APPENDIX 5

RENEWABLE & LOW CARBON ENERGY RESOURCE ASSESSMENT METHODOLOGY

This appendix contains the methodologies used to produce the various renewable and low carbon resource estimates. Overall the methodology has used guidance from the SQW Energy report entitled "Renewable and Low-carbon Energy Capacity Methodology – Methodology for the English Regions" issued by DECC in January 2010. The document defines the methodologies, resource data and constraints to be used for a range of renewable and low carbon resources. However in certain cases, some changes have been made to improve upon the level of detail specified in the SQW Energy methodology. The methodology requires the potential resource to be expressed in four different ways:

- Capacity (MW)
- Energy (MWh/y)
- Percentage contribution to Herefordshire's total annual consumption
- CO_2 savings.

Herefordshire's total annual consumption (5,177 GWh/y) was taken from the DECC 2007 report. DEFRA's carbon savings figures of 0.543 kg/kWh for renewable electricity and 0.204 kg/kWh for heat (assumed to be normally produced from natural gas) have been used to calculate the CO_2 savings for each renewable technology.

In almost all cases a Geographic Information System (GIS) was used for the resource assessment. The following sections explain the detail methodologies and data layers used for the wind, biomass, hydro-electric, solar, heat pump, CHP and other technology assessments.

Wind

The wind resource methodology is divided into three sections large, medium and small wind. The resource assessment for large and medium scale wind started with a GIS layer of the Herefordshire county boundary. This polygon was then split by the UK Wind Atlas one kilometre grid, ward, parish and postcode boundaries. The wind speeds at 10m, 25m, 45m above ground level (agl) and the ward, parish and postcode names were saved as attributes to each of the split polygons.

Large Scale Wind Resource

A wind speed up log law calculation was used to extrapolate the annual mean wind speed at 85m agl from the 45m reference height in the UK Wind Atlas. A surface roughness value of 0.03 was used in the calculation. The resultant speed up factor was 1.087.

The potential installed capacity was estimated from the land area within each ward, district, planning authority and the county boundary. This was based on the benchmark figure of 9MW/km^2 from the SQW Energy methodology.

The number of turbines for each area was back calculated from the installed capacity by dividing it by 2.3MW, the turbine capacity suggested in the SQW Energy methodology. An Enercon E82 2.3MW turbine was subsequently used as the reference turbine for energy calculations, etc. This turbine is representative of the scale of turbine used in large commercial windfarms for the average wind speed values for Herefordshire.

Each discrete area falls within a specific 1km grid square with an identified wind speed at a reference height of 85m. The total number of turbines within each of these discrete areas were then used as a multiplier of the annual energy output for the reference turbine derived from its published energy curve at the given wind speed.

The SQW energy methodology identifies several resource levels for large commercial scale wind turbines. Cumulatively each level further constrains the resource. Each level is detailed below.

Level 1 – Natural Resource

Level 1 gives the total natural wind resource, utilising all the land within Herefordshire without exception.

Level 2 - Benchmark Figures

No meaningful output could be achieved at level 2 as this simply defines the turbine capacity and the packing density as used to establish the resource at level 1. The benchmarks defined at level 2 are used throughout the resource assessment.

Level 3 - Technically Accessible Resource

Level 3 gives the technical wind resource following removal of low wind speed areas. Low wind speed areas are defined as less than 6m/s at a height of 85m above ground level.

Level 4 - Physically Accessible Resource

Level 4 is the physically accessible wind resource after non-accessible areas have been removed, this includes: roads, railways, inland waters, built-up areas, airport and MoD training sites.

The Ordnance Survey 1:50,000 Vector Map dataset was the base mapping used to develop the various constraint layers used in the resource assessment. Most features found within this dataset are defined by lines. To produce the constraint layers these features require offsets to be built around them to define the inaccessible areas. The offsets used for the various features are defined in Table A3.1 below.

Table A3.1: Feature Offsets

Feature	**Offset (m)**
A roads &	20
Primary road	10
B roads	12.5
Motorways	15
Private / Local street / minor/ pedestrian roads	2
Railways	10
Inland waters	5
Powerlines	2.5

Built up areas and woodland areas were also identified using the vector map data categories. Active airports were selected from a database of airfields and their perimeters were identified and digitised from Google Earth. Ministry of Defence training areas were digitised from the Ordnance Survey 1:50,000 base mapping.

Level 5 - Practically Accessible Resource (exclusion areas)

Level 5 gives the practically viable wind resource after various exclusion areas have been removed. These include; ancient semi-natural woodland and sites of historic interest (Scheduled Ancient Monuments, Listed Buildings, Registered Historic Battlefields, Registered Parks and Gardens and World Heritage Sites). Other exclusion areas were generated by creating offsets from the features listed in level 4. These features and their associated offsets are shown in Table A3.2.

Table A3.2:Exclusion Area Offsets	
Feature	**Offset**
Roads (Motorway, Primary, A & B)	150m (turbine topple height +10%)
Railway	150m (turbine topple height +10%)
Settlements	600m (mitigation against noise impacts)
Airports	5km (safeguarding mitigation)
Rivers	50m (landowner over sail)

Level 6a - Practically Accessible Resource (Environmental Constraints)

Level 6.1 gives the practically viable wind resource potential following exclusion of selected environmental designations including: SPAs, SACs, NNRs, SSSIs and Ramsars.

Level 6b Practically Accessible Resource (Landscape Constraints)

Level 6.2 gives practically viable wind resource following removal of all National Parks, Areas of Outstanding Natural Beauty and Heritage Coast.

Level 7 – MOD Consideration

The MOD operates a network of air defence radars across the UK. Windfarms have the potential to compromise the operational usefulness of this network and as a result many windfarms are refused at planning. To account for this in this wind resource study, a percentage reduction in the overall regional resource was sort from the MoD.

Medium Scale Wind Resource

A wind speed up log law calculation was used to estimate the annual mean wind speed at 30m agl from the 25m reference height in the UK Wind Atlas. A surface roughness value of 0.03 was used in the calculation. This resulted in a speed up factor of 1.027. The reference turbine used for the medium scale wind resource assessment was a ACSA 225kW turbine. This turbine is a copy of a Vestas V27, a well proven 27m diameter turbine which is no longer in production, and is expected to be a popular choice for projects supported by the Feed in Tariff. Installed capacity was estimated based on 4 turbines occupying an area of 1 km^2 (900kW/km^2). Total energy output was then derived from the number of turbines and the energy curve for the ACSA 225kW turbine using the appropriate annual mean wind speed at 30m.

The resource base layers constructed as part of the large scale wind resource up to level 4 were also used for the medium scale wind resource assessment. The constraints used for level 5 differed slightly in the size of some of the exclusion zones. The main differences were 400m offsets from buildings and a 3km offset around airports. As an addition constraint, the large wind resource areas left at level 6b were also removed. This step was taken so that the medium scale wind resource was not counted twice with the large scale wind resource assessment. The constraints at levels 6 were then applied as for the large scale wind resource.

Small Scale Wind Resource

Building categories were identified within the Local Land and Property Gazetteer and each assigned an appropriate scale of micro-turbine. The turbine scales considered were 1.5kW, 6kW and 15kW. The scales of turbine used was based on the inference of space, ie terraced houses have little distance between private outside amenity space and were therefore given only 1.5kW turbines. Detached houses generally have more space and therefore 6kW turbines were used. Industrial premises generally have more space and were therefore given 15kW turbines. Overlapping properties such as flats were removed from the list. Specifically a 1.5kW Swift, a 6kW Proven and a 15kW Proven were used.

Again annual mean wind speeds were extrapolated from the UK Wind Atlas based on the hub height of the selected turbine for each address. To account for the reduction in wind speed experienced in built up areas due to the increased surface roughness caused by large numbers of buildings, a wind speed scaling factor was also applied. An urban/sub-urban/rural classification for each of the buildings was derived from the DEFRA Rural Definition dataset and the wind speed scaling factors are shown in Table A3.3 below applied.

Table A3.3: Scaling Factors

Classification	**Scaling Factor**
Urban	56%
Sub-urban	67%
Rural	100%

A wind speed cut off of 4.5 m/s at the reference hub height of each turbine was selected as an economic threshold below which the turbine would not be cost effective. All buildings below this wind speed threshold were excluded from further analysis. The annual output of the turbine on each remaining building was then estimated from the scaled annual mean wind speed and the appropriate turbine's energy curve. These were then aggregated by ward, parish, postcode and county.

Biomass

Energy Crops and Forest Residues

The available energy crop resource has been assessed by applying a series of restrictions and constraints to the natural resource. The natural resource has been determined from energy crop yields. The potential yields for Miscanthus and Short Rotation Crop (SRC) in Herefordshire was obtained from DEFRA. This data classifies the potential for energy crops in terms of low, medium and high yields.

The natural resource was then limited to the technically accessible resource. This restricts the natural resource to suitable land dependent on agricultural practices and climatic conditions. The Agricultural Land Classification (ALC) data, also supplied by DEFRA, was applied to the energy crop yields. The ALC provides a method for assessing the quality of agricultural land to assist informed choices for agricultural development. Land is graded based upon physical or chemical limitations to agricultural use. The most suitable land for agricultural development falls within Grades 1, 2 and 3. For the purpose of this resource assessment, energy crop yields were restricted to agricultural land graded 1 - 3. All other land areas were excluded. Current land use of these areas has not been considered and it should be noted that areas identified as suitable for energy crops are currently likely to be utilised for other agricultural crops.

The technical resource was further restricted by wind speed. Miscanthus crops grow to a significant height and can be affected by high winds, which flatten the crop and impacts the final yield. Miscanthus was therefore determined as the dominant energy crop in areas with annual mean wind speeds below 6m/s at a height of 10m agl. SRC was considered the dominant crop for areas with wind speeds above this. Wind speed data was derived from the UK Wind Atlas from DECC.

The technical resource was then constrained to the physically accessible and the practically viable resource. This was determined by excluding the following areas from the technical resource:

- Ancient and Natural Woodland
- Road

- Rail
- Rivers
- Lakes
- Settlements
- Sites Special Scientific Interest
- Special Protection Areas
- Special Areas of Conservation
- RAMSAR (protected Wetlands)
- National nature reserves
- Local nature reserves
- Scheduled Ancient Monuments
- Battlefields
- Country Parks
- Parks and Gardens
- Local Authority Conservation Areas
- Countryside Rights of Way
- Existing Habitats (Phase 1)

Areas of Outstanding Natural Beauty (AONB), National Parks and Heritage Coasts were not considered constraints to the biomass yield as crops can still be cultivated in these areas.

The practical resource was then assessed to determine the total available yield for both Miscanthus and SRC along with the potential energy generation achievable.

The Natural Woodland Area, obtained from Ordnance survey, was mapped along with the Miscanthus and SRC resource. This data is already constrained and it was not necessary to restrict the resource in the same manner as the energy crops.

The conversion factors shown in Table A3.4 below were applied to estimate the amount of oven dry tonnes of fuel produced per hectare per annum. These figures were established by Wardell Armstrong in previous projects based on expected crop yields from varying agricultural land characteristics and climatic changes[1]. These figures are more refined than

[1] *Wardell Armstrong: Devon Biomass and Woodfuel Opportunities*

those suggested in the SQW Energy guidance and should provide an accurate representation of the available yields.

Table A3.4: Energy Crop and Forest Residue Yields

Yield Category	ALC	Miscanthus odt/ha/yr	SRC odt/ha/yr	Wood odt/ha/yr
Low	1	16	9	2
	2	15	8	
	3	14	7	
Medium	1	18	11	
	2	17	10	
	3	16	9	
High	1	20	13	
	2	19	12	
	3	18	11	

The resulting tonnages were then converted into MWh based upon energy conversion factors obtained from the Biomass Energy Centre[2], as shown in Table A3.5 below.

Table A3.5: Energy Conversion Factors

Fuel	MWh/odt
Miscanthus	4.8
SRC	5.1
Wood	5.15

Note: Herefordshire Council requested maize to also be considered as a direct alternative to miscanthus. The methodology for miscanthus was therefore repeated using the crop data for maize.

Waste wood

Data for waste wood has been taken from the Bioregional Consulting document, November 2009 entitled "Herefordshire Woodfuel Supply Chain". In addition data for commercial and industrial waste was sourced from the 2009 Entec published report "Herefordshire Minerals and Waste Planning Assessment". Figures for the waste wood component of the waste stream were obtained from research carried out by SWAP, SLR and Viridor. These indicate C&I waste contains approximately 5% wood and C&D waste approximately 7%.

Municipal and Commercial Waste

The following elements were addressed:

- Municipal Waste.
- Biogas:

[2] *Biomass Energy Centre: Potential outputs of biofuels per hectare, per annum* - http://www.biomassenergycentre.org.uk/portal/page?_pageid=75,163231&_dad=portal&_schema=PORTAL

- Landfill Gas
- Sewage Gas
- Construction, Demolition and Excavation Waste.

Data was sourced from:

- The Planning Application and Environmental Statement submitted for the EfW Plant at the Hartlebury Trading Estate dated May 2010.
- Landfill Gas – The Environment Agency.
- Construction, Demolition and Excavation Waste – The West Midlands Regional Assembly.

Animal Wastes

Livestock data was sourced from DEFRA (2009 figures). The SQW Energy methodology figures of 80% of the resource for animal manure being available as a resource was applied with gas generation of 25m^3/t for cattle and 26m^3/t for pig manure.

Poultry litter was addressed using data which indicated the number of broiler birds at 8,998,723. The tonnage of excreta was calculated using 8,500 birds per tonne per day giving 386,416 tonnes per annum.

Hydro-Electricity

Low Head and Environment Agency Mapped Sites

The SQW Energy methodology recommends using the Environment Agency's (EA) recent report "Mapping Hydropower Opportunities in England and Wales (2009)" for the hydro-electric resource assessment. This was a mapping exercise of all barriers on watercourses that have potential for hydroelectric power production. These sites were graded in terms of potential power output, environmental sensitivity and whether they provide the opportunity for a "win-win" situation for both developers and environmental interests through for example, provision of a fish pass. The raw data behind this report was obtained for Herefordshire from the EA and analysed as follows.

Head has been estimated/measured by the EA at the location of each of the barriers in three different ways, which were used to determine the maximum head for each site (a 4th method was listed but was not relevant to any of the sites within Herefordshire). The EA data contains the water head difference at the barrier itself, the difference between 5m upstream of the barrier and 5m downstream and also 25m upstream and downstream. It is assumed that the EA has calculated the power output based on the maximum head available, their own flow data (not supplied) and an assumed design flow of the mean flow in the water course (based on the EA Good Practice Guidelines). Flow rates have been deduced using a notional “water-to-wire” system efficiency of 75% and a site capacity factor of 45%., based on the authors' experience.

Sites with a projected power output of less than 2kW, a barrier or 5m upstream /downstream head of less than 1.5m or a 25m upstream/downstream head of less 2m have been excluded as being non-viable.

The remaining sites have been split into two groups: those with power output above 10kW and those with power between 2kW and 10kW. The results were then processed into two spreadsheets in order of descending power potential with the following column headings:

Heading	**Meaning**
Obstruction ID	EA identifier for the weir or other barrier
Feature	e.g. Weir
Type	Natural or unnatural (man-made)
Barrier Head	Water level difference at the barrier in meters
Head 5m upstream / downstream	Water level difference between 5m upstream and 5m downstream of the barrier in meters
Head 25m upstream /downstream	Water level difference between 25m upstream and 25m downstream of the barrier in meters
Power	Projected power output in kW
Mean Flow	Estimated mean river flow
Maximum Head	Maximum head measurement of the 3 measurements (above)
Annual Energy Yield	Projected annual energy output in Mwh
Environmental sensitivity	EA environmental sensitivity score
HMWB designation	Designation as a “highly Modified Water body”
Catchment	River catchment name
Easting	East coordinate in meters (intake point)
Northing	North coordinate in meters (intake point)
Potential Win/Win	EA's judgement on whether the site is a potential “win-win” for hydropower and environment

CO_2 displacement	Estmates CO_2 displacement from conventional power generation, if hydropower were installed
Developability Score	An assessment score as to how much the site lends itself to hydropower development (only for sites over 10kW).

The developability score is somewhat arbitrary based on limited information. It is a summation of the following with a theoretical maximum score of 9 (though in the absence of any low sensitivity sites, this maximum score reduces to 7).

Sensitivity: Low = 4, Medium = 2, High = 0
Power: <20kW = 0, 20-200kW = 1, >200kW = 2
Head: <2.5m = 0, 2.5-10m = 1, >10m = 2
HMWB: If watercourse is a HMWB then 1 else 0

High Head Sites

The high head resource assessment was undertaken by examining contour lines adjacent to watercourses on 1:50,000 OS maps of Herefordshire and identifying potential sites and their catchment areas. Again all of the sites identified were processed into a spreadsheet. Almost certainly there will be small sites that have been missed but the technique should have picked up everything over 10kW. However there will be some inaccuracies arising from:

- Catchments with springs (i.e. not just fed by local rainfall)
- Rainfall and evaporation rates varying from catchment to catchment
- Subjective location of the intakes and outflows (generally the intake point has been placed at the top edge of a convex slope and often just downstream of a confluence)
- A total annual run off of 0.8m to the watercourse has been assumed
- Gross head has been estimated from contours

The following assumptions were used to estimate potential installed capacity and annual energy production from each site:

- Design flow: Qmean
- Hands-off flow: Q95
- System efficiency: 70% (includes head loss in penstock)
- Capacity factor: 45%

GIS Mapping

All three sets of data were then loaded in to a GIS and thematically mapped to produce site location maps colour coded by annual output.

Solar

The SQW Energy methodology provides parameters for opportunities and constraints for renewable energy technology deployment. These have been modelled for Herefordshire. However, certain changes and assumptions have been made to improve upon the detail provided in this resource assessment. The guidance recommends that, at a micro level, solar energy can be harnessed through either solar water heating (SWH) or solar photovoltaic (PV) technology. The suitability of both systems will be dependent upon:

(a) available roof space
(b) orientation and exposure of the roof

The suitability of SWH will also depend on the hot water demand on site. Generally there is high demand for hot water in domestic properties but a low demand in commercial and industrial properties. The guidance only provides SWH assessment parameters for the residential building stock. Solar PV is suitable for residential and non-residential buildings and therefore the guidance provides parameters for each building type.

The deployment of either technology in practice is limited to the available roof space. Either or both technologies can be installed on a property but the installed capacity will remain approximately the same, i.e. a 2kW PV array will require the same area as a 1kW PV and 1kW SWH array. The guidance therefore provides a single capacity parameter for both technologies.

Table A3.6 below shows the parameters for assessing potential capacity for solar energy as provided in the SQW Energy guidance.

Table A3.6: Assessment Parameters for Solar Technology

Parameter	Description	Assessment Requirement
Existing roof space	Number of roofs suitable for solar systems	• Domestic properties - 25% of all properties • commercial properties - 40% of all establishments • Industrial buildings - 80% of the stock
New Developments	Number of new roofs suitable for solar systems	• Assume 50% of all new domestic roofs will be suitable for solar systems
System Capacity	Average generation capacity of an individual system (kW)	• Domestic - 2kW thermal or electric • Commercial 5kW (electric only) • Industrial - each region use their own assumptions

Source: *SQWENERGY Renewable and Low-carbon Energy Capacity Methodology – Methodology for the English Region*

The guidance offers no specific constraint parameters to solar energy deployment as they are accounted for in the opportunity parameter assumptions shown in the table.

In this report it has been assumed that 50% of the domestic buildings deemed suitable for solar deployment will be installed with SWH. The remaining 50% will be installed with solar PV. This has been done for the purpose of calculating CO_2 savings. CO_2 conversion factors are based on DEFRA guidance.

Following the SQW Energy guidance, all the suitable domestic properties were modelled with a 2kW system. Annual output for this installed capacity was estimated at 1700kWh/yr after losses for both types of system[3]. Commercial solar PV systems were modelled with a 5kW system, achieving an annual output of 4,540kWh/yr. Industrial solar PV systems were modelled with a 10kW system, achieving an annual output of 9,090kWh/yr.

Existing building data was obtained from the Local Land and Property Gazetteer (LLPG) provided by Herefordshire Council, as discussed in Chapter 3. Domestic properties were extracted from the dataset and those with matching address points were combined to provide the total number of existing domestic roofs in the county. The parameters provided in the guidance were then applied to these properties. Non-residential data was also taken from the LLPG supplied by the Council. The numbers of commercial and industrial buildings were extracted based on the classification attributed to each building within the dataset.

Future building estimates were obtained directly from Herefordshire County Council, as discussed in Chapter 2. This was restricted to domestic buildings and the future potential generating capacity modelled as above.

Heat Pumps

The SQW Energy methodology provides parameters for opportunities and constraints for heat pump technology deployment. These have been modelled for Herefordshire. However, certain assumptions have been made to improve the detail provided in this resource assessment. The guidance recommends that, at a micro level, energy can be harnessed through either ground source heat pumps (GSHP) or air source heat pumps (ASHP).

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[3] Based on an insolation level of 1130kWh/m^2/yr or supplying approximately 70% of domestic hot water.

GSHPs provide space and water heating by extracting heat stored in the ground. This is achieved through either an open loop system, which pumps warm water from an aquifier and returns it a lower temperature, or a closed loop system, which circulates liquid through a closed tube sunk into a borehole or a trench and absorbs heat from the ground around it. Electricity is required to run the system. Generally GSHPs are most suitable to suburban or rural locations where space is available for installation and thay are particularly suited to areas with no mains gas supply.

ASHPs provide space and water heating by extracting ambient heat from the air. Electricity is required for this process. The variation of outside air temperature causes the electricity demand and carbon efficiency to fluctuate, which means that ASHPs are generally overall less efficient than GSHPs. The advantage of ASHP systems is that they can be deployed in areas where outside space is limited, eg urban locations.

THE SQW Energy guidance suggests that most buildings will be suitable for the deployment of either a GSHP or an ASHP. Table A3.7 below shows the parameters for assessing potential capacity for heat pumps as provided in the guidance.

Table A3.7:Assessment Parameters for Heat Pump Technology

Parameter	Description	Assessment Requirement
Existing building stock	Number of roofs suitable for solar systems	• Domestic properties – 100% of all off gas grid properties – 75% of all detached and semi-detached on gas grid properties – 50% of terraced properties – 25% of flats • Commercial properties – none stated
New developments	Number of new roofs suitable for heat pumps	Assume 50% of all new domestic properties
System capacity	Average generation capacity of an individual system kW	• Domestic - 5kW • Commercial - 100kW

Source: *SQWENERGY Renewable and Low-carbon Energy Capacity Methodology – Methodology for the English Region*

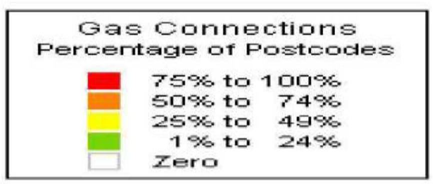
The guidance offers no specific constraint parameters to heat pump deployment as they are accounted for in the opportunity parameter assumptions shown in the table above.

The guidance provides no assessment requirements for commercial and industrial properties. The majority of these buildings are likely to have a large floor areas and high heating requirements which could not be met efficiently by heat pumps. It has therefore been assumed that 25% of commercial properties will be suited for heat pumps. Industrial properties have been excluded from the study.

The CO_2 savings arising from heat pumps differ significantly depending on whether the system is ground sourced or air sourced. For the purpose of this study, CO_2 savings were modelled for both systems. CO_2 savings arising from installation to off gas grid properties were calculated from fuel oil emission factors, whilst on gas grid properties and new developments were calculated using natural gas emission factors.

Following the SQW Energy guidance, the suitable domestic properties were modelled with a 5kW system. Annual output for this installed capacity was estimated at 10,000kWh/yr for both types of system[4]. Commercial heat pumps were modelled using a 100kW system, achieving an annual output 200,000 kWh/yr.

Existing building data was obtained from the Local Land and Property Gazetteer (LLPG) provided by Herefordshire Council, as discussed in Chapter 3. Gas grid data was extracted from the *Herefordshire Woodfuel Supply Chain* Report undertaken by BioRegional Consulting for Herefordshire County Council. The report provided a map showing gas connections based on a percentage of postcodes, as shown below:



Source: *Herefordshire Woodfuel Supply Chain*

The mid-points of each range were taken and applied to the postcode areas to determine the number of houses connected to the gas grid in each area. This data was then combined with the LLPG data to determine the type of building and whether it was connected to the gas grid. The SQW Energy parameters were then applied to this dataset. All commercial buildings deemed suitable for heat pumps were assumed to be connected to the gas grid.

Future building estimates were obtained from Herefordshire County Council, as discussed in Chapter 3. The future potential heat pump capacity was modelled for the County using this data and the parameters used above fro the existing buildings.

[4] Based on a heating period of 2000 hours per annum.