Renewable and Low-carbon Energy Capacity Methodology

Methodology for the English Regions

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Contents

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1: Introduction

Background

1.1 In September 2009, SQW Energy and Land Use Consultants were commissioned by the Department of Energy and Climate Change (DECC) and the Department of Communities and Local Government (CLG) to develop a methodology for assessing the opportunities and constraints for deploying renewable and low-carbon energy development in the English regions.

1.2 Research undertaken in 2008 for CLG found that there were considerable inconsistencies in the way renewable energy capacity had been defined, assessed and fed through to the setting of targets in Regional Spatial Strategies[1]. In order to ensure that work in the regions is sufficient to deliver a step change in renewable energy deployment across the country, and to reduce the inconsistencies between regional assessments, the Government set out a commitment in the UK Renewable Energy Strategy (2009)[2] to support the regions in reviewing their assessments and targets for renewable energy.

1.3 To underpin this work the Government committed to developing a robust methodological approach and criteria for identifying the opportunities and constraints for renewable energy deployment in any given area at a strategic level. This document aims to fulfil that commitment, and has been prepared with the involvement of key stakeholders with an interest in planning and renewable energy.

1.4 The methodology is in line with government policy as currently set out in PPS1 Supplement on Climate Change[3] and PPS22 on Renewable Energy[4]. It is 'policy neutral' as it is driven by the existing policy framework and does not introduce or suggest policy changes. The existing policy framework itself, including PPS1 and PPS22, is however subject to ongoing revision and development. This document will be revised as appropriate to reflect national policy.

Objectives of the methodology

1.5 The key objectives of the methodology are:

- to help regions assess the potential for renewable energy in their area in a consistent way;
- for each regional assessment to underpin the evidence base for setting ambitious targets for renewable energy and a clear strategy to support their delivery in the Regional Strategy;

[1] *Renewable Energy Capacity in Regional Spatial Strategies: Final Report* (2008) Arup.
[2] *The UK Renewable Energy Strategy* (July 2009) DECC
[3] *Planning Policy Statement: Planning and Climate Change - Supplement to Planning Policy Statement 1* (2007) CLG
[4] *Planning Policy Statement 22: Renewable Energy* (2004) ODPM

- to help regions plan for substantial new development in locations and ways which provide for energy, in particular heat, to be gained where there are clear opportunities for new or extended decentralised energy systems;
- and to support Government policy and targets.

1.6 To this end, the methodology provides detailed guidance on the full range of parameters and assumptions that may be used by the regions in undertaking their regional renewable and low-carbon energy assessments.

1.7 It is not intended that this methodology should be used in the assessment of specific sites.

Approach to developing the methodology

1.8 This document sets out best practice based on the extensive range of existing work on energy and resource capacity assessment. Work has involved a comprehensive literature review of existing regional renewable energy assessments and other relevant publications, as well as consultation with key stakeholders. A full list of the references used to inform the preparation of this methodology is provided in Annex C.

1.9 Consultation with key stakeholders took the form of telephone interviews, face to face meetings and a series of workshops. Consultees were also invited to submit written comments on the draft methodology which were used to inform the preparation of this report. Consultees included regional government offices, regional energy agencies/ organisations, government agencies (e.g. Natural England, Environmental Agency, English Heritage, Forestry Commission), technical experts and representatives from industry.

Structure of this report

1.10 The remainder of this report is structured as follows:

Chapter 2 presents an overview of the methodology in terms of principles, scope, definitions and process

Chapter 3 explores the detailed parameters which should be used to assess the opportunities and constraints for each renewable energy category

Chapter 4 provides high-level guidance on how low-carbon energy options could be considered in the assessment

Annex A provides a detailed review of the evidence base behind the parameters and assumptions used

2: Methodology overview

2.1 This chapter provides an overview of the methodology which regions may apply when undertaking their assessment of renewable and low carbon energy potential. It includes a summary of the general scope, definitions, and assessment process to be used. Detailed assessment methodologies for each of the renewable energy categories are provided in Chapter 3, and the low-carbon energy categories are covered in Chapter 4.

Scope and definitions

2.2 The core energy categories covered by the methodology include:

- Renewable energy
- Low Carbon Energy, including heat

2.3 The resource and technological scope for the detailed regional assessment focuses on land-based renewable energy categories only (i.e. not offshore sources). These include both commercial scale renewables and microgeneration (on-site and building-integrated renewables).

2.4 Table 2-1 provides the full list of the renewable energy categories and sub-categories covered by this methodology. These are broadly consistent with the general categories that have been used in the existing renewable energy assessments undertaken by the regions to date.

2.5 Several further categories that appear in the literature have been excluded from the list as either their potential in the UK is deemed to be negligible (such as deep geothermal energy and surface-water source heat pumps) or cannot be quantified in terms of installed capacity (such as solar passive design).

2.6 Low-carbon energy categories are mentioned in this document at a high-level and refer to combined heat and power (CHP) generation (and tri-generation to include cooling) and district (community) heating schemes.

Table 2-1: Renewable categories covered by this methodology

Category	Sub-category level 1	Sub-category level 2
Wind (onshore)	Wind – commercial scale	
	Wind – small scale	
Biomass	Plant biomass	*Managed woodland* *Energy crops* *Waste wood* *Agricultural arisings (straw)*
	Animal biomass (*aka EfW*)	*Wet organic waste* *Poultry litter*
	Municipal Solid Waste (MSW) Commercial & Industrial Waste (C&IW)	
	Biogas (*aka EfW*)	*Landfill gas* *Sewage gas*
	Co-firing of biomass (with a fossil fuel)	
Hydropower	Small scale hydropower	
Microgeneration	Solar	*Solar Photovoltaics (PV)* *Solar Water Heating (SWH)*
	Heat pumps	*Ground source heat (GSHP)*[5] *Air source heat (ASHP[6])*

Source: SQW Energy

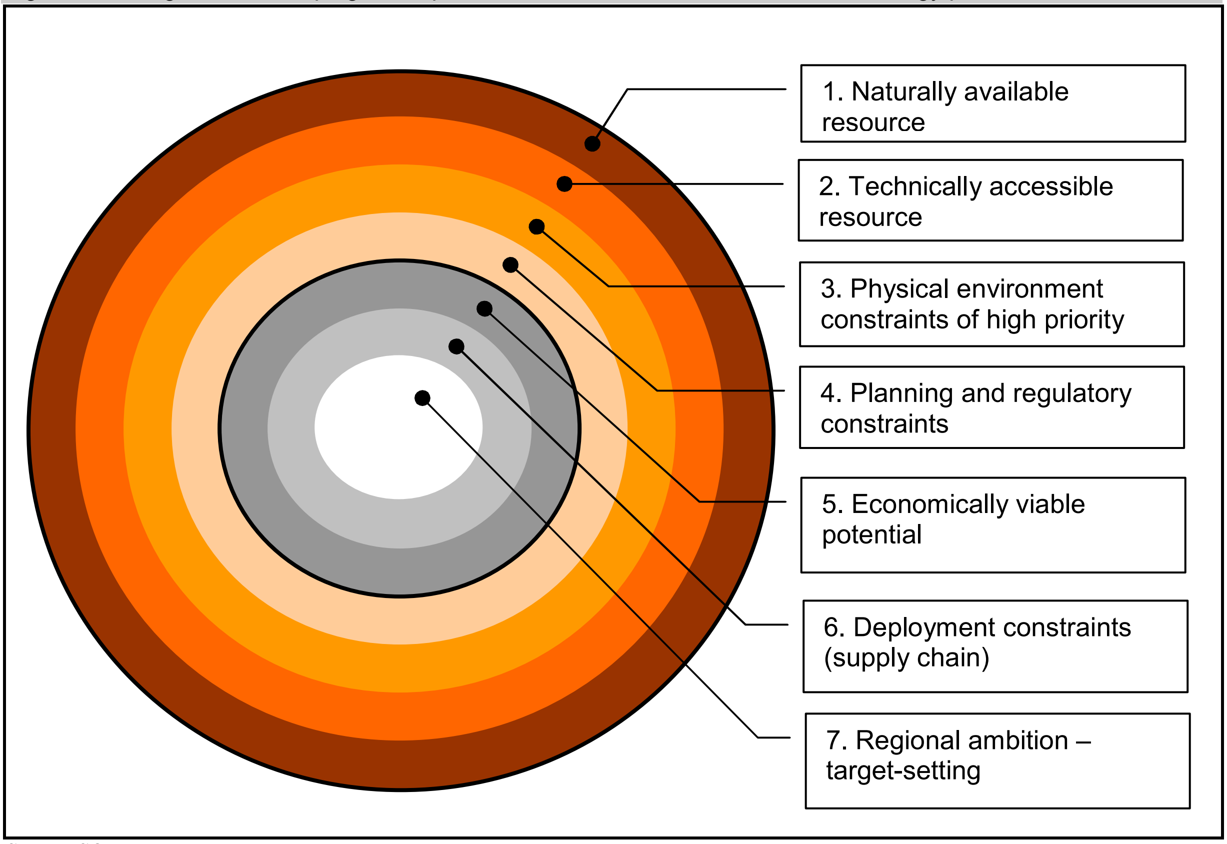
Opportunities and constraints assessment

2.7 Developing the regional evidence base involves a sequential process. Layers of analysis are applied that progressively reduce the total <u>theoretical</u> opportunity to what is <u>practically</u> achievable.

2.8 Figure 2-1 below provides a summary of the key stages involved in developing a comprehensive evidence base and analysis in order to inform regional targets for renewable energy.

[5] This category covers horizontal trench and vertical borehole systems across the closed loop and open loop types (open loop GSHP uses ground water from an aquifer)
[6] Only those systems that achieve a coefficient of performance (COP) in line with the Renewables Directive 2009

Figure 2-1 Stages for developing a comprehensive evidence base for renewable energy potential



Source: SQW Energy

2.9 This methodology covers the first four stages of the assessment. The methodology does not cover stages 5 to 7, which ultimately lead to target-setting.

2.10 In broad terms, Stages 1 and 2 represent the opportunity for harnessing the renewable energy resource on the basis of what is naturally available vis-à-vis the limitations of existing technology solutions. Some natural resources, for example solar and wind, are available in abundant supply. In these cases the analysis focuses on what the available technology can capture and convert into useful energy. Therefore, the two stages can be combined into an overall opportunity analysis, with each being explored to the relevant extent (depending on the nature of the renewable resource and conversion technology).

2.11 Stages 3 and 4 address the constraints to the deployment of technologies in relation to the physical environment and planning/regulatory limitations. They comprise the 'Constraints analysis' of the methodology. Table 2-2 provides a summary of the assessment process which the regions can use to gather the evidence for Stages 1 to 4.

2.12 Under stage 5, "economic constraints" refer to e.g. the cost of the technology, energy commodity prices and cost of capital. "Supply chain constraints" (stage 6) refer to e.g. maturity and capacity of the supply chain to deliver the required renewable fuel or technology (equipment) and to deploy the technology (including qualified engineers and installers).

2.13 **This methodology is intended to help each region to produce a robust regional level evidence base. As such, the specified assessment process will produce results on resource availability and potential for capacity deployment which relate to the region as a whole.**

Table 2-2: Assessment process summary

Main element	Stage and description
Opportunity analysis	**Stage 1. Naturally available resource** Regions need to explore and quantify the naturally available renewable energy resource within their geographical boundary. This will be based on data and information analysis including resource maps and inventories. **Stage 2. Technically accessible resource** Regions need to estimate how much of the natural resource can be harnessed using commercialised technology (currently available or expected to reach the market by 2020). This will be based on applying parameters regarding the deployment of technology. The entire area of the region needs to be taken into account.
Constraints analysis	**Stage 3. Physical environment constraints** Regions need to explore the physical barriers to deployment such as areas where renewables schemes cannot practically be built – e.g. large scale wind turbines on roads and rivers. This layer of constraints will reduce the overall deployment opportunity. The analysis will be based on GIS maps and various relevant regional inventories. **Stage 4. Planning and regulatory constraints** Regions need to apply a set of constraints relevant to each renewable technology that reflects the current planning and regulatory framework, such as excluding from the assessment areas and resources which cannot be developed due to e.g. health & safety, air/water quality, environmental protection.

Source: SQW Energy

2.14 For both the Opportunity and Constraints analyses, a series of parameters have been set out for each renewable energy category – these are presented in detail in Chapter 4 of this document.

2.15 The parameters vary between the different renewables categories and require different levels of data input and assessment. Some of the information and assessments required are available at the national level (e.g. for small scale hydro) and therefore detailed assessments do not need to be undertaken at the regional level. However for most on-shore renewables categories regional (bottom-up) assessments are necessary. The level of assessment required is clearly indicated in Chapter 4, where the parameters and data sources to be used are provided and explained.

2.16 With regard to national designated landscapes (e.g. National Parks, AONBs) and international and national nature conservation areas (e.g. SPAs, SACs, SSSIs etc), detailed consultations with Natural England concluded that these areas should not be excluded from the assessment as they have the potential to deliver renewable energy. Guidance is provided at the end of Chapter 4 setting out the key steps that regions may follow when assessing the potential for these areas to accommodate the various categories of renewable energy. It is suggested that regions undertake the assessment of potential within designated areas in parallel with the general regional assessment, with the findings feeding into the overall regional evidence base at a later stage.

Outputs to be provided in the regional evidence base

2.17 This report sets out the methodology that regions may follow when undertaking their regional assessments of renewable energy potential. As outlined earlier in this Chapter, the methodology only covers the initial stages of regional assessment (opportunities and constraints - environmental, technical and planning).

2.18 For low-carbon energy options, the regions are encouraged to indicate what opportunities exist within their geographical boundary (see Chapter 4).

3: Detailed assessment of the potential for installed capacity by renewable energy category

3.1 This chapter provides detailed guidance on how regions may assess their renewable energy resource in order to arrive at an estimate for potential installed capacity in MW. For each renewable energy category identified, a set of parameters has been defined that covers assessment Stages 1 to 4 as outlined in Chapter 2: Methodology. For the practical reasons outlined in Chapter 2, the parameters relevant to Stages 1 and 2 have been combined into an 'Opportunity analysis' and those relating to Stages 3 and 4 have been grouped under a 'Constraints analysis'.

3.2 In order to arrive at an estimate for the total potential installed capacity for each energy category, the regions need to sequentially apply the parameters listed in the tables below.

3.3 A detailed review of the literature, common practice, and justification for both why each parameter is included and at what benchmark value is provided in Annex A.

3.4 A range of further parameters relevant to the various renewable energy categories have been considered but have not been included in the methodology, on the basis that they would not provide additional clarity and accuracy to the evidence base at the regional level. For instance some parameters refer to site-specific opportunities/constraints and others relate to economic and supply chain constraints, which are outside the scope of this methodology. Annex A also provides a review of these parameters and the reason for not applying them in the assessments.

Wind: on-shore (commercial scale)

Definition and scope

The natural energy of the wind can be harnessed to drive a generator that produces electricity.

Commercial scale wind refers to on-shore wind farm developments for commercial energy generation and supply. Most such developments are connected to the national grid, however private-wire schemes are also an option and some already exist. Configurations of groups of wind turbines or individual turbines are used.

Assessing the resource potential and the deployment opportunities relates primarily to the wind speeds available within the region and the ability of current technology to harness this resource in terms of turbine design (size, efficiency) and installation requirements.

3.5 The potential installed capacity for commercial scale on-shore wind energy development can be calculated by sequentially applying parameters 1 to 7 detailed in Table3-1 below.

Assessment approach and methodology

Table 3-1: Detailed assessment of opportunities and constraints for on-shore wind (commercial scale)[7]

No	Parameter	Description	Assessment requirement	Where to source data from
Opportunity assessment - natural and technically accessible resource				
1	Wind speed	Average annual wind speed in a 1sq km grid - indicating wind availability (m/s)	Apply a lower limit of 5m/s measured at 45m above ground level (agl) – i.e. consider all areas with wind speed at and above 5m/s at 45m agl .	UK Wind speed database (NOABLE)[8]
2	Wind turbine size	Typical capacity of turbines	Apply standard average turbine size of 2.5 MW installed capacity (dimensions:, tip height: 135m, rotor diameter:100m, hub height: 85m)	no data required
3	Wind turbine density	Maximum installed capacity in a unit of area (MW/km^2)	Apply distance between turbines of 5 rotor diameters or a benchmark of $9MW/km^2$ – whichever results in the greater capacity deployment figure.	no data required
Constraints assessment - physically accessible and practically viable resource				
4	Non-accessible areas	Areas where wind turbines cannot be installed due to physical environment constraints	Exclude from the assessment the following areas (footprint): • Roads (A, B and motorways) • Railways • Inland waters (rivers, canals, lakes and reservoirs) • Built-up areas (settlement polygons) • Airports • MOD training sites	GIS layers: OS Strategi®[2] - includes data on roads, railways, inland waters and built-up areas (cities, towns, villages – as polygons) MOD
5	Exclusion areas	Areas where wind developments are unlikely to be permitted.	Exclude from the assessment the following areas: • Ancient semi-natural woodland • Sites of historic Interest (but no buffer to be applied) • Buffer around roads and rail lines: tip height + 10% (=150m) • Buffer around all built-up areas (settlement polygons – as defined in OS Strategi®): 600m • Buffer around all airports and airfields: 5Km. • Civil Air Traffic Control	GIS layers: OS Strategi® Multi Agency 'MAGIC' database www.magic.gov.uk MOD

[7] Whilst the presented methodology deals with a significant amount of detail and produces detailed results against some parameters, it is only intended to inform the regional-level evidence base and not to be used for identifying broad locations for development or site-specific decisions.
[8] The NOABLE database is a good high-level and publicly available database that can be used for high-level analysis; however, where site specific assessment is to be undertaken, more detailed and accurate data sources will be required. NOABLE is therefore suitable for use for the regional-level assessments and provides a useful basis for consistency among the regions.

No	Parameter	Description	Assessment requirement	Where to source data from
			constraints • MOD training areas • Explosive safeguarded areas, danger areas near ranges	
6	Designated Landscapes and Nature Conservation Areas	Potential for renewable energy within these areas	For internationally and nationally recognised landscape and nature conservation designations, apply the 5-step approach specified at the end of Chapter 3 in order to assess the overall type and level of renewable energy infrastructure that could be accommodated within these designations.	Multi Agency 'MAGIC' database www.magic.gov.uk
7	MOD constraints	Additional exclusion areas relating to MOD sites and radar issues	Consult with the MOD for specific regional advice on any additional constraints that may need to be applied including: • MOD sites (other operational and unused land) • Air defence and air traffic control radar – request MOD to indicate what amount (ha, km^2 or %) of the accessible resource should be further excluded from the assessment due to radar constraints. • Other safeguarded areas • Danger areas and MOD bye laws	MOD Aviation safeguarding maps http://www.restats.org.uk/safe_guarding_maps.htm

Source: SQW Energy and Land Use Consultants

Wind – small scale

A sub-category of onshore wind is the small scale wind installations which can be defined as having capacity of less than 100 kW and typically comprise single turbines. Small scale wind schemes have different characteristics to large scale developments which is reflected in the assessment parameters and the values applied.

The majority of small scale wind installations are ground-based developments, with only few that are building integrated (on top roofs). Small scale ground-based turbines, by their nature have lower hub/tip heights of about 15m agl and are viable at lower wind speeds (4.5 m/s at 10m agl). They are typically installed on-site and supply the on-site demand first before spilling the excess to the grid and therefore they are by definition located in or next to built-up areas. This means that they can extend the deployment of wind capacity into areas where large developments are likely to be significantly constrained. At the same time, the number of small wind installations is in practice a function of the number of buildings or sites and not deployable on a per km^2 basis.

3.6 The potential installed capacity for small scale on-shore wind can be calculated by sequentially applying the parameters detailed in Table 3-2 below.

Table 3-2: Detailed assessment of opportunities and constraints for small scale wind

No	Parameter	Description	Assessment requirement	Where to source data from
Opportunity assessment - natural and technically accessible resource				
1	Address points	Areas and sites where small wind is potential viable	Identify all built-up areas by using address point data. Also estimate the total number of residential and non-residential buildings	Ordnance Survey Address Point Dataset
2	Wind speed	Average annual wind speed in a 1sq km grid - indicating wind availability (m/s)	Apply a lower limit of 4.5m/s measured at 10m above ground level (agl) – i.e. consider all address points with wind speed at and above 4.5m/s at 10m agl	UK Wind speed database (NOABLE)
3	Wind turbine size	Typical capacity of turbines	Apply standard average turbine size of 6 kW installed capacity per address point	No data required
Constraints assessment - physically accessible and practically viable resource				
4	Mean wind speed scaling factor	Lowering of the average wind speed due to obstructions in built-up areas	Apply the following 2-step approach: 1. Categorise built-up areas as urban, sub-urban and rural at ward level 2. Apply wind speed scaling factor from wind installer standard MIS 3003 for each of the three area categories (urban: 56%; suburban: 67%; rural: 100%) and exclude all address points where the resulting average wind speed is less than 4.5 m/s at 10m agl Note that this approach does not take into account site specific constraints such as actual building height and roof shape, neighbouring buildings, high trees and other physical obstacles. Such detailed assessment is not required at the regional level and is only possible by applying a ward-by-ward spatial analysis.	(1) Defra Rural-Definition dataset (ward level) (2) Microgeneration Installation Standard (MIS) 3003

Source: SQW Energy and Land Use Consultants

Biomass

Definition and scope

Biomass is a diverse category with regard to the type of available fuels, fuel conversion technology and type of energy output.

Fuels – different fuel categories have been used in the literature and a single agreed categorisation is still difficult to identify. The EU Renewable Energy Directive and the UK Biomass Strategy, however, provide more comprehensive (and legally binding) definitions for biomass fuels. Generally, biomass fuel can arise from plants (woody or grassy), animals (manure, slurry) and human activity (commercial, industrial and municipal waste). All of these options are considered in the guidance. In most cases, the useful fuel is in a solid or gaseous form. Bioliquids (i.e. liquid fuel for energy purposes other than for transport) are also available and varied, however they are not directly included in this guidance as (1), they compete with the other biomass fuel categories for natural resource (productive land or bio waste) and therefore are not an additional resource, and (2) they often need to be imported to meet commercial scale demand (e.g. palm seed oil), for which regional resource assessment in not appropriate. Biofuels (e.g. biodiesel and bio-ethanol) are those fuels used for transport purposes and are not included in the assessment as they fall outside the scope of this methodology.

Conversion technology – three main processes are currently available and used: (1) direct combustion of solid biomass, (2) pyrolysis and gasification of solid biomass and (3) anaerobic digestion of solid or liquid biomass. Biomass fuels are in principle suitable for use in combined heat and power (CHP) plants, however, its use has not been exploited to its full potential in the UK. Assessing the capacity potential for biomass CHP however will not change the total outcome for the regional biomass opportunity and therefore is not required. Certain principles and considerations specifically regarding CHP are however provided in the low-carbon categories material in Chapter 5.

Energy output – this can be in the form of electricity or heat. Both options are explored in this guidance and for fuels that can viably be converted to either output, the two options are provided.

Assessment approach and methodology

3.7 Regions can benefit from having an understanding of their available biomass resource, both as an indicator for potential biomass schemes and as an economic development opportunity. There is an emerging market for the national supply of biomass fuels in the UK, including imported fuels. At the large and medium plant scale there are few physical environment or planning factors that could seriously constrain deployment. However, the potential installed capacity of biomass fuelled energy supplies (as heat and/or electricity) uptake will largely depend on market forces mainly with regard to fuel supply and cost, which are outside the scope of this guidance. In this context, it is not appropriate to quantify the total potential for installed capacity in a region.

3.8 Therefore, the following guidance on biomass sets out steps for making a regional inventory of the biomass feedstock that can be produced and its availability for energy purposes. The feedstock estimates may be converted into the equivalent potential contribution to total installed capacity, by applying benchmarks for calorific value and generation plant fuel demand, but this should not be seen as a target or a limitation to development of this market.

Plant biomass

3.9 Four types of 'clean' plant biomass are considered: managed woodland, dedicated energy crops, industrial woody waste and agricultural arisings (straw). Arboricultural arisings from the pruning of trees are a potential fifth source of plant biomass which is not directly covered in this methodology as the quantity may be difficult to assess (especially from private estates) and also logistically may be difficult to source. The nature of the fuel resource is such that direct combustion is seen as the most viable approach to conversion to useful energy from economic and carbon perspectives, although other approaches are also available, such as pyrolysis and gasification. Therefore, this methodology uses direct combustion as the basis for calculating the potential for installed capacity. Most fuels are suitable for both electricity and heat generation in plants of varying sizes[9].

3.10 The potential installed capacity for plant biomass energy development can be calculated by applying sequentially the parameters for each of the four subcategories in Table 3-3 below.

Table 3-3: Detailed assessment of opportunities and constraints for plant biomass

No	Parameter	Description	Assessment requirement	Where to source data from
Managed woodland				
Opportunity assessment - natural and technically accessible resource				
1a	Existing and potential future feedstock	Amount of biomass available in the Region - oven dry tonnes (odt)	To assess the volume of woodfuel in the region apply one of two options: **Option 1**: Use the Forestry Commission Research tool that provides data on regional woodfuel resource by different types of forestry product at a sustainable level of production. This is a comprehensive tool and its outputs are based upon forest inventory collected between 1995 and 2003 and it forecasts total standing and forecast biomass availability to 2021. (This option uses existing and available data) **Option 2**: Bring forward and increase the accuracy of the National Forest Inventory (NFI) woodfuel forecast by the Forestry Commission which is expected to be released in 2011 (for conifers) and 2012 (for broad leaves). The NFI has been designed such that additional field samples can be made	(1) Forest Research of the Forestry Commission: Woodfuel Resource tool and data www.forestresearch.gov.uk/fr/infd-6w9gju (2) see: www.forestry.gov.uk/inventory (3) National Inventory Woodlands and Trees

[9] Agricultural arisings (straw) is only viable for larger electricity generation due to the volume of fuel required.

No	Parameter	Description	Assessment requirement	Where to source data from
			(through a "top-up" scheme) so that the planned reports can either be brought forward in time or made to produce results at a greater precision, or both. (This option requires requesting substantial new data to be produced by the FC, which is likely to be charged)	
2a	Fuel requirement	Required amount of biomass per MW capacity (odt/MW)	For electricity: apply a benchmark of 6,000 odt/year per 1 MW for electricity to convert the amount of total biomass feedstock to installed capacity. For heat: apply standard calorific values of woodfuel categories: 18 GJ/odt (for low grade timber, and stemwood >14cm diameter and conifer stumps); 12.5 GJ/odt (stemwood l<14cm diameter, branches, tips and foliage). For all categories, apply plant conversion efficiency of 80% and plant availability of 80%	Biomass Energy Centre: Typical calorific values of fuels
Constraints assessment – physically accessible and practically viable resource				
3a	Exclusions of woodfuel potential	Environmental and market constraints that limit woodfuel availability	Apply the following exclusions to the total woodfuel resource: • woodfuel that is uneconomic to harvest • woodfuel that will or could go to alternative markets, such as construction, paper etc.	Forestry Commission Current breakdowns and levels of timber and biomass going into different uses: http://www.forestry.gov.uk/website/forstats2009.nsf/0/824A4E0E2DDEDC858025731B00541EFF?open&RestrictToCategory=1 www.forestry.gov.uk/statistics
Energy crops				
Opportunity assessment - natural and technically accessible resource				
1b	Existing resource	Existing areas of established SRC, miscanthus and SRF	Use uptake data from Woodland Grant Scheme (SRC prior to 2005) and Energy Crops Scheme (SRC and miscanthus since 2001)	National Non-Food Crops Centre. [http://www.nnfcc.co.uk/metadot/index.pl?id=2179;isa=Category;%20op=show
2b	Available land	Amount of land available for growing energy crops (ha)	Estimate the potential against three scenarios as follows: 1. High scenario[10]: Technical potential – assume that all available arable land and pasture will be planted with energy crops and refer to Defra's Energy Crop Opportunity Maps for yield bands and benchmarks. Quantify for each energy crop category defined and where spatial overlaps occur use the energy crop with the highest yield band. Exclude all constrained areas, as defined in 5b below	Rural Payments Agency (PRA/IACS) with Defra agricultural land classification. (1) Defra Regional Energy Crop Opportunity Maps and Guidance: http://www.defra.gov.uk/foodfarm/growing/crops/industrial/energy/opportunities/em.htm (2) request data from RPA (3) request data from Natural England

[10] It has to be acknowledged that in practice this scenario is neither possible nor desirable due to other uses of the land, most notably for food production. Therefore, this scenario is only theoretical

No	Parameter	Description	Assessment requirement	Where to source data from
			2. Medium scenario – 'Business as usual' – assume that energy crops are planted only on land no longer needed for food production, i.e. all abandoned arable land and pasture 3. Low scenario – assume new crops will only be planted to the extent of submitted application to the Energy Crop Scheme (ECS) for 2010.	
3b	Yield	Amount of fuel produced from a hectare as oven dried tonnes (odt/ha)	Apply the following biomass yields: • 10 odt/ha – short rotation coppice (SRC) • 15 odt/ha – miscanthus Increase these yields by 10% for 2020.	no data required
4b	Fuel requirement	Required amount of biomass per MW capacity (odt/MW)	For electricity: apply a benchmark of 6,000 odt/year per 1 MW for electricity to convert the amount of total biomass feedstock to installed capacity. For heat: apply standard calorific values of woodfuel categories: 12.5 GJ/odt (for woodchip); 17 GJ/odt (for wood pellets); 13 GJ/odt (for baled miscanthus). For all fuel categories, apply plant conversion efficiency of 80% and plant availability of 80%	no data required
Constraints assessment - physically accessible and practically viable resource				
5b	Exclusion areas – fuel production	Arable and grass land where energy crops MAY not be allowed	Exclude from the assessment the following areas: • Permanent pasture/grassland • Public rights of way (PRoW) • PRoW buffer – 3m (Miscanthus), 5m (SRC) • Common land • SPS Cross compliance buffers alongside field boundaries • Nature conservation and historic designations	Multi Agency 'MAGIC' database www.magic.gov.uk
6b	Environmental impacts	Areas where adverse environmental impacts are possible due to energy crops	Explore areas subject to potential adverse environmental impact and consult the respective responsible agencies for guidance: • water stressed areas – consult the Environment Agency • biodiversity impacts (e.g. farmland bird species) – consult Natural England • protected landscapes (National Parks and AONBs) - no blanket exclusion should be applied, however a maximum block limit may be applied; consult Natural England	GIS data from EA and NE

No	Parameter	Description	Assessment requirement	Where to source data from
Waste wood				
Opportunity assessment - natural and technically accessible resource				
1c	Existing and potential new feedstock	Amount of biomass waste from sawmills, construction and furniture - tonnes	For sawmill co-product, carry out a regional level assessment on sawmill throughput – consult the Forestry Commission for data and estimates. For construction wood waste (including wood from demolitions) - use national level data and disaggregate on the basis of new housing allocations. Regions should supplement this data with their own estimates of regional build rates. For future additional feedstock - apply an increase to the existing feedstock of 1% (0.1) per year	Forestry Commission WRAP
2c	Fuel requirement	As per managed woodland	As per managed woodland	no data required
Constraints assessment - physically accessible and practically viable resource				
3c	Available feedstock	Amount of biomass available for energy (as competing with other uses)	Assume 50% of the resource is available for energy due to competing uses. For a more detailed assessment, refer to WRAP and Defra	No data required
Agricultural arisings (straw)				
Opportunity assessment - natural and technically accessible resource				
1d	Existing feedstock	Amount of straw currently available in the Region - tonnes	Use data of existing feedstock of all wheat and oil seed rape (OSR) straw only.	Defra Agricultural and horticultural survey – England
2d	Fuel requirement	Required amount of straw per MW capacity	For electricity - apply a benchmark of 6,000 t of baled straw per 1 MW capacity (heat generation is not seen as a viable use of straw)	no data required
Constraints assessment - physically accessible and practically viable resource				
3d	Available feedstock	Amount of biomass available for energy (as competing with other uses)	Apply 3-step approach to estimating the regionally available feedstock: 1. main competing demand – animal bedding: apply a benchmark of 1.5 tonnes of straw per annum per head of cattle in the region 2. from the total amount of straw produced in the region (parameter 1d above), subtract the either the total animal bedding requirement or 50% of the total amount of straw, whichever is the less (i.e.	Defra Agricultural and horticultural survey – England

No	Parameter	Description	Assessment requirement	Where to source data from
			resulting in the greater figure for available feedstock) 3. compare the result with regional agricultural practices and make region-specific adjustments (up or down) – to be properly justifies with evidence	

Source: SQW Energy and Land Use Consultants

Animal biomass (EfW)

3.11 Two sub-categories of animal biomass are considered: wet organic waste (manure, slurry) and dry organic waste (poultry litter). The former is typically converted to energy through anaerobic digestion (AD) that produces bio-gas (although other approaches are possible) – this is used as the benchmark for the regional assessment. The latter is most commonly converted to energy by direct combustion (although AD is also possible if mixed with other wetter wastes) - this is used as the benchmark for the regional assessment. Both types of fuel can be used for either power or heat generation, although the heat application would be used with a CHP plant. Therefore, estimating the potential electric capacity is what this methodology uses for the regional assessment.

3.12 The potential installed capacity for animal biomass energy development can be calculated by sequentially applying the parameters for each of the two sub-categories in Table 3-4 below.

Table 3-4: Detailed assessment of opportunities and constraints for animal biomass

No	Parameter	Description	Assessment requirement	Where to source data from
Animal biomass - wet organic waste				
Opportunity assessment - natural and technically accessible resource				
1a	Existing feedstock	Amount of manure and slurry (including bedding) and food waste from the food and drinks industry available in the Region (tonnes)	Manure and slurry: use data on the number of livestock multiplied by a manure facture (i.e. amount of manure per head per year); use bedding data (per head) from ADAS and Defra figures. Food and drink waste: use data from Defra and the Food and Drink Federation	ADAS Manure Management Database (MMDB); Defra Agricultural and horticultural survey – England Food and Drink Federation
2a	Biogas yield	Amount of biogas generated from the feedstock (m3/tonne)	Use the following assumptions on yield: • Cattle: 25 m^3/t • Pigs: 26 m^3/t • Food & drinks: 46 m^3/t	UK National Non-Food Crops centre (NNFCC): http://www.biogas-info.co.uk
3a	Feedstock requiremen t	Required amount of biogas per MW capacity	Apply a benchmark of 37,000 tonnes of wet organic waste required per 1 MW capacity per year.	no data required
Constraints assessment - physically accessible and practically viable resource				
4a	Limits to extraction	Amount of wet organic waste that	Assume 80% of the resource can be collected	no data required

No	Parameter	Description	Assessment requirement	Where to source data from
		can be collected adhering to health and safety regulations		
5a	Competing uses	Available wet organic waste considering competing demands (fertiliser; compost)	Manure and slurry: assume 100% of total resource is available for energy Food and drink waste: assume 50% of total resource is available in practice due to competing uses.	no data required
Animal biomass - poultry litter				
Opportunity assessment - natural and technically accessible resource				
1b	Existing and potential new feedstock	Amount of poultry litter generated in the Region (tonnes)	Use Data on poultry numbers (broiler birds only) and excreta factor for head of poultry (from Defra) to calculate the total resource produced per year.	Defra Agricultural and horticultural survey – England
2b	Feedstock requirement	Required amount of poultry litter per MW capacity	Apply a benchmark of 11,000 tonnes of poultry litter required for 1 MW capacity per annum.	no data required
Constraints assessment - physically accessible and practically viable resource				
3b	Available feedstock	Available poultry litter considering competing demands	Assume 100% of the resource is available for energy	no data required

Source: SQW Energy and Land Use Consultants

Municipal Solid Waste (MSW) and Commerical & Industrial Waste (C&IW)

3.13 These waste categories consist of household waste, commercial and industrial waste and include construction and demolition debris, sanitation residue and waste from streets. This methodology is limited to the organic fraction of MSW which can be used to derive power through direct combustion, anaerobic digestion, and pyrolysis and gasification. While direct combustion requires a high oxygen environment in order to be feasible, the other methods use far less oxygen. Pyrolysis and gasification are related processes of breaking down organic material under high heat to form a gas with significant energy content.

3.14 While direct combustion is currently the primary method of waste to energy conversion in the UK, and the reference case for this methodology, the other techniques are being increasingly promoted, e.g. through the introduction of a banded Renewables Obligation.

3.15 The potential installed capacity for MSW energy development can be calculated by sequentially applying the parameters in Table 3-5 below. The potential for C&IW energy development is harder to assess as there is no central data holding; This would need to be explored through regional intelligence on C&IW producers.

Table 3-5: Detailed assessment of opportunities and constraints for Municipal Solid Waste

No	Parameter	Description	Assessment requirement	Where to source data from
Opportunity assessment - natural and technically accessible resource				
1c	Existing and potential new feedstock	Amount of MSW generated in the Region (tonnes)	Collate information from all local waste management plans	Defra's quarterly MSW statistics http://www.defra.gov.uk/evidence/statistics/environment/wastats/bulletin10qtr.htm
2c	Feedstock requirement	Required amount of MSW per MW capacity	Apply a benchmark of 10 kilo tonnes of MSW required for 1 MW capacity per annum.	no data required
Constraints assessment - physically accessible and practically viable resource				
	n/a		No significant constraint parameters identified	no data required

Source: SQW Energy and Land Use Consultants

Biogas (EfW)

3.16 Two sub-categories of bio-gas are considered: landfill gas and sewage gas. The former arises from existing landfill sites and new waste sent to landfill. Landfill sites typically release biogas for up to 30 years and is therefore a finite resource with most current sites likely to be at or near the end of their life by 2020. Similarly, new waste volumes are expected to decrease considerably as a result of waste legislation and targets, thus the overall landfill gas resource is not expected to make a large contribution to renewable energy beyond 2020.

3.17 In both cases, the resulting gas can be used for either power or heat, however as the generation plant needs to be on/near-site to the landfill/sewage treatment work, heat will only be viable through a CHP plant, if CHP is appropriate in the first place. Therefore, estimating the potential electric capacity is what this methodology uses for the regional assessment.

3.18 The potential installed capacity for bio-gas energy development can be calculated by sequentially applying the parameters for each of the two sub-categories in Table 3-6 below.

Table 3-6: Detailed assessment of opportunities and constraints for bio-gas

No	Parameter	Description	Assessment requirement	Where to source data from
Landfill gas				
Opportunity assessment - natural and technically accessible resource				
1a	Available resource	Amount generated in the Region (m^3)	Refer to the inventory of landfill sites and their size and capacity to calculate total available biogas resource.	Environment Agency's Waste Management Licence Data OFGEM RO Register
2a	Lifetime of resource	Number of years the resource will be available for energy purposes	Refer to the inventory of landfill sites and their age	As above
Constraints assessment - physically accessible and practically viable resource				
	n/a		No significant constraint parameters identified	no data required
Sewage gas				
Opportunity assessment - natural and technically accessible resource				

No	Parameter	Description	Assessment requirement	Where to source data from
1b	Available resource	Amount generated in the Region	Refer to the inventory of sewage treatment sites and their size and capacity to calculate total available resource.	Water utilities
2b	Potential new resource	Future additional capacity	Refer to water utility business plans and forecasts	Water utilities
Constraints assessment - physically accessible and practically viable resource				
	n/a		No significant constraint parameters identified	no data required

Source: SQW Energy and Land Use Consultants

Co-firing of biomass (with another fossil fuel)

3.19 Co-firing involves the combustion of two different types of materials at the same time. In the UK, biomass (usually of a woody nature) is used with fossil fuel in a single boiler to produce electricity. Typically, a coal mill can handle up to 10-15% biomass. Due to the large volumes required on a continuous basis, a significant part of the biomass comes from imports. Biomass co-firing does not increase the overall capacity of the plant (i.e. it does not add new energy generation capacity) but effectively displaces some fossil-fuel capacity, typically coal or oil.

3.20 This methodology explores the opportunities for lowering the carbon emissions of existing and potential new fossil-fuel plants in the region through co-firing with plant biomass. The approach presented can be used to estimate the maximum technical potential for co-firing, although in practice the availability and market price of biomass fuel, including imports will determine the extent of co-firing taking place.

3.21 The potential capacity for co-firing of biomass with another fossil fuel (coal or oil), can be calculated by sequentially applying the parameters in Table 3-7 below.

Table 3-7: Detailed assessment of opportunities and constraints for biomass co-firing

No	Parameter	Description	Assessment requirement	Where to source data from
Opportunity assessment - natural and technically accessible resource				
1	Available plant	Total capacity of coal and oil fired plant in the Region (MW)	Estimate total coal and oil-fired plant capacity (MW) in 2015 (taking into account plants that are scheduled for closure as a result of the Large Combustion Plant Directive)	DUKES inventory of coal and oil-fired plants
2	Co-firing threshold of plant	Percentage of biomass fuel that can be used in coal-fired plants	Apply a benchmark of 10% of combusted fuel to be from biomass	no data required
Constraints assessment - physically accessible and practically viable resource				
3	Policy framework	Timeframe of direct policy support for biomass co-firing	Assume that co-firing of biomass will be an attractive option until at least 2027 (financial incentives through the Renewables Obligation will continue until 2027).	no data required

Source: SQW Energy and Land Use Consultants

Hydro

Definition and scope

Hydro power involves harnessing the power of flowing or falling water through a turbine in order to produce electricity. The parameters determining the amount of electricity produced include the turbine generating capacity, the turbine discharge flow (the volume of water passing through the turbine at any given time, which will change depending on the time of year) and available head (the vertical distance between the point where the water is highest and the turbine). The larger the head, the more gravitational energy can be converted to electrical energy. Hydropower can also be combined with storage (pumped storage), by pumping water from a low elevation to a high elevation at times of plentiful supply of electricity for release when needed.

For the purposes of assessing the hydropower resource, small-scale hydro power (under 20MW) is considered because opportunities for large-scale hydro (e.g. large dams) are becoming more and more limited. This is because most of the major sites for hydro have already been used along with environmental concerns over the adverse impact of large-scale hydro on local ecosystems and habitats and changes to the natural river flow and intensity. In contrast, small-scale hydro installations can be sited at small rivers and streams with little adverse impact on the river's ecology, for example, on fish migration patterns.

Assessment approach and methodology

3.22 Regions may use the Environment Agency's report 'Mapping Hydropower Opportunities in England and Wales' (2009) to identify the total resource available and the proportion that is accessible and viable for development in their areas.

Microgeneration

Definition and scope

Microgeneration typically refers to renewable energy systems that can be integrated into buildings to primarily serve the on-site energy demand. They are applicable to both domestic and non-domestic buildings and can be connected to the grid although this is not required as most of the output is used on-site. Thus microgeneration systems are typically designed and sized either in relation to the on-site demand or in proportion to the physical constraints on-site such as available space, which ever is more appropriate.

Microgeneration technologies cover the full range of renewable energy categories: wind, solar, biomass, hydropower and heat pumps. In terms of assessing the regional opportunities and constraints for deployment, some of these categories are already captured in full in the earlier sections of this chapter. Their full potential is not directly constrained by the built environment and more specifically by what can be installed on-site as other deployment options are available, e.g. off-site or large scale capacity development. These categories include, biomass (all sub-categories) and hydropower.

Technologies that directly depend on the built environment capacity to take microgeneration systems are solar – solar water heating (thermal) and solar photovoltaics (electric) – and heat pumps – grounds source heat pumps and air source heat pumps. Assessing the potential of these four sub-categories is detailed in this section.

Assessment approach and methodology

Solar energy

- Solar water heating (SWH) depends on three site-specific factors: (1) available roof space (to install the system), (2) orientation and exposure of the roof (to be able to capture enough solar radiation), and (3) hot water demand on-site (SWH is typically sized to supply 50% of the hot water demand[11], although some systems offers space heating service as well). SWH systems are suitable for most domestic buildings, where the biggest potential is, and for some energy intensive non-domestic buildings. The assessment therefore focuses on the residential building stock.
- Solar PV depends only on two of the above site-specific factors: (1) available roof space (to install the system) and (2) orientation and exposure of the roof (to be able to capture enough solar radiation). Solar PV systems are equally suitable for domestic and non-domestic buildings although the actual update is currently and potentially in the future mainly across the housing stock. Domestic buildings tend to have pitched roofs and therefore orientation is a strong factor, unlike commercial and industrial

[11] Various sources including Solar Trade Association (2009) and Housing Corporation (2005) *Solar Water Heating Factsheet*

buildings, which often have flat roofs. The capacity assessment explores the entire regional building stock.

3.23 Deployment of either solar technology in practice is subject to available suitable space for installation. A building may have either or both technologies installed, however the total capacity of the system(s) will not vary considerably, i.e. a large system of either technology or two systems, one of each technology. Therefore, the assessment uses a single set of parameters for both categories to avoid double counting.

3.24 The potential capacity for solar energy can be calculated by sequentially applying the parameters in Table 3-8 below.

Table 3-8: Detailed assessment of opportunities and constraints for solar energy

No	Parameter	Description	Assessment requirement	Where to source data from
Opportunity assessment - natural and technically accessible resource				
1	Existing roof space	Number of roofs suitable for solar systems	Apply the following assumptions for number of suitable roofs: • Domestic properties - 25% of all properties (including flats) • Commercial properties - 40% of all hereditaments • Industrial buildings - 80% of the stock	CLG Statistics English Housing Survey (EHS) ONS data
2	New developments	Number of new roofs suitable for solar systems	Assume that 50% of all new domestic roofs will be suitable for solar systems	RSS new housing provisions
3	System capacity	Average generation capacity of an individual system kW	Apply the following assumptions for average system capacity: • Domestic - 2kW (thermal or electric) • Commercial - 5kW (electric only) • Industrial - each region use their own assumption	no data required
Constraints assessment - physically accessible and practically viable resource				
	n/a		No specific parameters have been defined as most constraints have already been taken into account in the assumptions applied for the parameters above.	no data required

Source: SQW Energy and Land Use Consultants

Heat pumps

- Ground source heat pumps (GSHP) extract the heat stored in the ground to provide space and water heating. They use electricity in the process. There are two broad sub-categories: (1) open loop systems typically pump warmer water up from an aquifer returning it at a lower temperature; these systems tend to be larger and more suitable for commercial buildings; and (2) closed loop systems, where liquid circulates through a closed tube put in the ground, which absorbs the ground heat. The ground component of closed loop systems can be installed horizontally in trenches or vertically in boreholes and while the former option requires a considerable amount of land per installation, the latter is relatively compact and can be installed in a small area of land adjacent to the building. Generally, GSHP is more suitable for suburban and rural areas where drilling down is more accessible. They are particularly suitable and economically viable in areas with no mains gas supply

- Air source heat pumps (ASHP) extract the ambient heat in the air to provide space and water heating. They use electricity in the process. As the outside air temperature varies considerable during the year, their energy and carbon efficiency varies as well and is lower overall compared with GHSP. Their advantage however is in their low space requirement and can be installed in most locations, including urban, where they are the alternative to GHSP.

3.25 The regional assessment of the potential for heat pumps is therefore based on the premise that most buildings (existing stock and new build) are suitable for the deployment of at least one of the heat pump options.

3.26 The potential capacity for the heat pumps, can be calculated by sequentially applying the parameters in Table 3-9 below.

Table 3-9: Detailed assessment of opportunities and constraints for heat pumps

No	Parameter	Description	Assessment requirement	Where to source data from
Opportunity assessment - natural and technically accessible resource				
1	Existing building stock	Number of buildings suitable for heat pumps	Domestic - 100% of all of-grid properties; for the remaining stock - 75% of detached and semi-detached properties, 50% of terraced properties and 25% of flats Commercial -	CLG Statistics English Housing Survey (EHS) ONS data
2	New developments	Number of new buildings suitable for heat pumps	50% of all new build domestic properties	RSS new housing provisions
3	System capacity	Average generation capacity of an individual system kW	Domestic - 5kW Commercial - 100kW	no data required
Constraints assessment - physically accessible and practically viable resource				
	n/a		No significant specific parameters have been defined as most constraints have already been taken into account in the assumptions applied for the parameters above.	no data required

Source: SQW Energy and Land Use Consultants

Designated areas assessment

3.27 In order to assess the potential for renewable energy deployment within international and national landscape and nature conservation designations the following 5-step approach can be applied:

Step 1: Identify the purposes of the landscape/ nature conservation area (reasons for designation)

Step 2: Identify which technologies might affect these purposes/ integrity of the designation

Step 3: Identify how each technology might affect the purposes/ integrity

Step 4: Identify the type and level of renewable and low carbon infrastructure that could be accommodated without compromising the purposes/ integrity of the designations

Step 5: Provide guidance on how to integrate renewable/ low carbon energy without compromising the purposes/integrity

3.28 In undertaking the five step approach, it is recommended that Natural England should be closely consulted on the scope and findings of the assessment.

4: Assessment of the opportunities and constraints for low-carbon energy deployment

Overview

4.1 Low – carbon energy is defined for the purposes of this methodology as combined heat and power (CHP) or tri-generation (to include cooling), and district heating schemes. Whilst not directly fulfilling commitments under the UK Renewable Energy Strategy, low carbon sources of energy supply will be an important part of the mix of technologies regions employ to reduce carbon emissions. In the long term, out to 2050, it will be increasingly necessary to decarbonise our energy supply; in the mean time, low carbon technologies represent potentially cost-effective alternative options.

4.2 For these reasons, and in support of their assessments of renewable capacity, regions may also seek to assess the capacity of their regions for generating low carbon energy.

4.3 However in relation to low carbon energy technologies, the assessment of deployment opportunities relies on typically economic benchmarks as opposed to technical ones. This means that a low-carbon scheme is deemed viable if it meets certain minimum economic criteria, such as the heat demand density thresholds. This approach uses a range of economic assumptions as to the cost of infrastructure, energy prices, building energy performance and consumer behaviour. The literature review and stakeholder consultation revealed that there is not an agreed set of benchmarks and assumptions and therefore this document does provide specific recommendations on those.

4.4 Unlike most renewable energy categories which are assessed on the basis of the supply side (i.e. resource availability), low-carbon opportunities referred to in this methodology are a function of available heat demand.

4.5 However, the low carbon capacity of a region cannot be calculated solely by assessing the heat demand of its properties, since the viability of CHP or district heating is dependent not only on the availability of heat, but the density of that heat demand. This is because the cost of pipe required to transport heat is very high, which also means that the plant used for generating the low carbon energy is likely to need to be close to its demand.

4.6 Undertaking development of CHP or district heating is both complicated and expensive, and it is important that regions and local authorities have a clear and appropriate evidence base to support their decisions. This evidence base is not only helpful for identifying appropriate opportunities to deploy low carbon energy, but also to support long term strategic land use planning. This is an important way in which communities and localities can create conditions capable of supporting low carbon technologies that may not otherwise have existed, such as co-locating supply with demand.

4.7 The Government is aware of commendable work across regions in the UK, to develop appropriate evidence bases such as heat maps, however, it is also aware of problems with consistency and with assumptions used. For this reason, the Government intend to take forward work in 2010 to develop a National Heat Map, which can be used by regions to inform the assessment of capacity for low carbon energy.

4.8 Opportunities for low-carbon energy can be influenced by local factors, for example space for installations. These local considerations will be relevant to exploring the potential for low-carbon energy in the region, but developing an evidence base commensurate with the strategic role of the Regional Strategy does not require a detailed examination of these factors. In any regional assessment of low-carbon energy opportunities, the following are likely to require consideration:

- Heat demand mapping – current and potential future demand, using the lowest special resolution level viable from a data availability and technically analysis perspective
- Assumptions on the proportion of the heat demand met through low-carbon capacity
- Assumptions on the operational regime of the low-carbon plant, e.g. running hours
- Strategic constraints on deployment, e.g. relating to supply and storage of fuels. .

4.9 The following sections provide an overview of the low-carbon categories as defined in the scope.

Combined Heat and Power (CHP) and Tri-generation

Definition and scope

4.10 Combined Heat and Power (CHP) is the simultaneous generation of usable heat and power (usually electricity) in a single process. The heat generated during this process is supplied to an appropriately matched heat demand that would otherwise be met by a conventional boiler. CHP systems are highly efficient, making use of the heat which would otherwise be wasted when generating electrical or mechanical power. This allows heat requirements to be met that would otherwise require additional fuel to be burnt.

4.11 A CHP plant can be run on fossil or renewable fuels. This methodology explores the potential capacity for CHP independent of what fuel is used. This approach complements the separate renewable capacity potential assessment in the previous chapters as the appropriate renewable fuels, e.g. biomass, can be fully utilised outside a CHP application. Therefore, the implied base parameters for CHP in terms of opportunities and constraints in this methodology are those for fossil fuel-fired, most commonly natural gas, CHP plant.

4.12 CHP technology is available at a large variety of scales from large centralised plants of hundreds of megawatts capacity to micro-scale domestic units. This methodology covers all scales except the domestic micro-scale (unit serving individual dwellings).

District heating

Definition and scope

4.13 District Heating (DH) (also known as Community Heating) is a system for distributing heat from a centralised location for residential and commercial heating requirements such as space and water heating. Multiple users are connected through a piped network to the main plant which can be conventional boilers, CHP, industrial waste heat or renewable energy sources such as biomass, geothermal, solar, heat-only boiler stations or other sources of heating and cooling. The physical elements of a community heating scheme are a central heat source, a heat distribution network and installations in each dwelling.

4.14 In order to make inferences about the viability of district heating, the concept of 'heat density' is used. This is defined as the annual heat demand divided by the number of hours in a year (8760), which is then divided by area in km^2. Higher density urban areas would have a higher heat demand per km^2 and hence would be expected to have lower District Heating costs and greater potential for a cost-effective scheme. Generally if heat density exceeds 3,000 kW/km^2, the heat density is considered to be high, which means that economically speaking DH will likely suit a high proportion of flats rather than houses.

Annex A: Detailed review and justification of the assessment parameters used and the values applied

A.1 The following tables explain in more detail the parameters defined in Chapter 3 and set out the justification for their inclusion in the methodology. An indication is also provided of the extent to which the parameters have been used in the assessments undertaken to date by the regions.

A.2 For each renewable energy category covered by this report, a list of additional relevant parameters is provided that have been considered when developing the methodology, but that have subsequently been excluded from the assessment. This is because they fall outside the purpose and scope of the methodology.

A.3 The explanatory notes have been prepared on the basis of discussions with key stakeholders, renewable energy experts and from a review of relevant literature.

Wind: on-shore (commercial scale)

Table A-1 Detailed explanation of onshore wind (commercial scale) parameters.

Parameter	Explanatory notes
1 Wind speed	Wind speed is a key parameter used in all of the existing regional assessments. The benchmark used for the minimum commercially viable average wind speed varies between 5m/s and 7m/s at 45m agl. In practice, most developers currently consider sites with wind speeds of over 6m/s at 45m agl and the windiest sites are being developed. The threshold wind speed largely depends on the electricity price and financial incentives available. As very windy sites become used up, progressively lower wind speeds are likely to be considered. Technically, areas with wind speeds at and above 5m/s at 45m agl are viable for large scale turbines. This is the accepted approach used by the wind industry in the UK. Adopting a 5m/s at 45m alg lower limit ensures that future opportunities (by 2020) are not ruled out on the basis of current economic conditions. For the target-setting process (which does not form part of this methodology), the regions may want to take account of prevailing economic conditions and so may wish to discretionally apply a higher lower limit. *This is a dynamic parameter (it is likely to change over time as technology evolves) which will be kept under review.*
2 Wind turbine size	Wind turbine sizes is a key parameter used in most of the existing regional assessments, as it feeds into the equation for calculating the maximum installed capacity potential. A range of sizes have been used, typically 600kW, 1.5MW and 3MW. The industry standard for planning applications which are currently been prepared or submitted is turbines of at least 2.5 MW installed capacity.
3 Wind turbine density	The existing regional assessments have assumed different on-shore wind farm densities. Most commonly, 9MW/km^2 has been used as a benchmark and it is proposed that this is used in the methodology: As technology develops, the efficiency of turbines will increase and therefore the amount of output energy generation per km will increase; however, this will not directly affect the nominal installed capacity per km^2. *This is a dynamic parameter which will be kept under review.*

Parameter	Explanatory notes
4 Non-accessible areas	Most of the existing regional studies and other literature recognise that the proposed list of non-accessible areas listed in Table 3-1 of the methodology are physically not suitable for the development of large wind turbines.
5 Exclusion areas	**Sites of historic interest** (including Scheduled Ancient Monuments, Listed Buildings, Conservation Areas, Registered Historic Battlefields and Registered Parks and Gardens, World Heritage Sites[12]). Most existing regional studies regard these sites as a constraint to development and some regions also apply buffers around them to take account of potential impacts on setting. Two options were considered in relation to sites of historic interest : 1. Assume all sites recognised for their historic importance are a constraint to wind energy development. 2. Require the regions to undertake assessments of what renewable energy development might be achievable within these areas without affecting the objectives of the designations or the outstanding universal value of World Heritage sites. Due to the extremely large number of sites that would need to be assessed, it was concluded that it would be unrealistic to undertake an assessment of the renewable energy potential for all sites recognised for their historic importance. It was also considered unnecessary to include buffers around historic sites to take account of issues relating to setting, as the relevance /importance of setting varies on a site by site basis. It is acknowledged there may be a perceived inconsistency with the methodology proposing that assessments should be undertaken of the potential for onshore wind within landscape and nature conservation designations but not within historic sites. It was concluded that the due to the large number of historic sites that would need to be considered and the low likely potential of these sites to accommodate wind energy developments, the resource required to undertake such assessments could not be justified. **Roads and rail lines**. Most regional studies apply buffer zones around A and B roads and motorways as a constraint to development on safety grounds, i.e. if a turbine collapses. The potential topple distance of turbines is used as a benchmark and ranges between 100m and 200m. Industry recommends a buffer zone equivalent to the topple distance + 10%. Using a 2.5MW turbine as a benchmark, tip heights range from 100m to 165m[13] and average at 135m, which including an extra 10% equates to 150m. *This is a dynamic constraint and may change as technology develops*. **Built-up areas**. Most existing regional studies apply a buffer zone around these to act as a proxy for safety (topple distance) and noise impacts, mainly to residential properties. The extent of the buffer varies from 400 to 600m. In practice, the minimum distance required between a wind farm and residential properties is site-specific, dependant on the proposed turbine and ambient background noise. There is no definitive guidance on this issue and therefore a rule of thumb has been used based on expert opinion (from wind farm noise specialists) which suggests that the minimum buffer distance that is required for a 2.5MW turbine (to take account of safety and noise constraints) is 600m. **Airports and airfields**. Previous regional studies have applied a buffer around airports and airfields due to the risks of interference with radar. Airport exclusion zones, according to the literature, range from 1km for heliports to 6km around major civilian and military airports, and as much as 76km in one study for certain airports. Other suggestions have been to the order of 15 or 30km, though the most common assumption seems to be the 6km exclusion zone. In reality, the actual radius required would depend on the height of the turbines along with the elevation of the radar installation, although this should only be calculated as part of the process of siting actual wind farms.
6 Designated landscapes and nature conservation areas	**Nationally important landscapes** (National Parks, AONBs[14] and Heritage Coasts). Most existing regional assessments have considered these as a constraint to large scale onshore wind energy developments and have excluded them from the assessments. However current planning policy does not strictly prohibit renewable energy projects within nationally important landscapes areas. It was recommended that with the need for the UK's renewable energy targets to be met, all designated landscape and nature conservation areas should to be assessed for their

[12] Please note that World Heritage Sites are not a statutory designation but rather are identified by 'inscription' on the UNESCO listing maintained by the international World Heritage Programme,
[13] This is based on the turbine heights (to blade tip) of the GE 2.5 MW, Nordex N80 (2.5MW), Liberty 2.5MW and Nordex N90 (2.5MW) turbines at the time of publication. .
[14] Areas of Outstanding Natural Beauty

Parameter	Explanatory notes
	potential for renewable energy and that excluding them from the assessment would be overly restrictive. Regarding buffer zones, in line with current national policy, the methodology does not propose the use of buffer zones around designated landscapes. **International and national nature conservation designations** (SPAs, SACs, RAMSARs, SSSIs, NNRs[15]). Most existing regional resource assessments acknowledge that these areas are a constraint to development and that wind farms will not normally be built in these areas. However, the extent of this restriction will vary on a site by site basis. Development within European designations may be subject to an Appropriate Assessment to ascertain if the integrity of the site will be adversely affected. Two options were considered in relation to nature conservation designations in the regional methodology as follows: 1. Assume all international and nationally designated nature conservation areas are a constraint to wind energy development. 2. Require the regions to undertake assessments of what renewable energy development might be achievable within these areas without adversely affecting the integrity of the designations. In line with the approach proposed for nationally recognised landscapes – the methodology proposes that the regions should undertake a high level assessment of the potential within these areas. In terms of applying buffer zones around the designations existing planning policy states that it is not appropriate to apply buffers for the purpose of the regional resource assessment.
7 MOD Constraints	**MOD sites** (other operational and empty land) – the MOD is willing to consider development of renewable energy within its estate. However this has to be considered carefully and often on site specific basis. Therefore, direct consultation with the MOD is required to establish the scope for such developments within each of the regions and the type and scale of schemes. **MOD defence radar** – defence radars require clear line of site to operate effectively. Their location and positioning however is classified information. It is difficult to judge the impact of defence radars on the regional resource assessment and therefore the MOD should be consulted directly to indicate what amount (ha, km2 or %) of the accessible resource (based on the assessment of the other parameters) should be further excluded from the assessment due to defence radar constraints.

Source: SQW Energy and Land Use Consultants on the basis of literature review and expert/stakeholder consultations

Table A-2 Parameters considered but not included in the assessment methodology

Parameter	Explanatory notes
Exclusion areas	**Inland waters**. Some regional studies apply a buffer around these areas and their extent varies from 100m (SE) to 150m (Y&H). The rationale is to account for potential construction impacts such as erosion, sedimentation and pollution caused by the construction of wind turbines and their associated infrastructure. Applying buffers is not considered necessary for a broad regional level assessment (as it is a site based issue) and therefore this is not included as a constraint in the methodology. **Local landscape designations**. (as identified in Local Development Plans - e.g. special landscape areas, areas of local landscape importance). Only one region included local landscape designations as a constraint to onshore wind energy development. Local landscape designations are not included as a constraint in this methodology in line with national planning policy. **Local nature conservation designations** (Local nature reserves). Most regions have not considered local nature conservation designations as a constraint to onshore wind energy development. Local nature conservation designations are not included as a constraint in this methodology in line with national planning policy.

[15] Special Protection Area (SPA), Special Areas of Conservation (SAC), RAMSAR convention site, Site of Special Scientific Interest (SSSI), National Nature Reserve (NNR)

Parameter	Explanatory notes
	Green belt (as identified in Local Development Plans). Most regions did not consider green belt to be a specific constraint when calculating deliverable resource at the regional scale. However, the South East, EM and WM did assume that green belts were a constraint to the development of large scale wind farms. There is an established precedent for wind farms being approved within green belt designations as they were not deemed to affect the 'openness' of the designation. The guidance in this broad regional methodology therefore states that green belts should not be considered as a constraint to wind energy developments. **Floodplains**. None of the regional studies include floodplains as a constraint to wind farm development and, as it is a site specific issue, it is not included as a constraint to wind energy development in this methodology.
Landscape character/ sensitivity assessment	This is the relative ability of different landscapes areas to accommodate wind energy development without adverse impacts on landscape character. Three regions have used landscape character assessments to inform their regional onshore wind energy resource assessments – SW, Y&H, NE. A landscape assessment can provide a useful tool for indicating the relative ability of different areas to wind turbine development. However it cannot indicate how much development can be accommodated in the landscape. In addition, it should not be interpreted as a definitive statement on the suitability, or otherwise of a particular landscape for wind energy. The results of a landscape assessment could feed into any of the stages of the regional renewable energy policy process i.e. in assessing the resource potential (the focus of this methodology), setting targets, developing criteria based policies and/or identifying broad locations. The impact of feeding in a landscape assessment early in the process is that it may lead to the practicable resource being heavily constrained to the extent that national renewable energy targets could not be met. The methodology does not propose that the regions undertake an assessment of landscape character to inform their analysis of regional onshore wind energy potential. They should however consider the value of undertaking a landscape assessment to feed into the setting of targets, criteria based policy and/or the identification of broad locations (these stages fall outside the scope of this methodology).
Cumulative impact	This parameter refers to the separation distance between wind farms (km) in order to avoid adverse cumulative impact in terms of visual and technical (e.g. radar interference) impact. The approach taken by the regions has varied considerably and where the cumulative impact has been considered as a constraint, the separation distance has ranged between 5km and 15km. The longer term view expressed is that the distance will not exceed 10kmby 2020. There is no national advice on suitable distances between wind farms. Two options were considered in the preparation of this methodology: Not to identify any constraints relating to cumulative impacts at the regional level, although it will lead to very high levels of practicable resource. Require the regions to undertake a landscape sensitivity analysis to inform appropriate distances between wind farms for the purposes of target setting. With either option, the consideration of cumulative impacts is not required for the purpose of the regional methodology.
Biodiversity assessment	None of the existing regional studies considered biodiversity as a constraint to development. In theory Biodiversity Action Plan (BAP) Priority Habitats could be excluded from the assessment although this would severely restrict the land available for development. It is also considered that biodiversity is best addressed at the site level as mitigation measures may enable development to proceed within these areas.
Wind farm size	This refers to the Generation capacity (MW) of a wind farm. Most regional studies have explored this parameter and have assumed a range of typical capacities between 5MW and >30MW. Maximum sizes have also been set in some cases. Applying a typical or maximum wind farm size affects the total accessible resource by way of determining how many separations will occur in the region, based on the cumulative impact parameter (above). As with cumulative impact, the regions may conduct further investigation into this area, but this should not be applied as a constraint at the regional levels resource assessment.
Proximity to grid	This refers to the distance to the nearest viable connection point. It is an important economic appraisal parameter that is explored at site level, but is not relevant at the regional level assessment. As economic conditions change and technology (both wind and power distribution) develops, grid connection costs can be mitigated to varying degrees even within

Parameter	Explanatory notes
	relatively remote locations.
Grid capacity	This refers to the availability of the distribution network to take the additional power output. It is an important parameter for assessing deployment potential and rate. However, it is an issue for national level decision-makers and should not be used to arbitrarily reduce the regional practical resource. In addition, as renewable deployment is a national priority, it can be assumed that the grid requirement will be met to enable sufficient capacity to be accommodated.

Source: SQW Energy and Land Use Consultants on the basis of literature review and expert/stakeholder consultations

Biomass

Plant biomass

Table A-3 Detailed explanation of the proposed methodology approach

Parameter	Explanatory notes
Managed woodland	
1a Existing and potential future feedstock	**In General** The available feedstock is dependent on several factors, each needing to be assessed reliably to produce a credible forecast. These factors include the size of woodland, its composition re tree species, the realisable annual yield of those species, and the different yields that are produced by those species on different soils, at different altitudes, under different climates etc. Studies have used different assumptions for yield and it is not always clear as to whether or not published yields refers to the total wood product available or the woodfuel resource only. Most regional studies have directly assumed the volume of woodfuel resource without specifying area of woodland. Among the most sophisticated approaches is that in SE using remote sensing of existing woodland area. Data on the woodland area in 2000 is available from the Forestry Commission's National Inventory of Woodland and Trees (NIWT), providing fine-grained GIS data (to minimum size of 2ha) and including breakdown by species and age class. This could be matched with estimates of harvestable woodfuel to give potential resource. The NIWT data source is being updated and, when complete in 2010, will be available as the National Forest Inventory. This will have an annual update cycle. At the national level, the Forestry Commission's (FC) Softwood Forecast (2005) forecasts stemwood extraction. The hardwood resource is much smaller (E4tech). Additional resource from under-used woodland being brought in to management is significant (E4tech). McKay and Hudson (2003) estimated availability of forestry residues at the Great Britain level (FC study). Regional studies in Y&H, EoE, SE and SW have estimated utilisable forestry resource. All except SE make estimate of dry weight harvestable resource but without stating yield assumptions. Study in SE uses average yield classes (broadleaves YC 3-4 and conifers YC15) and assumes that wood fuel resource is 30% of maximum sustainable yield. Further, in 2010 there will be a Forestry Commission Wood Fuel Implementation plan that will supercede the current Woodfuel Strategy. **Option 1** At present, a web-based tool developed by Forest Research (a part of FC) directly provides regional estimates of the annual production of the standing and forecast woodfuel resource from different types of forestry products (e.g. stemwood, poor quality timber, tips and branches). This is a comprehensive tool and is based on forest inventory collected between 1995 and 2003 and forecasts total standing and forecast biomass availability to 2021. Industry look for a 25-30 year time frame and therefore this study may be of limited use as a result. The figures are estimates of the annual sustainable production that can be made available taking account of technical and environmental constraints. Economic or market constraints are not taken into account. Figures do not include production from woodlands <2ha in area. The study refers to the total wood product available. However, a significant amount of the stemwood resource is already committed to timber production (especially from the National Forest Estate) and a position must be taken as to what proportion of total woody biomass may be available as feedstock. This proportion will largely depend upon the prices received by owners from

Parameter	Explanatory notes
	the alternative consumers (e.g. feedstock prices Vs paper pulp prices). The Forest Research tool provides estimates for production of stumps and roots from conifers and broadleaves. While harvesting of stumps from commercial conifer plantations can be expected, it is considered that all roots and broadleaved stumps are unlikely to be harvested (taking account damage to soils and harvesting methods in broadleaved (mostly privately owned) woodlands. Therefore, the data on these should be excluded from the regional assessment. **Option 2** The National Forest Inventory work programme currently being undertaken by the Forestry Commission has, as one of its objectives, the provision of biomass forecasts for GB, country and region. To achieve this FC have mapped all GB woodlands down to 0.5Ha, using aerial photography. This map has been base lined to give a complete picture of woodland area as of 2007. As well this as a total of 15,000 1 ha sample squares will be assessed over a five year period in order to provide feedstock forecasts with confidence intervals of +/- 1%, +/- 2 % and circa +/-5% respectively. The final reports will be produced in 2014, but as field data comes in, interim reports will be produced based upon these starting in 2011 for conifer and 2012 for broadleaves. As a result of being based upon only a partial data set confidence intervals in the interim reports will be wider. Once one full cycle has been completed the next will commence and the woodfuel and biomass forecast will be updated annually from there on in. These figures will be the Official Statistics for GB Government and Forestry Commission is currently considering applying to upgrade these to National Statistics. Regions can directly bring forward and tailor reports through the NFI Using the 'Top Up' Scheme. The FC recognises that for full development of woodfuel, regions may require greater accuracy than the strategic NFI alone can provide (circa +/- 5% for total standing resource). With this in mind FC have designed the 'top up' scheme, where stakeholders can invest in extra field sampling to increase the accuracy of the forecasts in the area that they are interested in. This investment may form a significant impetus to proving the viability of a scheme and achieving competitive advantage. This can be achieved either through increasing the accuracy of forecasts or by bringing forward forecasts in time. SWE and Y & H have already taken the opportunity to invest in woodfuel evidence to support industry development. By buying 250 sample squares, SWE brought their conifer forecast forward from 2011 to 2009, giving a competitive advantage for 2 years and increased accuracy in the long term. Alternatively Y&H required a more accurate Blvd woodfuel forecast and bought 700 sample squares to achieve this. Therefore customers can both set when they need a forecast by and to what accuracy they need it. If the core NFI will not meet this FC will advise on how much extra funding would be required to do so.
2a Fuel requirement	For electricity: most regional studies do not discuss directly the conversion from to woodfuel resource to installed capacity. Assumptions used include 5,000 odt/MW (Y&H) and 8,000 odt/MW (SW). This typically refers to larger dedicated plants of 5-40 MWe capacity, which are more economically viable. For heat: detailed calorific values are rarely provided in regional studies (although these are probably used in the underlying analysis). Where quoted, these are generalised across the woodfuel types. In practice, the difference between higher quality material (low grade timber and larger diameter stemwood) and poor quality material (branches and foliage) should be acknowledged. In addition, the energy conversion efficiency of different types of plant might be considered. Domestic heat only boilers are likely to be less than 80% efficient and higher quality woodfuel is preferred. Whereas large boilers and CHP should be greater than 80% efficient and will take all types of woodfuel. Such detailed consideration, however, would need to make market structure assumptions which lies outside the scope of this methodology. A more detailed approach suggested by the Forestry Commission (based on kWh units and non-domestic boilers) is as follows: • For woodchip boilers assume using woodchip with a moisture content of 30%, a calorific value of 3,500 kWh per tonne (both hard and softwood), boiler efficiency of 85% and boiler operating time of 1100 hours per year • For pellet systems apply the same assumptions as above, but change calorific value to 4,800kWh per tonne • For power generation - this is not as straight forward as fuel types and conversion technologies will vary considerably. As a starting point assume a mix of fuels including other elements such as tree surgery residue, brash, woodchips, a smattering of SRC and Miscanthus and some waste wood. Calorific value of this selection of materials will be highly variable. FC recommend to use 2,900kWh per tonne, based around the assumption that

Parameter	Explanatory notes
	the main fuel source will be fairly wet woodchip (40 - 45% MC) topped up with drier waste wood and energy crops. It would be difficult to improve on this unless you resort to specific assumptions for each power plant using biomass in the UK - this would obviously take more resources to achieve. With regard to conversion technologies, the typical assumption for biomass power plants are based on steam turbines with an efficiency of 25% (where most of the energy is lost as heat). An assumption for power station operating hours of 8,000 hours a year is applied. Using large scale combined heat and power (2MWe and bigger) would not result in changes in the assumptions except that the overall efficiency would increases to 60%. Key source of information is: http://www.biomassenergycentre.org.uk
3a Exclusion of woodfuel potential	A range of environmental and market constraints limit woodfuel availability for energy purposes. There are detailed statistics and data from the Forestry Commission that demonstrate how various types of woody biomass are being used. Whilst the actual application of some types is driven by market conditions and vary over time, the categories listed for exclusion are seen as largely unavailable or uneconomic for energy purposes.
Energy crops	
1b Existing resource	Not taken into account in regional studies, perhaps due to the fact that these areas were relatively insignificant when regional assessments were made. The most complete and accurate source of data are the Woodland Grant Scheme (SRC establishment grant aided to 2004) and the Energy Crops Scheme (SRC and miscanthus establishment aided since 2001). National level data is reported by the National Non-Food Crops Centre. [http://www.nnfcc.co.uk/metadot/index.pl?id=2179;isa=Category;%20op=show]. Area planted outside these schemes is difficult to determine. Overall the area planted with energy crops is small compared to existing woodland and to potential energy crop area.
2b Available land	The amount of available land for energy crops largely depends on agricultural practices in each region, as well as assumptions for global commodity prices and various political factors. Suggestions range from applying a blanket 25% of pasture/arable land (EoE) to all set aside (up to 2008) and bare fallow/land withdrawn from production, plus 90% of abandoned pasture land. Aylott et al (2008) model energy production obtained by planting SRC on 10% of arable land, 20% of improved grassland and 100% of set-aside grassland in England and Wales (supplying 7% of UK electricity production or 48% of UK combined heat and power (CHP) production), but there appears to be no empirical basis for the selection of the proportions of land area. Despite research into Short Rotation Forestry (SRF), this features very little in regional and national assessments. Regional studies have not taken account of agricultural land classification, which is a gap that should be considered. Grade 1 and most grade 2 land is unlikely to be economically suitable for energy crops, while most grade 5 land will be climatically and environmentally unsuitable. This leaves Grades 3 and 4 and the main option for energy crops. .
3b Yield	For short rotation coppice, assessments in NW and Y&H use yield of 10 odt/ha/yr. Same figure is used in the Biomass Task Force report (2005). The figure of 10 odt/ha per year for SRC is widely used and accepted but will vary according to soil and climatic conditions. When agricultural marginal land is considered, lower yields would need to be applied. The latest modelling by Aylott et al (2008) suggests it is optimistic. A figure of 8 odt/ha/yr is more realistic (mean modelled yields, across 49 sites in England, ranged between 4.9 and 10.7 odt/ha/yr) For miscanthus, SW assessment states that miscanthus has higher yield (16-18 odt/ha/yr). However, a more realistic achievable figure in commercial rather than trial situations is 15 odt/ha/yr. Miscanthus cannot be considered for the North West and the North East as it is not viable in these regions.
4b Fuel requirement	The same considerations apply as for woodfuel from managed woodland, although it should be acknowledged that material harvested from SRC and miscanthus is generally more consistent.

Parameter	Explanatory notes
	Conversion rates provided by the Biomass Energy Centre are considered reliable (see left):
5b Exclusion areas	Designated land (SSSI, Scheduled Monuments and registered common land) are unlikely to be available for conversion to energy crops. In addition, the Environmental Impact Assessment (Agriculture) (England) Regulations 2006 control activity on uncultivated land and semi-natural areas. This is likely to severely constrain the cultivation and planting of energy crops on permanent pasture and moorland. Some protected landscapes (e.g. Cotswolds AONB) have produced policy statements about impacts of energy crops) but have no statutory basis for enforcing this. Land that cannot be planted under the Energy Crops Scheme is listed in the Scheme Handbook at: http://www.naturalengland.org.uk/ourwork/farming/funding/ecs/
6b Environmental impacts	None of the regional assessments take account of environmental constraints to limit the area that can be planted with energy crops. Rowe et al (2009) reviewed the environmental impacts of large scale deployment of bioenergy crops in the UK and found a range of effects. However, most of these are not safeguarded by statutory guidance or designations and are therefore outside the scope of this study. EA have expressed concern about impact of large scale SRC planting in water stressed areas (e.g. EoE) but research reviews (for instance Stephens et al 2001) suggest that, at a catchment scale, likely densities of energy crops, even close to generation plants, is unlikely to have noticeable effect on groundwater or river base flows.
Industrial wood waste	
1c Existing and potential new feedstock	The amount of existing feedstock from industrial waste has had limited consideration at Regional level; thus it is appropriate to use national data from WRAP and the Forestry Commission until regional data is available.
2c Fuel requirement	As per managed woodland.
3c Available feedstock	The main competing use of waste wood is in the manufacturing of wood panels using co-product. The 2007 figure for this use, according to WRAP (2009) is 58%. They have estimated that this figure is now lower due to the recession and a corresponding reduction in demand for panel wood (9% lower). An additional 20% in the form of sawdust is used for animal bedding which is thought to be a constant requirement (WRAP, 2009).
Agricultural arisings (straw)	
1d Existing feedstock	The existing feedstock is based on the amount of available arable land, with both wheat straw, which is currently used for animal bedding, and oil seed rape (OSR) straw, which is not currently collected, considered. Barley straw is generally excluded from assessments as this is fed to cattle and cannot be diverted.
2d Fuel requirement	The fuel requirement is based on existing straw power plants. For example, Ely straw power plant has a capacity of 38 MW, requiring 200,000 tonnes per annum (c. 5,300 t per 1MW). Other assessments are closer to 8,000 per MW.
3d Available feedstock	For competing uses, an EC DG JRC study has assessed the amount of straw used by cattle – both per head of cattle (1.5 tonne/year/head) and as a percentage of the straw available regionally (0%-70% or 20%-100%, depending on the author and on regional agricultural practices). The same report maintains that there is no clarity as to how energy will compete with other uses in the future. Some authors recommend that even in a favourable market context, farmers should not contract 100% of their straw for energy uses only, mainly in the interest of flexibility as energy generators will typically require long-term contracts for security of supply. Therefore, less that 100% should be considered as the actually available resource for energy purposes.

Source: SQW Energy and Land Use Consultants on the basis of literature review and expert/stakeholder consultations

Table A-4 Parameters considered but not included in the assessment methodology

Parameter	Explanatory notes
Market model	This refers to the size and location of plant – for instance a regional market model could be to push for a few large centralised plants (especially power generation) or to focus on a distributed model of numerous small scale installations (e.g. boilers for heat). The impact of such a decision will be (1) in the total capacity installed as affected by the difference between the fuel requirement of power and heat plants and (2) in the level of dependence on heat networks and the requirement not to have small distributed capacity in air quality management areas. This parameter is addressed through the comparison in the methodology between the different energy output options (power and heat). It is also partially captured by the constraints analysis (e.g. exclusion areas).

Source: SQW Energy and Land Use Consultants on the basis of literature review and expert/stakeholder consultations

Animal biomass (EfW)

Table A-5 Detailed explanation of the proposed methodology approach

Parameter	Explanatory notes
Wet organic waste	
1a Existing feedstock	For the amount of manure and slurry, it is assumed that this is only collectable whilst animals are housed indoors. Bedding (mainly straw or sawdust) will be mixed up with the manure or slurry so will be included in the AD feedstock.
2a Bio-gas yield	Due to its moisture content, animal manure is most suited for the recovery of bio-gas in an AD plant, as opposed to incineration. Biogas yields for different types of manure are taken from Halcrow (2001). Although different manures generate differing yields, the bio-gas generated has a reasonably consistent calorific value of 20MJ/m^3.
3a Feedstock requirement	The required amount of biogas per 1 MW capacity assumes an average methane content of biogas of 55%, a power output of 11.04 kWh/m3 of methane, running hours of 90% and an average feedstock biogas yield of 35m^3/t.
4a Limits to extraction	The capacity to extract this resource is limited due to difficulties in handling and transporting the waste. For example, some of the waste may not be in sufficient volumes or accessible enough to justify the collection of this resource.
5a Competing uses	Food and drink industry waste is used for by-products (37%), fertiliser (17%) and compost (3%). By-products include other food stuffs and animal feed. (Defra/Food and Drink Federation (2008) *Mapping waste in the food industry*. [http://www.fdf.org.uk/publicgeneral/mapping_waste_in_the_food_industry.pdf])
Poultry litter	
1b Existing and potential new feedstock	Currently 1% of the potential resource is used. This is projected to grow to 50% in 2015 and 100% in 2020. There is also the potential for wet grass and other primary vegetative feedstocks to be used for AD in future.
2b Feedstock requirement	The required feedstock figure is base on an average from several examples of power plants using poultry as a fuel (11kt/MW): • Thetford plant – 38.5MW uses 420kt/pa (1MW = 10,9kt/pa) • Eye plant – 12.7MW uses 140-160kt/pa (1MW = c. 11.8kt/pa) • Westfield plant – 9.8MW uses 110kt/pa (1MW = 11.2kt/pa)
3b Available feedstock	Typical competing uses of poultry litter are for mushroom compost and direct spraying (pre-treated and diluted) on land as fertiliser. The value of this resource as a high-grade fertilizer is dependent on the type and amount of bedding material, litter type and the nutrients included in the poultry feed. It is reasonable to assume that poultry litter with higher amounts of nitrogen and other valuable nutrients will be used for these competing agricultural uses.

Source: SQW Energy and Land Use Consultants on the basis of literature review and expert/stakeholder consultations

A.4 No additional parameters of direct relevance to the regional assessment were identified

Municipal Solid Waste

Table A-6 Detailed explanation of the proposed methodology approach

1c Existing and potential new feedstock	The regional assessments for waste are based on assumptions relating to the % of waste arisings, % of recycling, use of waste, and need for new waste management facilities etc. The siting or identification of broad locations for energy to waste plants will need to take account of planning/ environmental issues in line with planning policy but environmental considerations do not need to be taken into account for the purpose of assessing regional resource.
2c Feedstock requirement	The literature estimated that 1 tonne of MSW could produce around 750kWh/t. At plant availability of 90%, 1MW capacity would require approximately 10.5kt per year.

Source: SQW Energy and Land Use Consultants on the basis of literature review and expert/stakeholder consultations

A.5 No additional parameters of direct relevance to the regional assessment were identified

Biogas

Table A-7 Detailed explanation of the proposed methodology approach

Parameter	Explanatory notes
Landfill gas	
1a Available resource	Regional studies have referred to the waste management authorities' inventories and forecasts. The methodology assumes that all landfill sites are suitable for collecting bio-gas and that there are no real planning constraints on this, in line with many of the Regional assessments.
2a Lifetime of resource	This is especially important for landfill gas because current landfill sites have a limited useful lifetime as sources of bio-gas and will be exhausted by around 2020. There is unlikely to be much new landfill gas resource due to the EU Landfill Directive which caps landfill, especially post-2014, and due to policies to promote other waste management processes such as AD, composting and recycling, which will reduce significantly the biodegradable fraction of landfill waste.
Sewage gas	
1b Available resource	While many of the Regional assessments predicted that there would be no significant uptake of this resource, some of the literature referred to the water utilities' inventories for quantifying potential. For the purposes of this methodology, it is assumed that all sewage works are suitable.
2b Potential new resource	To assess the future resource, the Regional studies have referred to the water utilities' forecasts, though it is generally thought in the literature that the potential for expanding this resource is limited as much of the resource is already captured and utilised. New resource will be highly dependent on projections for the expansion of water treatment as a result of population growth.

Source: SQW Energy and Land Use Consultants on the basis of literature review and expert/stakeholder consultations

Table A-8 Parameters considered but not included in the assessment methodology

Parameter	Explanatory notes
Potential new resource (landfill gas only)	Most assumptions are that a very limited new amount will be available and that existing landfill sites will be exhausted by 2020.
Overall - physically available resource	All resource is currently accessible and no planning or environmental constraints apply

Source: SQW Energy and Land Use Consultants on the basis of literature review and expert/stakeholder consultations

Co-firing of biomass (with coal)

Table A-9 Detailed explanation of the proposed methodology approach

Parameter	Explanatory notes
1 Available plant	Theoretically all solid and liquid fuel plant can be co-fired with biomass, therefore the existing regional capacity of coal and oil-fired plants needs to be quantified, which is a straightforward process. However, given that the UK generation fleet is ageing and on the basis of exiting and forthcoming legislation, such as the Large Combustion Plant Directive (LCPD), some plants will be decommissioned in the near future. These plants need to be excluded from the inventory as they will not support biomass co-firing in the future. Any confirmed new coal-fired plants coming on-line over the next decade should be included, although in practice given their higher efficiency it is not certain if they will technically and economically be in a position to take biomass feedstock.
2 Co-firing threshold of plant	The technical potential is for up to 15% biomass in the mix, and the fraction at most plants that are already co-firing is between 5%-10%. Most of the large generators in the UK have or are co-firing biomass[16].
3 Policy framework	The current Renewables Obligation gives support to co-firing power plants up to 2027. Beyond this time, it is likely that the resource will not be economically viable.

Source: SQW Energy and Land Use Consultants on the basis of literature review and expert/stakeholder consultations

Table A-10 Parameters considered but not included in the assessment methodology

Step / parameter	Explanatory notes
Biomass feedstock availability and origin	In order to ensure that co-firing of biomass contributes to the regional and national renewables (low-carbon) capacity, continuous fuel supply is required. This can be sources locally/nationally and through imports. In practice, while a proportion of the fuel demand will be sourced locally, due to the large volumes required the majority of feedstock is likely to be imported. From a generation capacity perspective it is not critical to establish where exactly the biomass comes from and this will largely depend of the market dynamics. It can however be assumed that availability will not be a significant barrier given that large volumes of biomass are produced and traded internationally. In practice, it is likely that the actual amount of co-firing at any given coal/oil-fired plant (e.g. as a % of total capacity or output) will vary over time. This parameter was therefore deemed as non-essential to the regional capacity assessment.

Source: SQW Energy and Land Use Consultants on the basis of literature review and expert/stakeholder consultations

Microgeneration

Solar energy

Table A-11 Detailed explanation of the proposed methodology approach

Step / parameter	Explanatory notes
1 Existing roof space	It is assumed that solar PV and hot water systems will only be installed on roofs. This is because of the convenience of roofs as installation spaces and because roofs receive substantial amounts of solar irradiation. Not all roofs are suitable, so only a certain proportion is accounted for in the methodology. This is either because they do not get enough sun due to their orientation or are architecturally unsuitable for the installation of solar systems. The following assumptions were found in the literature and was adopted in this methodology: • Domestic properties (including flats) – 50% will have a suitable aspect features; 95% will not have planning constraints and 80% will not be subject to shading. Therefore, only 25% of the properties are likely to be suitable for installing solar • Commercial properties – 40% will not have issues with shading • Industrial premises – the majority (80%) will be suitable for installing solar. Wall mounted systems are also available, especially solar PV, however these still represent a very niche market and if included in the assessment on the basis of available wall space will distort the regional results, unjustifiably raising the expectation on solar.

[16] BERR (2005) *Best practice brochure: Co-firing of biomass*

Step / parameter	Explanatory notes
2 New developments	A higher percentage (50%) is proposed for new developments because PV, for example, can easily be incorporated into new buildings (Building Integrated Photovoltaics).
3 System capacity	For solar thermal, the peak thermal output of $1m^2$ of panel is around 0.7kW. Thus for an average size of domestic system of $3m^2$, it is assumed that they will have an individual capacity of 2kW. It is assumed that commercial systems will be larger due to increased availability of space. For systems on industrial sites, Regions are given the flexibility to decide on capacity depending on the kind of industry and consequent premises that are in the Region. System capacity is a dynamic parameter which is changing constantly as system efficiencies improve.

Source: SQW Energy and Land Use Consultants on the basis of literature review and expert/stakeholder consultations

Table A-12 Parameters considered but not included in the assessment methodology

Step / parameter	Explanatory notes
Solar irradiation	While some Regional studies calculated the mean, peak and minimum solar irradiation, this parameter is not considered for the methodology. This is because the regional variations across the UK are not significant enough to justify an ‘adjustment factor’ and also the assessment focuses on estimating the installed capacity, which is only indirectly linked to system efficiency.

Source: SQW Energy and Land Use Consultants on the basis of literature review and expert/stakeholder consultations

Heat pumps

Table A-13 Parameters considered but not included in the assessment methodology

Step / parameter	Explanatory notes
1 Existing building stock	Only a certain proportion of the existing building stock is suitable for the installation of heat pumps, especially ground source heat pumps. Constraints to potential include lack of suitable space (particularly pertinent for closed-loop GSHPs), lack of access to a suitable aquifer (for open-loop GSHPs) and the cumulative effects of open-loop GSHPs on aquifers.
2 New developments	The percentage is higher for new build domestic properties because heat pumps can be designed into the building or premises and hence spacing issues which apply to retrofitting, especially in urban areas, are not such a significant constraint.
3 System capacity	While this has not been explored at the Regional level, the Environment Agency have produced estimates of typical capacity for GSHPs: Domestic – 2-15kWth Commercial – 50kWth-1MW To date, systems have been much smaller than the higher numbers in the range, however, with an average of 5kW for domestic and 100kW for commercial systems. This is a dynamic parameter which is changing constantly as heat pump technology improves.

Source: SQW Energy and Land Use Consultants on the basis of literature review and expert/stakeholder consultations

Table A-14 Parameters considered but not included in the assessment methodology

Step / parameter	Explanatory notes
Ecological constraints	This constraint relates to the impacts that GSHPs have on aquifers and only applies to open-loop ground source heat pump systems. This constraint was not explored at the Regional level and, since ecological impacts on aquifers can be avoided through using other types of system (e.g. closed-loop systems), it is thought that this is not an absolute constraint to the potential for this technology.

Source: SQW Energy and Land Use Consultants on the basis of literature review and expert/stakeholder consultations

Annex B: List of acronyms

B.1 Regional acronyms

Table B-1 English regions

Acronym	Region
EoE	East of England
EM	East Midlands
NE	North East
NW	North West
SE	South East
SW	South West
WM	West Midlands
Y&H	Yorkshire and Humber

Table B-2 Other acronyms

Acronym	Extended form
AD	Anaerobic Digestion
Agl	Above ground level
AONB	Area of Outstanding Natural Beauty
ASHP	Air Source Heat Pumps
CHP	Combined Heat and Power
CO2	Carbon Dioxide
Defra	Department for the Environment, Food and Rural Affairs
EA	Environment Agency
EfW	Energy from Waste
GIS	Geographic Information System
GJ	Gigajoule
GSHP	Ground Source Heat Pumps
GVA	Gross Value Added
GW	Gigawatt
GWh	Gigawatt Hours
IACS	Integrated Administration and Control System
IRS	Integrated Regional Strategies
kW	Kilowatt
LDD	Local Development Documents
LSOA	Lower Super Output Areas

Acronym	Extended form
MMDB	Manure Management Database
MOD	Ministry of Defence
MW	Megawatt
MSW	Municipal Solid Waste
MWh	Megawatt Hours
NFI	National Forest Inventory
NIWT	National Inventory of Woodlands and Trees
NNR	National Nature Reserve
Odt	Oven dried tonnes
ONS	Office of National Statistics
ORED	Office for Renewable Energy Development
OSR	Oil seed rape
PPS1	Planning Policy Statement 1
PPS22	Planning Policy Statement 22
PRoW	Public Right of Way
PV	Solar Photovoltaic
RDA	Regional Development Agency
REEIO	Regional Economy Environment Input Output (model)
RES	Renewable Energy Strategy
RSS	Regional Spatial Strategy
SAC	Special Areas of Conservation
SHI	Site of Historic Interest
SIC	Standard Industrial Classification
SNH	Scottish Natural Heritage
SPA	Special Protection Area
SRC	Short Rotational Coppice
SRF	Short Rotation Forestry
SSSI	Site of Special Scientific Interest
SWP	Solar Water Heating
WRAP	Waste and Resources Action Programme
YC	Yield Class
ZVI	Zones of Visual Influence

Annex C: Bibliography

Table C-1 Literature identified and review status (in alphabetical order by Scope)

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