although consideration must be given to operational requirements such as the need to harvest in the winter) but not permanent waterlogging. The Department for the Environment Food and Rural Affairs (DEFRA) has published a series of regional maps indicating the local suitability of land for energy crops[20]. The Short Rotation Coppice map shows that the Worcestershire area has a medium suitability i.e. it is expected to produce yields of between 8 and 10 oven dry tonnes (odt) per hectare per year. Specialist equipment is required for both the planting and harvesting of SRC, with the type of harvesting equipment being dependent on the fuel specification of the end user, therefore ensuring appropriate access for this machinery is an important consideration. To be eligible for a grant under the energy crop scheme the proposed site must be at least 3ha in total, although this can consist of smaller plots. However, international studies show that 6 to 10 hectares is the minimum commercially-viable size for a SRC plantation. In Worcestershire only 55% of the 4361 farms are greater than 5 hectares, so this could limit the suitability of SRC for a number of farms. SRC can be beneficial for biodiversity as the ground cover encourages presence of invertebrates, small mammals and birds. Headlands (areas at the ends of the rows for vehicle turning) provide habitat opportunities for a wide range of plants and animals. Under the energy crops scheme a proposed SRC site must be assessed to ensure there are no significant adverse impacts on the environment and the impact on local landscape, ecology, archaeology and public access must be considered.

3.25. **Miscanthus** is a wood perennial originating from Asia which has the potential for very high rates of growth. Miscanthus is planted in the spring and once planted can remain in the ground for at least 15 to 20 years, reaching up to 3.5m in height. Bamboo-like canes are harvested annually in the winter or early spring. The first year's growth is insufficient to be economically worth harvesting and the highest yields aren't achieved until the crop is fully matured, three years after planting. At the most productive experimental sites, yields have exceeded 16 dry tonnes per hectare, however Defra predict the average yield to be 12 dry tonnes per hectare per year. The highest yields of Miscanthus will only be obtained when there is sufficient water for the crop to grow, as the annual rainfall, along with the soil's water retention, have a strong influence on the crop growth. Miscanthus has deep fibrous roots which may damage archaeological features, so growth in sensitive areas should be avoided. The annual fertiliser demands of the crop are very low and once the crop is mature, little weed control is required. Research in the UK on the impacts of miscanthus is ongoing,

[20] Defra Miscanthus yield map & SRC yield map
http://www.defra.gov.uk/farm/crops/industrial/energy/opportunities/index.htm

however research completed so far has shown that it can enhance biodiversity for a range of wildlife and also provides cover for wildlife. The DEFRA potential yield map for Miscanthus shows that Worcestershire has a high suitability for growing the crop, suggesting that yields would be at least 12 dry tonnes per hectare.

3.26. **Straw**: The UK cereal straw (wheat and barley) resource is significant, but in addition to its potential use as an energy crop it is also used as bedding and feed for livestock and is ploughed into the soil due to its resource value as a fertiliser and organic matter supplement. Due to increases in fertiliser prices the amount of straw being ploughed back into the soil has increased. Despite this, it is estimated in Worcestershire that there is a surplus of straw exported away from the County which could be utilised for energy production[21]. With the removal of set-aside and a buoyant market for cereals, the area of wheat and oil seed rape crops is likely to increase and therefore the amount of the by-product straw will also increase. Nationally, demand for straw comes from the Ely dedicated biomass plant which consumes 200,000 tonnes of straw annually, and if completed the proposed Sleaford Renewable Energy Plant in Lincolnshire will require an additional 240,000 tonnes[22] per annum. The UK Biomass Strategy estimates that 3Mt/yr of cereal straw can be used for biomass in the UK without affecting existing markets.

3.27. **Others:** Rotation, that is not growing the same crop year on year on the same ground, is a key farm management tool which, if used effectively, can radically reduce cost and improve yield. Dedicated annual energy crops could become attractive to arable farmers as a 'break crop' which breaks the cycle of normal cropping and provides diversity in rotations. Break crops can have several benefits including pest and disease control, nutrient use efficiency, higher economic returns and improved weed management. A number of break crops including field peas, beans and linseed are vulnerable for replacement owing to their relatively low yields and therefore poor returns. Triticale is a hybrid of wheat which has high yield potential as well as good disease and environmental tolerance which could be grown in rotation with other crops. Triticale is widely grown in Eastern Europe for energy purposes and can yield up to 18 tonnes per hectare. The advantage of triticale is it is planted and harvested annually therefore could be used as a 'break crop' between growing of other crops, enhancing rotational benefits. Trials would be necessary to assess the suitability of Triticale or other species to land in Worcestershire.

3.28. Worcestershire is a fairly rural County, with a farmed area of nearly 128,000 hectares consisting of approximately 22600 holdings[23], therefore there is potentially a significant energy crop and straw resource for biomass energy production. The resource available for biomass is dependent on the type of crop grown and the area of land given to growing the crop. The two categories of land of particular interest for growing of energy crops are set aside land and arable land. In the 2001 resource assessment of renewable energy in the West Midlands, it was assumed that the area available for energy crops was equal to 10% of all arable land and all set aside land. However, with the removal of set-aside land and its associated subsidies it is likely

[21] Countrywide Farmers, Personal Communication 21st August 2008

[22] Eco2 Ltd (2008): Environmental Statement Volume 3, Non-technical Summary. http://www.sleafordrep.co.uk/info/ESVol3/902%20Re-sub%20ESVol4%20NTS.pdf

[23] Defra (June 2007): Agricultural and Horticultural Survey http://www.defra.gov.uk/esg/work_htm/publications/cs/farmstats_web/2_SURVEY_DATA_SEARCH/survey_data_search_overview.htm

that some set aside land will be converted for use as arable land. The price of energy crops must therefore be competitive with food crops, biofuel crops and other non-food crops if land is to be given to growing them. Even if the economics are favourable, farmers must also want to grow energy crops. Factors that will influence this include the following:

- SRC and miscanthus are perennial crops that once planted can remain in the ground for 15-20 years; growing this crop represents a risk to farmers as future crop prices and demand can not be predicted accurately. However, emerging annual energy crops such as Triticale could provide a viable alternative energy crop to overcome this difficulty.
- For long-term energy crops such as SRC and Miscanthus, rotational benefits cannot be realised.
- Energy crops are often managed externally therefore reducing diversification of the farm and farmers' control over their own land. This may be seen as desirable by some farmers.
- Crop prices are constantly fluctuating dependant on demand. The price for energy crops needs to be competitive with other crops that can be grown on similar land.
- Energy crops typically require less fertiliser and pesticides then food crops. If the price of fertiliser and pesticides continues to rise, then energy crops will become more attractive in comparison to food crops due to lower input costs.
- The majority of land in Worcestershire is highly suitable for growing Miscanthus and has medium suitability for SRC. Appropriate access to fields is also needed, alongside the ability to use machinery for growing and planting the crops.
- Energy crop grants and subsidies will make the growing of energy crops more attractive.
- Use of set aside land – this could either be converted to arable land for the growing of food crops, or used for energy crops.
- Availability of contracts to supply power plants over a number of years, with a fixed price per tonne. Where there is a definite buyer for the energy crops produced, then farmers are more likely to choose to grow crops as the risk has been reduced.

3.29. The use of crops for energy production is still in the early stages of development so there are a large number of factors influencing the market, making it difficult to predict. Due to the complicated nature and uncertainties involved, the biomass resource in Worcestershire is predicted using the potential resource as identified in the UK Biomass Strategy. The Strategy states the potential to use up to a further 350,000 hectares across the UK for biomass fuel and energy crops by 2020. This is equivalent to a total land availability of 1 million hectares for biofuel and energy crops, equivalent to 17% of the total UK arable land. The energy from crops resource calculations for Worcestershire has been assumed that 12% (of arable land in Worcestershire) would be used for biofuels and 5% for energy crops because these crops tend to be annual and do not need to become established over a number of years - so farmers can easily convert land to this use.

3.30. The use of crops for energy production is still in the early stages of development so there are a large number of factors influencing the market, making it difficult to predict. Due to the complicated nature and uncertainties involved, the biomass resource in Worcestershire is predicted using the potential resource as identified in the UK Biomass Strategy. The Strategy states the potential to use up to a further 350,000 hectares across the UK for biomass fuel and energy crops by 2020. This amounts to a total land availability of 1 million hectares for biofuel and energy crops, equivalent to 17% of the total UK arable land. Biofuel crops tend to be annual and therefore farmers are more likely to convert land to biofuel crops in preference to energy crops such as SRC or Miscanthus which take a number of years to become established. Therefore it has been assumed that 12% of arable land in Worcestershire will be used for biofuels and 5% for energy crops.

3.31. The potential for energy crops in Worcestershire was calculated using land areas from the Defra Agricultural Survey and a number of assumptions as listed below:

- Energy crops: 5% of the total crops and bare fallow land and set aside land is available for the growth of energy crops. 4% of the land area is used for growth of SRC and 1% for growth of Miscanthus. These ratios were assumed by IT Power on the basis that energy crops require a number of years to become established and that farmers are likely to continue to grow food crops such as wheat or barley in order to obtain both crop value and biomass value from the resultant straw.
- SRC: assume yield of 10 tonnes/hectare and calorific value of 19 GJ/tonne.
- Miscanthus: assume yield of 12 tonnes per hectare and calorific value of 17 GJ/tonne.
- Straw: assume an average yield of 8 tonnes per hectare from cereal crops, of which 80% is recoverable straw. 30% of the recoverable straw is available for use as fuel[24]. Calorific value of 14 GJ/tonne used for straw.

Table 4 Potential Energy Crop Resource in Worcestershire

	Bromsgrove	Malvern Hills	Wychavon	Wyre Forest	Worcestershire
Total Cereal Land (Ha)	2388	10396	14521	2534	**30258**
Crops & Bare Fallow (Ha)	3598	18028	24953	4233	**51483**
Set aside Land (Ha)	342	1532	2009	389	**4318**
Potential SRC (tonnes)	1576	7824	10785	1849	**22320**
SRC Energy Content (GJ)	29311	145523	200602	34387	**415159**
SRC (MWh)	8148	40456	55767	9560	**115414**
Potential Miscanthus (tonnes)	473	2347	3236	555	**6696**
Miscanthus Energy Content (GJ)	8179	40606	55974	9595	**115843**
Miscanthus (MWh)	2274	11288	15561	2667	**32204**
Potential Straw available (tonnes)	4585	19961	27880	4865	**58095**
Straw energy conent (GJ)	64196	279457	390324	68117	**813327**
Straw Energy Content (MWh)	17846	77689	108510	18936	**226105**
Total (MWh)	**28268**	**129433**	**179838**	**31163**	**373723**

The data for Redditch and Worcester has been suppressed by Defra to prevent disclosure of information about individual holdings therefore they are not present in the resource table.

24 IT Power assumption based on consultation and previous experience

Table 5 Energy Available from Energy Crops in Worcestershire

SRC & Miscanthus	Energy Contained (MWh)	Potential energy output (MWh)						Potential Installed Capacity (MW)		
		Electricity only		Heat only		CHP		Electricity only	Heat only	CHP
		MWh	Homes	MWh	Homes	MWh	Homes			
Bromsgrove	10422	3127	947	8859	449	8859	385	0.4	1.2	1.2
Malvern Hills	51744	15523	4704	43982	2230	43982	1910	2.2	6.2	6.2
Wychavon	71328	21398	6484	60629	3074	60629	2633	3.0	8.5	8.5
Wyre Forest	12227	3668	1112	10393	527	10393	451	0.5	1.5	1.5
Worcestershire	**147618**	**44285**	**13420**	**125476**	**6361**	**125476**	**5450**	**6**	**18**	**18**

Straw	Energy Contained (MWh)	Potential energy output (MWh)						Potential Installed Capacity (MW)		
		Electricity only		Heat only		CHP		Electricity only	Heat only	CHP
		MWh	Homes	MWh	Homes	MWh	Homes			
Bromsgrove	17846	5354	1622	15169	769	15169	659	0.8	2.1	2.1
Malvern Hills	77689	23307	7063	66036	3348	66036	2868	3.3	9.3	9.3
Wychavon	108510	32553	9865	92234	4676	92234	4006	4.6	13.0	13.0
Wyre Forest	18936	5681	1721	16096	816	16096	699	0.8	2.3	2.3
Worcestershire	**226105**	**67831**	**20555**	**192189**	**9743**	**192189**	**8347**	**10**	**27**	**27**

Straw, SRC & Miscanthus	Energy Contained (MWh)	Potential energy output (MWh)						Potential Installed Capacity (MW)		
		Electricity only		Heat only		CHP		Electricity only	Heat only	CHP
		MWh	Homes	MWh	Homes	MWh	Homes			
Bromsgrove	28268	8481	2570	24028	1218	24028	1044	1.2	3.4	3.4
Malvern Hills	129433	38830	11767	110018	5578	110018	4778	5.5	15.5	15.5
Wychavon	179838	53951	16349	152862	7750	152862	6639	7.6	21.5	21.5
Wyre Forest	31163	9349	2833	26489	1343	26489	1150	1.3	3.7	3.7
Worcestershire	**373723**	**112117**	**33975**	**317665**	**16105**	**317665**	**13797**	**16**	**45**	**45**

Animal Manure

3.32. Table 6 indicates the number of animals required to produce one tonne of organic waste and the corresponding biogas yield for each feedstock. These are likely to be subject to seasonal variation but represent annual averages.

Table 6 Biogas Production and energy output potential from one tonne of various fresh feedstocks[25]

Feedstock	No of animals to produce 1 tonne/day	Dry Matter content (%)	Biogas yield (m3/tonne feedstock)	Energy value (MJ/m3 biogas)
Cattle Slurry	30	12	25	24
Pig Slurry	275	9	25	23
Laying Hen Litter	8500	30	120	25
Broiler Manure	12500	60	75	22
Food Processing Waste	N/A	15	46	23

[25] British Biogen Anaerobic Digestion of farm and food processing residues Good Practice Guidelines http://www.mrec.org/biogas/adgpg.pdf

Table 7 Defra Agricultural Survey Data 2007

	Cattle (Dairy only)		Pigs		Poultry (layers only)		Totals	
	No. of animals	No. of holdings	No. of animals	No. of holdings	No. of animals	No. of holdings	No. of animals	No. of holdings
Bromsgrove	4089	132	7841	22	25206	69	37136	223
Malvern Hills	5755	267	4679	53	6813	175	17247	496
Redditch	#	#	#	#	#	#	#	#
Worcester	#	#	#	#	#	#	#	#
Wychavon	6546	241	14714	46	67163	164	88422	451
Wyre Forest	1395	38	5593	16	35520	63	42508	118
Worcestershire	18903	735	34591	142	134969	485	188462	1362
West Midlands	300204	8463	235283	975	2914044	3108	3449531	12546

3.33. Some data for Redditch and Worcester has been suppressed to prevent data being released about individual holdings, this is represented by the hatch symbol in the table.

3.34. The total estimated potential from animal manure and poultry in Worcestershire is presented in Table 8 this has been calculated from the number of animals as given in the Defra Agricultural Survey 2007 shown in Table 7. It is difficult to make a precise estimation of the total potential for Worcestershire since there are many project specific factors which determine the viability of a project. Therefore IT Power has assumed that 50% of the total animal slurry feedstock could be used for anaerobic digestion for energy use[26].

Table 8 Animal Manure Potential Energy Resource

	Bromsgrove	Malvern Hills	Wychavon	Wyre Forest	Worcestershire
No. of cattle (dairy only)	4089	5755	6546	1395	**18903**
Biogas from cattle (m3/yr)	621794	875260	995501	212179	**2874812**
Energy content from cattle (MWh)	4149	5840	6642	1416	**19181**
No. of pigs	7841	4679	14714	5593	**34591**
Biogas from pigs (m3/yr)	130088	77627	244110	92789	**573892**
Energy content from pigs(MWh)	832	496	1561	593	**3669**
No. of poultry (layers only)	25206	6813	67163	35520	**134969**
Biogas from poultry (m3/yr)	64943	17555	173043	91516	**347742**
Energy content from poultry (MWh)	451	122	1203	636	**2417**
Total (MWh)	**5432**	**6458**	**9405**	**2645**	**25267**

Table 9 Energy available from animal manure resource

Cattle, Pigs and Poultry		Potential energy output (MWh)					Potential Installed Capacity (MW)		
		Electricity only		Heat only	CHP		Electricity only	Heat only	CHP
	Energy Contained (MWh)	MWh	Homes	Homes	MWh	Homes			
Bromsgrove	5432	2173	658	234	4345	189	0.3	0.6	0.6
Malvern Hills	6458	2583	783	278	5166	224	0.4	0.8	0.7
Wychavon	9405	3762	1140	405	7524	327	0.5	1.1	1.1
Wyre Forest	2645	1058	321	114	2116	92	0.1	0.3	0.3
Worcestershire	**25267**	**10107**	**3063**	**1089**	**20214**	**878**	**1**	**3**	**3**

Food waste

3.35. Around 300,000 tonnes of municipal waste (household waste) is produced annually in Worcestershire. At present organic waste is not separated out although a separate organic waste collection is being considered in Wychavon.

[26] IT Power assumption based on consultation and previous experience.

3.36. Major food manufacturers within Worcestershire were contacted with the aim of determining the amount of food waste potentially available for energy use. It appears that the quantities of food waste are low (< 5000 tonnes per annum[27]) and in addition some of this waste already goes into animal feed. However as this is commercially sensitive information it was not possible to get definitive quantities.

3.37. Animal manure and food waste resources provide ideal feed stocks for the Anaerobic Digestion process. Manure contains a wide range of bacteria necessary to foster the digestion process and is a good feedstock as it is a waste product with little, or even negative value and its disposal by traditional methods brings problems with odour and ground contamination. The slurry produced by dairy cattle is a particularly suitable feedstock because cattle are typically kept indoors for up to 6 months per year and their manure must be collected and disposed of. The quantity of food waste resource will be dependent on what food manufacturers are present in the area and the waste produced. If household food waste could be collected in the area for anaerobic digestion this would increase the fuel supply for Anaerobic Digestion.

3.38. A typical large scale anaerobic digestion plant in the UK uses up to 30,000 tonnes of food chain waste per year and produces 1MW of electricity. The relatively low volumes of food waste generated in the County make the economics of such a plant in Worcestershire unlikely to be favourable unless waste is collected from outside the County.

Summary

3.39. The results show the energy production possible with the available resource and how this resource could be used for electricity generation, heating or CHP. Table 10 shows the potential energy from all biomass feedstocks by Local Authority. The total energy potential in Worcestershire is approximately 400 GWh, equivalent to the total electricity requirements of 37,000 typical homes or the heat requirements of 17,000 homes. Straw contributes the most significant amount of energy and the local authorities with the highest potentials are Malvern Hills, Bromsgrove and Wychavon. These results are discussed further in the next section in relation to the constraints which apply to biomass projects.

[27] Estimation based upon a telephone survey of key food producers in Worcestershire.

Table 10 Potential energy from biomass feed stocks by local authority

	Energy Contained (MWh)	Potential energy output (MWh)						Potential Installed Capacity (MW)		
		Electricity only		Heat only		CHP		Electricity only	Heat only	CHP
		MWh	Homes	MWh	Homes	MWh	Homes			
Bromsgrove										
Energy Crops	10422	3127	947	8859	449	8859	385	0.4	1.2	1.2
Straw	17846	5354	1622	15169	769	15169	659	0.8	2.1	2.1
Cattle, Pigs and Poultry	5432	2173	658	4617	234	4345	189	0.3	0.6	0.6
Total	**33700**	**10653**	**3228**	**28645**	**1452**	**28374**	**1232**	**1.5**	**4.0**	**4.0**
Malvern Hills										
Energy Crops	51744	15523	4704	43982	2230	43982	1910	2.2	6.2	6.2
Straw	77689	23307	7063	66036	3348	66036	2868	3.3	9.3	9.3
Cattle, Pigs and Poultry	6458	2583	783	5489	278	5166	224	0.4	0.8	0.7
Total	**135891**	**41413**	**12549**	**115507**	**5856**	**115184**	**5003**	**5.8**	**16.2**	**16.2**
Redditch										
Wychavon										
Energy Crops	71328	21398	6484	60629	3074	60629	2633	3.0	8.5	8.5
Straw	108510	32553	9865	92234	4676	92234	4006	4.6	13.0	13.0
Cattle, Pigs and Poultry	9405	3762	1140	7995	405	7524	327	0.5	1.1	1.1
Total	**189244**	**57714**	**17489**	**160857**	**8155**	**160387**	**6966**	**8.1**	**22.6**	**22.5**
Wyre Forest										
Energy Crops	**12227**	**3668**	**1112**	**10393**	**527**	**10393**	**451**	0.5	1.5	1.5
Straw	18936	5681	1721	16096	816	16096	699	0.8	2.3	2.3
Cattle, Pigs and Poultry	2645	1058	321	2248	114	2116	92	0.1	0.3	0.3
Total	**33808**	**10407**	**3154**	**28737**	**1457**	**28605**	**1242**	**1.5**	**4.0**	**4.0**
Worcestershire										
Woodland	8236	2471	749	7000	355	7000	304	0.3	1.0	1.0
Energy Crops	147618	44285	13420	125476	6361	125476	5450	6.2	17.6	17.6
Straw	226105	67831	20555	192189	9743	192189	8347	9.5	27.0	27.0
Cattle, Pigs and Poultry	25267	7672	2325	16304	827	15345	666	1.1	2.3	2.2
Total	**407226**	**122260**	**37048**	**340969**	**17286**	**340010**	**14767**	**17.2**	**47.9**	**47.8**

Constraints

3.40. The constraints to large scale **biomass power projects** are:

- Biomass resource: The total resource available depends on land availability in proximity to the project location (transport distance is important). In the short term however, the available resource depends on the demand for biomass fuel and this often presents a "chicken and egg scenario" since farmers are unlikely to invest in the supply side until demand is certain and similarly potential users are unlikely to commit until the fuel supply is certain.
- Space available for the plant and fuel storage: This depends on the size of plant. Typically, a 1.5MW plant will require a site area of around 0.5 hectares and a 40MW plant may require 5 hectares.[28]
- Access for fuel deliveries: Regular fuel deliveries will be required. Typically a 2.5MW plant would require 25 deliveries (using a 38 tonne lorry) per week.
- Access to water for cooling: As in fossil fuel power stations, water is required to cool and condense the exhaust gas from the turbine. Up to 20m^3 of water per day can be abstracted without a licence. Small biomass plants, around 2-3 MW do not require large amount of water therefore borehole water can be used, however larger plants (for example 20 MW biomass plants) would require substantially greater volumes of

[28] Office of the Deputy Prime Minister (December 2004) Planning for Renewable Energy, A companion guide to PPS22
http://www.communities.gov.uk/documents/planningandbuilding/pdf/147447.pdf

water, therefore locating near to a river is favourable. When siting larger biomass plants the Catchment Area Management Plan should be considered to ensure plants are not located in areas of water stress.

- Access for grid connection, this is discussed in Section 10.
- National support for biomass power production: In 2003 Bio-Energy Capital Grants worth a total of over £25 million were awarded for eight bio-power and CHP systems. Out of the eight projects only one is now operating and a further two are under construction. A 21.5MW plant in Winkleigh, Devon was refused planning permission as it was felt there was not sufficient biomass fuel supply within the local area to meet the plant requirements. Two other potential sites are on indefinite hold. Two more are progressing.

3.41. The constraints on the widespread use of **biomass for heating** are:

- Biomass resource
- Infrastructure for processing and storage - the number of biomass heating installations is constrained by the number of buildings with suitable access for deliveries of fuel and space for storage. Worcestershire is predominantly a rural County, therefore space will not be as significant a limitation as a densely populated urban area however space may still be a constraint in some circumstances. Ideally a wood chip store is designed so that the wood fuel can be simply tipped into it, rather than requiring special equipment to blow chips into the fuel store.

3.42. The constraints to the use of **anaerobic digestion** are:

- Availability of animal manure and other substrate. For animal manure this depends on the number of animals and whether they are kept indoors or outside.
- Composition of feedstock – including type of animal manure (which affects biogas yield) and dry matter content (which affects the size of digester required)
- Location of feedstock
- Local energy demand
- Availability of finance
- Market for digestate - The digestate (the treated liquid from anaerobic digestion plants) has the potential for use as a fertiliser and soil conditioner, which can provide an additional revenue stream for the operators of anaerobic digestion plants.
- Fuel storage capacities.
- A study looking into Anaerobic Digestion in Leicestershire[29] concluded that the smallest size of plant that is economically viable is one of a size sufficient to process the slurry from 3000 cattle plus food waste. PPS22 also states that centralised AD facilities handling large quantities of sewage sludge or MSW may be more economically viable for plant operators. However on-farm digestors have a number of advantages over Centralised AD facilities, as the waste is located close to the

[29] EnConsult (May 2007): Biogas in Leicestershire, A Technical Feasibility Study for Leicestershire, Anaerobic Digestion – A Renewable Energy Resource.
http://www.leics.gov.uk/search.htm?qt=biogas+&col=all&flag=&submit=search

plant, transport movement will be minimal and the location of the plant is unlikely to cause issues. The economics need to be taken on a case by case basis.

Economics

3.43. All biomass developments have a variety of ancillary project costs such as legal costs and installation costs, including civil engineering costs and grid connections.

3.44. Build costs are due to fuel storage, the need for large plant room and stack/chimney. The fuel can be stored underground or above ground. Usually underground systems are more applicable and feasible for smaller boiler systems. In a biomass project the legal costs can be particularly high, due to complex contractual obligations.

Typical site development costs for small scale biomass plants are shown in the table below.

Table 11 Small scale cost[30]

Site capacity kW	Approximate costs £
50	£20,000 - £30,000
100	£45,000 - £55,000
200	£92,000 - £112,000
500	£210,000 - £240,000
800	£345,000 - £375,000

3.45. Larger Biomass plants are subject to much larger build costs.

Potential Funding Sources[31]

3.46. National incentives and grant programmes for biomass energy are summarised below:

Capital Grants: for which only small and very small heat plant can qualify. A capital grant is assumed to be 25% of capital costs

The **Bio-energy Infrastructure** Scheme provides grants to help the development of the supply chain required to harvest, process, store and supply biomass to heat, combined heat and power, and electricity end-users. For further information see http://www.defra.gov.uk/farm/crops/industrial/energy/infrastructure.htm

The **Bio-energy capital grants scheme** supports the installation of biomass-fuelled heat and combined heat and power projects in the industrial, commercial and community sectors in England. The fourth round of the scheme is closed for new applications. Subject to funds being available, Defra hopes to run a fifth application round. http://www.defra.gov.uk/farm/crops/industrial/energy/capital-grants.htm

30 IT Power estimation based upon installed costs of various sized systems

31 Carbon Trust (October 2005) Biomass Sector Review

Potential Capacity

3.47. Table 12 summarises the energy capacities and potential sizes for biomass energy under the three scenarios, this is presented in more detail in Appendix 5. Where the biomass resource is utilised in a combined heat and power plant approximately 40% of the energy will be available as electricity and 60% as heat. The final biomass breakdown is likely to be a mixture of the three different options outlined below.

Table 12 Energy capacities for biomass resource under different scenarios

12.1 Electricity only

District	Scenario 1		Scenario 2		Scenario 3	
	MW	MWh	MW	MWh	MW	MWh
Bromsgrove	0.5	3424	0.9	6665	1.5	28374
Malvern Hills	1.9	13722	3.7	26533	5.8	115184
Redditch	0.0	0	0.0	0	0.0	0
Worcester	0.0	0	0.0	0	0.0	0
Wychavon	2.7	19169	5.2	36995	8.1	160387
Wyre Forest	0.5	3419	0.9	6624	1.5	28605
Totals	5.6	40126	11.0	78582	17.2	340010

12.2 Heat only

District	Scenario 1		Scenario 2		Scenario 3	
	MW	MWh	MW	MWh	MW	MWh
Bromsgrove	1.3	9394	2.5	18115	4.0	28645
Malvern Hills	5.4	38514	10.4	74263	16.2	115507
Redditch	0.0	0	0.0	0	0.0	0
Worcester	0.0	0	0.0	0	0.0	0
Wychavon	7.6	53779	14.5	103487	22.6	160857
Wyre Forest	1.3	9537	2.6	18393	4.0	28737
Totals	15.8	112603	30.9	219932	47.9	340969

12.3 CHP

District	Scenario 1		Scenario 2		Scenario 3	
	MW	MWh	MW	MWh	MW	MWh
Bromsgrove	1	9339.7	2.5	17979	4.0	28374
Malvern Hills	5	38449.3	10.4	74101	16.2	115184
Redditch	0	0.0	0.0	0	0.0	0
Worcester	0	0.0	0.0	0	0.0	0
Wychavon	8	53684.6	14.5	103252	22.5	160387
Wyre Forest	1	9510.5	2.6	18326	4.0	28605
Totals	16	112411.1	30.8	219452	47.8	340010

12.4 Assuming that 60% of biomass resources is used for heating projects and 40% for electricity

District	Scenario 1		Scenario 2		Scenario 3	
	MW	MWh	MW	MWh	MW	MWh
Bromsgrove	1	7006	2	13535	3	28536
Malvern Hills	4	28597	8	55171	12	115378
Redditch	0	0	0	0	0	0
Worcester	0	0	0	0	0	0
Wychavon	6	39935	11	76890	17	160669
Wyre Forest	1	7090	2	13685	3	28684
Totals	**12**	**82628**	**22**	**159281**	**35**	**333268**

The greatest power output is possible when the biomass resource is used for CHP due to the higher efficiency of this process. If the biomass resource is used for heating and electricity in separate processes the overall power produced is lower as can be seen by comparison in tables 12.3 and 12.4.

3.48. These values for the various scenarios were developed by taking into account the following considerations:

Woodland

3.49. It is estimated that one third of the woodland in Worcestershire is currently actively managed therefore this is the amount of resource that has been considered as available as a fuel source under Scenario 1. Typically, nearly all of Forestry Commission owned woodland, and 70% of non Forestry Commission owned woodland, is actively managed for timber production, therefore with policies in place to ensure woodland residues are available as an energy resource it has been estimated that 70% of predicted resource will be available under Scenario 2. Scenario 3 assumes no barriers to development of the resource and therefore all woodland residues will be available for energy production.

Energy crops

3.50. At present the market and potential for energy crops is extremely uncertain and without any significant drivers acting as an incentive it is felt that this resource will not be developed. This is reflected by a minimal estimation of energy crops resource available under scenario 1. Scenario 2 assumes that this situation could be improved with a clearer energy crops scheme and also further research into annual energy crops such as Triticale which would minimise the number of risks and disadvantages associated with growing long term energy crops. Scenario 3 assumes that 5% of all suitable land is available for growing energy crops.

Anaerobic digestion

3.51. Scenario 1 assumes only limited energy production from animal manure and poultry litter due to the difficulties associated with establishing an anaerobic digestion plant. Under Scenario 2 it is likely that policies and incentives will be in place to encourage development of anaerobic digestion plants therefore greater take up is anticipated. Under Scenario 3 it is likely that the food waste resource can also contribute to an anaerobic digestor's feedstock.

Resource utilisation

3.52. How the resource is utilised and the sizing of plants has not been identified as this will be dependent on the availability of the estimated resource and also the specific site and heat/electricity loads that the biomass plant would need to meet.

3.53. Unlike hydro and wind technologies, the biomass site is of less importance and the major factor determining the development of the technology is the available resource. Therefore a number of areas appropriate for biomass power plants were identified rather then specific sites. Potential areas suitable for a biomass plant were determined by the constraints listed in 3.40. In addition preference should be given to previously developed land and brownfield sites where possible. The biomass plant should be located near to the biomass resource as biomass is bulky and therefore relatively expensive to transport and emissions from transportation should be minimised. The impact on local amenities should be considered and screening should be used to reduce the visual impacts of a plant. Other considerations include the need for a water source for the larger plants.

3.54. Eight areas were identified as potentially suitable for biomass generation in Worcestershire, as shown in Appendix 2. When examining the spatial positioning of these sites it is unrealistic that all would be developed as there is insufficient resource for a reasonably sized plant at each site. In addition there appears to be a large area to the south west which is not served, this is predominantly due to poor road access and limited numbers of towns to utilise heat produced. When considering specific sites it is important that any flood risk is taken into account, as detailed in Appendix 4.

3.55. Three areas marked as Worcester, Twyford and Offenham are considered most appropriate for development due to their good transport links and high heat demands. Although the biomass resource available in Worcester Local Authority is extremely limited it is well placed to utilise the extensive resource available in Wychavon and Malvern Hills. It is likely that a large scale plant will only be possible at either Twyford or Offenham as the biomass resource is not sufficient to support two large scale plants.

Combined Heat & Power (CHP)

3.56. A CHP plant requires a localised heat demand. IT Power assessed the Advantage West Midlands heat/energy mapping, but this was found to be a high level study which highlights areas of dense population as requiring heat demand, and does not focus on particular buildings or large developments. The heat mapping suggests that both current and predicted future domestic and industrial heat demands are concentrated in the built up areas. CHP plants on the outskirts of these areas may be most appropriate as they will be accessible for delivery of fuel, likely to have sufficient space for storage and be able to meet some of the heat demand of the built up area.

3.57. Although biomass-fired combined heat and power is feasible, CHP is suited to situations where there is a constant base heat demand. As mentioned previously, potential sites for CHP can be where there is: a process heat required in industry or food processing; where there is significant heat demand such as hotels, leisure centres, residential centres and university campuses; or where there is a high density of potential heat loads that can be linked by a district heating network. Often this proves difficult, especially in summer months, though excess heat could potentially be used to drive absorption chillers. Absorption chillers use heat to drive a cooling process, this can potentially cool water which could be circulated through a separate cooling network used for air conditioning. Cooling networks are suited to offices and retail areas rather than residential centres as there is typically no distribution system for cooling in a house.

3.58. Large scale biomass CHP could be considered on large new developments that may be needed to deliver the proposed housing growth set out in the Regional Spatial Strategy Phase 2 Preferred Option. In large new developments the heat network can be installed as part of the development, but in existing built up areas a new heating network requires substantial upheaval. New housing developments will see a reduced heating demand as the Building Regulations are set to increase energy efficiency of houses and buildings generally so other users of heat must also be considered. Also large developments take many years to construct and any CHP system being considered is likely to be modular to enable expansion as the development expands.

3.59. The potential for CHP has therefore been calculated using the biomass resource available in each area and assuming that this can all be used in CHP plants, although no specific sites have been identified at this time.

3.60. Heating only by biomass (excluding CHP), especially when using wood chip as a feedstock, is suited to large buildings such as schools, hospitals and community centres and potentially agriculture practices such as heating greenhouses and drying processes. Biomass heating systems do require additional operation and maintenance over conventional gas and oil systems in particular addition flue cleaning and ash disposal. In locations where there is no mains gas biomass heating already provides an economic alternative. More processed fuel stock such as wood pellets which are currently not manufacturer in Worcestershire are suited to smaller systems.

4 WIND POWER

Technology

4.1. Wind turbines are used to convert the energy in wind into electricity. Wind turbines can generate a few Watts to multi-Megawatts. Each turbine operates most effectively at a typical wind speed of between 10-15 m/s. Due to the varying nature of wind speed the electrical output from a turbine is variable.

4.2. Wind turbines operate most effectively in a strong and turbulence-free wind. The presence of buildings, trees and surrounding hills means that wind speed can be reduced. This is significant as the power in the wind is proportional to the cube of the wind speed, meaning that a small increase in wind speed results in a considerable increase in the amount of energy being generated. For instance, a 20% increase in wind speed means a 70% increase in instantaneous power. This also means at low wind speeds of 2-4 m/s, very little energy is generated, making large scale development uneconomic.

4.3. For the purposes of the Worcestershire assessment small turbines (250 kW), medium turbines (1.5 MW) and large turbines (2.5 MW) are considered.

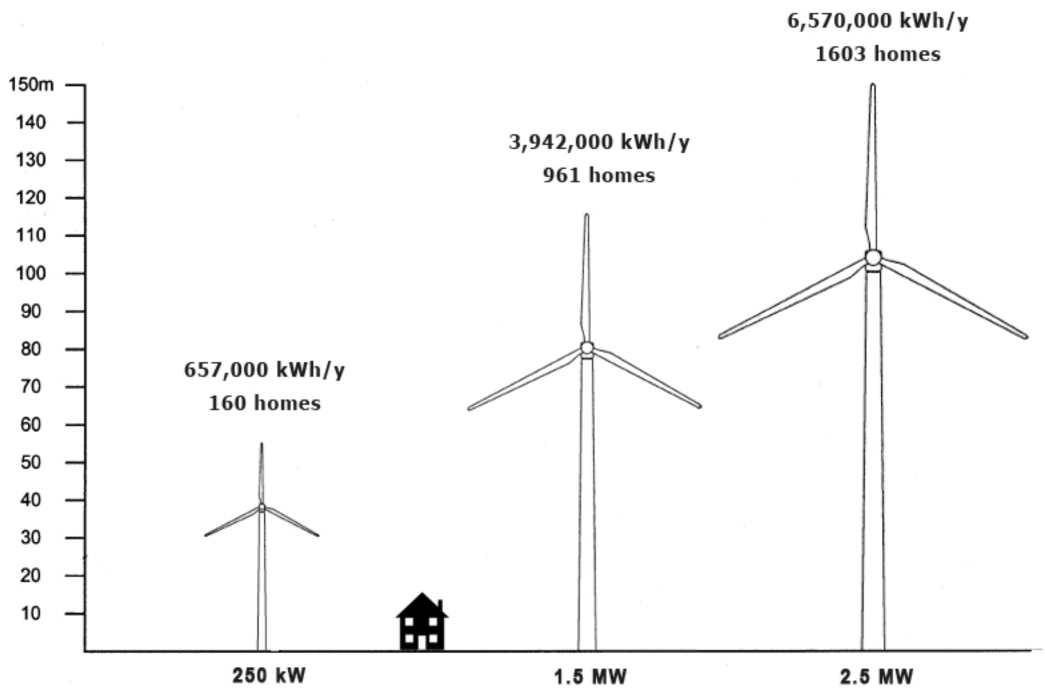


Figure 3 Approximate sizes of typical three-bladed turbines by installed capacity, showing typical annual energy output. The figure for the number of homes supplied is based on the average UK household consumption of 4100 kWh/year (OFGEM)[32] and a 30% capacity factor.

[32] Office of the Deputy Prime Minister (December 2004): Planning for Renewable Energy: A Companion Guide to PPS22

Figure 4 Horizontal Axis Wind Turbine (2.1 MW)

4.4. Wind power is the most developed of all renewables and to date wind developments have favoured areas of high wind resource such as Scotland, Wales and Cornwall. Wind turbines can be deployed singly, in small clusters, or in larger groups known as wind farms. Factors that may influence the size of a development include the physical nature of the site, the capacity of the local electricity distribution network, and the organisation undertaking the development.

4.5. Typically, medium to large turbines are horizontal axis turbines with three blades. Two-bladed turbines are available but are less common. Vertical axis turbines are available but not typically installed in large-scale commercial projects, as vertical axis turbines have been found to be unreliable.

4.6. Wind developments typically require well-exposed sites free from surrounding obstacles such as woodlands and buildings which will increase the turbulence in the wind. Higher turbulence levels in the wind will result in weaker wind turbine performance. The sites are also required to have adequate road access, able to accommodate trailers carrying the longest loads (usually the blades), as well as the heaviest and widest loads (generally the cranes required in erection). Amendments to existing roads can be necessary to gain access to some sites.

Resource

4.7. The most effective means of establishing the wind resource in an area is through detailed site monitoring. However, for the Worcestershire resource assessment this is impractical due to the duration and cost implications so a broader approach has to be adopted. In the UK we are fortunate to a have the ETSU NOABL (National Oceanic and Atmospheric Administration (NOAA) Boundary Layer) wind speed database developed by ETSU for the DTI (Department of Trade and Industry) in 1997. The NOABL database provides the estimated wind speed across every 1 km square in the country at 10 m, 25 m and 45 m above ground level.

4.8. The wind speed data in the NOABL database is the result of an air-flow model that estimates the effect of topography on wind speed. However, there is considerable potential for variation between NOABL and real wind speeds. There is also no allowance for the effect of local thermally-driven winds such as sea breezes or mountain/valley breezes or local roughness such as buildings and trees, which can have a considerable effect on wind speeds. As a result the NOABL data must only be used as a guide and should be followed by on-site measurements and detailed assessment, once a particular site is identified.

4.9. The NOABL database uses the Ordnance Survey grid 1km system for Great Britain allowing the data to be plotted using GIS software. The result of plotted data at 45m is given in Figure 5. The wind speeds at 45m are plotted rather than the wind speeds at lower levels as the hub heights of large turbines typically range from 40m to 80m.

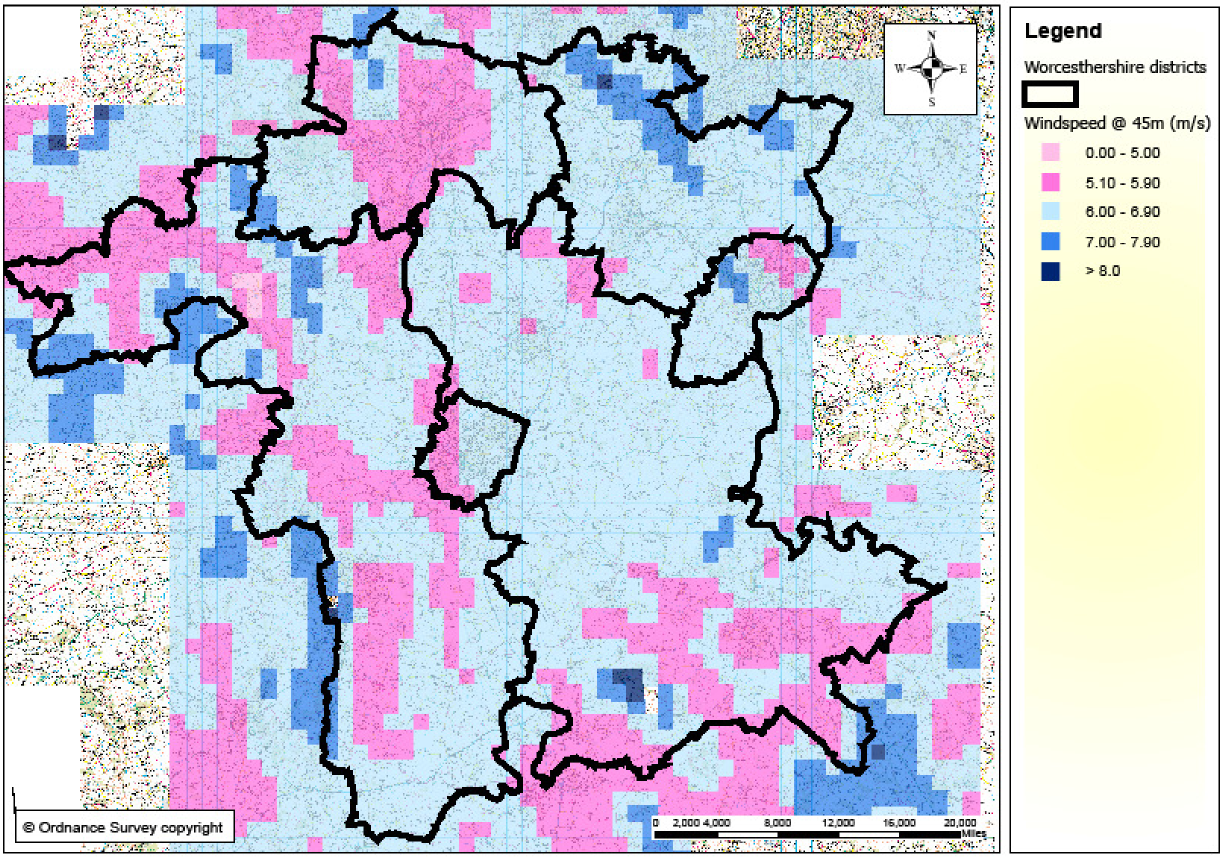


Figure 5 NOABL Wind speed data at 45m above ground level for Worcestershire

4.10. The NOABL database indicates the highest wind speed at a height of 45m for the County of Worcestershire is 9.0 metres per second (m/s). For the purposes of site identification, sites with wind speeds of 6 m/s and above were used, however ideally sites with over 7 m/s are most favourable. Currently in the UK an annual average wind speed of 6 m/s or more is generally required for a large project to be regarded as economically viable. Future changes in electricity prices and government incentives could have a considerable impact on the viability of a development.

4.11. In comparison to the rest of the United Kingdom, Worcestershire is not a prime County for wind farm development as there are limited areas with good mean annual wind speeds (> 7m/s). Population is relatively dispersed limiting areas suitable for development. As a result the County lends itself to smaller developments of 1-6 large turbines (1.5-2.5 MW turbines) as well as more medium-scaled turbines of 250 kW – 1.5 MW.

Constraints

4.12. To obtain the potential wind capacity for Worcestershire a detailed site search was undertaken. The key constraint to wind farm development is wind resource. For the purposes of this study, sites with estimated mean annual winds speeds of greater than 6 m/s at 45m in the NOABL database have been considered.

4.13. Having established areas with an estimated annual wind speed of greater than 6 m/s, a number of other key constraints were then applied, so narrowing down further potential search areas. The constraints and how they have been applied in this study are listed and discussed below:

- Local topography
- Noise
- Areas of Outstanding Natural Beauty (AONB)
- Sites of Special Scientific Interest (SSSI's)
- Special Areas of Conservation (SAC's)
- Scheduled Ancient Monuments
- Common land
- Green belt
- Topple distance to major arteries (for safety 150m (or turbine height) from major roads and railways is used)
- Air traffic and electromagnetic interference considerations
- Communication and microwave links
- 50 m buffer zone to footpaths (a wind farm is less likely to be approved if it blocks access to a public footpath)
- Access

Local topography

4.14. The lay of the land can have significant impact on wind speed and flow. The prevailing wind in the UK is from the south west and so sites which were on the leeward side of a hill were discounted from the search. This is due to reduced wind speeds which occur on the leeward side.

Noise

4.15. Noise from wind turbines arises from blades passing though the air and the gearbox (where one exists). Current guidance[33] suggests that noise should be limited to an absolute level within the range of 35–40dBA. In addition "noise from the wind farm should be limited to 5 dB(A) above background for both day- and night time". Property owners who have an interest in a wind development may accept noise levels up to 45 dBA. The simplest, most effective method of reducing noise is by maintaining a distance between the turbines and any residential properties. A typical minimum guidance distance is 350m. Other factors also come into consideration, such as background noise levels (for example a motorway), noise profile of turbine and whether the property owner has an interest in the development.

4.16. To assist in site identification, 'address point' data was used with a buffer zone of 350m. The address point data defines and locates residential, business and public postal addresses in Worcestershire. A limitation of using address point data is that there is no distinction between residential and business addresses. This is important as there is some potential for leniency in the 350m buffer around business addresses

[33] The assessment and rating of noise from wind farms, ETSU, 1996.

as noise level limits for business can be slightly higher, as disturbance for sleeping is less of an issue. High background noise levels such as those experienced next to major motorways also need to be taken into consideration, as this too could potentially allow some leniency in the 350m buffer.

4.17. To assist in the site search, satellite images were used to try and help distinguish business addresses from residential addresses.

Areas of Outstanding Natural Beauty (AONB)

4.18. AONBs are areas of land with "a precious landscape whose distinctive character and natural beauty are so outstanding that it is in the nation's interest to safeguard them." In Worcestershire there are parts of two areas designated as AONB, these being the Malvern Hills to the west and the Cotswolds to the south. The development of large wind turbines is not prohibited in these areas, but their development is seen as inappropriate as they do not enhance the distinct character of the areas. For the purposes of this study, the areas falling within the AONBs have been examined, but any potential sites have been included only within the most optimistic, unconstrained scenario 3.

Sites of Special Scientific Interest (SSSI)/ Special Areas of Conservation (SAC)

4.19. These are sites which are important due to their flora, fauna or geology. In Planning Policy Statement 22 SSSIs are regarded as National Designations and the following policy applies:

> PPS22 states (page 13) "...planning permission for renewable energy projects should only be granted where it can be demonstrated that the objectives of designation of the area will not be compromised by the development, and any significant adverse effects on the qualities for which the area has been designated are clearly outweighed by the environmental, social and economic benefits."

4.20. Due to the potential disruption to flora and fauna during construction of a wind farm, along with the potential impact on fauna during a wind turbine's operation, proposed developments in SSSIs / SAC are commonly not granted planning permission. As a result, for the purposes of this study SSSIs / SAC have been discounted from the wind farm site search.

Common Land

4.21. Common Land can be considered for development, but from a developer's perspective Common Land presents potential access issues and makes obtaining agreement for development difficult. In this study common land has been included in the site search.

Green Belt

4.22. Green belt from the perspective of site identification has not been set as a constraint. Green belt land designation does not prohibit development but the developer "will need to demonstrate very special circumstances that clearly outweigh any harm by reason of inappropriateness and any other harm if projects are to proceed. Such very special circumstances may include the wider environmental benefits associated with increased production of energy from renewable sources."[32]

Air traffic and electromagnetic interference considerations

4.23. Wind energy developments may cause adverse impacts on aircraft flight safety and radar use for air traffic control and aircraft instruments. Early consultation between developers and statutory authorities can help with siting and mitigation measures.

4.24. The movement of a wind turbine can interfere with radar, as it may be interpreted as a moving object. This could cause it to be mistaken for an aircraft or reduce the ability to track aircraft by radar in the vicinity of a wind energy development.

4.25. Developers will need to consult with the statutory authorities to establish whether there any restrictions that would apply. Broadly restrictions are unlikely to apply to developments beyond 15km from an airfield. For the purposes of this study, consideration was given to:

- Coventry Airport
- Birmingham Airport
- Wolverhampton Half Penny Green Airport
- Gloucestershire Airport

Five of the sites identified were within 15km of these airports.

4.26. A general discussion was held with the Ministry of Defence (MoD), who highlighted there were no major MoD sites in the County which would potentially inhibit development, however each site should be treated on a site by site basis.

4.27. In addition to aviation, communication links such as microwave corridors need to be taken into consideration. These are clear air corridors between two masts allowing data to be transmitted between the two points. Placing a turbine between the points would interfere with the signal and is unlikely to be permitted.

4.28. Both air traffic and electromagnetic interference considerations must be considered on a site by site basis. Typically these require detailed studies and the cost is typically borne by the developer.

Site Access

4.29. Wind turbines are large structures with blade lengths ranging from 15m for a 250 kW to 40m for a 2.5 MW wind turbine. The logistics in whether blades and tower can be delivered to site needs to be taken into consideration as blades come as one unit. This either restricts sites to smaller turbines with shorter blades or prevents the site from being developed as currently not economically viable. The ideal is to have sites close to main trunk roads and motorways with no sharp bends, and without the obstacles of street furniture such as signs, bollards, traffic lights, buildings, roundabouts and trees and hedges.

4.30. In assessing sites in Worcestershire the local road infrastructure has been taken into consideration. Sites with extreme access gradients and small single access roads have been either discounted or noted in the final site listing. In addition bridges need to be able to take the weight of the turbine components in particular the nacelle (the main section which houses gearbox and generator which is on top of the tower) which can be up to 70 metric tonnes or even greater depending on make and model. The final decision as to whether some sites are practically possible to access would come down to an access study by potential developers. Where it is clear that access is unrealistic, sites have been discounted.

Landscape and the Historic Environment

4.31. Worcestershire County Council is at the forefront of landscape character assessment and has classified the whole County in terms of landscape type. The landscape character under which each of the potential sites identified in this study falls has been highlighted in Appendix 6.

4.32. Each specific site would need to be assessed on its specific merits and include a visual impact assessment; this is beyond the scope of this study and would have to be undertaken on a site by site basis.

4.33. The study has examined the historical environment and historic buildings however this has not been exhaustive. Where there has been historic environment of specific high value the sites have been discounted.

4.34. The constraints highlighted above were combined in an ArcView, Geographical Information Systems (GIS) database which was then overlaid on 1:50 000 Ordnance Survey map. The specific location of these sites is given in Appendix 8.

Economics

4.35. When developing wind farms the economies of scale apply as the same infrastructure costs for access tracks/road, electricity connection and development costs (planning/legalities) apply. The precise costs for wind farm development are site dependent. The cost for developing wind turbines in Worcestershire is likely to be slightly higher as sites are suited to 1-4 turbines rather than large developments in addition access to many of the sites is through small single track roads which could inhibit large turbine installation.

4.36. The capital cost of a wind farm is made up of several components (see Figure 6). A typical cost breakdown indicates that nearly two-thirds of costs are associated with the wind turbines themselves. About a quarter of the cost is for other necessary installations including roads, foundations, and electricity cables: the remainder covers installations, planning, legalities and other costs.

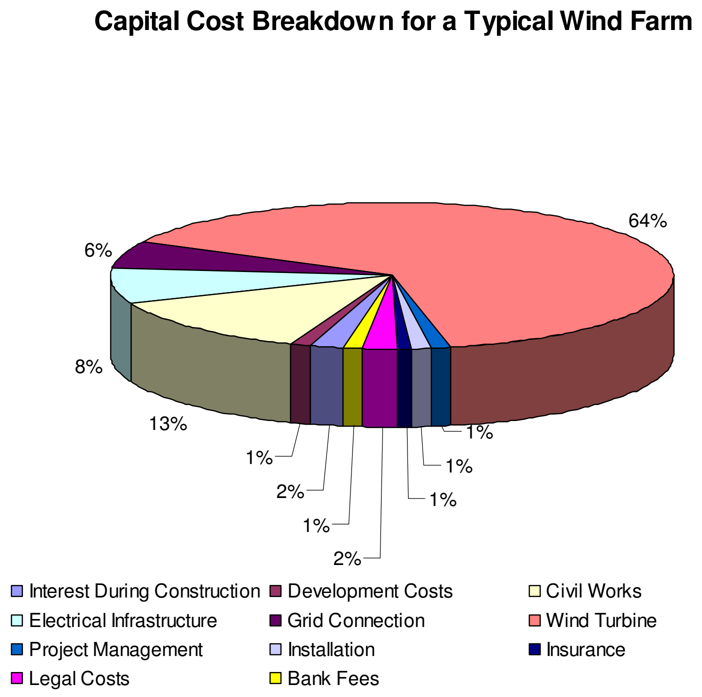


Figure 6 Capital cost breakdown for a typical wind farm.

4.37. Capital costs for wind farms in the UK have dropped significantly since the first commercial Wind Farm was built in 1990, and are currently less than £700 per kilowatt[34] of installed capacity. The cost of installed wind power is expected to reduce further in the future, through both improved products and economies of scale from the increased production of turbines.

4.38. Operation and maintenance costs vary considerably from £8/kW per year to £25/kW per year[35].

Typical site development costs related to Worcestershire are outlined in Table 13.

Table 13 Site development cost

Site capacity MW	Approximate costs £
0.25	175,000-225,000
0.5	350,000-400,000
1.5	1,050,000-1,200,000
2.5	1,750,000 – 2,000,000
5	3,500,000 – 4,000,000

[34] BWEA Wind Energy Fact sheet 3

[35] The Economics of Onshore Wind Energy - DTI Wind Energy Fact Sheet 3

Potential Capacity

4.39. Once the constraints highlighted in section 4.12 were applied, 27 potential sites were identified and can be viewed in Appendix 6. These sites were then prioritised 1 to 3 as to their potential for development. (1 being good to 3 being poor). Priority 1 and 2 sites were then visited to assess the suitability for potential development. Comment on the outcome of the site visit is made in Appendix 6.

4.40. The prioritisation was based upon a number key factors, such as proximity to residential areas, access, and perceived potential visual impact in the region. The identification of potential sites within this study is under no circumstance confirmation that the sites will be developed. Identification of land owners and consultation would be required by potential developers, and any scheme would need to be taken through the planning process.

4.41. Sites examined have considered small 250 kW, medium 1.5 MW and large 2.5 MW size wind turbines. This is because many of the sites identified had potential access issues due to small single track roads and sharp bends. Adopting various sizes of wind turbines has allowed the consideration of more sites than if just single large 2.5 MW turbines were examined. It must be noted that final in-depth access studies, typically undertaken by the developer, could deem some of the sites undevelopable, but this was not possible to ascertain as part of this study.

4.42. The number of turbines per site has been based upon a typical 3 rotor diameter spacing between turbines side by side and 5 rotor diameters from front to back relative to southwest prevailing wind. The number of turbines is only indicative and will vary dependent upon the final land areas made available due to land ownership.

4.43. Consideration was given to the Malvern Hills AONB to the west and the Cotswolds AONB to the south. Though hilly and with high wind resources according to the NOABL wind resource database, Worcestershire's section of the Malvern Hills was found not to have suitable sites for large scale wind turbine installation. This was, in part, due to the high housing density on the Worcestershire side and the fact that the prevailing wind is from the south west and any suitable sites were on the leeward side, so being substantially sheltered. The Cotswolds AONB to the south also presented reasonable wind speeds with Great Hill being of particular interest.

4.44. Every effort has been made to identify potential sites for wind turbines in Worcestershire however the listing is not exhaustive as there are limitations with regards to applying the address point buffer zone approach as discussed in section 4.15.

A summary of the scenario outputs is given in Table 14

Table 14 Summary of wind power potential per scenario

District	Scenario 1			Scenario 2			Scenario 3		
	MW	MWh/year	Approx. No. turbines	MW	MWh/year	Approx. No. turbines	MW	MWh/year	Approx. No. turbines
Bromsgrove	0	0	0	12.5	27375	7	20	43800	12
Malvern Hills	3	6570	2	5	10950	5	13.25	29018	13
Redditch	0	0	0	0	0	0	0	0	0
Worcester	0	0	0	0	0	0	0	0	0
Wychavon	40.5	88695	18	61	133590	30	62.25	136328	35
Wyre Forest	3.75	8213	3	4.25	9308	7	5.25	11498	11
Totals	**47.25**	**103478**	**23**	**82.75**	**181223**	**49**	**100.75**	**220643**	**71**

4.45. The wind capacity Scenario 1 assumes that sites with priority 1 as outlined in Appendix 6 are developed, Scenario 2 assumes priority 1 & 2 sites and Scenario 3 assumes all sites are developed. The calculations of MWh generated per annum assume a 25% capacity factor.

5 HYDROPOWER

Technology

5.1. Hydropower harnesses the potential energy in water as it moves from a high to a low point. The key equipment in a hydropower scheme is a water turbine and a generator. The distance from the high to low point is referred to as the head. Based on the topography of Worcestershire, only low head type turbines are suitable. Low head refers to schemes where the distance between the high and low point in which the water falls is less than 3m.

5.2. There are two types of turbine typically suited to harnessing the potential energy on low head hydro schemes, these being the Propeller and Kaplan turbines.

Propeller/Kaplan - type turbines

5.3. These are 'reaction' turbines, with propellers similar to those on ships, which run full of water and create pressure differences across their blades to extract energy from the available head. There are four main variations of Propeller/Kaplan turbines:

i. Basic propeller turbine (fixed rotor blades, fixed guide vanes)
ii. Kapellar (fixed propeller rotor, adjustable guide-vanes)
iii. Semi-Kaplan (fixed guide vanes, adjustable rotor blades)
iv. Full Kaplan (adjustable guide vanes, adjustable rotor blades)

5.4. There are various configuration options for the turbine and associated equipment to be installed, although the basic components are always the same: an intake (where water is diverted from the river), a set of guide vanes (to guide water at right approach speed and angle to the turbine), a runner (the rotating part of the turbine), and a draft tube (a device to take water out of the turbine and recover energy).

Typical turbine types that could be installed in Worcester include:

- vertical-axis Kaplan
- tube turbine
- siphon turbine
- open flume turbine
- bulb turbine
- pit Kaplan (right-angle drive)
- submersible turbine (mini-bulb turbine)

Detail on these various types of turbine are given in Appendix 8.

Resource

5.5. Hydropower currently accounts for around 8.5% of the renewable energy generated in the UK[36]. The majority of this capacity comes from large dam projects installed many years ago. However there is significant potential for further development of smaller hydropower projects, making use of existing infrastructure such as old weirs and mill sites. In the UK there are around 20,000 former watermills that have fallen into disrepair but many of these offer opportunities for rehabilitation with modern turbines. Weirs, locks and water utility assets such as reservoirs and water transfer schemes may also provide suitable sites for 'Mini-Hydro' generation.

5.6. Although there is still no internationally agreed definition of Small hydro, the upper limit is usually taken as 10 MW. The projects of interest to this study are within the scope of 'Mini' to 'Small' hydro, where Mini hydro is classified as schemes below 1 MW[37], where other classifications are:

- micro-hydro = between 5 kW and 100 kW
- pico-hydro = below 5 kW

5.7. There are about 150 hydro projects between 80 kW and 10 MW in the UK, but these total only about 200 MW capacity. England and Northern Ireland have the greatest number of 'small' hydroelectric projects in the UK, but their total contribution is still only 0.05% of the UK's electricity supply.

5.8. Estimates vary on the remaining potential for small hydro power, from about 300 to 700 MW of installations less than 10 MW[38] with an additional 500 MW existing for low-head hydro schemes of heads less than 3 metres. However, not more than a half of this total is thought to be economically exploitable because of various technical and environmental constraints to development. Some of the constraints are: site location being in environmentally sensitive areas, stringent requirements for fish screening, and concerns about visual and noise impact of hydropower schemes. Mitigation measures can be put in place for some of the issues but they are likely to make schemes more expensive and economically less attractive.

5.9. Lately there has been renewed interest in small hydropower and a growing number of pico-, micro- and mini-hydro projects are being developed. This is being driven partly by UK government policies, such as the 2007 Energy White Paper and 2006 Micro-Generation Strategy, but mainly by the value of electricity sales from grid-connected hydro, due to the price that the Renewable Obligation (RO) gives and the growing base-price of electricity.

Rivers in Worcestershire

5.10. The main two rivers in Worcestershire are the Rivers Severn and Avon, plus some tributaries of these two rivers. A snapshot of the main rivers in the County is shown in Figure 7.

[36] Department for Business, Enterprise and Regulatory Reform/National Statistics (July 2008) UK Energy in Brief.

[37] 1 Megawatt = 1000 kW

[38] http://www.small-hydro.com/index.cfm?Fuseaction=countries.country&Country_ID=79

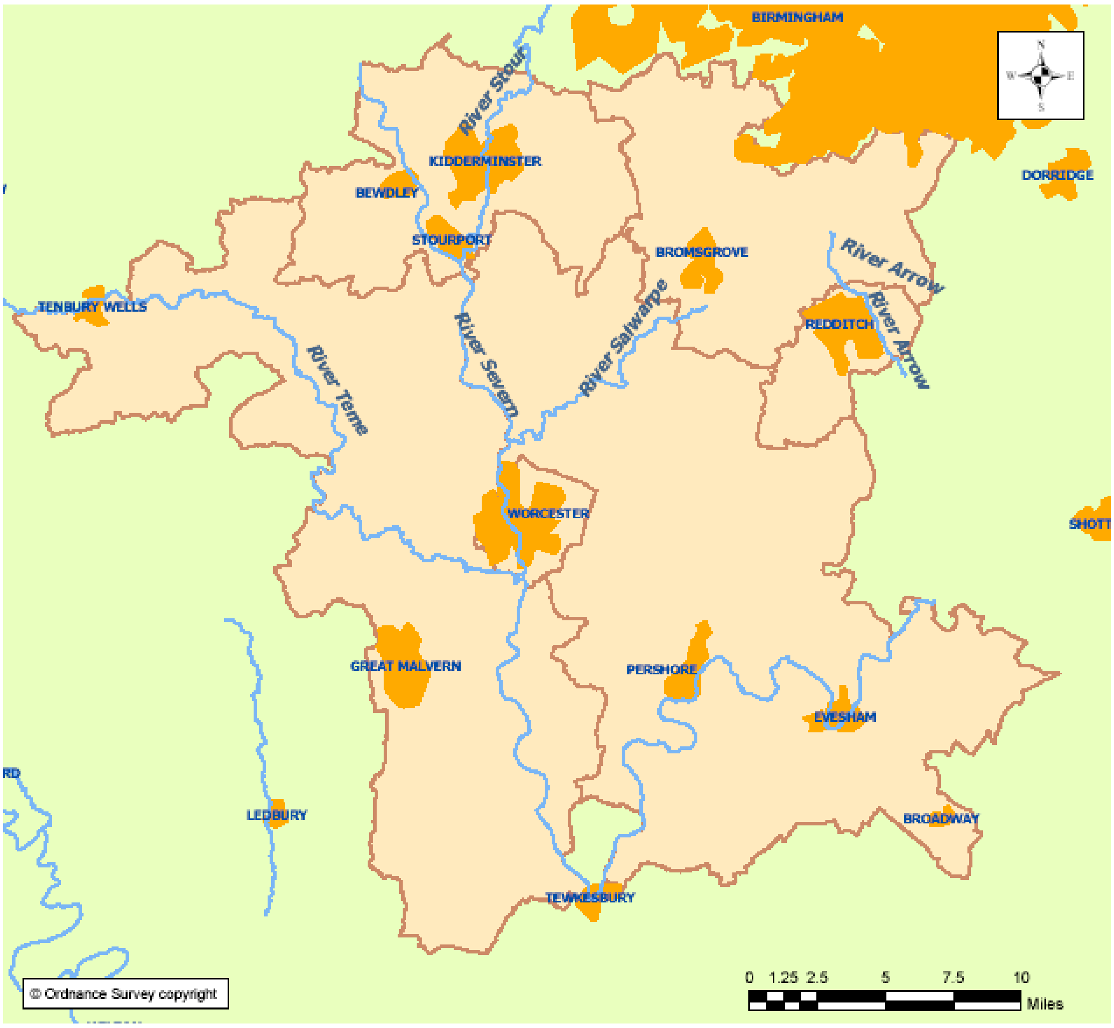


Figure 7 Basic River Map of Worcestershire

5.11. Brief descriptions of the rivers shown in Figure 7 are given below. The river flow data relevant to the location of potential hydropower scheme is given in appropriate sections of this report.

- **River Arrow:** River Arrow is a major tributary of the River Avon.
- **River Avon:** River Avon rises in Warwickshire and passes through Worcestershire and is used for navigation.
- **River Salwarpe:** Rising near Bromsgrove, it passes Stoke Prior, Upton Warren, Wychbold, Droitwich before joining the Severn.
- **River Severn:** The Severn is the longest river in Great Britain, which rises in Wales and passes through various counties before becoming the Severn Estuary joining the Bristol Channel. The River Severn, like the Avon, is used for navigation.
- **River Stour:** The River rises in the north of Worcestershire in the Clent Hills and is a major tributary of the River Severn, and it is about 25 miles in length.
- **River Teme**: Runs to the north of Tenbury Wells on the Shropshire/Worcestershire border, on its way to join the River Severn south of Worcester. The whole of the River Teme is designated as a Site of Special Scientific Interest (SSSI). However, it

may still be possible to develop a hydropower scheme even if a site is a designated SSSI. There may be some additional requirements to be met if a hydropower scheme is proposed at a designated site. A feasibility study for a specific scheme can elucidate on the requirements, if any.

Hydropower Potential in Worcestershire

5.12. A review of all the hydropower schemes in Worcestershire identified in the Salford University Study 'UK Small hydro potential' 1989 was carried out. This included both the sites which were deemed unsuitable for development by the study, as well as those which were considered suitable, as the eligibility criteria is likely to have changed since 1989. A detailed investigation of Ordnance Survey maps (nos. 138,139,149,150) was carried out to identify any additional sites. This evaluation of Worcestershire has shown some potential for small-scale hydropower (projects of less than 1MW) but only at a limited number of sites as shown in Table 15. All of these sites can be theoretically developed.

5.13. A hydropower scheme producing 18 kW is reported to be in operation at Fladbury Mill, near Pershore. An old waterwheel at this site has also been restored to run a 4kW alternator. There are also hydro-electric development companies, based in Worcestershire, engaged in hydropower development.

Table 15 Summary of hydro sites for initial consideration

	Location	Town	River/Stream	Maximum Head (m)	Power (kW)
1	Pershore Lock	Pershore	River Avon	2.5	294
2	Fladbury Lock	Fladbury	River Avon	2.0	221
3	Nafford Lock	Birlingham	River Avon	1.7	198
4	Wyre Mill	Pershore	River Avon	1.1	135
5	Strensham Lock	Strensham	River Avon	1.2	150
6	Cleeve Prior	Welford-on-Avon	River Avon	1.7	196
7	Holt Fleet Lock	Holt Heath	River Severn	2.3	1084
8	Larford Lock	Stourport	River Severn	1.2	575
9	Bevere Lock	Worcester	River Severn	Unknown	Unknown
10	Diglis Lock	Worcester	River Severn	1.6	769
11	Eardiston	Eardiston	River Teme	2.2	266
12	Powick Bridge	Worcester	River Teme	Unknown	Unknown

5.14. Another option for hydropower not considered is the use of rubber inflatable weirs for power generation. As the name suggests the weir height can be lowered or increased depending on the river flows by inflating/deflating the weir. This means that in times of high rainfall the weir can be lowered to offer minimal resistance, and in times of low rainfall water levels can be maintained with the height of the weir. One company, the Upper Severn Hydro & Navigation Company Ltd. (Severn Hydro), wishes to develop several of these inflatable weirs on the upper reaches of the Severn (from Ribbesford to Ironbridge) to both restore navigation to 40 km of the Upper Severn and potentially install hydro power systems. Their studies estimate that with a gross head of 2.1 m with good flow rates and the installation of three 1 MW turbines they could generate about 4 GWh a year[39]. Although these may be an option on Worcestershire's rivers they have not been included in the figures in the report. This is in part since inflatable weirs have yet to be used in the UK, the risk of flooding on the rivers in Worcestershire is serious, and based on IT Power's experience from its involvement with a number of hydropower schemes, any additional in river structures whether inflatable/deflatable are unlikely to be seen favourably by the Environment Agency. The final decision as to whether this would be accepted would be determined through a formal planning application but any such development is going to have to indicate without reasonable doubt that the development of any structures does not impose any increased flood risk.

Constraints

5.15. There are eight main constraints on the selection of potential sites. In the overall resource assessment carried out for the development of hydroelectric generation in Worcestershire the following were considered:

i. Head – the power capacity of a potential hydro site depends crucially on the vertical drop of water at the site (creating water pressure). Although the water flow is also an important parameter, there is a minimum 'head' that is typically acceptable for the viable development of small hydro resources in the UK. The figure is about 1 metre of vertical drop. In reviewing the potential sites in Worcestershire, the most important constraint was to only look at sites with 1 m of head or above and to consider sites with 3 m and above as strong candidates. These were included in Table 7.

ii. Access – the second most important constraint is access to the potential hydro site. In most small hydro-power developments there is a need for construction equipment to reach the site, especially for the civil works. Therefore a site should ideally have vehicular access.

iii. Land availability – related to access, particularly for hydro sites in built-up areas, the availability of land for construction of the powerhouse is a crucial concern, as many potential (riverside) sites may not have any immediately available land for the plant.

iv. Grid connection – Typically small hydro schemes in the UK are grid connected. Ideally it is best to offset the site building's electrical demand rather than to sell the electricity generated back to the grid. Grid connection is beneficial to ensure demand can be met when the hydro scheme cannot fulfil the buildings electrical demand.

[39] http://www.severnhydronav.com

v. Flow – as basic flows are already known from published hydrological studies for the main rivers, initial resource assessment has only considered on those rivers and streams (which display a low head potential) with mean flows of about 500 litres/sec (or 0.5 m^3/s), which would give at least a reasonable 'pico-hydro' level capacity (5 kW) at low heads.

vi. Environmental impacts – there are numerous potential environmental concerns for hydropower developments, and within built-up areas the important ones will be visual and noise impacts (particularly during construction), and concerns about impacts on fish and other aquatic animals, which would have to be resolved with the Environment Agency and Natural England if a development was proposed.

vii. Climate Change - Climate Change is likely to increase the instances of high river flows and flood risks especially during winter months. Run of river hydro schemes where the head is due to a weir will see reduced generation output at periods of high flows as the head available will be reduced. Where power houses are at risk of flooding they should be made water-tight. In summer months there could well be reduced flow, leading to a reduction in potential generation. All sites identified in this study are already in potential flood risk areas.

viii. Listed structures - Certain weirs may be within the curtilage of listed buildings. This could well prevent, restrict or impose certain requirements on a hydro development.

Economics

5.16. The costs for hydro power vary, from site to site, giving consideration to available head (classification of low, medium and high) and scheme size. In general, the larger the scheme the lower the cost per kilowatt for production. The most important parameter in dictating costs is the available head. The higher the head available, the lower the cost per kW of the scheme. This is because for any specific turbine, *a halving of the head will lead to one third of the output power for the same capital cost*. This is the main reason why low-head projects are so difficult to realise.

5.17. Although the head is the most critical parameter in determining the specific cost, other areas which can greatly affect cost are:–

- Distance to the grid and cost of connection
- Access to site (for cranes, diggers and ready-mix lorries)
- Screening requirements and means for disposing of the trash

It should be noted that the first two factors affecting the cost are not unique to hydropower and are applicable to other technologies.

5.18. The decision on one area of the design will also have knock-on effects to the other areas. Hence one has the option of spending more on the turbine in order to save on civil costs (this applies particularly to the siphon and submersible turbine options). Or one can save on civil costs by using the existing works and accepting a smaller but more cost-effective scheme.

5.19. The capital cost of a hydro power scheme can be broken down into several categories (see Figure 8, taken from a low head hydro scheme). A typical cost breakdown indicates that most significant expenditure is in the civil engineering requirement, this is particularly the case for low head hydro. The Electro-Mechanical equipment costs are also significant, this can be more so for higher head schemes. This is then followed by the grid connection requirement and associated development, planning and legal costs that can be encountered.

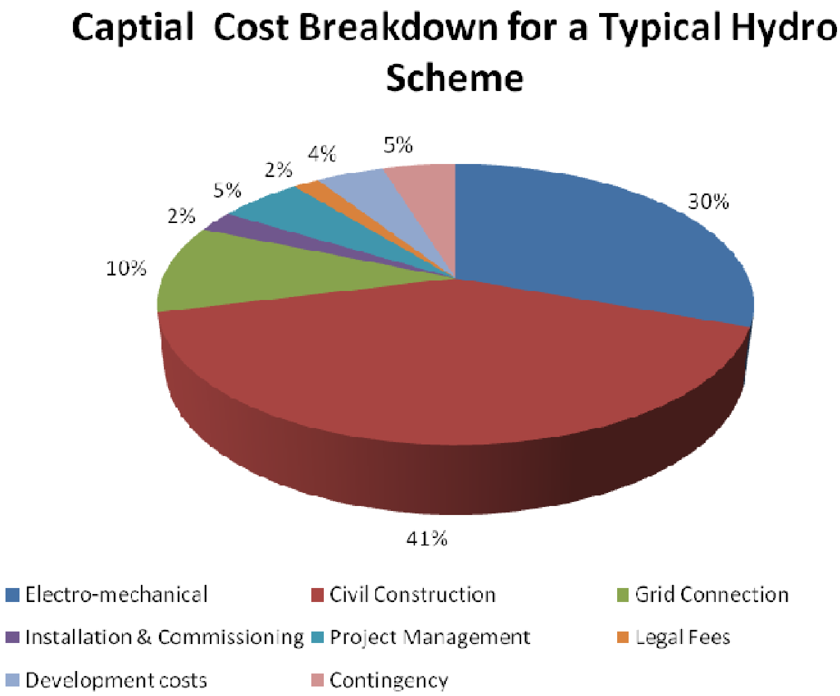


Figure 8 Capital cost breakdown for a typical hydro power scheme

Potential Capacity

5.20. Out of six rivers identified in 5.11, only three of them – the Severn, the Avon and the Teme were shortlisted for further investigation as only these were deemed to have some potential because the other smaller rivers have very low flows.

5.21. Appendix 12 shows potential schemes that could be realistically developed. It has to be noted that the economics of a scheme are largely dependent on the head of the scheme (given other parameters are the same) and hence some of the sites considered were analysed and rated entirely based on the head when no other information was available. Table 16 summarises the estimated hydro power capacity for each scenario.

Table 16 Summary of hydro power estimated capacity per scenario

District	Scenario 1		Scenario 2		Scenario 3	
	MW	MWh	MW	MWh	MW	MWh
Bromsgrove	0	0	0	0	0	0
Malvern Hills	1	5910	1	5910	1	5910
Redditch	0	0	0	0	0	0
Worcester	1	3369	1	3369	1	3369
Wychavon	1	2247	1	3112	1	5225
Wyre Forest	1	2518	1	2518	1	2518
Totals	**3**	**14044**	**3**	**14909**	**4**	**17022**

6 CAPACITY SUMMARY

6.1. The renewable energy assessment identified an unrestricted (Scenario 3) electricity generation total from all renewable sources of 570 214 MWh (122 MW capacity), as shown in Table 17. This assumes all sites are developed, however the reality is that not all sites will be viable due to a multitude of factors. In addition this value assumes that all the biomass resource is used just for electricity generation.

Table 17 Total renewable energy generation (assuming Biomass is as electricity only)

District	Scenario 1		Scenario 2		Scenario 3	
	MW	MWh	MW	MWh	MW	MWh
Bromsgrove	0	3424	13	34040	21	72174
Malvern Hills	6	26203	10	43393	20	150112
Redditch	0	0	0	0	0	0
Worcester	1	3369	1	3369	1	3369
Wychavon	44	110111	67	173697	72	301939
Wyre Forest	5	14149	6	18449	7	42620
Totals	**56**	**157255**	**97**	**272949**	**122**	**570214**

6.2. A more refined approach would be to consider 60% of the biomass resource for heat generation and 40% for electricity generation. Using this method increased the proportion of biomass and the overall MWh which can be achieved through renewable energy generation as the efficiencies for generating heat relative to electricity from biomass are greater. This gives an overall unrestricted capacity of 570 932 MWh in Scenario 3.

Table 18 Total renewable energy generation (assuming biomass at 60% heat and 40% electricity generation)

District	Scenario 1		Scenario 2		Scenario 3	
	MW	MWh	MW	MWh	MW	MWh
Bromsgrove	1	7006	14	40910	23	72336
Malvern Hills	8	41078	14	72031	27	150306
Redditch	0	0	0	0	0	0
Worcester	1	3369	1	3369	1	3369
Wychavon	47	130877	73	213592	80	302222
Wyre Forest	5	17820	7	25511	9	42700
Totals	**62**	**200149**	**109**	**355413**	**140**	**570932**
Approximate no. of houses that total energy could supply	**N/A**	**8693**	**N/A**	**15436**	**N/A**	**24796**

Current energy usage

6.3. The majority (92%) of electricity in the West Midlands comes from large power stations with only 2% coming from renewables, 3% combined heat and power and 3% waste incinerators. The renewable capacity is mainly made up of landfill gas and sewage gas with minor contributions from hydropower and biomass[40]. Information was not available as to how this is broken down in relation to Worcestershire.

[40] The Alternative Energy Guide, Bioenergy West Midlands.

6.4. The electrical and gas use (2006) and heating oil use (2005) for Worcestershire and its districts is shown in Table 19. As can be seen in the table the average domestic consumption is higher in Worcestershire then both the West Midlands and Great Britain. However the average consumption for industrial and commercial sectors is lower than the West Midlands and Great Britain averages. This is likely to be because the County is more rural with less commerce and industry than other counties.

Table 19 Electricity and Gas Consumption 2006[41]

District	Average Electricity use - Domestic (GWh) (2006)	Average Electricity Consumption – Commercial (GWh) (2006)	Average gas Consumption - Domestic (GWh) (2006)	Average Gas Consumption – Commercial (GWh) (2006)	Electricity Consumption - all consumers (GWh) (2006)	Gas Consumption - all consumers (GWh) (2006)	Heating Oil Consumption - all consumers (GWh) (2005)
Bromsgrove	4.972	50.89	20.85	286.4	350	914	182
Malvern Hills	5.272	44.49	18.26	288.03	322	478	273
Redditch	4.29	119.47	16.92	520.7	428	822	171
Worcester	4.21	86.04	16.2	456.18	488	887	177
Wychavon	5.24	85.92	17.47	1,059.98	717	1,318	386
Wyre Forest	4.52	74.58	17.53	434.41	454	892	252
WORCESTERSHIRE	**4.75**	**76.9**	**17.87**	**507.61**	**2,759**	**5,311**	**1,438**
WEST MIDLANDS	**4.49**	**86.1**	**18.22**	**621.89**	**27,736**	**57,848**	**12,059**
GREAT BRITAIN	**4.46**	**81.95**	**18.24**	**605.79**	**317,832**	**628,733**	**208,083**

6.5. The total electrical and thermal requirement for Worcestershire for 2006 is estimated to be 9 508 000 MWh (summing the cells highlighted in red in Table 19). Figures for heating oil consumption were not available so 2005 data were used in the calculation.

Renewable energy generation in context

6.6. The total estimated renewable energy generation in Scenario 2 is 355 413 MWh, this equates to just 3.7% of the total estimated electrical and thermal energy demand for 2006.

Table 20 Total renewable energy generation (assuming 60% heat and 40% electricity for biomass) as a percentage of total electrical and thermal energy demand for 2006.

	Scenario 1	Scenario 2	Scenario 3
Total estimated renewable generation MWh	200149	355413	570932
Percentage of overall energy consumption in 2006	2.1%	3.7%	6.0%

6.7. Extrapolating (using an annual factor of 1.055 from trend line of current consumption) the total electricity demand for Worcestershire to 2020 would give an estimated energy demand of approximately 10 030 000 MWh. This would reduce the percentage of renewable generation to 3.5% of overall energy consumption for Scenario 2 generation output. Table 21 gives an indication of the potential renewable

[41] BERR Regional and local authority electricity consumption statistics 2005,2006. April 2008
http://www.berr.gov.uk/whatwedo/energy/statistics/regional/other/page36195.html

generation as a percentage of total estimated electrical and thermal energy demand for 2020. This assumes that energy consumption increases, however energy efficiency measures could well see the consumption figure remain static or reduce in future years.

Table 21 Total renewable energy generation (assuming 60% heat and 40% electricity for biomass) as a percentage of total estimated electrical and thermal energy demand for 2020.

	Scenario 1	Scenario 2	Scenario 3
Total estimate renewable generation MWh	200149	355413	570932
Percentage of overall energy consumption 2020	2.0%	3.5%	5.7%

7 GRID CONNECTION

7.1. Grid connection is the responsibility of the Distribution Network Operator (DNO). In Worcestershire, this is Central Networks, and they are responsible for the electricity grid below 132 kV distribution. At or above 132kV the National Grid Company is responsible. Connection of renewables within Worcestershire will typically be the jurisdiction of Central Networks as there are no large (in the region of mega MW) potential renewable generating sites in the County.

7.2. In the majority of cases the renewable energy systems are connected to the electricity grid as power production is often intermittent (depending on the technology type) and the storage of energy is expensive. More importantly connection to the electricity grid allows a generator to sell electricity.

7.3. Consultation was held with Central Networks regarding the grid connection capabilities and costs. Central Networks aim to accommodate all requests for connection within their jurisdiction. Connections are considered on a case by case basis as they are dependent upon a number factors.

Factors influencing connection

7.4. The physical infrastructure which connects a distributed generator (such as a biomass electrical generation plant) to a DNO (Distribution Network Operator) network can be divided into two sections: That owned by the developer, and that owned by the DNO.

7.5. The developer has sole responsibility for the design, installation and operation of the equipment on its side of this interface, although the DNO will want to ensure itself that this equipment does not pose a hazard to their distribution network, and so guidelines are outlined for the developer. The DNO will assume responsibility for operation and maintenance of all infrastructure on their side of the interface, but the design and installation of any new DNO-owned infrastructure is a matter for dialogue and agreement between the developer and the DNO.

7.6. The detailed tasks that must be undertaken in getting connected vary with the size of the generation plant that is being developed. In general the larger the plant, the more complex the connection requirements.

Distance

7.7. The distance from the potential generator to suitable connection is one of the most influencing factors. Ideally renewable generation is within 1-2km of a primary substation as this minimises costs of connection. Under this study it was not possible to gain the precise location of substations for the potential sites highlighted.

Local Loads

7.8. If the generator can be connected to an existing user network then there may be significant cost benefits to the generator in reducing the Generator Distribution Use of System (GDUoS) charges. These are annual charges paid by the generator for use of the system. Also electricity purchased from an energy supplier can cost three times more than electricity purchased direct from the generator.

Capacity of existing network

7.9. The ability of the existing electricity network to take the additional power from a new generator is very important. This is established by the DNO who undertakes a site specific grid capacity study. In the event the existing network is not able to take the addition a power the developer may well have to bear some or all the additional cost depending on the site location.

Connection costs

7.10. Larger systems generally incur a connection charge. Central Networks no longer charge for 'deep connection charges' which refers to fundamental grid strengthening such as a new substation and line replacement, instead they only pass on 'shallow connection charges' this refers to the lines to connect a site to the grid.

7.11. The cost for connection is assessed on a case by case basis and is extremely variable and dependent on the work required to the network to accommodate the generation system. Therefore Central Networks were unable to give typical/average costs for a connection.

7.12. The first stage in establishing a new connection is to commission Central Networks to do a generator connection study to determine the work required to make the new connection and associated costs. These studies are done on a case by case basis.

8 RENEWABLES OBLIGATION

7.13. A key driver to the likely development of large scale renewable energy projects is the economic viability. The key economic influencing factors are the wholesale price per MWh generated (current November 2008 forward price is £133 per MWh) and the market price for the Renewable Obligation Certificates (ROC) which can be claimed per MWh (1 ROC = 1 MWh) of renewable electricity generated and injected into the grid. The ROC is claimed in addition to the sale of the electricity and is obtained by the renewable energy generator from the Office of Gas & Electricity Markets (OFGEM).

7.14. The Renewables Obligation (RO) requires licensed electricity suppliers to source a specific and annually increasing percentage of their electricity sales from eligible renewable sources. For 2007/08 the level of the RO is 7.9% rising to 15.4% in 2015/16. Electricity suppliers can meet their obligation by either presenting Renewable Obligation Certificates (ROCs); paying a buyout price (£34.30 per MWh in 2007/08 rising each year with inflation); or a combination of the two. Proceeds from the buy-out fund are paid back to suppliers in accordance with how many ROCs they have presented, compared to the total number of ROCs presented for the obligation period. At the end of an obligation period the money in the buyout fund is recycled to those suppliers who presented ROCs on a pro rata basis. See Figure 9 for flow diagram of how ROCs operate.

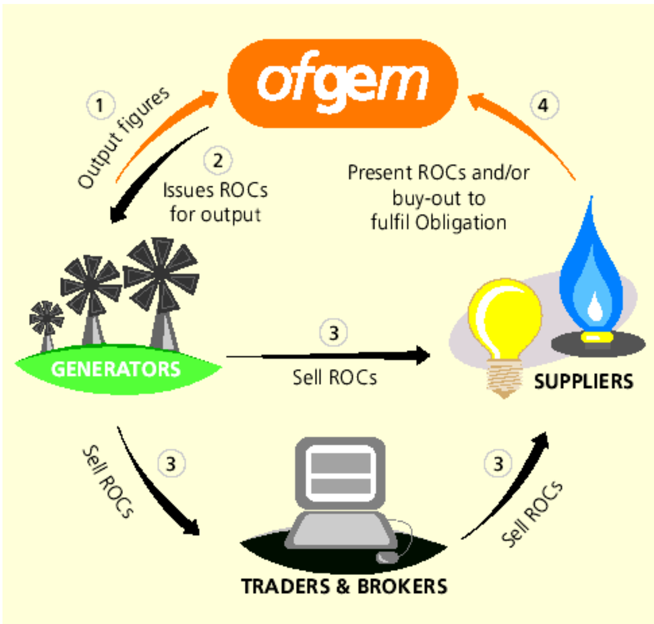


Figure 9 Graphical representation of how the Renewable Obligation operates[42]

7.15. Currently 1 MWh generated from all renewable sources receives 1 ROC. From 2009 some biomass technologies will be eligible for up to 2 ROCs per MWh[43] which will encourage further potential development as the project economics improve.

[42] OFGEM

9 CRITIQUE OF POLICY

Regional

9.1. The West Midlands Regional Energy Strategy[44] includes a target of 5% of electricity consumption from renewable generation, rising to 10% by 2020. Consultation took place with Worcestershire's neighbouring counties as to their current status with respect to renewable energy capacity and policy. This consultation highlighted that each of the counties was currently carrying out capacity studies however the results have yet to be made available. The policies of neighbouring authorities can have an impact on the policy of Worcestershire and on the siting of potential plants that may be in the 'border' areas and therefore it is worth considering the results of the ongoing research from adjacent authorities, when available.

Worcestershire Climate Change Strategy

9.2. The Worcestershire Partnership has made a commitment in the Worcestershire Community Strategy to 'tackle the causes and effects of climate change'.

9.3. To that effect the Worcestershire Partnership Environment Group (WPEG) has set up the Worcestershire Climate Change Group (WCCG) to develop its strategy and action plan. The Worcestershire Climate Change strategy covers the period from 2005-2011.

9.4. It recognises the important contribution renewable energy can make in tackling climate change and reducing carbon dioxide emissions. It sets targets for emissions reductions and the production of renewable energy.

9.5. The strategy hopes to use the planned reduction in fossil fuel use to provide more jobs locally in the renewable energy and energy efficiency sectors.

9.6. At the time the strategy was developed (2004), an estimated 5% of the total electricity produced from renewable sources in the West Midlands region was from Worcestershire. This was mainly using landfill gas at Hill and Moor landfill near Pershore and landfill sites at Martley. There is also a biomass wood fuelled boiler plant which is used to heat the County Hall building in Worcester. Small scale ground source heat is used at the Malvern-hills science-park and Duckworth Trust Pump house centre. There are also some small scale solar and wind installations on some housing developments.

9.7. To move forward the strategy has identified using biomass (from energy crops and waste), solar energy, running water, wind and small scale ground source heat pumps. These options are seen as fitting with Worcestershire's natural resources availability.

9.8. The salient features relating to renewable energy from the strategy objectives are:

- To increase the production of renewable energy from 5% to 12.5% of the regional target by 2010 and to have 155 GWh of electricity, 30 GWh of heat and 5.5 million litres from bio fuels annually by 2011.

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43 Reform of the renewables obligation, Statutory consultation on the renewable obligation order. June 2008 http://www.berr.gov.uk/energy/sources/renewables/policy/renewables-obligation/key-stages/ro-consultation-2009/page46709.html

44 West Midlands Regional Assembly, et al (November 2004): West Midlands Regional Energy Strategy.

- To purchase renewable energy and electricity and to encourage and promote the public sector to lead the way
- To encourage high density developments which can exploit renewable energy effectively for example, district heating schemes.
- To identify further opportunities of generating energy from landfill gas
- To include policies and plans for the exploitation of renewable energy resources in all strategic and local development plans

Policy in context of estimated capacity

9.9. Achieving the current policy as laid down in the Worcestershire Climate Change Strategy of 155 GWh electricity from renewable energy is attainable relative to the resource and potential sites. The timeframe by 2011 is unlikely considering the duration for development to undertake feasibility, planning and construction is typically in excess of 2 years and there are currently few proposed renewable developments.

9.10. Similarly the policy target of 30 GWh heat from renewable energy is also unlikely to be achievable.

9.11. With respect to attaining the Government's national target of 15% renewables by 2020, or the West Midlands regional targets, at current energy use this is unattainable (see Table 21) given potential resource and capacity in the region. Worcestershire would have to see dramatic reduction in energy consumption as well as meeting the short fall (1 149 228MWh) of with micro-generation.

9.12. A possible policy figure would be 3.5% by 2026. This is probably realistic and attainable and would have to combine both energy efficiency and bold steps in moving renewable energy projects forward in Worcestershire. Though this figure does not match the Government targets it is still extremely challenging given population growth and requirement for new developments in the County as these will see pressure on overall energy consumption.

9.13. Implementing staged targets for Worcestershire such as those suggested in Table 22 would enable monitoring and assist in achieving the long term target.

Table 22 Suggested staged Worcestershire Renewable Energy Targets

	Year		
	2015	2020	2026
Staged renewable energy targets as a percentage of total energy consumption in that year (excluding transport)	1.5%	2.5%	3.5%

Other potential policies

9.14. Other potential policies that could be considered by Worcestershire include policies similar to those of the London Boroughs of Merton and Croydon. The London Boroughs of Merton and Croydon have been at the forefront of policy development and implementation. In October 2003 the London Borough of Merton adopted the Unitary Development Plan (UDP) policy PE 13 which is often referred to as the Merton

Rule. Croydon adopted a similar policy which has recently been incorporated into the Unitary Development Plan.

Merton Rule
Policy PE13 reads: "The council will encourage the energy efficient design of buildings and their layout and orientation on site. All new non-residential development above a threshold of 1,000 sqm will be expected to incorporate renewable energy production equipment to provide at least 10 % of predicted energy requirements. The use of sustainable building materials and the re-use of materials will also be encourage, as will the use of recycled aggregates in the construction of buildings. This will be subject to the impact on the amenity of the local environment, taking into account existing character of the area."

Croydon Unitary Development Plan (UDP) Chapter 8
Policy EP16 reads: "The Council will encourage all developments to incorporate renewable
energy, but will require proposals for non-residential developments exceeding 1 000 square metres gross floorspace, and new residential developments comprising 10 or more units, whether new build or conversion, to incorporate renewable energy production equipment to off-set at least 10 % of predicted carbon emissions, except where:

a) the technology would be inappropriate;
b) it would have an adverse visual or amenity impact that would clearly outweigh the benefits of the technology; and
c) renewable energy cannot be incorporated to achieve the full 10 %. Where the 10% requirement cannot be achieved on major developments, a planning obligation will be sought to secure savings through the implementation of other local renewable energy schemes."

These policies have stimulated micro-generation on new developments, rather than large scale renewables.

Further the UK's "Building a Greener Future: policy statement"[45] sets out the intention for all new homes to be zero carbon by 2016. This is a staged target achieving 25% carbon improvements by 2010, 44% by 2013 and a zero carbon target by 2016. Though not strictly aimed at renewables the targets will require generation onsite to achieve the required targets and these could be met by single large plant on large new developments. However since new homes in Worcestershire will only account for a small percentage of the housing stock such a policy would have minimal impact on County renewable energy targets.

9.15. The suggested staged renewable energy targets set at County level would assist in providing a focus for renewable energy development in Worcestershire. However such targets need to be challenging and attainable, rather than targets set to achieve

[45] Department for Communities and Local Government (June 2007): Building a Greener Future: policy statement

headlines. Setting targets alone is insufficient to stimulate installations on the ground. This has to be followed through with other policy measures and a change in acceptance of renewables within the local context and at the planning phase. Public concern over the impact of renewables is understandable but some development is required to achieve a more sustainable energy supply both locally and nationally. Development must therefore be put into the context of the County and at a national level. Although the potential renewable generation in Worcestershire might seem small it is still important in its role in helping to meet the national renewable energy targets. Indeed this should stimulate energy efficiency measures in Worcestershire so reducing consumption and improving the percentage that renewable energy could supply in the region. Regional renewable developments bring awareness of power generation and energy consumption to the wider public and can become land marks, such as the single large wind turbine at Green Park, Reading adjacent to the M4.

9.16. The potential generation values obtained in this study are considerably lower than those in the Renewable Energy Prospects for the West Midlands study[46]. This is, in part, because the Regional study involved a less localised assessment as it dealt with a wider area. In addition IT Power undertook a more detailed assessment which applied further constraints and included site visits which discounted many potential sites. IT Power believe the figures in this report are more accurate with respect to the realistic large scale potential.

10 POLICY RECOMMENDATIONS

10.1. National, regional and local planning policies are crucial in realising the potential for renewables. National planning guidance includes:

- Planning Policy Statement 22 (PPS22): Renewable Energy
- Planning Policy Statement 1: Delivering Sustainable Development
- Planning Policy Statement: Planning and Climate Change - Supplement to Planning Policy Statement 1

10.2. The guidance states that planning authorities need to assess their area's potential for accommodating renewable and low carbon technologies as well as stating that substantial new developments will need to gain a significant proportion of their energy supply from renewable technologies. It also calls on developers and councils to consider the potential for connecting developments to neighbouring community heat and power schemes that can serve an entire local community.

10.3. This study provides Worcestershire authorities with information on the local opportunities for large scale renewables. In order to realise the potential identified, policy intervention is needed to encourage large scale renewable energy development in Worcestershire. Actions to take include:

- Development of attainable staged County level targets to which Districts are agreed.
- Supported policies within:
  - Local development framework

[46] Halcrow for Government Office for the West Midlands, (November 2001) Renewable Energy Prospects for the West Midlands.

  - Community strategies
  - Economic development plans
  - Environmental strategies
  - Forestry frameworks

- Other wider actions – e.g. training and promotional activities
- Development of local expertise, building on existing successes. This will ensure benefits from employment and income generation are maximised.
- Collaboration between authorities. Biomass plants can utilise resource from a number of Counties so authorities should be kept informed. The cumulative impact of wind turbines can be detrimental to the landscape character and authorities should keep each other informed of developments being considered.
- Consistency in long term policy. Policy developed should remain consistent over the long term so as to provide potential project developers with confidence to invest. A good example of this is the continuation of ROCs to 2028 so providing consistency and confidence in project financing.
- Where a potential renewable energy site is on County Council property, the Council could consider taking the lead and look to develop the site through an Energy Service Company (ESCO).

Encouraging appropriate large scale renewable energy development

10.4. The information contained within this report provides each authority within Worcestershire with information on the potential for renewable energy development within their area.

10.5. IT Power recommends that the results for the medium scenario (Scenario 2) be adopted as targets for renewable energy development by 2026 and monitor progress towards the targets.

Table 23 Renewable Energy Capacity Scenario 2 (assume 60% heat and 40% electricity from biomass resource)

District	Scenario 2	
	MW	MWh
Bromsgrove	14	40910
Malvern Hills	14	72031
Redditch	0	0
Worcester	1	3369
Wychavon	73	213592
Wyre Forest	7	25511
Totals	**109**	**355413**
Approximate no. of houses that total energy could supply	**N/A**	**15436**

10.6. To reach these targets, significant renewable energy development such as wind and biomass should be encouraged within planning policy. This is still a challenging target given the limitations in Worcestershire.

10.7. Authorities should ensure that their development control planners are familiar with the technologies found to be suitable in their area. There are a number of national training initiatives to provide development control planners with specific guidance on considering renewable energy technologies. http://www.planningrenewables.org.uk

10.8. Ensuring the general public and communities are familiar with renewable energy technologies is also important in ensuring development proposals are accepted locally. One good way to help develop public awareness is the development of exemplar projects.

10.9. In order to maximise local benefits it will be important to develop criteria for community involvement and/or ownership. DBERR provides guidance on community involvement in wind energy development[47]. The guidance includes a protocol and best practice guidelines to support public engagement, a 'toolkit' for community benefits, and a report on bankable models for community ownership for wind energy developments. Local reward can be a financial contribution tied to the generation, though funds obtained need to be carefully managed and made transparent for the local good.

10.10. The authorities should build on existing relationships and co-operate to implement the recommendations of this project.

[47] http://www.berr.gov.uk/energy/sources/renewables/policy/renewables-advisory-board/community-involvment-wind/guidance-local-authority-officers/page35088.html

11 CONCLUSIONS

11.1. The potential renewable capacity for Worcestershire is subject to a multitude of factors from policy through to site and planning constraints and financial constraints. Large scale renewable energy has a part to play in Worcestershire energy supply but is not a panacea to Worcestershire's CO_2 targets and energy needs.

11.2. Worcestershire, relative to other counties, is limited in its renewable energy resources. The most significant resource in terms of electrical generation is from wind power with 181 223 MWh potential generation (Scenario 2). Relative to other regions in the UK, Worcestershire's wind resource is relatively low although there are localised areas of reasonable wind resource. Scenario 2 is presented here as it is believed to give the most realistic renewable generation potential.

11.3. Worcestershire's dispersed population pattern is the most significant limiting factor to the identification of potential renewable sites in Worcestershire; this is especially so in the identification of suitable sites for wind turbines.

11.4. Biomass as a potential resource is extremely complex and difficult to calculate due to unlimited number of scenarios which can be considered ranging from the estimation of areas used for cultivation through to the effect of future crop prices and subsidies. Biomass is able to provide up to 78 582MWh potential generation (Scenario 2) if solely used for electrical generation. In reality biomass will be used for both electrical generation in a potential mix of large scale generation plant, smaller generation plant, CHP systems, through to providing just thermal energy in boilers. The make up and ratio of use for electricity and heat is very much dependent on local developments and it is extremely difficult to ascertain due to the unlimited number of possibilities. However if an assumption of 60% of the resource is used for heat and 40% is used for electricity generation then total potential generation increases dramatically due to the increase in efficiencies in heat generation rather than electricity generation. For Scenario 2 the total biomass contribution would become 159 281 MWh - an increase of 49%. This highlights a need for a consistent approach in presenting the final potential renewable energy resource.

11.5. As might be expected hydro power has the least potential of only 14 909 MWh due to the limited potential head drops in the region.

11.6. The overall total generation (Scenario 2) is estimated at 355 413 MWh. This equates to approximately 3.7% of current (2006) energy demand and potentially 3.5% of estimated energy demand in 2020. Table 24 summarises the results of the study and assumes that 60% biomass resource is used for heat and 40% is used for electricity in each of the scenarios.

Table 24 Total renewable generation summary assuming 60% biomass is used for heat and 40% is used for electricity.

District	Scenario 1		Scenario 2		Scenario 3	
	MW	MWh	MW	MWh	MW	MWh
Bromsgrove	1	7006	14	40910	23	72336
Malvern Hills	8	41078	14	72031	27	150306
Redditch	0	0	0	0	0	0
Worcester	1	3369	1	3369	1	3369
Wychavon	47	130877	73	213592	80	302222
Wyre Forest	5	17820	7	25511	9	42700

Totals	**62**	**200149**	**109**	**355413**	**140**	**570932**
Approximate no. of houses that total energy could supply	**N/A**	**8693**	**N/A**	**15436**	**N/A**	**24796**

11.7. Taking these figures into account Worcestershire County will be unable to achieve the Government target of 15% of energy usage to come from renewable generation within the County simply because the resource is not available. Even if a dramatic shift in energy usage were possible this is still unattainable. However, Worcestershire can contribute to the renewables targets and could realistically aim for 3.5% of total energy (electrical and thermal) usage for the County by 2026 and aim for stages as in Table 25.

Table 25 Suggested staged Worcestershire Renewable Energy Targets

	Year		
	2015	2020	2026
Staged renewable energy targets as a percentage of total energy consumption in that year (excluding transport)	1.5%	2.5%	3.5%

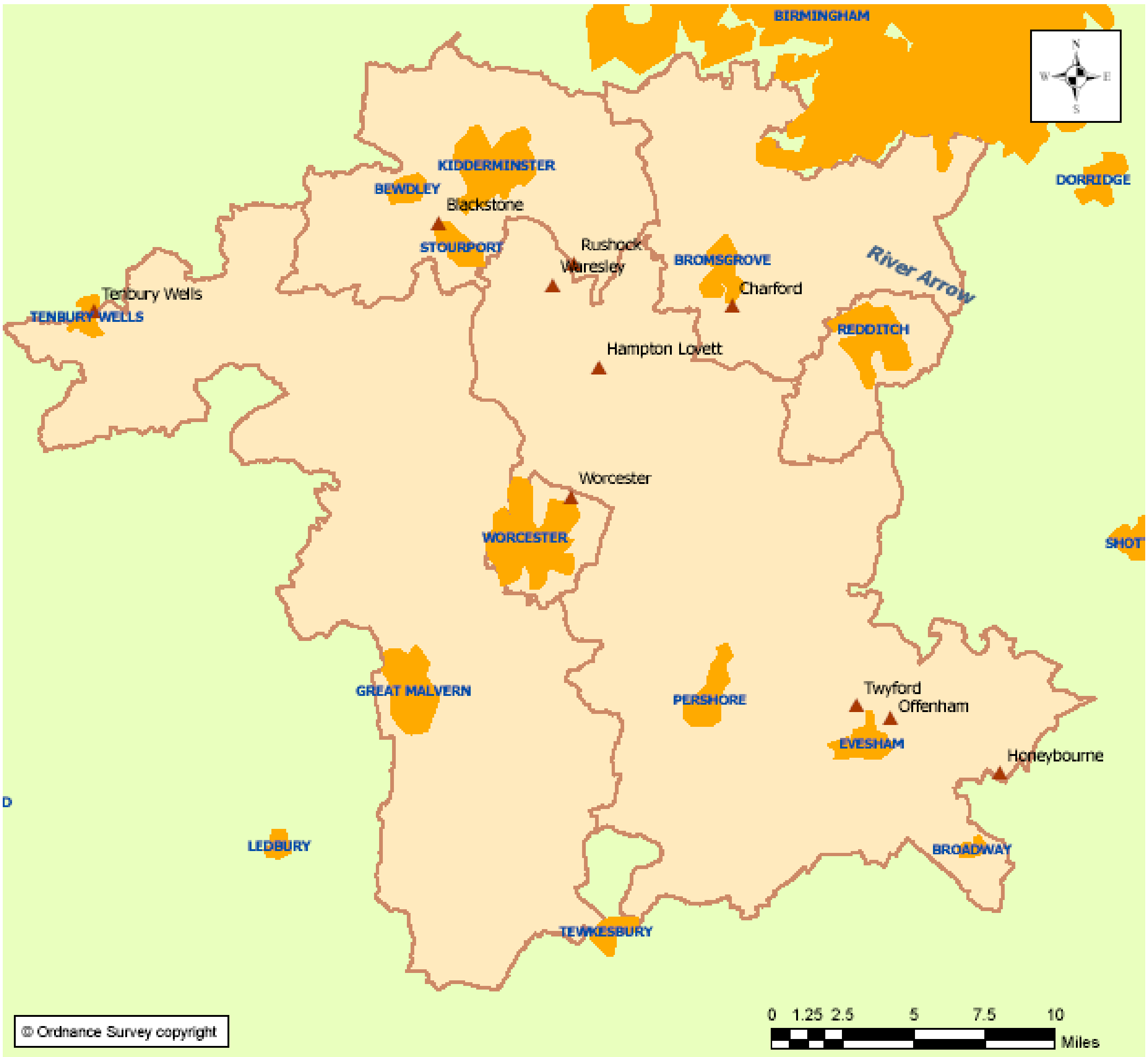
11.8. Though this does not appear as bold as Government or regional targets this is still considerably challenging for Worcestershire and would require a multi-faceted approach to ensure that renewable energy makes a substantial contribution.

12 APPENDICES

Appendix 1 Biomass Consultations

Organisation	Name and position	Notes
Forestry Commission	Simon West, Partnership and Policy Manager	Woodland inventory data, woodfuel resource in Worcestershire, Forestry Commission initiatives
Forestry Commission	Ian Tubby, Co-director Biomass Energy Centre	Perceptions of grant schemes, barriers to biomass development
National Farmers Union, West Midlands	Sarah Faulkner, NFU Policy Advisor (Environment)	Barriers to biomass development, farmers perception of biomass, energy crops in region
Bioenergy West Midlands/Harper Adams University	Dr Andrea Humphries, Lecturer Sustainable Technologies	Bioenergy West Midlands activity, Harper Adams University CHP generator, barriers to biomass development
Countrywide Farmers	Julie Jones Ford, Renewables Manager	Countrywide Farmers Activity
Countrywide farmers	Alistair Folley	Straw production and use in County
Worcester County Council, Waste Services Management	Richard Woodward	Waste production and disposal
Worcester County Council, Countryside service	Andy Maginnis	Woody waste from parks/highways maintenance
Ringway	Steve Jenkins	Waste from highways maintenance
Worcester County Council, Countryside service	Rob Stevenson	Woody waste from Worcester Woods Country Park
National Farmers Union	Jonathon Scurlock, Renewable Energy Advisor	Energy crop and straw potentials, crop economics
Various Food Manufacturers located within Worcestershire	Various	Volumes of food waste.

Appendix 2 Map indicating potential areas for biomass plants



Appendix 3 Potential areas suitable for biomass plant either electrical or CHP

Name	District	Likely Plant size* (MW)	Comment
Charford (Aston fields industrial estates)	Bromsgrove	2.5	The area was selected as already has an industrial estate, good transport links and potential local heat demand. However the site is in a flood risk zone.
Tenbury	Malvern Hills	2.5	Tenbury is located close to potential wood chip resource. There is a need to ensure fuel deliveries are not taken through the town centre as roads are narrow. Flood risk zone.
Worcester	Worcester	20	The area is ideally positioned to utilise Wychavon and Malvern Hills biomass resource. In particular Worcester is suited to a large 20 MW plant as biomass would have to be bought from outside the County and the area has good road access with the A449 and M5. The area is also located close to potential electricity demand. The area also has potential access to water from the River Severn. The area is in the green belt and flood risk zone so needs to be taken into consideration.
Hampton Lovett	Wychavon	2.5	The area is located closed to Wychavon and Malvern Hill biomass resource as well as a potential local heating demand. The site is designated for employment in Local plan and has good rood access.
Offenham	Wychavon	2.5	Good road access
Waresley	Wychavon	2.5	Limited local heat demand however road access is good.
Honeybourne	Wychavon	2.5	Limited local heat demand but on a rural industrial estate.
Twyford	Wychavon	2.5	On a river, good road access
Blackstone	Wyre Forest	2.5	Good road access within green belt and landscape protection area any development would have to be sympathetic to these landscape designations
Rushock	Wyre Forest	2.5	Green belt and limited local heat demand but good road access

*The likely plant size is only indicative and could well be larger if resource were bought in from outside the County. The colour coding in the table above indicates that the proximity of the sites make it likely that only one of the sites would be developed as there would be insufficient resource within the County to sustain the likely plant size.

Appendix 4 Biomass Scenario Calculations

Scenario 1	Energy Contained (MWh)	Potential energy output (MWh)						Potential Installed Capacity (MW)		
		Electricity only		Heat only		CHP		Electricity only	Heat only	CHP
		MWh	Homes	MWh	Homes	MWh	Homes			
Bromsgrove										
Woodland	0	0	0	0	0	0	0	0.0	0.0	0.0
Energy Crops	1042	313	95	886	45	886	38	0.0	0.1	0.1
Straw	8923	2677	811	7585	385	7585	329	0.4	1.1	1.1
Cattle, Pigs and Poultry	1086	435	132	923	47	869	38	0.1	0.1	0.1
Total	**11052**	**3424**	**1038**	**9394**	**476**	**9340**	**406**	**0.5**	**1.3**	**1.3**
Malvern Hills										
Woodland	0	0	0	0	0	0	0	0.0	0.0	0.0
Energy Crops	5174	1552	470	4398	223	4398	191	0.2	0.6	0.6
Straw	38844	11653	3531	33018	1674	33018	1434	1.6	4.6	4.6
Cattle, Pigs and Poultry	1292	517	157	1098	56	1033	45	0.1	0.2	0.1
Total	**45310**	**13722**	**4158**	**38514**	**1953**	**38449**	**1670**	**1.9**	**5.4**	**5.4**
Redditch										
Woodland	0	0	0	0	0	0	0	0.0	0.0	0.0
Energy Crops	0	0	0	0	0	0	0	0.0	0.0	0.0
Straw	0	0	0	0	0	0	0	0.0	0.0	0.0
Cattle, Pigs and Poultry	0	0	0	0	0	0	0	0.0	0.0	0.0
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.0**	**0.0**	**0.0**
Worcester										
Woodland	0	0	0	0	0	0	0	0.0	0.0	0.0
Energy Crops	0	0	0	0	0	0	0	0.0	0.0	0.0
Straw	0	0	0	0	0	0	0	0.0	0.0	0.0
Cattle, Pigs and Poultry	0	0	0	0	0	0	0	0.0	0.0	0.0
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.0**	**0.0**	**0.0**
Wychavon										
Woodland	0	0	0	0	0	0	0	0.0	0.0	0.0
Energy Crops	7133	2140	648	6063	307	6063	263	0.3	0.9	0.9
Straw	54255	16277	4932	46117	2338	46117	2003	2.3	6.5	6.5
Cattle, Pigs and Poultry	1881	752	228	1599	81	1505	65	0.1	0.2	0.2
Total	**63269**	**19169**	**5809**	**53779**	**2726**	**53685**	**2332**	**2.7**	**7.6**	**7.5**
Wyre Forest										
Woodland	0	0	0	0	0	0	0	0.0	0.0	0.0
Energy Crops	1223	367	111	1039	53	1039	45	0.1	0.1	0.1
Straw	9468	2840	861	8048	408	8048	350	0.4	1.1	1.1
Cattle, Pigs and Poultry	529	212	64	450	23	423	18	0.0	0.1	0.1
Total	**11220**	**3419**	**1036**	**9537**	**483**	**9511**	**413**	**0.5**	**1.3**	**1.3**
Worcestershire										
Woodland	823.5863	247.0759	74.87149	700.0484	35.49041	700.0484	30.40384	0.0	0.1	0.1
Energy Crops	14762	4429	1342	12548	636	12548	545	0.6	1.8	1.8
Straw	113052	33916	10277	96095	4872	96095	4173	4.8	13.5	13.5
Cattle, Pigs and Poultry	5053	1534	465	3261	165	3069	133	0.2	0.5	0.4
Total	**133691**	**40126**	**12159**	**112603**	**5709**	**112411**	**4882**	**5.6**	**15.8**	**15.8**

Scenario 2	Energy Contained (MWh)	Potential energy output (MWh)						Potential Installed Capacity (MW)		
		Electricity only		Heat only		CHP		Electricity only	Heat only	CHP
		MWh	Homes	MWh	Homes	MWh	Homes			
Bromsgrove										
Woodland	0	0	0	0	0	0	0	0.0	0.0	0.0
Energy Crops	5211	1563	474	4429	225	4429	192	0.2	0.6	0.6
Straw	13385	4015	1217	11377	577	11377	494	0.6	1.6	1.6
Cattle, Pigs and Poultry	2716	1086	329	2308	117	2173	94	0.2	0.3	0.3
Total	**21312**	**6665**	**2020**	**18115**	**918**	**17979**	**781**	**0.9**	**2.5**	**2.5**
Malvern Hills										
Woodland	0	0	0	0	0	0	0	0.0	0.0	0.0
Energy Crops	25872	7762	2352	21991	1115	21991	955	1.1	3.1	3.1
Straw	58267	17480	5297	49527	2511	49527	2151	2.5	7.0	7.0
Cattle, Pigs and Poultry	3229	1292	391	2745	139	2583	112	0.2	0.4	0.4
Total	**87368**	**26533**	**8040**	**74263**	**3765**	**74101**	**3218**	**3.7**	**10.4**	**10.4**
Redditch										
Woodland	0	0	0	0	0	0	0	0.0	0.0	0.0
Energy Crops	0	0	0	0	0	0	0	0.0	0.0	0.0
Straw	0	0	0	0	0	0	0	0.0	0.0	0.0
Cattle, Pigs and Poultry	0	0	0	0	0	0	0	0.0	0.0	0.0
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.0**	**0.0**	**0.0**
Worcester										
Woodland	0	0	0	0	0	0	0	0.0	0.0	0.0
Energy Crops	0	0	0	0	0	0	0	0.0	0.0	0.0
Straw	0	0	0	0	0	0	0	0.0	0.0	0.0
Cattle, Pigs and Poultry	0	0	0	0	0	0	0	0.0	0.0	0.0
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.0**	**0.0**	**0.0**
Wychavon										
Woodland	0	0	0	0	0	0	0	0.0	0.0	0.0
Energy Crops	35664	10699	3242	30314	1537	30314	1317	1.5	4.3	4.3
Straw	81383	24415	7398	69175	3507	69175	3004	3.4	9.7	9.7
Cattle, Pigs and Poultry	4703	1881	570	3997	203	3762	163	0.3	0.6	0.5
Total	**121749**	**36995**	**11211**	**103487**	**5246**	**103252**	**4484**	**5.2**	**14.5**	**14.5**
Wyre Forest										
Woodland	0	0	0	0	0	0	0	0.0	0.0	0.0
Energy Crops	6113	1834	556	5196	263	5196	226	0.3	0.7	0.7
Straw	14202	4261	1291	12072	612	12072	524	0.6	1.7	1.7
Cattle, Pigs and Poultry	1322	529	160	1124	57	1058	46	0.1	0.2	0.1
Total	**21638**	**6624**	**2007**	**18393**	**932**	**18326**	**796**	**0.9**	**2.6**	**2.6**
Worcestershire										
Woodland	5765	1730	524	4900	248	4900	213	0.2	0.7	0.7
Energy Crops	73809	22143	6710	62738	3181	62738	2725	3.1	8.8	8.8
Straw	169579	50874	15416	144142	7308	144142	6260	7.1	20.3	20.3
Cattle, Pigs and Poultry	12634	3836	1162	8152	413	7672	333	0.5	1.1	1.1
Total	**261787**	**78582**	**23813**	**219932**	**11150**	**219452**	**9531**	**11.0**	**30.9**	**30.8**

Scenario 3	Energy Contained (MWh)	Potential energy output (MWh)						Potential Installed Capacity (MW)		
		Electricity only		Heat only		CHP		Electricity only	Heat only	CHP
		MWh	Homes	MWh	Homes	MWh	Homes			
Bromsgrove										
Woodland	0	0	0	0	0	0	0	0.0	0.0	0.0
Energy Crops	10422	3127	947	8859	449	8859	385	0.4	1.2	1.2
Straw	17846	5354	1622	15169	769	15169	659	0.8	2.1	2.1
Cattle, Pigs and Poultry	5432	2173	658	4617	234	4345	189	0.3	0.6	0.6
Total	**33700**	**10653**	**3228**	**28645**	**1452**	**28374**	**1232**	**1.5**	**4.0**	**4.0**
Malvern Hills										
Woodland	0	0	0	0	0	0	0	0.0	0.0	0.0
Energy Crops	51744	15523	4704	43982	2230	43982	1910	2.2	6.2	6.2
Straw	77689	23307	7063	66036	3348	66036	2868	3.3	9.3	9.3
Cattle, Pigs and Poultry	6458	2583	783	5489	278	5166	224	0.4	0.8	0.7
Total	**135891**	**41413**	**12549**	**115507**	**5856**	**115184**	**5003**	**5.8**	**16.2**	**16.2**
Redditch										
Woodland	0	0	0	0	0	0	0	0.0	0.0	0.0
Energy Crops	0	0	0	0	0	0	0	0.0	0.0	0.0
Straw	0	0	0	0	0	0	0	0.0	0.0	0.0
Cattle, Pigs and Poultry	0	0	0	0	0	0	0	0.0	0.0	0.0
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.0**	**0.0**	**0.0**
Worcester										
Woodland	0	0	0	0	0	0	0	0.0	0.0	0.0
Energy Crops	0	0	0	0	0	0	0	0.0	0.0	0.0
Straw	0	0	0	0	0	0	0	0.0	0.0	0.0
Cattle, Pigs and Poultry	0	0	0	0	0	0	0	0.0	0.0	0.0
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.0**	**0.0**	**0.0**
Wychavon										
Woodland	0	0	0	0	0	0	0	0.0	0.0	0.0
Energy Crops	71328	21398	6484	60629	3074	60629	2633	3.0	8.5	8.5
Straw	108510	32553	9865	92234	4676	92234	4006	4.6	13.0	13.0
Cattle, Pigs and Poultry	9405	3762	1140	7995	405	7524	327	0.5	1.1	1.1
Total	**189244**	**57714**	**17489**	**160857**	**8155**	**160387**	**6966**	**8.1**	**22.6**	**22.5**
Wyre Forest										
Woodland	0	0	0	0	0	0	0	0.0	0.0	0.0
Energy Crops	12227	3668	1112	10393	527	10393	451	0.5	1.5	1.5
Straw	18936	5681	1721	16096	816	16096	699	0.8	2.3	2.3
Cattle, Pigs and Poultry	2645	1058	321	2248	114	2116	92	0.1	0.3	0.3
Total	**33808**	**10407**	**3154**	**28737**	**1457**	**28605**	**1242**	**1.5**	**4.0**	**4.0**
Worcestershire										
Woodland	8236	2471	749	7000	355	7000	304	0.3	1.0	1.0
Energy Crops	147618	44285	13420	125476	6361	125476	5450	6.2	17.6	17.6
Straw	226105	67831	20555	192189	9743	192189	8347	9.5	27.0	27.0
Cattle, Pigs and Poultry	25267	7672	2325	16304	827	15345	666	1.1	2.3	2.2
Total	**407226**	**122260**	**37048**	**340969**	**17286**	**340010**	**14767**	**17.2**	**47.9**	**47.8**

Appendix 5 Wind Consultations

Organisation	Contact Name	Address	Notes
Cotswold AONB	Malcom Watt / Planning	Fosse Way Northleach GLOUCESTERSHIRE GL54 3JH	Current AONB policy does not favour large scale development.
Malvern Hill AONB	Paul Esrich	Manor House Grange Road Malvern WORCESTERSHIRE WR14 3EY	Currently reviewing management plan. Current AONB policy does not favour large scale development.
Highways Agency	Ian Reidy, Policy advisor	Broadway, 5 Broadway, Broad Street, Birmingham, B15 1BL.	Current guidance on the minimum distance from major roads is the height of the turbine plus 50m
Ministry of Defence	John Wilson	Defence Estates	There are no perceived radar issues. Though each site would have to be treated on a site by site basis on formal application.

Appendix 6 List of potential wind sites and comments

Scenario 1

No.	Name	District	NOABL Windspeed @45m	Number of turbines	Scenario	Size of turbine*	Total Capacity (MW)	Eastings	Northings	Landscape character	Green belt	Aiport	Comments
7	Eldersfield	Malvern Hills	6.1	2	1	Medium	3	379731	230457	Settled Farmlands with Pastoral Land Use	-	Gloucestershire airport (approx. 13 km)	Potential access issues due to single track roads and in proximity to Staunton.
14	Throckmorton	Wychavon	6.1	4	1	Large	10	396977	248981	Village Claylands	No	-	Disused airfield. Site access good but some residences nearby.
17	Church Lench	Wychavon	6.5	6	1	Large	15	403780	248570	Timbered Plateau Farmlands	No	-	-
20	Bishampton	Wychavon	6.0	6	1	Large	15	398313	252069	Village Claylands	No	-	-
26	Shenstone	Wyre Forest	6.3	1-2	1	Medium	3	386624	272700	Estate Farmlands	Yes	-	Potential access issues due to small roads, suitable for small wind turbines
27	Elmley Lovett	Wyre Forest	6.0	1	1	Small	0.25	387237	270550	Principal Timbered Farmlands	Yes	-	Potential access issues due to single track roads, suitable for small wind turbines
	Total						**46.25**						

* Small 250 kW, medium 1.5 MW and large 2.5 MW

Scenario 1 considers a conservative approach and assumes that only sites which present few substantial barriers to development will be constructed. There is assumed to be no change in current policy towards renewable energy development.

Scenario 2 offers a pragmatic approach to the development of renewables and assumes favourable planning and economic circumstances that would encourage development.

Scenario 3 is the most optimistic scenario and assumes that there are no barriers to the development of the sites identified and that all the resource will be utilised. The reality is that Scenario 3 is highly unlikely to be achieved as there are so many influencing factors as discussed under each technology.

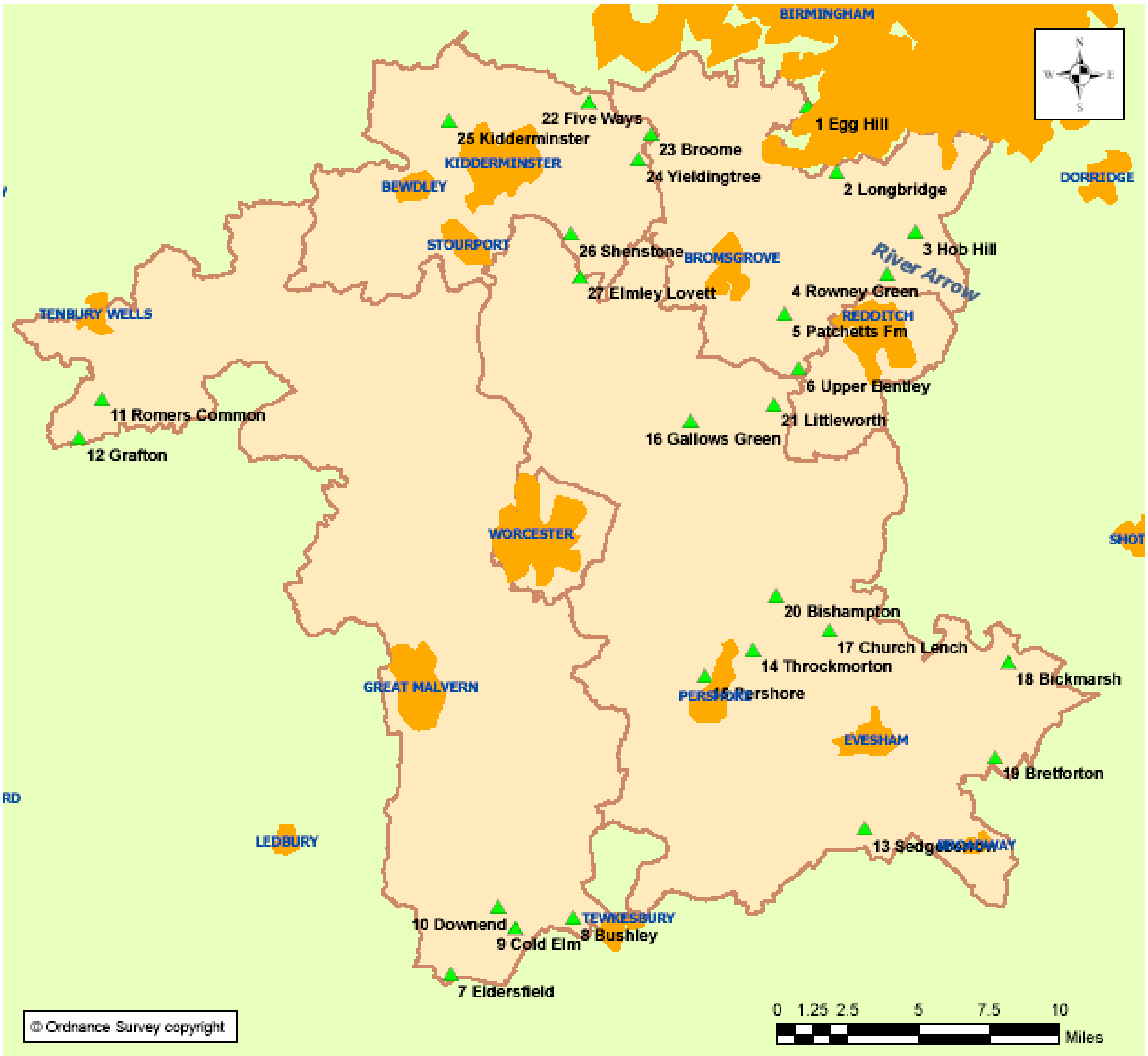
Scenario 2 (includes sites in Scenario 1)

No.	Name	District	NOABL Windspeed @45m	Number of turbines	Scenario	Size of turbine	Total Capacity (MW)	Eastings	Northings	Landscape character	Green belt	Aiport	Comments
2	Longbridge	Bromsgrove	6.8	1	2	Medium	1.5	401736	276196	Principal Wooded Hills	Yes	-	Close proximity to a residential area and in a Landscape Protection Area.
3	Hob Hill	Bromsgrove	6.7	1	2	Medium	1.5	406244	272747	Principal Wooded Hills	Yes	-	Located near to the M42 the site has potential access issue due to single track roads and is within Landscape Protection Area.
4	Rowney Green	Bromsgrove	6.0	2	2	Large	5	404609	270430	Wooded Estatelands	Yes	-	Potential access issues due to single track roads
5	Patchetts Fm	Bromsgrove	6.5	2-3	2	Medium	4.5	398803	268085	Principal Timbered Farmlands	Yes	-	Site could affect the setting of the local Conservation Area
8	Bushley	Malvern Hills	6.4	2	2	Medium	1.5	386743	233722	Estate Farmlands	No	Gloucestershire airport (approx. 14 km)	-
11	Romers Common	Malvern Hills	6.7	2	2	Small	0.5	359896	263285	Timbered Plateau Farmlands	No	-	Potential access issues due to single track roads.
13	Sedgeberrow	Wychavon	6.0	2-3	2	Medium	4.5	403366	238756	Village Farmlands with Orchards	No	-	Site with good access, but limited by limited wind speed and remote grid connection. Visible from Cotswold AONB. Communication mast nearby could present an issue.
18	Bickmarsh	Wychavon	6.2	4	2	Medium	9	411543	248265	Village Claylands	No	-	Potential access issues due to single track roads
19	Bretforton	Wychavon	5.9	1-2	2	Medium	3	410768	242862	Village Claylands	No	-	Fairly good access from behind the hill. Limited wind speed and no power cables nearby. Possibly visible from Cotswold AONB
21	Littleworth	Wychavon	6.3	2-3	2	Medium	4.5	398158	262952	Wooded Estatelands	No	-	Fairly good access to the site, close to the grid.
23	Broome	Wyre Forest	6.2	1-2	2	Small	0.5	391183	278418	Estate Farmlands	Yes	-	Site suitable for small wind turbines. Close proximity to Holy Cross might be an issue
24	Yieldingtree	Wyre Forest	6.2	1-2	2	Small	0.5	390448	276896	Estate Farmlands	Yes	-	Potential access issue due to single track roads and close to Belbroughton and Drayton
	Total						82.75						

Scenario 3 (includes sites in Scenario 1 & 2)

No.	Name	District	NOABL Windspeed @45m	Number of turbines	Scenario	Size of turbine	Total Capacity (MW)	Eastings	Northings	Landscape character	Green belt	Aiport	Comments
1	Egg Hill	Bromsgrove	7.0	1	3	Medium	1.5	400078	279996	Timbered Plateau	Yes	-	Potential access issue due to single track roads, near to a residential area and local nature reserve could present an issue.
6	Upper Bentley	Bromsgrove	6.3	3-4	3	Medium	6	399614	265020	Principal Timbered Farmlands	Yes	-	Close proximity to a densely populated area (Redditch)
9	Cold Elm	Malvern Hills	6.2	3	3	Medium	3	383426	233139	Estate Farmlands	No	Gloucestershire airport (approx. 13 km)	Visible from the Malvern Hills AONB
10	Downend	Malvern Hills	6.0	5	3	Medium	4.5	382472	234335	Principal Settled Farmlands	No	-	Proximity to densely populated area and visible from to Malvern Hills AONB
12	Grafton	Malvern Hills	7.2	3	3	Small	0.75	358565	261030	Timbered Plateau Farmlands	No	-	Potential access issue due to single track roads and remote grid connection. The site is within an Area of Great Landscape Value
15	Pershore	Wychavon	6.1	2	3	Small	0.5	394212	247513	Principal Village Farmlands	No	-	Site with good potential, although nearby communication masts may be a problem area is also proposed for housing in the South Worcestershire Joint Core Strategy Preferred Options.
16	Gallows Green	Wychavon	6.1	2-3	3	Small	0.75	393434	262020	Principal Timbered Farmlands	No	-	Close to electricity grid, but access to the site is problematic due to single track roads.
22	Five Ways	Wyre Forest	6.4	3	3	Small	0.75	387609	280198	Sandstone Estatelands	Yes	Wolverhampton airport (approx. 13 km)	Good access to site. Proximity to Blakedown may be an issue, and possible interference with nearby communications mast.
25	Kidderminster	Wyre Forest	7.1	1	3	Small	0.25	379666	279133	Principal Wooded Hills	Yes	Wolverhampton airport (approx. 12.5 km)	Potential access issues due to single track roads, near to Special Wildlife Site and also in a Landscape Protection Area.
	Total						**100.75**						

Appendix 7 Map indicating potential wind turbine sites



Appendix 8 Detailed maps indicating potential wind turbine sites.

Appendix 8 – Potential wind sites

Wyre Forest

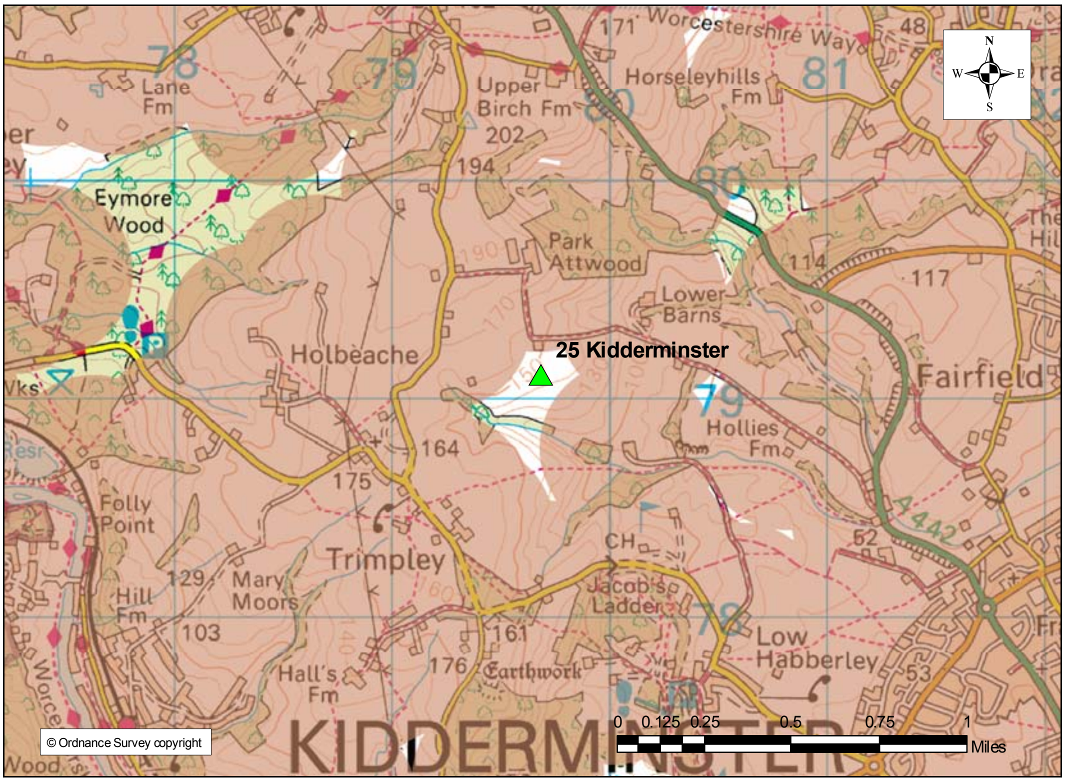


Figure 1- Potential wind site: Kidderminster, Wyre Forest

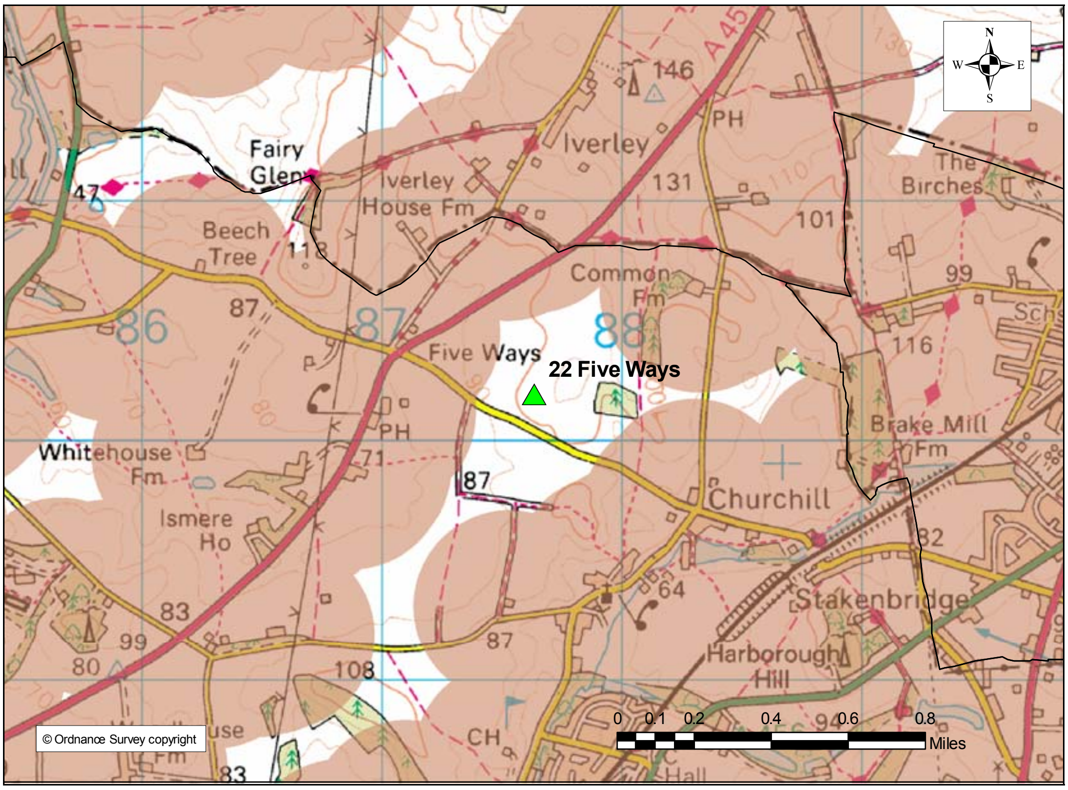


Figure 2- Potential wind site: Five Ways, Wyre Forest

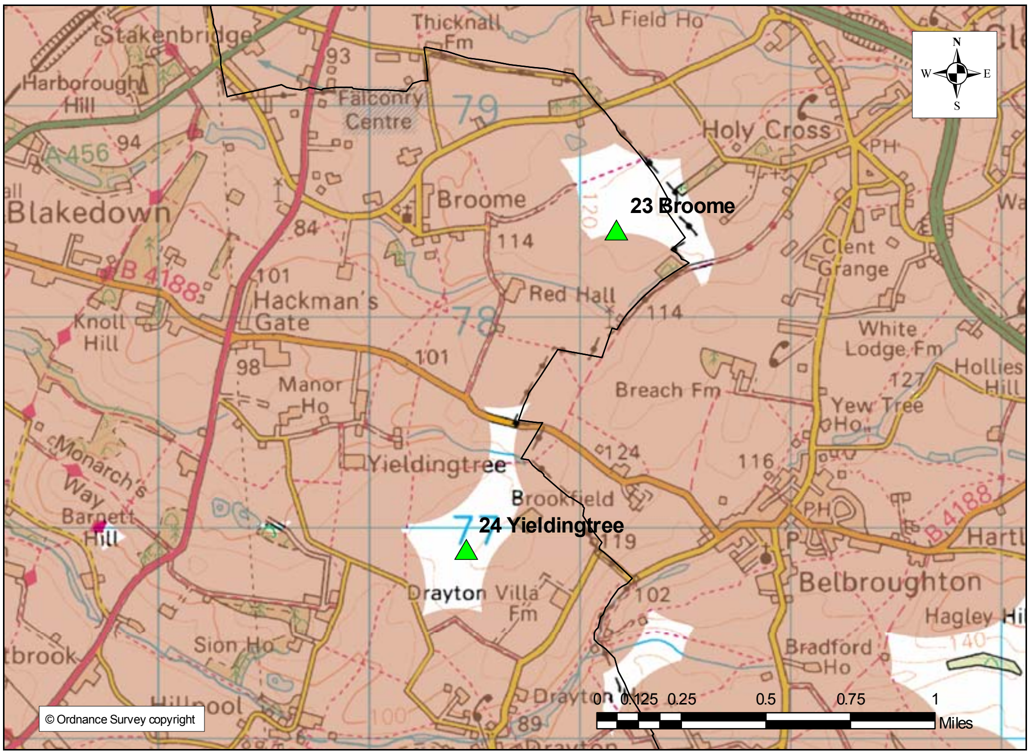


Figure 3- Potential wind sites: Broome and Yieldingtree, Wyre Forest

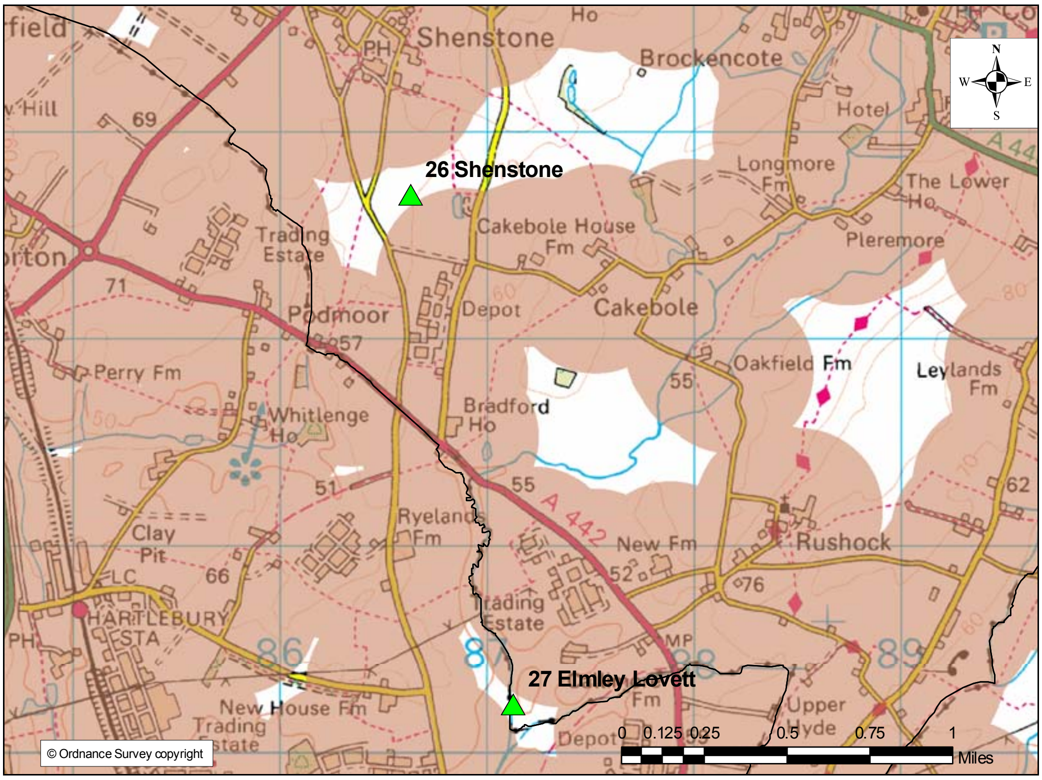


Figure 4- Potential wind sites: Shenstone and Elmley Lovett, Wyre Forest

Bromsgrove

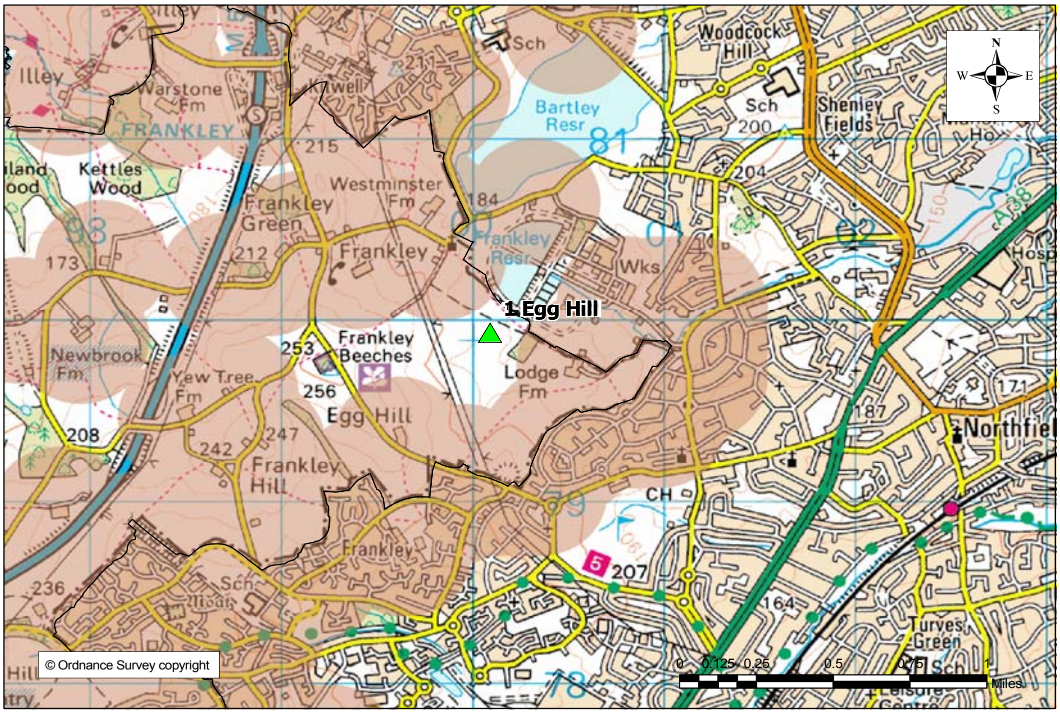


Figure 5- Potential wind site: Egg Hill, Bromsgrove

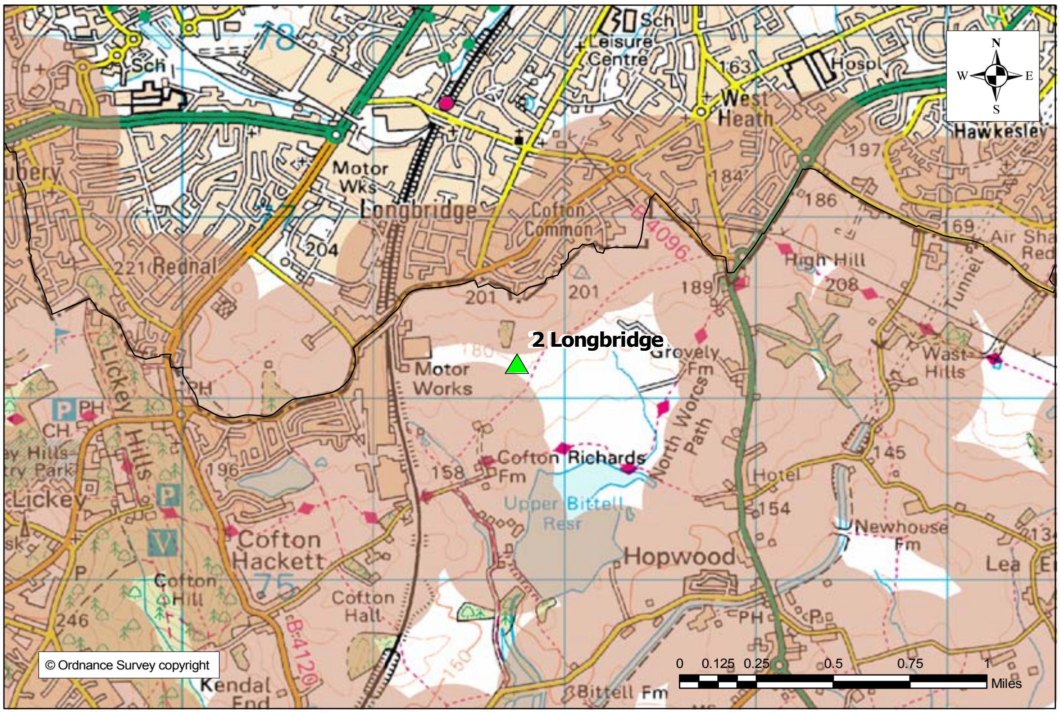


Figure 6- Potential wind site: Longbridge, Bromsgrove

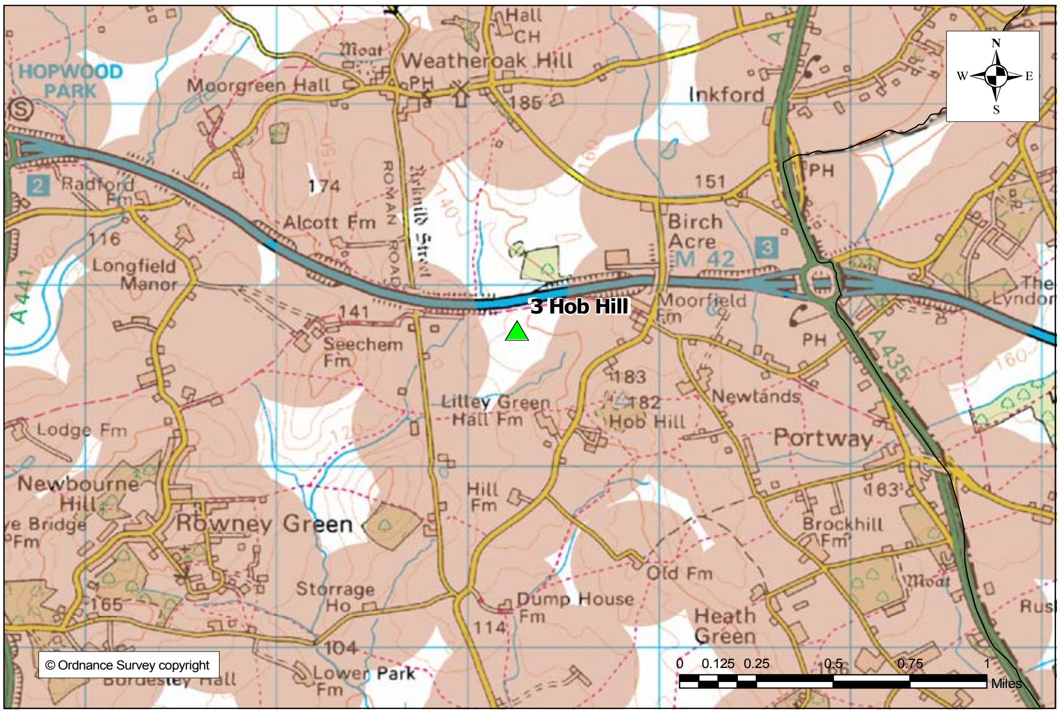


Figure 7- Potential wind site: Hob Hill, Bromsgrove

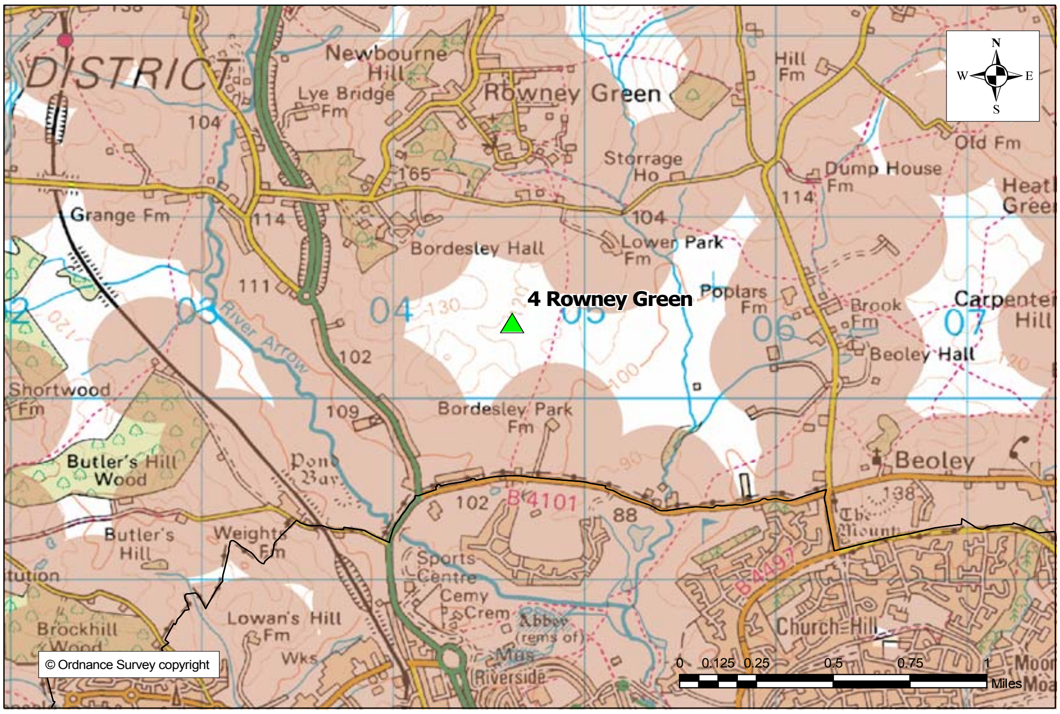


Figure 8- Potential wind site: Rowney GreenHob Hill, Bromsgrove

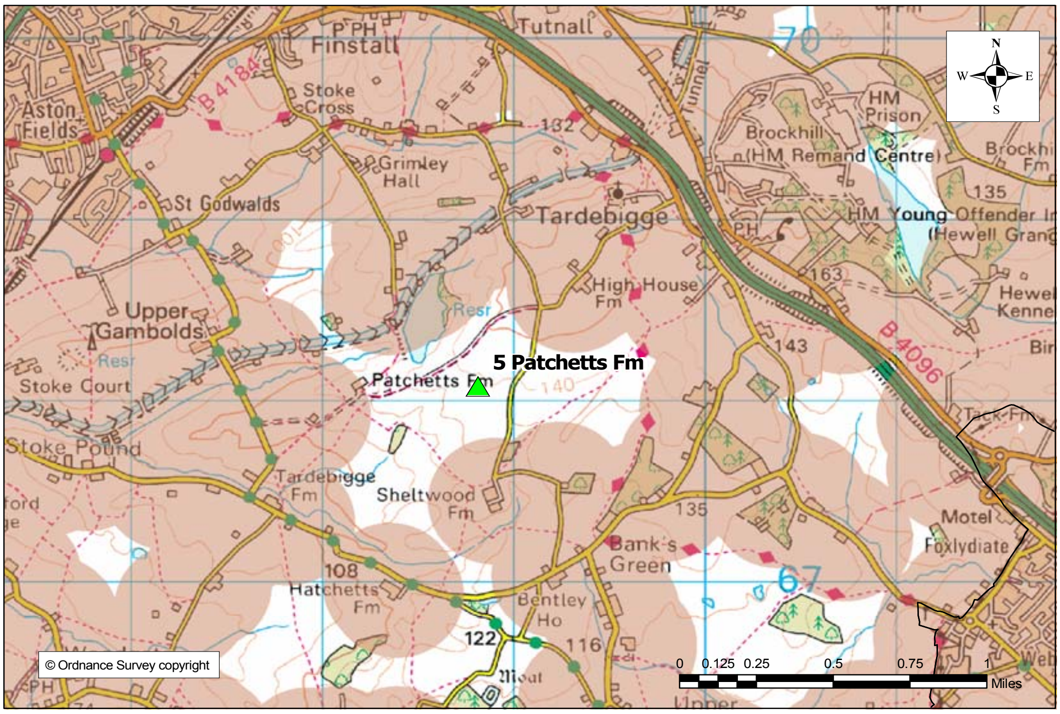


Figure 9- Potential wind site: Patchetts, Bromsgrove

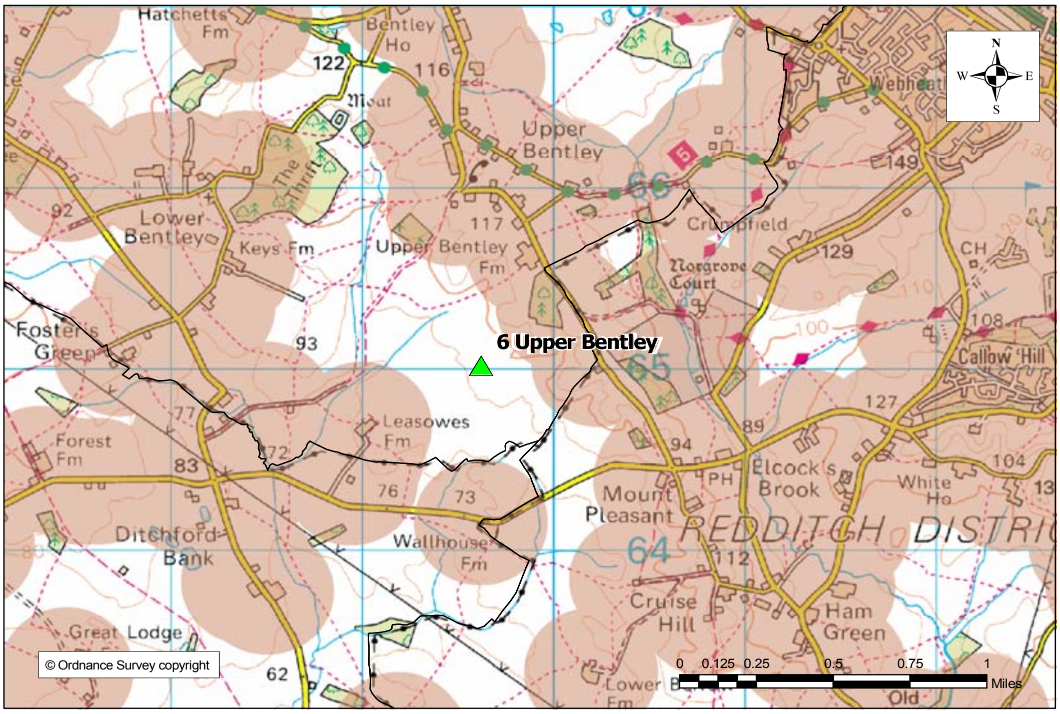


Figure 10- Potential wind site: Upper Bentley, Bromsgrove

Wychavon

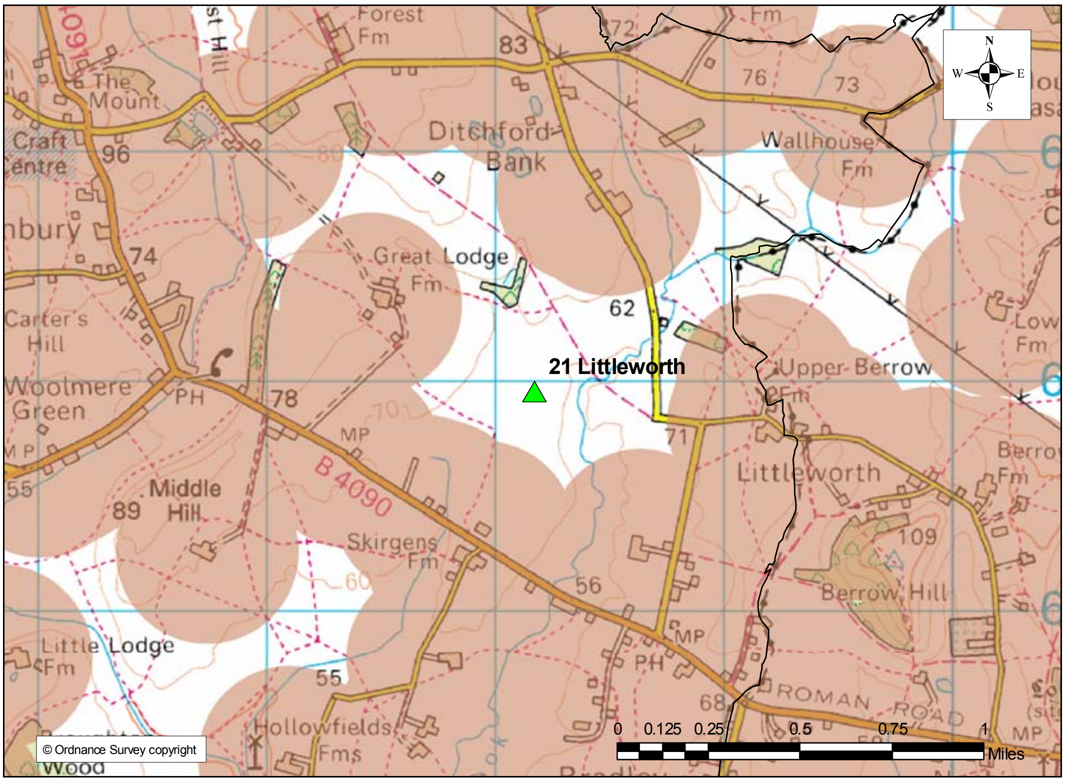


Figure 11- Potential wind site: Littleworth, Wychavon

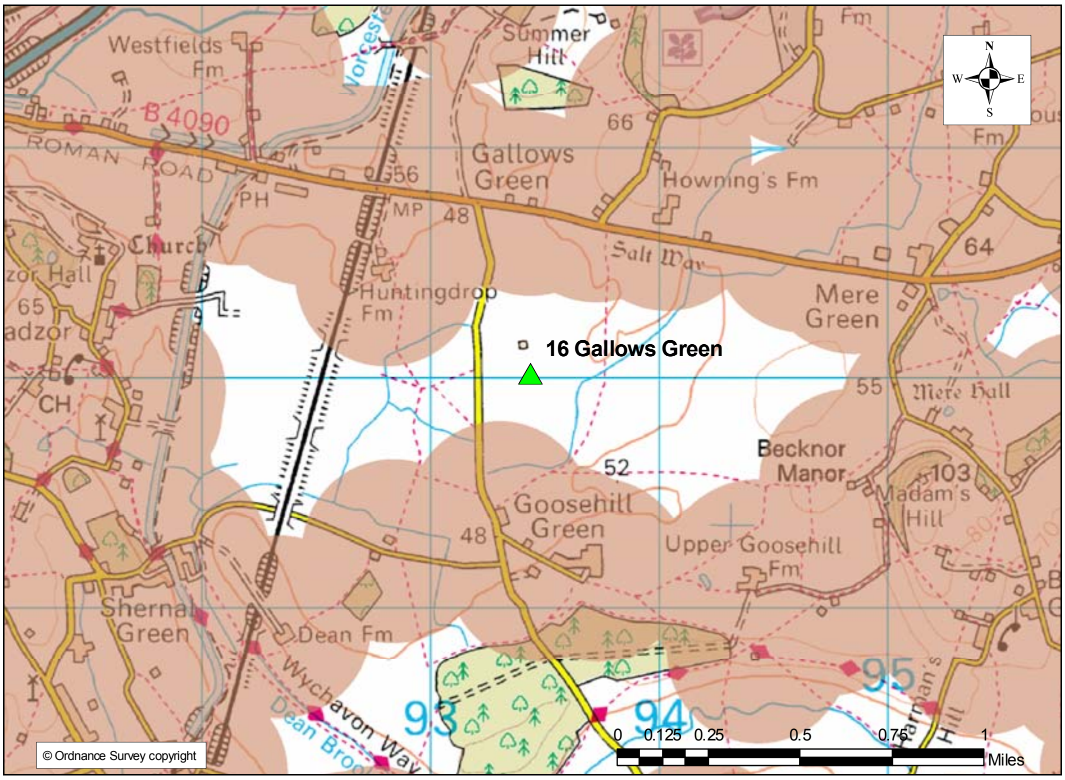


Figure 12- Potential wind site: Gallows Green, Wychavon

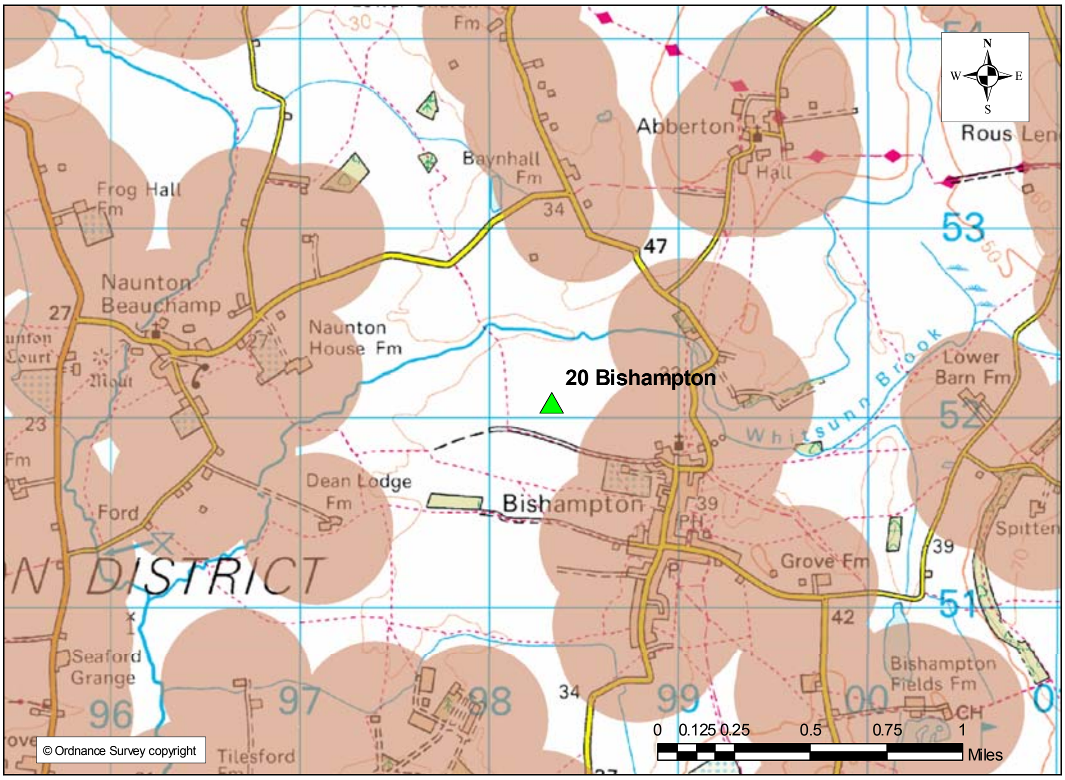


Figure 13- Potential wind site: Bishampton, Wychavon

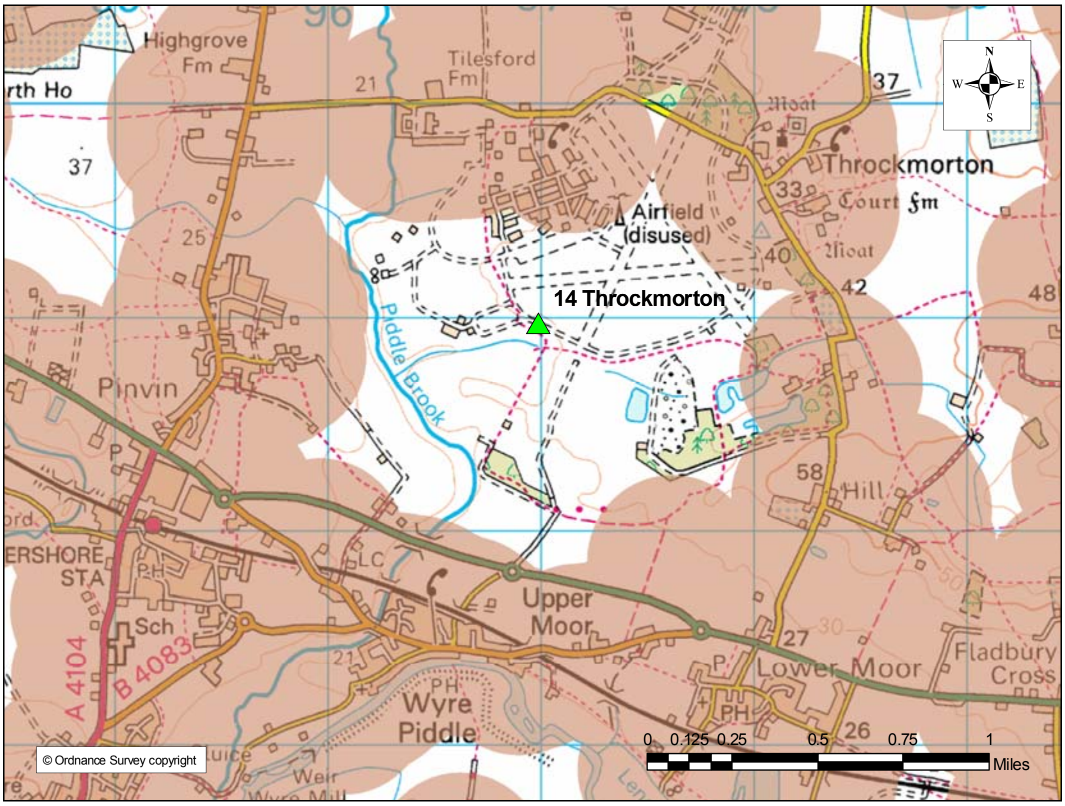


Figure 14- Potential wind site: Throckmorton, Wychavon

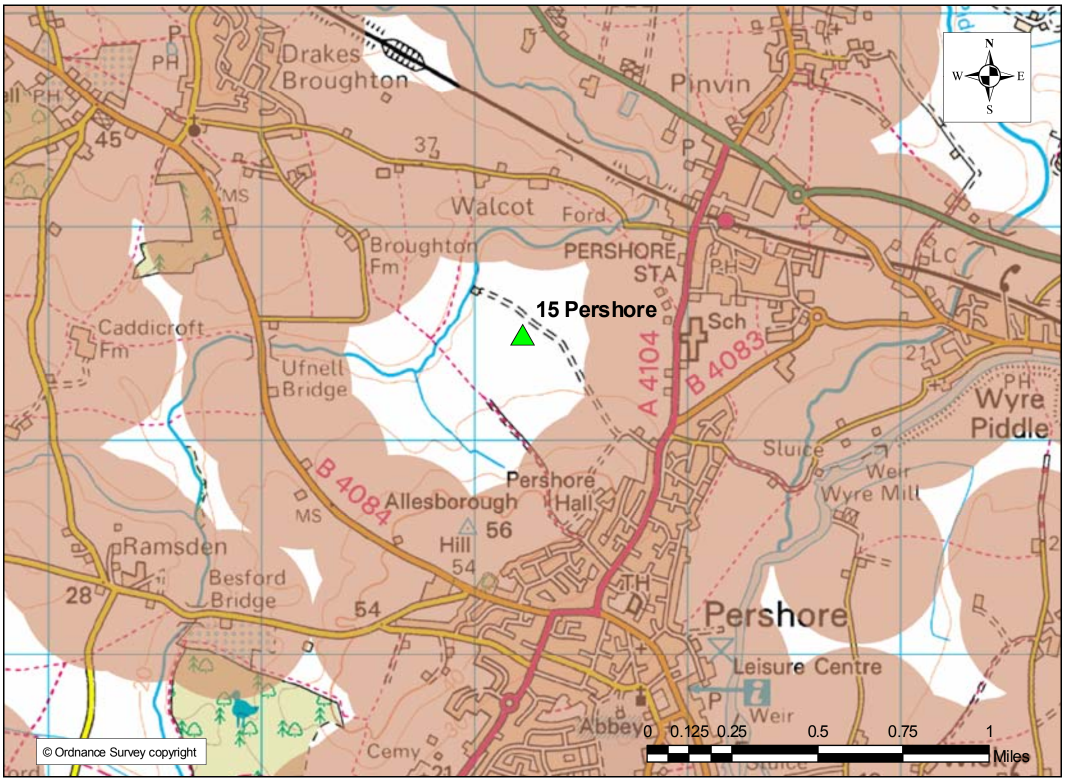


Figure 15- Potential wind site: Pershore, Wychavon

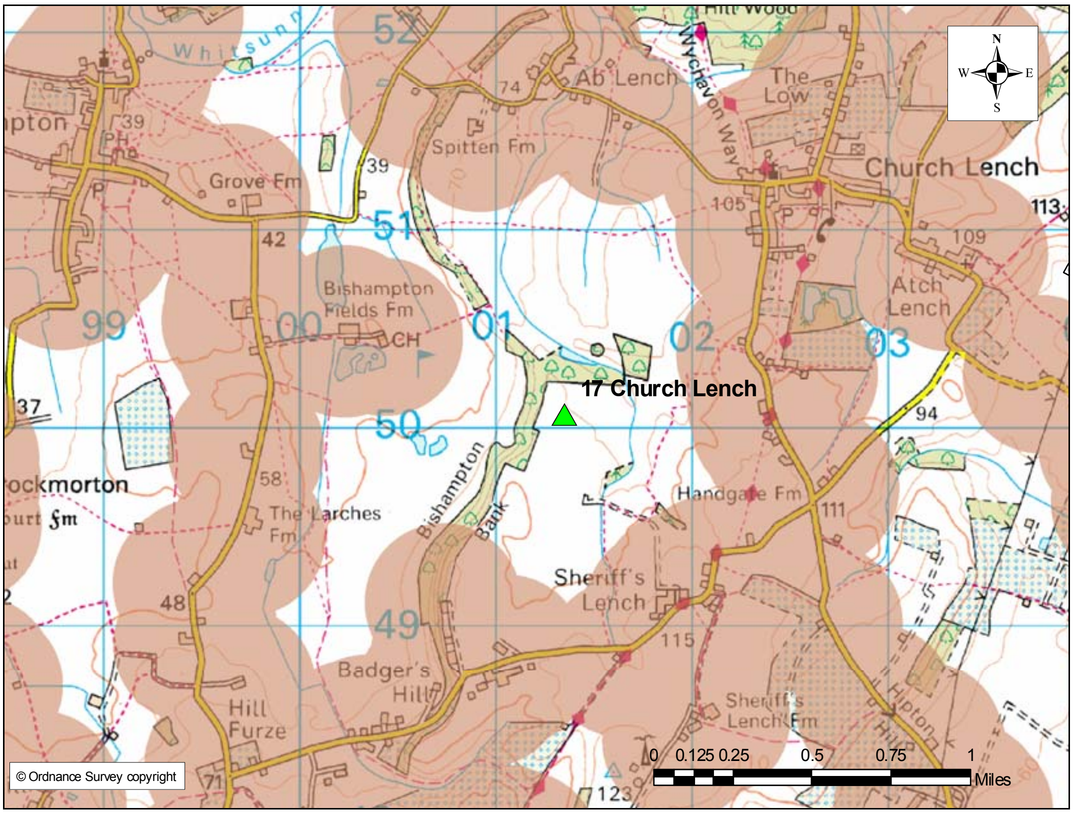


Figure 16- Potential wind site: Church Lench , Wychavon

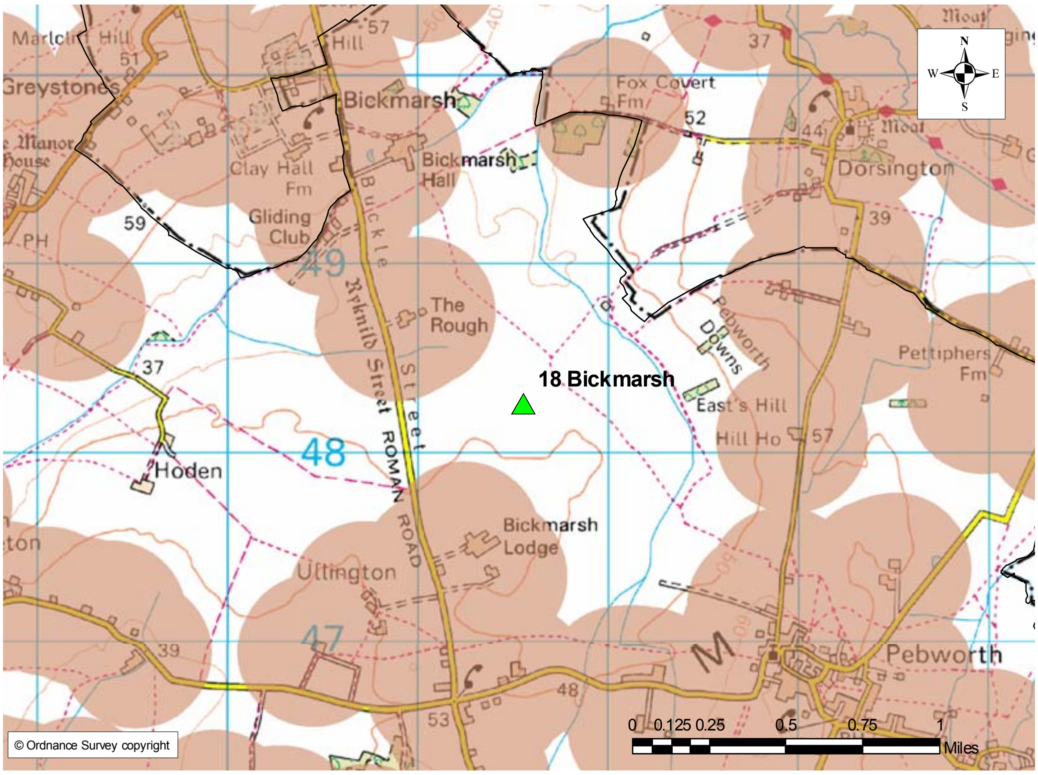


Figure 17- Potential wind site: Bickmarsh, Wychavon

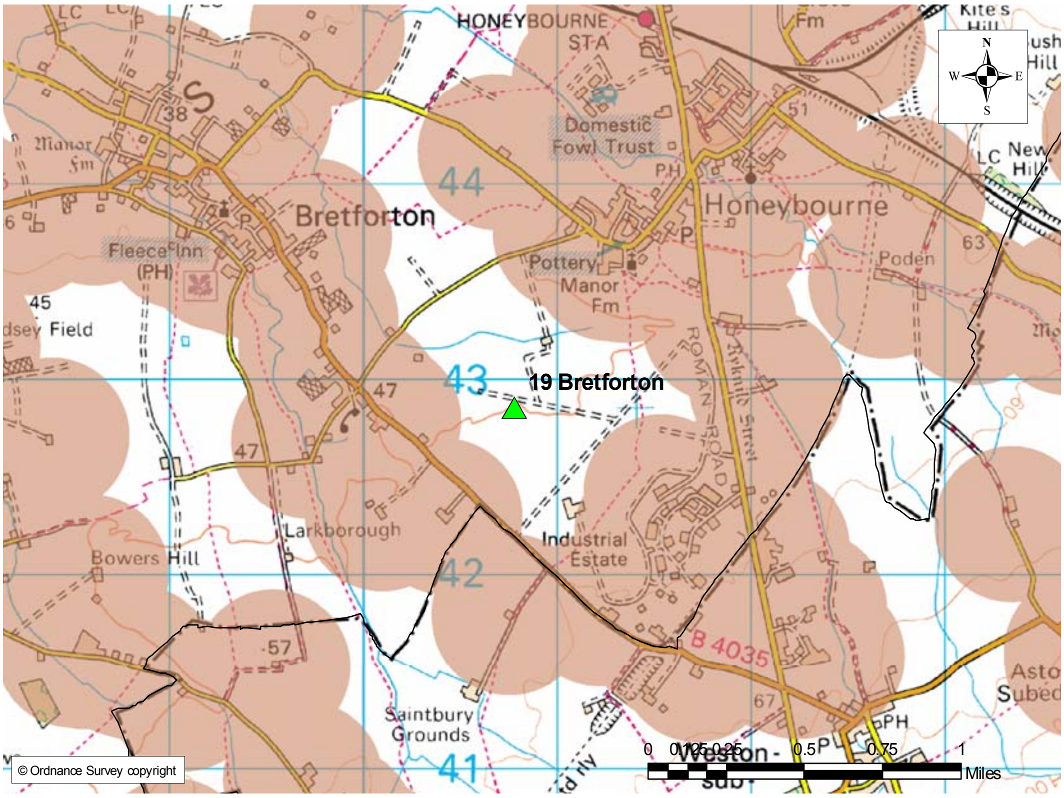


Figure 18- Potential wind site: Bretforton, Wychavon

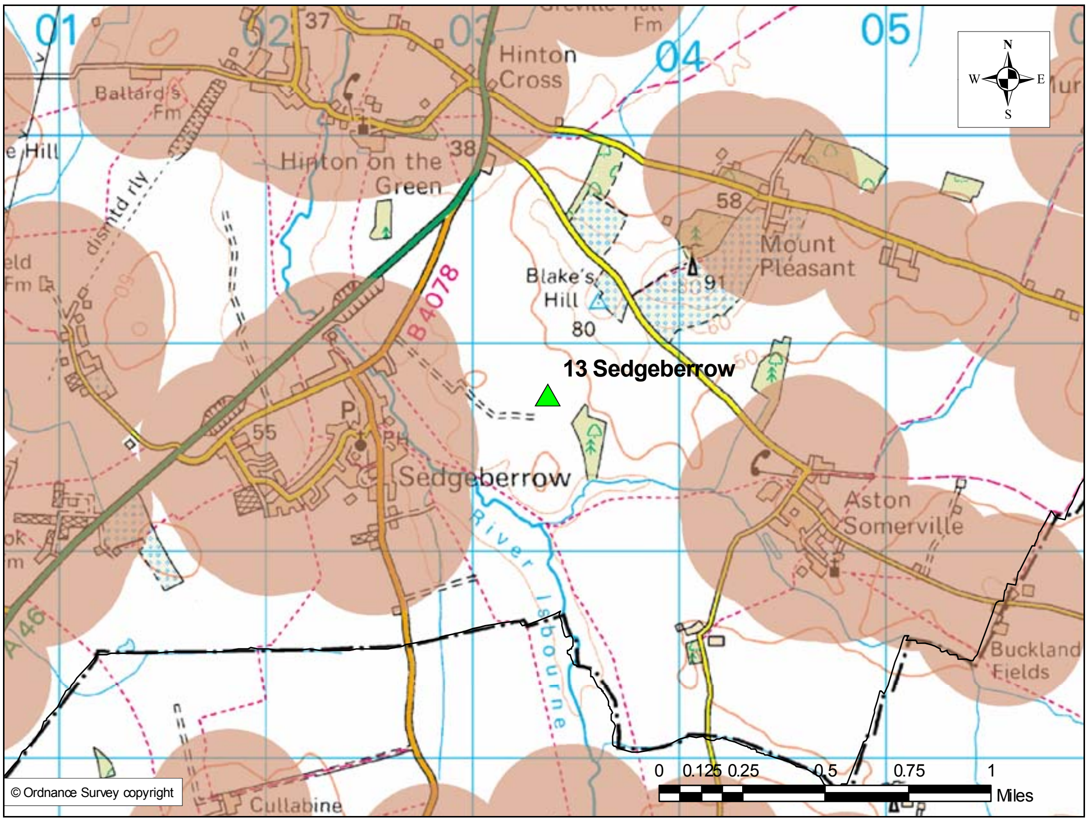


Figure 19- Potential wind site: Sedgeberrow, Wychavon

Malvern Hills

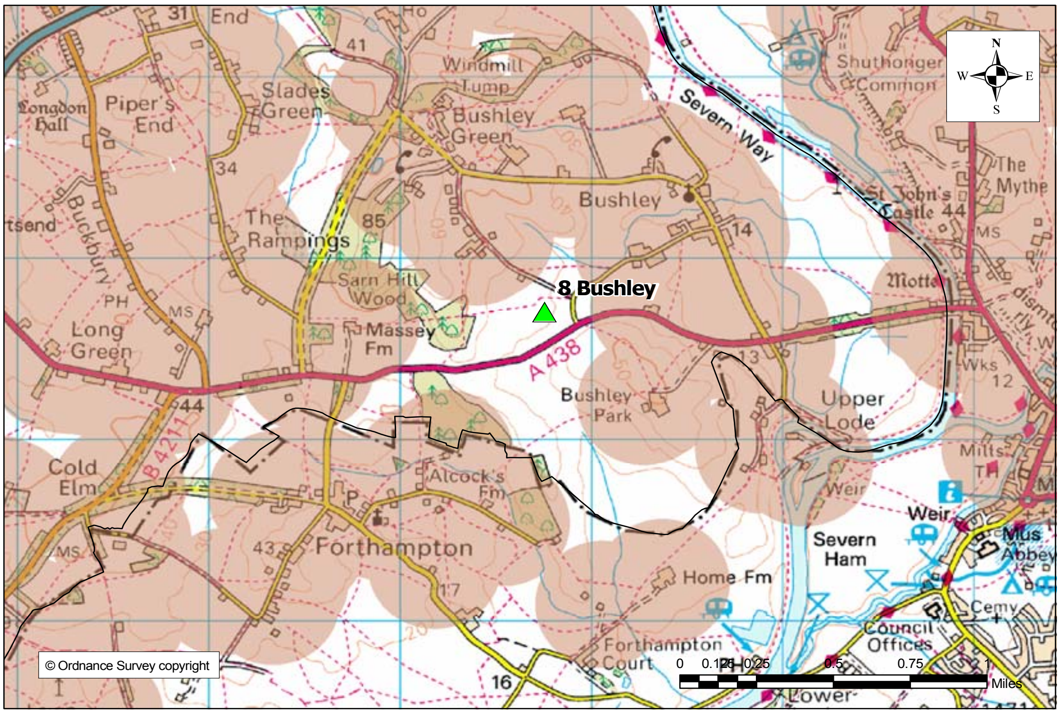


Figure 20- Potential wind site: Bushley, Malvern Hills

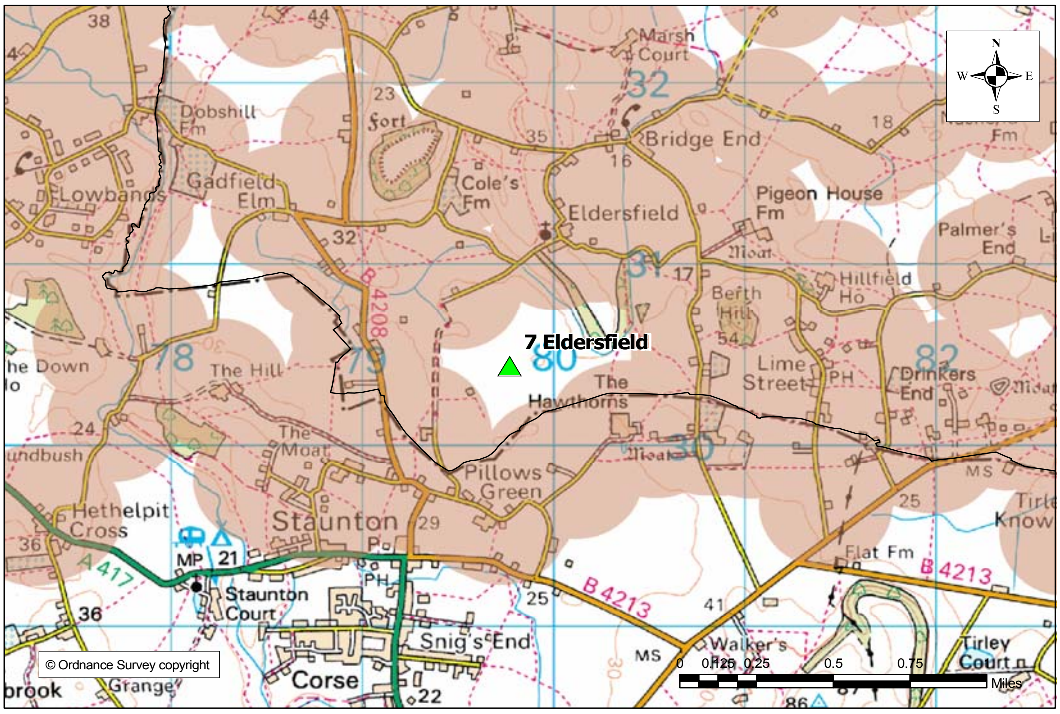


Figure 21- Potential wind site: Eldersfield, Malvern Hills

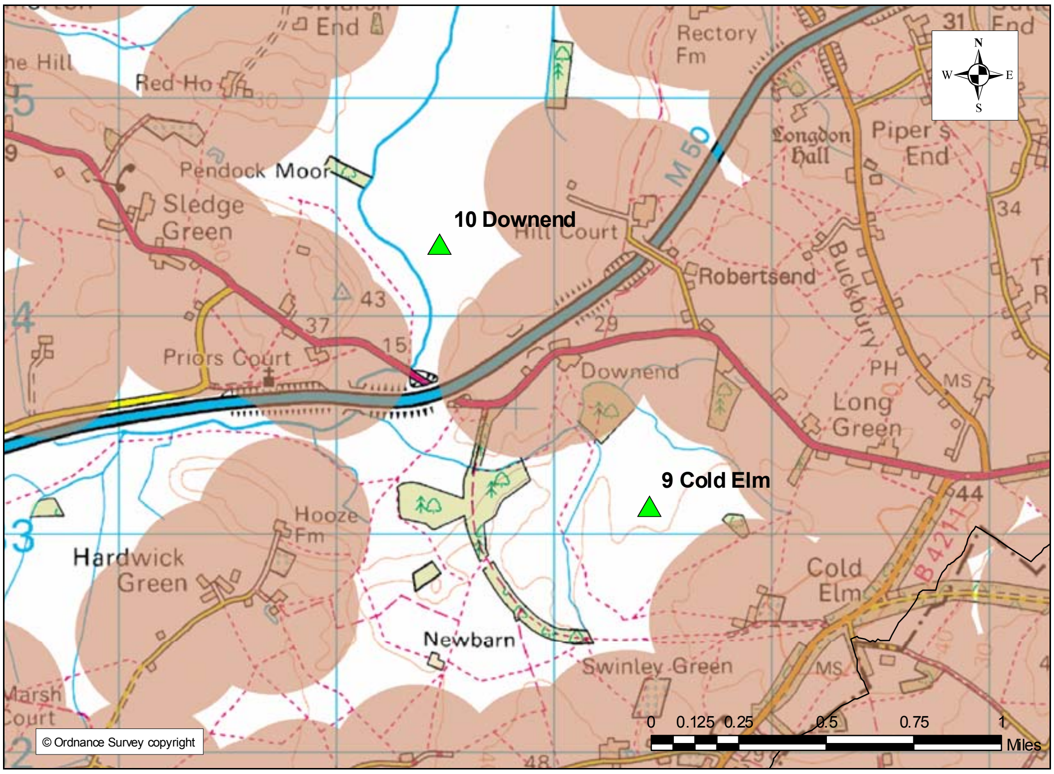


Figure 22 - Potential wind site: Cold Elm and Downend, Malvern Hills

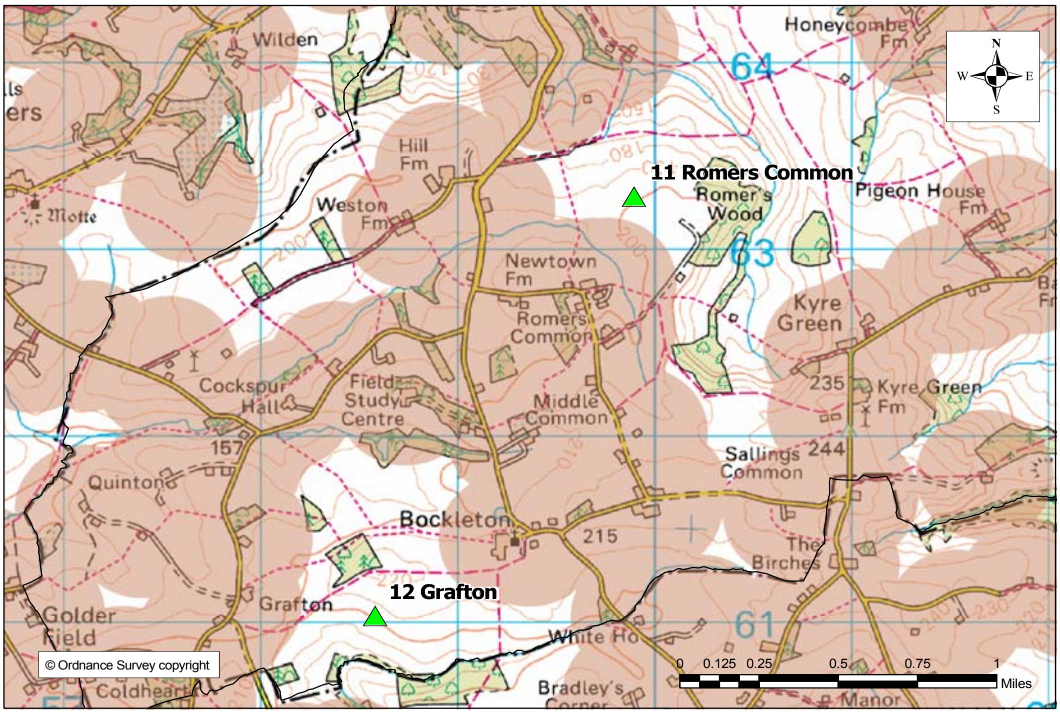
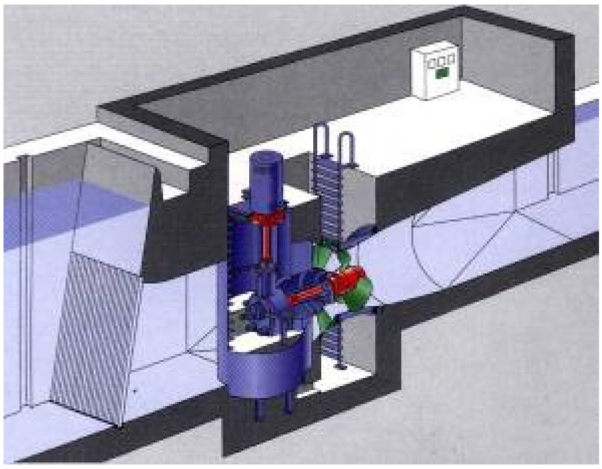


Figure 23- Potential wind sites: Grafton and Romers Common, Malvern Hills

Appendix 9 Types propeller and kaplan turbines.

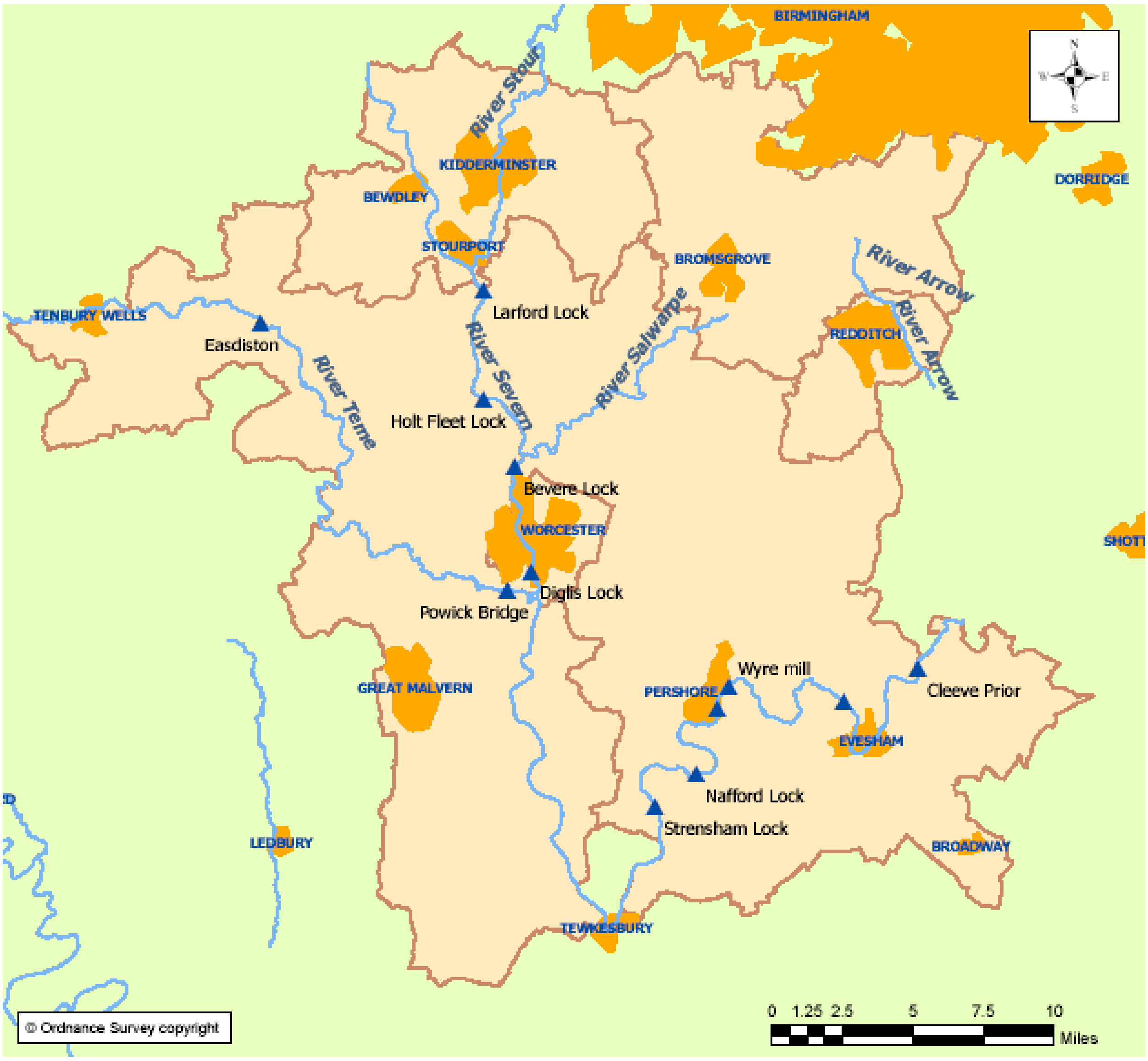
Vertical-axis This orientation has several advantages: the generator can be located above flood level, the turbine unit is relatively easy to inspect and remove for maintenance, and the draft tube (guiding the exit flow back to the river) can be oriented in any direction, which adds to the flexibility of the layout.	
Tube Turbine A tube turbine describes a propeller machine in which the tube surrounding the propeller has an 'elbow' put into it so that the shaft of the runner can be brought out to mate up with the speed-increasing device and generator. The choice of layout of a tube turbine is dictated by the existing site conditions, the available head, and most importantly the ratio of the head to the rotor diameter (H:D ratio).	
Siphon Turbines A special case of the tube turbine is the siphon turbine and is suitable for low head sites due to the advantage that the siphon creates extra height to fit the turbine so involves much reduced excavation and civil works. However, a disadvantage of this type of turbine is that it will have a greater visual impact and may also require extra sound-proofing to ensure that noise disturbance is minimised.	
Open flume turbines An open flume turbine is one in which there is no intake section narrowing down to feed the flow into the turbine, instead the guide-vanes sit in a large open chamber. This arrangement is usually most suited to replacing old open-flume Francis machines in existing mill structures. There are fewer turbine components, but more work required on site to assemble the machine.	No Picture Available
Bulb Turbines For larger schemes (>500kW per turbine) which can bear higher costs, the bulb-turbine (and vertical-shaft Kaplan) are well-proven solutions first implemented in the 1930s.	No Picture Available

Pit Kaplan (right-angle drive) The Pit-Kaplan was originally devised as a low-cost alternative to the bulb turbine. In this arrangement the shaft of the runner passes into a sealed 'pit' which runs from the base of the intake up into the powerhouse. The flow passes either side of the pit to reach the guide-vanes and runner. The pit itself contains a right-angle drive gearbox from which a vertical shaft ascends into the powerhouse to drive the generator. An alternative arrangement utilises a belt drive in place of the gearbox to reduce costs. The pit-Kaplan has been common among recent low-head schemes in Germany.	
Submersible turbines (mini-bulb turbines) The conventional bulb turbines were designed so that the bulb was large enough for human access to allow inspection and maintenance of the gearbox and generator. This concept becomes unworkable for very small schemes. However mini-bulb turbines are now available in which the generator is submerged in a small water-tight bulb as depicted in figures below, a design transferred from submersible pump technology. With this concept, there is no need for a powerhouse above the turbine, the generator automatically receives water-cooling, and the visual and noise impacts of the scheme are greatly reduced.	

Appendix 10 Hydropower Consultations

Organisation	Contact Name	Address / Phone No.	Notes
The Environment Agency	Paul Flynn, Development Control Technical Specialist	Hafren House Oxon Business Park Welshpool Road Shelton Shrewsbury Shropshire SY3 8BB	EA would to discuss issues relating to hydropower. However each specific site is treated individually and on a case by case basis.
British Hydropower Association	Ellan Parry	12 Riverside Park Station Road Wimborne Dorset, BH21 1QU	Source for Hydro Sites in the UK, including Worcestershire. In their view, given that the Malvern Hills and River Severn are in Worcestershire, the county is likely to have some good hydropower potential.
Lower Avon Navigation Trust	John Taplin	Mill Wharf Mill Lane Wyre Piddle Nr Pershore Worcestershire WR10 2JF	LANT are open to discussion with possible hydro developers, are involved on a scheme themselves with a Hydropower firm in Evesham, therefore are supportive of future developments if all correct environmental measures are taken.
Upper Severn Hydro & Navigation Company Ltd.	Charles Kenchington	Unit 8 (c/o TQ Exel Ltd) Mendip Business Park Mendip Road Rooksbridge Somerset BS26 2UG	Wish to reinstate navigation with the use of inflatable Weirs
British Waterways	Richard Mercer, Head of Utilities	West Midlands Waterways 64 Clarendon Rd Watford Herts WD17 1DA	BW have plans to develop Wind and Hydropower in their sites, including locks. BW are open to discussion with possible hydro developers who agree to their terms and conditions (provided for a particular scheme)

Appendix 11 Map indicating potential hydro sites



Appendix 12 List of potential hydro sites

District	Site	Town	Head (m)	Flow - Q30 [48](m3 /s)	Installed Capacity (kW)	Annual Energy Output (kWh)	River	Scenario	Comments
Wychavon	Pershore Lock	Pershore	2.5	16.00	288	1,261,440	Avon	1	Not able to confirm head during the visit. Access good. Appears to have limited land.
Wychavon	Fladbury Lock	Fladbury	2.0	15.00	225	985,500	Avon	1	1.25 m of head measured during high flows, so good head. Private land. Potential availability and space issue.
Malvern Hills	Holt Fleet Lock	Holt Heath	2.3	64.11	1084	4,746,954		1	
Malvern Hills	Larford Lock	Stourport	1.2	64.11	575	2,517,950	Severn	1	Access is good
Worcester	Diglis Lock	Worcester	1.6	65.40	769	3,368,676	Severn	1	Could not view (no access to the site as building works ongoing).
Malvern Hills	Eardiston	Eardiston	2.2	16.43	266	1,163,294	Severn	1	
Wychavon	Nafford Lock	Birlingham	1.7	16.00	198	865,348	Teme	2	

[48] 30th Percentile flow used as design flow – a good preliminary estimate

Appendix 13 Detail maps indicating potential hydro sites

Wychavon

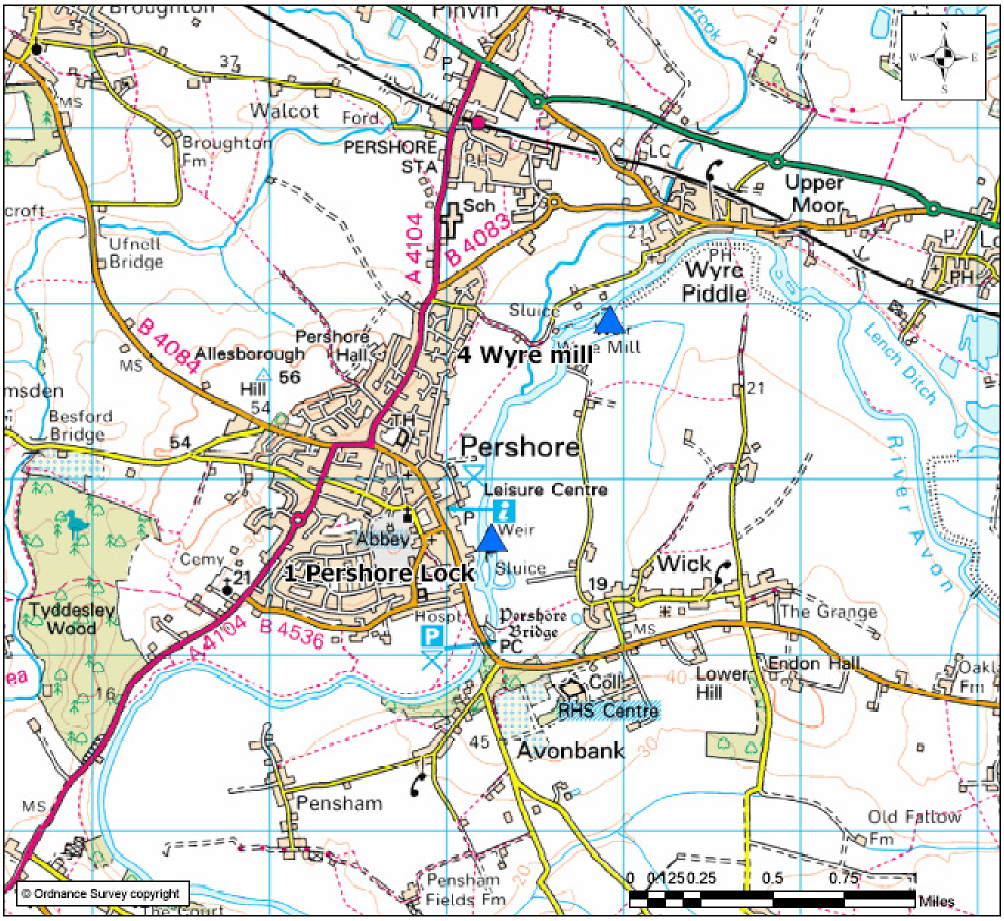


Figure 10 - Potential hydro sites: Pershore Lock and Wyre Mill, Wychavon

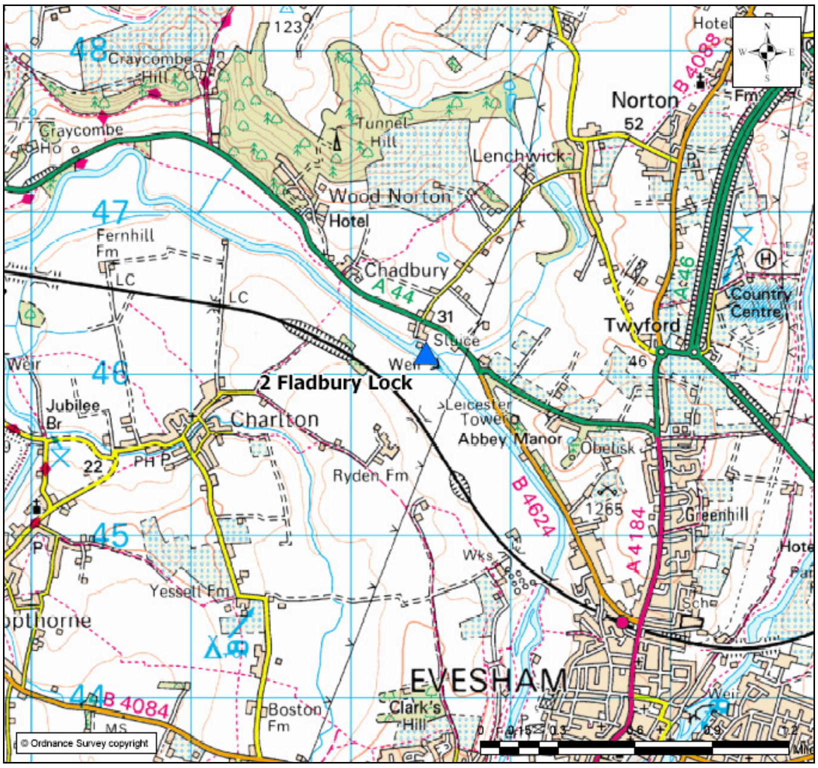


Figure 11 - Potential hydro site: Fladbury Lock, Wychavon

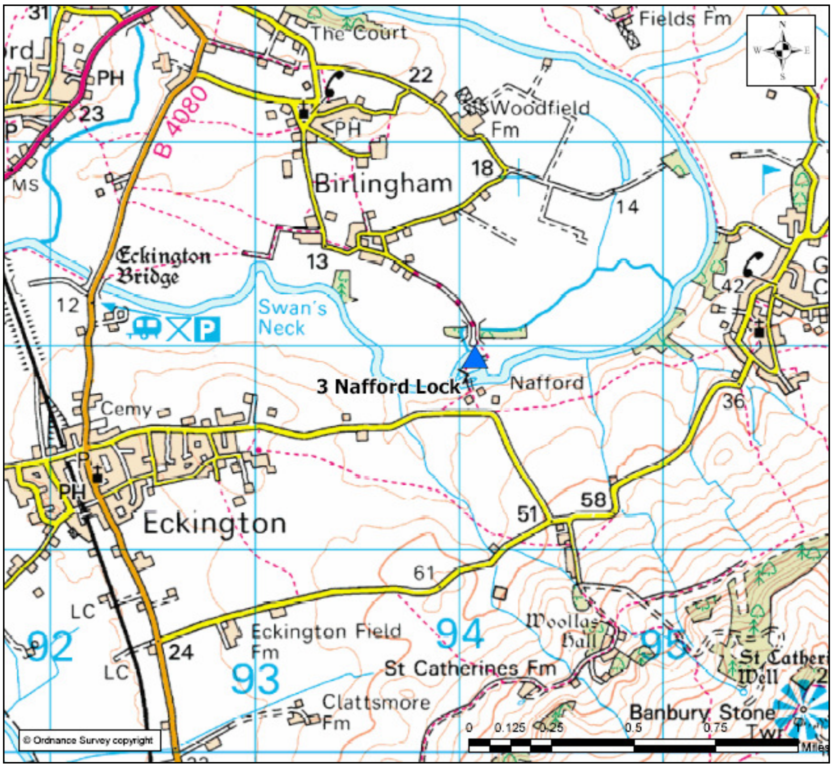


Figure 12 - Potential hydro site: Nafford Lock, Wychavon

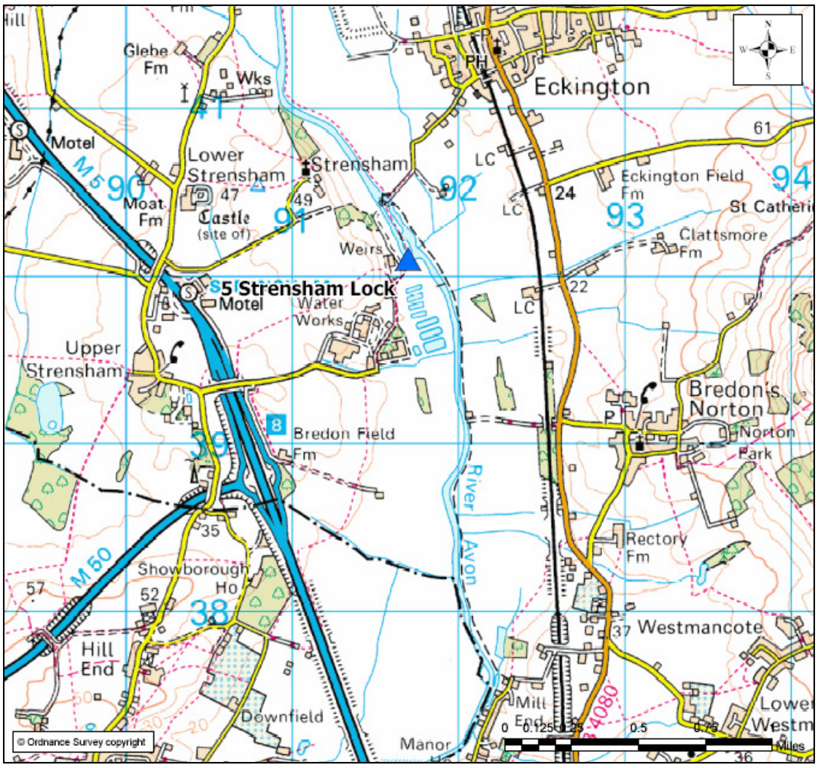


Figure 13 - Potential hydro site: Strensham Lock, Wychavon

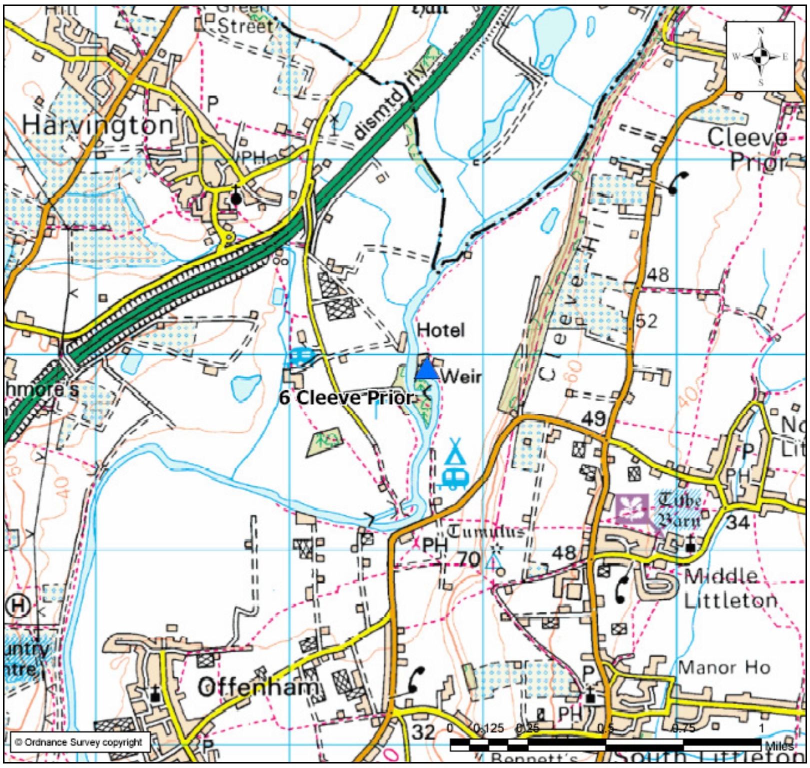


Figure 14 - Potential hydro site: Cleeve Prior, Wychavon

Malvern Hills

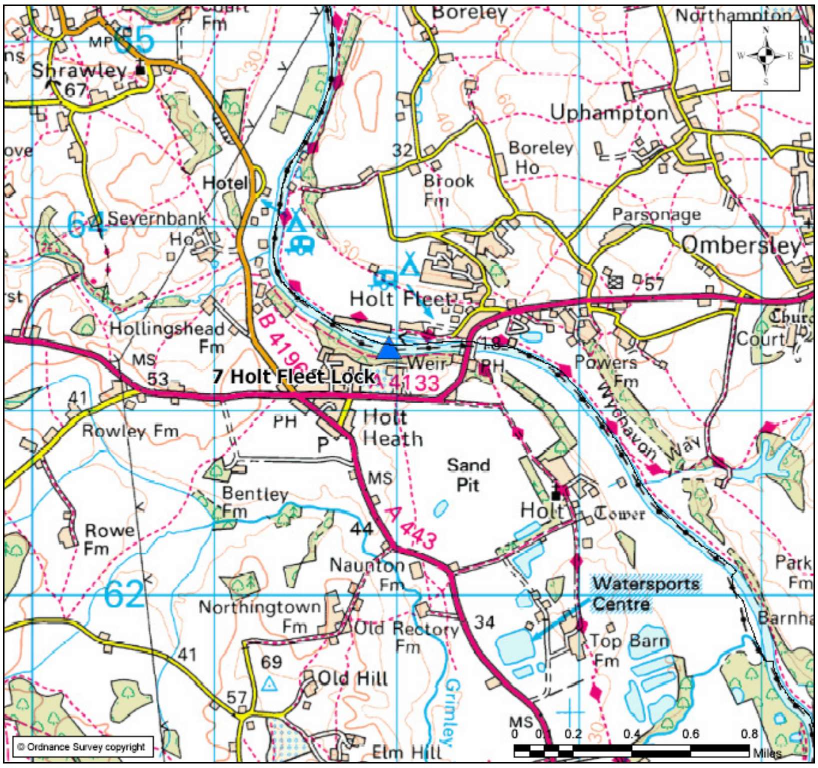


Figure 15 – Potential hydro site: Holt Fleet, Malvern Hills

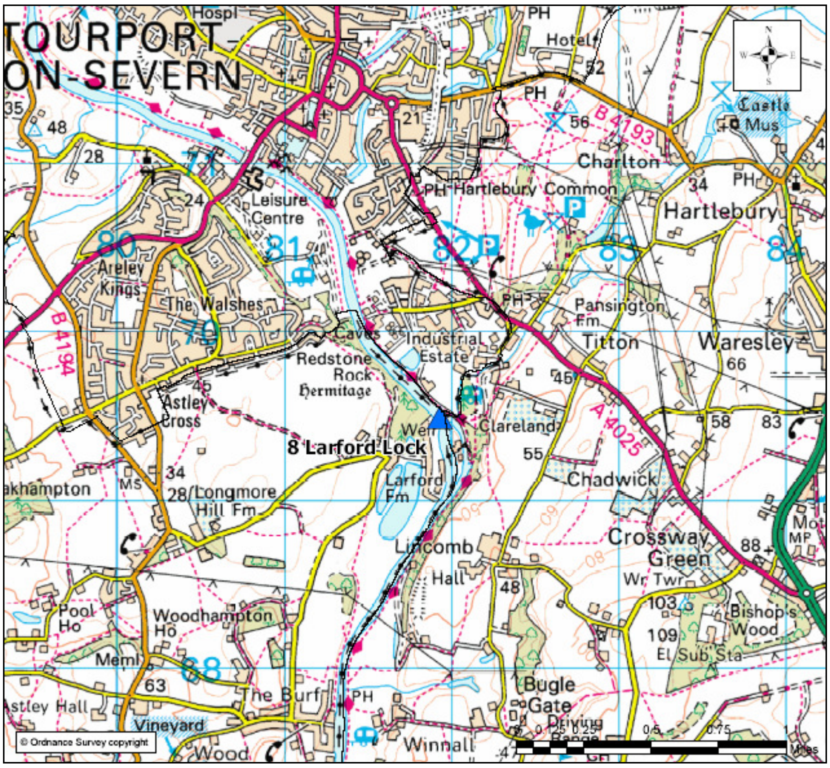


Figure 16 - Potential hydro site: Larford Lock, Malvern Hills

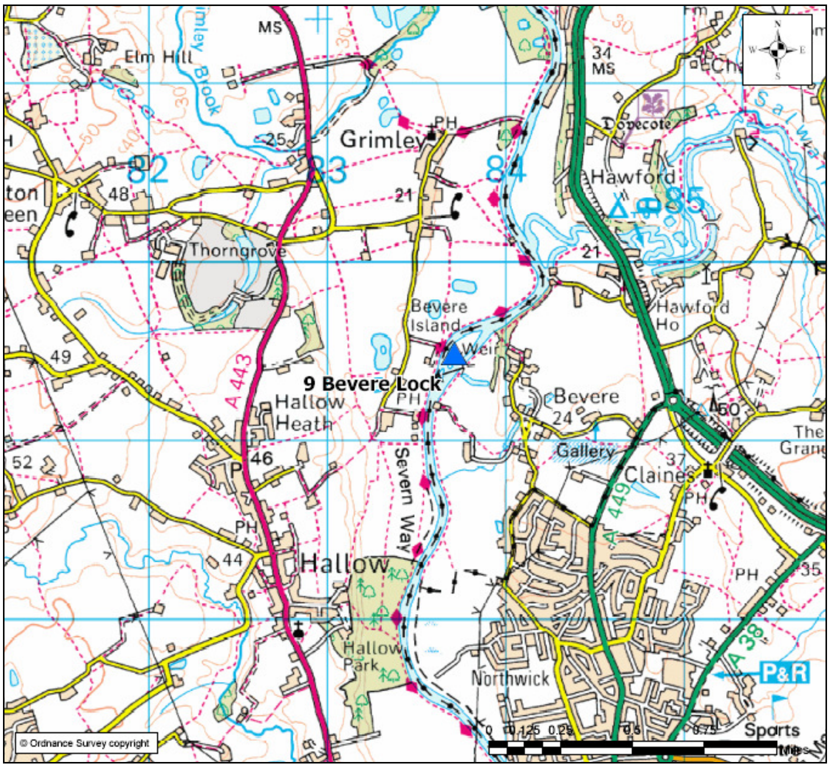


Figure 17 - Potential hydro site: Bevere Lock, Malvern Hills

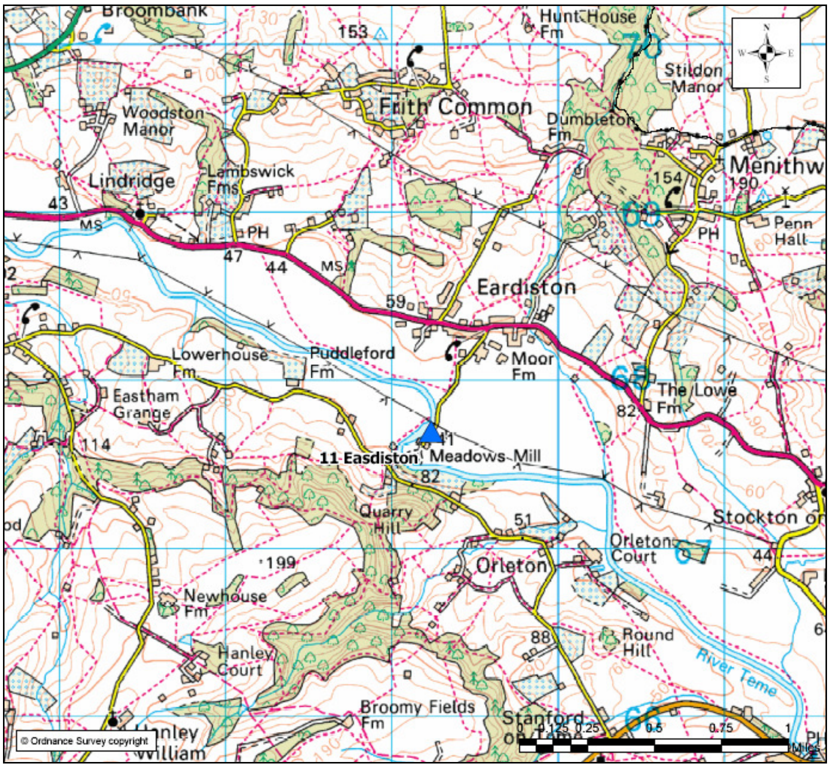


Figure 18 - Potential hydro site: Easdinton, Malvern Hills

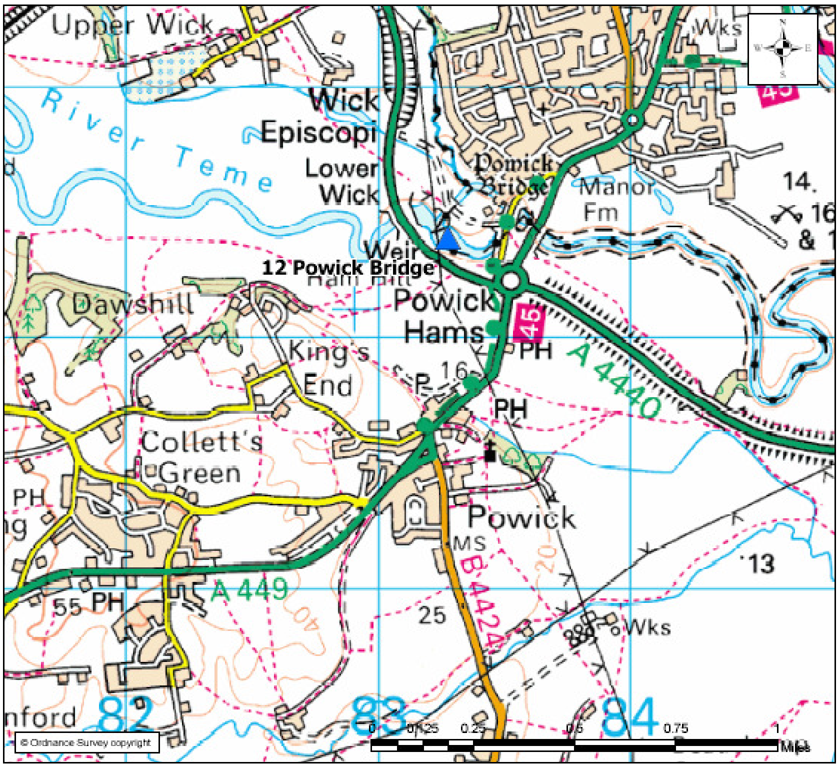


Figure 19 - Potential hydro site: Powick Bridge, Malvern Hills

Worcester City

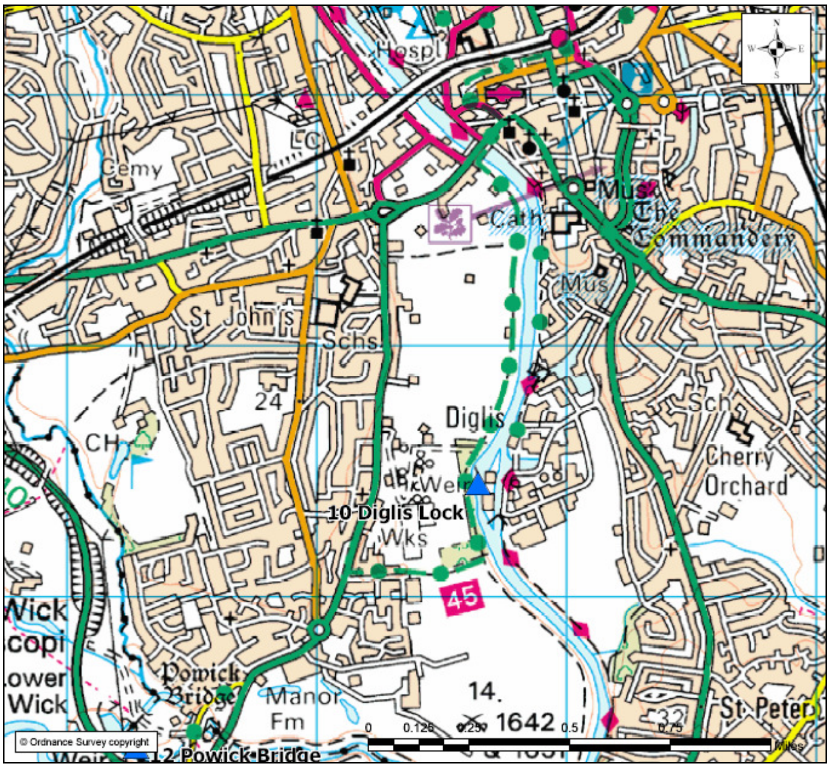


Figure 20 - Potential hydro site: Diglis Lock, Worcester City