Department for Energy Security & Net Zero

RENEWABLE ENERGY STATISTICS

Data Sources and Methodologies

Contents

Introduction

This note documents the data sources and methodologies used in producing the Department for Energy Security and Net Zero (DESNZ, and its predecessors) for renewable energy statistics, covering electricity and heat generation, and transport for the UK.

Since 1989, renewable energy data have been collated in **RESTATS**, the UK's Renewable Energy STATisticS database, and is the primary source of accurate, timely statistics for UK renewable energy sources. The data enable monitoring progress against national and international targets, such as the 2009 Renewable Energy Directive (15 per cent of energy from renewable sources by 2020 for the UK). In addition, certain metrics such as load factors enable the comparison of individual scheme performance against technology wide averages.

The UK data are published on, and available for download from, the GOV.UK web site, principally in the Digest of UK Energy Statistics (DUKES) and Energy Trends publications. They additionally contribute to statistics produced by the Statistical Office of the European Communities (Eurostat) and the International Energy Agency (IEA), in establishing the wider deployment of renewable technologies and enabling country comparisons.

Scope

RESTATS contains information, at installation level where available, specifically those technologies supported by various measures. Key data collected are shown in Table 1:

Table 1: Overview of data held in RESTATS database

Technology	**Details**
Wind (onshore and offshore)	Electricity
Solar photovoltaics	Electricity
Hydro (large- and small-scale)	Electricity
Marine (wave and tidal)	Electricity
Bio-energy[1]	Electricity, Heat
Heat pumps	Heat
Solar thermal	Heat
Deep geothermal	Heat
Liquid biofuels	Transport
Metrics	
Electrical capacity	kW / MW[2]
Generation	kWh / MWh / ktoe (heat)[3]
Consumption	kWh / MWh / ktoe
Fuel input	Litres / ktoe
Derived metrics	
Load factors	
Meta data	
Technology	
Location	If available
Commissioning date	If available
Support mechanism	RO / RHI / FiT[4] etc.
Consuming sector	Domestic/Industry etc.

[1] Landfill gas, sewage sludge digestion, animal biomass (poultry litter, meat and bone), anaerobic digestion (AD: farm and food wastes), municipal solid waste (MSW: biodegradable part), wood, waste wood, plant biomass, paper and packaging.
[2] kW – kilowatt; MW – Megawatt
[3] kWh – kilowatt hour; MWh – Megawatt hour; ktoe – thousand tonnes of oil equivalent
[4] Renewables Obligation (RO), Renewable Heat Incentive (RHI), Feed in Tariff (FiT)

DESNZ Energy Statistical Publications

Renewables statistics collected for the RESTATS project, along with associated analyses, are disseminated in various DESNZ energy related publications, the key ones being DUKES (annual) and Energy Trends (quarterly). These publications are classed as National Statistics and are published to a previously announced timetable available via the following link:

https://www.gov.uk/search/research-and-statistics?content_store_document_type=upcoming_statistics&organisations%5B%5D=department-for-energy-security-and-net-zero&order=release-date-oldest

Table 2 shows details of scheduled publications and when they are published:

Table 2: Publication timetable for renewables statistics

Publication	Product	Frequency	Date	Time lag
DUKES Chapter 6	Commentary	Annual	Final Thursday in July	7 months
	Tables 6.1-6.7, 6.1.1			
Energy Trends Section 6; quarterly / monthly updates	Commentary	Quarterly	Final Thursday in quarter,	1 quarter
	Tables 6.1-6.2			
Energy Trends articles	Renewable Energy in year - 1	Annual	Final Thursday in June	6 months
	Renewable Electricity in Scotland, Wales, Northern Ireland, and the regions of England	Annual	Final Thursday in September	9 months
Regional Renewable Electricity	Tables; key source for tables in annual Energy Trends Regional article	Annual	Final Thursday in September	9 months

Further information on the excel tables listed in Table 2 above is provided in table 3 below:

Table 3: DUKES renewable energy tables

	Table	Description	Dates covered
DUKES	6.1-6.3	Commodity balances for renewable *energy* sources, by technology and sector	1996+
	6.4	*Electricity* installed capacity and generation, by technology	1996+
	6.5	*Electricity* load factors, by technology[5]	1996+
	6.6	Renewable fuel used for *Electricity*, *Heat* and *Transport*, by technology	1996+
	6.7	Progress under the 2009 EU RED (measured as specified in the directive)[6], split by electricity, heat and transport	2009+
	6.1.1	Renewable fuel used for *Electricity*, *Heat* and *Transport*, Electricity generation and installed capacity	2002+
Energy Trends	ET6.1	Quarterly electricity generation, capacity and load factors (standard method), by technology and UK country	2010+
	ET6.2	Quarterly liquid biofuels used in transport	2005+
		Monthly electricity generation, capacity and load factor (standard method), by technology and UK country	2010+
Regional[7]		Regional statistics generation	2003+
		Regional installed capacity	2003+
		Regional number of sites	2003+
		Regional standard load factors	2003+
		Regional unchanged configuration load factors	2003+
		Regional economic activity (Gross Value Added (GVA) measure)	2003+
		Renewable electricity by local authority; number of sites, electrical capacity, and generation	2014+

[5] See section on Load Factors for descriptions of the various measures and details of calculations
[6] See Appendix 3 for more information
[7] For some sites, particularly small-scale Feed in Tariff installations or older wind turbine / Solar PV schemes, no location information is available. These are therefore placed in an “unallocated” line in the Regional and Local Authority tables. In Energy Trends 6.1, these are allocated across the four countries, to maintain consistency with the overall UK figures presented.

Data Collection

Sources of data

No one approach to data collection is completely effective in producing an up to date, accurate picture of renewable energy in the UK. There are therefore different data collection methodologies depending on the level of data readily available.

For generation supported by various measures, detailed site level data are available.

The key measures relating to renewables generation are:

- Renewables Obligation (RO); now closed to new schemes but will continue to provide support to existing schemes until 2037.
- Feed in Tariffs (FiT); small scale schemes up to 5 MW; now closed to new schemes but will continue to support existing schemes until 2034.
- Domestic Renewable Heat Incentive (RHII); currently open to new applications but due to close in March 2022.
- Non-Domestic Renewable Heat Incentive (RHI); closed to new applications on 31st March 2021
- Renewable Heat Premium Payment; closed to new applications on 31st March 2014
- Contracts for Difference (CfD)
- Electricity Market Reform (EMR)
- Combined Heat and Power Quality Assurance programme (CHPQA)
- Renewable Transport Fuel Obligation (RTFO) (administered by Department for Transport (DfT))

For certain technologies either not supported by a measure, or where coverage is limited, a **"gap analysis"** is undertaken. This includes the annual **municipal solid waste survey**. Planning work begins late November to update the (e-) mailing lists with a full survey commencing in mid-January. A Waste-to-Energy Questionnaire tailored for EfW is used that addresses issues relating to use of waste as a renewable fuel. Survey return forms are collected and collated from January through to March. Gap analysis surveys also include ad hoc surveys such as the 2014 domestic wood consumption survey used to update the baseline.

For other technologies where surveys are not feasible, top-down estimates are based on market data combined with informed assumptions (such as heat pump characteristics and annual updates for domestic wood).

As part of this methodology note, a summary table of data sources by technology in excel format has been published and additional information is included in technology sections at: https://www.gov.uk/government/publications/renewable-energy-statistics-data-sources-and-methodologies

Table 4 below shows additional information by data source and how they are accessed:

Table 4 summary of data sources and access

Data Source	Owner	Frequency of data	Description	Years covered
Administrative data				
ROCs Register	Ofgem	Monthly	Name, Country, Technology, Installed Capacity, ROCs per MWh, Month of output, ROCs issued	2002+
Feed-in Tariff (FiT) Register	Ofgem (DESNZ summary)	Monthly	Installation level register of all schemes on FITs	2010+
Renewables Heat Incentive (RHI) Register	Ofgem	Monthly	Contribution from these schemes is increasing and data are now being used to measure growth rates against an agreed baseline figure (e.g., Plant Biomass)	2010+
Contract for Difference (CfD)	LCCC	Live database	Sites registered for support under CfDs	2016+
CHPSTATS, the Combined Heat and Power STATisticS database	Ricardo on behalf of DESNZ and Defra[8]	Annually	Data on schemes accredited under CHP quality assurance scheme (CHPQA)	1992+
RTFO data	DfT	Annually	Type and quantity of biofuels used for transport	2008+
Hydrocarbon oils bulletin data (National statistics)	HM Revenue & Customs	Quarterly	Hydrocarbon oils bulletin data (National statistics).	2002+
Wood chip/pellet trade data	HM Revenue & Customs	Monthly	Volumes of exports and imports of wood pellets and chips, by commodity code and nation	2009+
Surveys (DESNZ / Ricardo)				
Major Power Producers (MPP) Survey	DESNZ	Monthly	MPPs currently defined as those organisations whose portfolio of projects have a	2005+

[8] Department for the Environment, Food, and Rural Affairs

			total installed capacity of ≥ 50MW	
Biofuels production survey	DESNZ	Annual gap analysis survey	Further info below in Section 10.9	2002+
Energy from Waste survey (EfW)	Ricardo	Annual gap analysis survey	Further info below in the dedicated section	1989+
Domestic Wood Use Survey	Ricardo / DESNZ	Gap analysis ad hoc survey (2014 baseline revision)	Baseline revision for domestic wood in year 2014 and back-corrected to 2008 but superseded in 2021. Further details in the dedicated Section.	2014
Surveys (Other)				
Cereal and Oilseed Production survey	Defra	2014	Information on straw consumption. Back corrected to 2010	2014
Research on burning in UK homes and gardens	Defra	2018-2019	Baseline data from survey, back corrected to 2008. Further details below in the dedicated Section.	2018
Databases				
Renewable Energy Planning Database (REPD)	DESNZ/ Barbour ABI	Quarterly	Renewable electricity schemes undergoing the planning process Currently limited to projects ≥ 1MW	2006+
ROCs Database of Accredited Generating Stations	Ofgem	Live database	Fields used: Name, Country, Technology, Declared Net Capacity, Commissioning Date, Registered address	2002+
ROO-FIT	Ofgem	Monthly	Preliminary accreditation under Feed in Tariff	Most recent year
Microgeneration Certification Scheme (MCS)	Gemserv	Monthly		2010+
British Hydropower Association Database	British Hydropower Association		New site data and information for cross checking	
Solar Thermal Markets in Europe Plus, archived material	European Solar Thermal Industry	Annual	Summary of EU sales data	2004+

	Federation (ESTIF)			
UK Solar Thermal Statistics	Solar Trade Association (STA)	Monthly	Summary of UK sales data; does not cover all sales so some estimation made	1990+
Clinical Waste; database of all UK clinical waste incinerators	Environment Agency (EA)	Gap analysis ad hoc survey	Starting point for the Gap Analysis Survey.	**2010+**
Non Fossil Fuel Obligation (NFFO) Database; includes Scottish Renewables Obligation (SRO) and the Northern Ireland NFFO (NI-NFFO)	Non-Fossil Purchasing Agency (NFPA) for England, Wales and Scotland	Monthly		1991+
Landfill Gas Sites list	Environment Agency (EA)	Gap analysis ad hoc survey	These data are used as a starting point for the Gap Analysis Survey.	
RenewableUK Wind Database	Renewable UK (formerly, the British Wind Energy Association)		Cross checking of addresses and Installed Capacities; data on small-scale wind	
DESNZ commissioned data				
Heat pump sales data	Building Services Research and Information Association (BSRIA)	Annual	Annual Information on number of new ASHP and GSHP installations	2008+
Cement industry production report.	British Cement Association (via DESNZ)	Annual	Type and quantity of renewable fuels (including tyres) used for cement production.	2000+
National Non Food Crops Centre (NNFCC) list of operational Anaerobic Digestion sites	Defra/DESNZ	Annual	Used in Farm AD; interactive map available.	2013+ (back corrected to 2010)
WRAP list of operational anaerobic digestion sites	Waste & Resources Action Programme (WRAP)	Annual	Map of operational AD sites	2014+
Stove sales data	HETAS	Annual	Growth estimates from HETAS.	2005+

Metrics

Electricity Capacity

Capacity is taken as that operational at the end of the reference period (i.e. year or quarter). For larger sites that are under construction, this may be only a portion of the final capacity. This particularly applies to wind farms (especially offshore), where turbines are installed and commissioned incrementally. For co-firing sites where capacity data are not available, it is calculated by dividing generation by the number of hours in the reference period.

Installed Capacity ("Nameplate Capacity")

Installed Capacity, is the capacity the manufacturer claims the plant can produce. Total Installed Capacity is used where possible; where this is not available (for example, non-MPP sites that are RO accredited, but not yet in receipt of ROCs), **Declared Net Capacity** (DNC) is used.

Declared Net Capacity (DNC)

DNC is defined as the maximum continuous rating of the generating sets in the stations that can be exported to the grid, i.e. less the power consumed by the plant itself and any grid constraints.

To take into account the intermittent nature of some of the renewable energy sources, a factor (B) is applied. Although this method is not directly used in Chapter 6 (It is however applied in Chapter 5), it is a requirement of International Energy Agency (IEA) reporting.

DNC represents the nominal maximum capability of a generating set to supply electricity to consumers; it is calculated from the following equations:

$$DNC = (\text{installed capacity} \times B) - (\text{in-house load})$$

B has the following values for the different renewable sources.

B	**Resource**
0.43	Wind
0.17	Solar
0.33	Tidal/Wave
0.55	Small-scale hydro
1.00	All Others

Electricity Generation

Actual Generation

When available, actual generation data are utilised. This is available from the following sources:

- MPP Survey
- ROCs issued data
- Annual Energy from Waste (EfW) survey
- CHP Stats

For ROCs, for each entry, generation-equivalent figures (MWh) are calculated as:

ROC issued/ROCs per MWh.

Estimated Generation

Actual generation data may not always be available either entirely, because the site is not covered by the data source, or partially due to time lags.

Where generation data are not directly available, an estimate is derived using the capacity and applying typical monthly load factors (by region if possible) from similar installations.

This particularly applies to ROCs issued data, where the final month of the quarter are not available in time for compiling the quarterly Energy Trends tables.

For FiTs schemes, few are covered by the MPP survey. Therefore, this is carried out at a detailed level, considering commissioning date, summarised in the following methodology:

www.gov.uk/government/statistics/energy-trends-december-2013-special-feature-article-estimating-generation-from-feed-in-tariff-installations

Where actual generation is available for some FiT-supported schemes, these values are deducted from the above estimates.

Curtailment

Curtailment is where generators are required to reduce their output or temporarily suspend generation by the National Grid. This occurs at times when the amount of electricity being supplied to the grid is greater than total demand. Curtailment tends to affect wind generation more than other technologies as it is harder to predict output for wind than it is for thermal electricity generation. The generation data presented in these statistics do not include the amount that has been curtailed. Therefore, total generation at times of curtailment is lower than could have been expected.

More details on how the grid is balanced can be found on the National Grid website at: https://www.nationalgrideso.com/electricity-explained/how-do-we-balance-grid .

Fuel Input

Actual Fuel Use

The following sources provide actual fuel inputs:

- MPP Survey
- Annual EfW survey
- CHP Stats

Estimated Fuel Use

For installations without fuel use data, this is estimated by applying **typical thermal efficiencies** to generation data. As for load factors, these are derived from sites where both generation and fuel use data are available.

For CHP schemes, the amount of fuel used is allocated between electricity and heat, according to the CHP methodology. Further information is available via the following link:

https://www.gov.uk/government/statistics/combined-heat-and-power-chapter-7-digest-of-united-kingdom-energy-statistics-dukes

Load Factors

Load factors measure of the ratio of actual electricity generated to the amount that could potentially be generated if the installed capacity were operating continuously throughout the year. There are different ways of estimating the load factor.

Load Factor based on average capacity

The installed capacity is calculated as the average of the capacity at the beginning and end of the year, expressed as:

$$\frac{E}{\frac{C_b + C_e}{2} \cdot h}$$

E	Electricity generated during the year (kWh)
C_b	Installed capacity at the beginning of the year (kW)
C_e	Installed capacity at the end of the year (kW)
h	Hours in year

Changes in capacity during the year can also affect load factors calculated using this methodology; for example, removing Ironbridge from the plant biomass load factor calculation in 2015 resulted in a 1.8 percentage point reduction in the load factor. This is because Ironbridge ceased operating in the latter part of the year, resulting in a larger impact to the numerator compared to the denominator which is averaged.

Load Factors on an "unchanged configuration" basis

To compensate for changes in capacity throughout the year, a second capacity measure is calculated on an **"unchanged configuration" basis**, and is included in DUKES Table 6.5. This calculation is restricted to those schemes that have operated continuously throughout the year without a change in capacity. One of the inputs to the unchanged configuration calculation is data on issued ROCs, and a site is included in the calculation only if it has been issued ROCs for each month during the calendar year. The formula for calculating the unchanged configuration load factors is:

$$\frac{E}{C_u \cdot h}$$

E Electricity generated during the year (kWh)

C_u Installed capacity operating throughout the year with unchanged configuration (kW)

h Hours in year

A full account of the exercise to derive these factors for wind can be found in *Energy Trends*, March 2006 pages 28 to 32[9].

Categorisation of schemes by consuming sector

For the purposes of informing policy, it is sometimes instructive to associate electricity generation figures from each scheme and the consumption of renewable heat with an economic sector in which most the energy is consumed. Schemes are therefore classified, where possible, in the RESTATS database according to the "Economic Sectors" in which they operate. These sectors include:

- Grid
- Own Use/Site
- Commercial
- Agricultural
- Industrial
- Domestic
- Public
- Utilities
- Other

[9] http://webarchive.nationalarchives.gov.uk/20101209103442/http://www.decc.gov.uk/media/viewfile.ashx?filepath=statistics/publications/trends/articles_issue/file43950.pdf&filetype=4&minwidth=true

Technologies

Wind

Onshore wind

Onshore wind is one of the most mature renewable energy technologies.

Multiple turbines are often sited together in ‘wind farms’ and the electricity generated is supplied to the electricity grid. In England and Wales, planning applications for large-scale (>50MW) wind farms are now handled by local authorities.

In the small-medium wind market (1.5–100 kW), generated energy is often used to satisfy on-site demand. Small-scale wind system technology can be subdivided into three categories: micro wind turbines (0–1.5 kW), small wind turbines (1.5–15 kW) and small–medium wind turbines (15–100 kW). The two main designs are the horizontal axis wind turbines (HAWT) and vertical axis wind turbines (VAWT).

In terms of operational characteristics, siting considerations and the value and nature of the market, small-scale wind systems vary markedly from large-scale units. Small-scale wind systems can be off-grid or on-grid; mobile or fixed; free-standing or building-mounted; or they can form part of combined installations, most commonly with photovoltaic systems. As a result, they have a greater range of applications, compared to large-scale wind turbines and can be used in commercial, public or domestic settings and as single or multiple installations providing power to communities.

Offshore wind

The Energy white paper[10] – which replaced the Renewable Energy Roadmap[11] after the UK exit from the EU – highlights offshore wind as a key technology that will help the UK reach its net-zero emissions by 2050. The paper sets a goal of up to 40 GW potential deployment by 2030.

In the development of the UK’s offshore wind capacity, the Crown Estate have run several leasing rounds under which areas of the seabed have been made available for the development of offshore wind farms. Round 1 started in December 2000, Round 2 in July 2003 and Round 3 in January 2010. Construction of some Round 3 capacity (Rampion) has

[10] https://www.gov.uk/government/publications/energy-white-paper-powering-our-net-zero-future
[11] https://www.gov.uk/government/collections/uk-renewable-energy-roadmap

already begun. The Crown estate published a detailed account of progress with operational offshore wind in 2016[12].

Hydro

Scale of schemes

Data are split by large and small schemes, using the following definitions:

Micro	Less than 50 kW
Small	Up to (and including) 5 MW
Large	Greater than 5 MW

Hydro generation is largely supported by administrative data; large scale via the MPP survey and ROCs data and small-scale from FiTs data.

Large-scale hydro cover plants with a capacity of 5 MW and over and most of these are located in Scotland and Wales where they mainly draw their water from high-level reservoirs with their own natural catchment areas

Hydro electricity generation schemes with a capacity below 5 MW are classified as small scale, with those less than 50kW referred to as micro-scale. These are schemes for either domestic/farm purposes or for local sale to electricity supply companies.

Historical Note

Prior to 2004 MPP was submitted in aggregate form and not broken down by site or size. This meant that some small-scale schemes were hidden within the generation data for the large-scale schemes.

Pumped Storage and Mixed

Generation for pumped storage is not included in renewables generation; however, the UK does have one plant, Foyers, which is primarily a pumped storage site but also receives natural flow supplies of water. In this case, a portion of generation is allocated to Natural Flow Hydro. This is calculated by the data provider (SSE):

Natural flow generation = Total generation – (Pumped storage electricity input*efficiency).

Whilst it is primarily a pumped storage site, the generation attributed to the natural flow component of this station can be calculated and is included in the large-scale hydro generation figures in this Chapter. However, the natural flow share of the capacity cannot be separated and is therefore not included.

[12] www.thecrownestate.co.uk/media/1050888/operationalwindreport2017_final.pdf

Solar photovoltaics (PV)

Photovoltaics (PV) is the direct conversion of solar radiation into direct current electricity by the interaction of light with the electrons in a semiconductor device or cell. Within the UK, PV installations are primarily either ground-mounted solar farms, usually built on low-grade farmland and disused facilities (e.g., airfields) or rooftop devices mostly retrofitted to existing buildings.

Pre-FiT estimates

Until 2009, Solar PV capacity was estimated from both aggregate estimates plus small individual site data under the RO. Some of this estimated capacity (14.6 MW) has been carried forward into future years, though sites subsequently accredited under the FiT and RO schemes, capacity and generation figures are deducted to avoid double counting. From 2010 to March 2019, it is assumed all new solar installations area captured in the current (listed) data sources. Since the closure of FiT in March 2019, only new solar installations which are registered with the Microgeneration Certification Scheme (MCS) are now captured in the data.

Marine energy (wave and tidal steam power)

In 2015, The Crown Estate announced a new programme of leasing for small scale wave and tidal current test and demonstration projects under 3MW. This allows developers to apply for leases when their technology is ready, and they have raised sufficient finance rather than being restricted to leasing calls. This provides greater opportunities for tidal turbines of 100kW or less to be deployed.

Wave Energy Scotland continue to provide research and development funding to a number of **wave developers** to look at ways of improving the performance and reliability of wave device subsystems and components. Innovate UK have also opened a call to support wave and tidal projects. Wave energy deployment in the UK is still limited to early prototypes. The UK Government review of tidal lagoons was published at the end of 2016. This concluded that tidal lagoons could play a cost-effective role in the UK’s energy mix. The review recommends a less than 500MW pathfinder project is identified to take forward as tidal lagoons would help deliver security of supply; they would assist in delivering our decarbonisation commitments; and they would bring real and substantial opportunities for the UK supply chain.

Deep geothermal

Deep geothermal electricity generation was supported under the RO and is now eligible for support under the Contracts for Difference. Deep geothermal energy for direct heat use, defined as coming from a drilling depth of at least 500m, is eligible for support under the

Renewable Heat Incentive. The tariff is currently set at 5.22p/kWh (commissioned on or after 4 December 2013) from 1 April 2015.

Landfill gas

Landfill gas is a methane-rich gas formed from the natural decomposition of organic material in landfill sites. The gas can be used to fuel reciprocating engines or turbines to generate electricity or used directly in kilns and boilers. In other countries, the gas is cleaned to pipeline quality or used as a vehicle fuel.

The load factor continues to steadily decrease, as the gas producing resource becomes depleted. Landfill operators respond to reducing gas yields by removing modular generating sets when it is no longer economic to run.

Sewage Sludge Digestion

The majority of sites are covered by CHP Quality Assurance (CHPQA) Programme.

For plants outside the CHPQA generation is sourced from ROCs data and estimates of electrical efficiencies and heat to power ratios typical of the technology and capacity are used to determine fuel inputs and heat outputs.

Anaerobic Digestion (AD)

The biomass fuel includes wet wastes such as animal manures and slurries, crop residues and food waste and/ or purpose grown crops such as maize. The biogas can be used for process heat, or for heat and electricity generation using a combined heat and power unit. Alternatively, the biogas can be upgraded to biomethane by removal of the carbon dioxide and cleaning/ conditioning the gas for use in transport applications or injection into the gas grid. Increasingly the energy requirements for the biomethane production are provided by an on-site CHP powered by biogas. The CHP unit may also export excess electricity to the grid.

The indigestible material left after the AD process is called digestate. This is rich in nutrients and can be used as a fertilizer. Digestate can be used whole and spread on land. Alternatively, it can be separated into liquor and fibres. Separated fibre can be used fresh as a soil conditioner or, after further aerobic composting to stabilise it, used as a compost product.

Information on operational AD sites in the UK was obtained from several sources including the CHPSTATS database, the AD portal run by the National Non-Food Crops Centre (NNFCC), Anaerobic Digestion & Bioresources Association (ADBA), the Renewable Energy

Planning Database, Waste & Resources Action Programme (WRAP), ROC, FiT and RHI returns and Ricardo internal information.

Electricity and heat production was estimated using CHPSTATS survey information, where available, or information from ROC, FiT and RHI if no survey information existed. Where none of these sources was available, the energy production was calculated from the capacity using an estimated load factor. The load factor was based on ROC data from operating schemes for electricity schemes, and on historic load factors for heat only schemes.

Biogas grid injection

Some AD and sewage gas is injected into the main GB gas network. In the renewables energy balance, this is considered a statistical transfer of biogas from renewables to natural gas. Prior to 2015, figures for biogas injected into the grid are reported together with sources used to generate heat to prevent disclosure of the few operational schemes. This is sourced from a variety of sources, including the ADBA, NNFCC, REPD, WRAP and RHI data.

Production rates of biogas (in Nm^3/h) for newly opened schemes are lower than at full load and the amount of biogas injected into the grid by those schemes is therefore estimated using a variable production rate for their first months of operation, at which point they are assumed to reach their declared maximum rate. Figures for subsequent years are then calculated using maximum production capacity.

Animal biomass

The first small-scale CHP poultry litter combustion project began generating towards the end of 1990 but was subsequently closed due to new emissions regulations. It provided useful data which resulted in the World's first poultry litter-fired power station in 1992 closely followed by a second in 1993. Further schemes started generating in 1998, 2000 and 2001. One of the earlier poultry litter projects was modified to be fuelled mainly by meat and bone; two additional schemes fuelled primarily by meat and bone have also been built.

Wastes

Domestic, industrial and commercial wastes represent a significant resource for materials and energy recovery. Unprocessed wastes may be combusted in purpose-built incinerators or the waste can be processed into a range of refuse derived fuels (RDF) for both on-site and off-site use. RDF can be partially processed to produce coarse RDF that can then be burnt in a variety of ways. By further processing the refuse, including separating off the fuel fraction, compacting, drying and densifying, it is possible to produce an RDF pellet. This pellet has around 60 per cent of the gross calorific value of British coal. Only the biodegradable portion of waste is counted in renewables statistics although non-biodegradable wastes are included in this chapter as "below the line" items. The paragraphs below describe various categories of waste combustion in greater detail.

Wastes include Municipal Solid Waste (MSW), General Industrial Waste (GIW), hospital waste and waste tyres. The European Union's Renewables Directive (RD) of October 2001 redefined what were to be regarded as eligible renewables[13]. This included only the non-biodegradable component of wastes (the same as the international definition used). Generation from these sources would be split between biodegradable sources and non-biodegradable sources using information on calorific values of the constituent parts.

Municipal solid waste (MSW) combustion

These wastes are primarily burnt in purpose-built combustion facilities fitted with enhanced flue gas treatment. There is considerable interest in the use of Advanced Conversion Technologies (ACT) as an alternative treatment technology but there are known to be technical issues with several of the facilities.

Information on the direct combustion of unprocessed MSW and the combustion of refuse derived fuels (RDF) was obtained via the RESTATS waste to energy survey

Only the biodegradable component of MSW is counted as renewable. For several years, research estimated that UK domestic waste had a biodegradable content of 67.5 per cent ± 1 per cent and this accounted for about 62.5 per cent of the energy generated from its combustion. Further research in 2009 resulted in an upward revision to 63.5 per cent.

Sample areas for the analysis of household collected waste are selected using ACORN socio-economic profiles (ACORN stands for A Classification Of Residential Neighbourhoods). This is based on the premise that households of similar socio-economic characteristics are likely to have similar behavioural, purchasing and lifestyle characteristics; this will be reflected in the quantity and composition of waste that those households produce.

The success of recycling initiatives has gradually changed the composition of waste available for combustion and the biodegradable content, reducing the share over the years. Additional research and evidence gathering indicated that the renewable content had fallen to 50 per cent in 2014.

As no time series data are available between 2009 and 2014, a linear change in composition over this period was assumed, see Table 5 below:

[13] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32001L0077

Table 5 biodegradable share of EfW

Years	Value	Source
Pre-2009	62.5%	Defra study
2009	63.5%	Defra study
2010	60.8%	Estimated (linear change between 2009 and 2014)
2011	58.1%	
2012	55.4%	
2013	52.7%	
2014+	50.0%	Various studies

General Industrial Waste (GIW) combustion

Certain wastes produced by industry and commerce can be used as a source of energy for industrial processes or space heating. These wastes include general waste from factories such as paper, cardboard, wood and plastics. A survey conducted in 2001 noted that GIW was now burnt in MSW waste-to-energy facilities. As no sites are solely burning GIW for heat or electricity generation, this feedstock is being handled under the MSW category.

Specialised waste combustion:

Specialised wastes arise because of a particular activity or process. Materials in this category include scrap tyres, hospital wastes, poultry litter, meal and bone and farm waste digestion.

Hospital waste

The combustion of clinical waste has been used to produce both heat and electricity. The results of the survey showed an ongoing process of centralisation and consolidation, in response to changes in pollution emissions and clinical waste regulations. Generation has now focused on larger plants with many smaller facilities closing as the cost of compliance with regulations made them no longer viable.

At present, all hospital waste is also considered non-biodegradable.

Information is based on a RESTATS survey undertaken in 2007, repeated in 2010 and reviewed again in 2013. Additional information on sites that reclaim energy is obtained from the Environment Agency’s clinical waste incineration database.

Tyres

Prior to 2017, all waste tyres were considered non-biodegradable. However, tyres do in reality have a renewable component and in order to provide a more accurate picture of waste’s contribution to renewable energy, the EU emissions assumption has been used.

Although a dedicated tyre incineration plant with energy recovery has not generated since 2000, the cement industry has burned some waste tyres in its cement and lime kilns. Although part of waste tyre combustion is of biodegradable waste, this small biodegradable content has currently been included under non-biodegradable wastes in this chapter.

Active Solar Heating

Planning permission is required for free-standing domestic solar panels of more than $9m^2$, but the more common form of installation is the roof mounted scheme which does not require planning permission.

Active Solar heating includes solar collectors used for domestic hot water (DHW) systems and swimming pools. For both components, consumption is estimated. Due to refinements to the methods (and limited revisions windows), there are breaks in the series at 2008.

Estimates of annual installations

First, the number of annual installations is estimated, consisting of two inputs:

- DHW: Using UK STA sales data, with scaling factor[14] of 1.2 applied, to take into account that the whole market is not covered by the UK STA.
- Swimming pools (not covered by the STA).

Pre-2010, the growth rate in swimming pool installations is higher.

Quantity of energy supplied

Second, the quantity of the energy supplied is estimated, based on the quantity of fossil fuel that is displaced by its use. The split between gas, electricity and oil (that would otherwise be used to provide the heating demands) are based on a model using a conversion methodology recommended by the IEA Solar Heat and Cooling Programme and ESTIF:

http://www.estif.org/no_cache/st_energy/area_to_energy_conversion_method/?sword_list[]=method

In the case of domestic hot water, the estimated split between gas and electricity displaced by this technology is 80% and 20%, respectively. In the case of swimming pools, the estimated split between gas, oil and electricity savings is 45%, 45% and 20% respectively, an estimate informed by the Solar Thermal Alliance (STA).

[14] From discussions between DESNZ, the STA and ESTIF

Equipment replacement

From 2010, the model incorporates **equipment replacement** after 20 years of operation and for a small reduction in efficiency with age of the system.

Plant Biomass

Energy crops, forestry residues and pellets

Miscanthus and Short Rotation Coppice (SRC) are grown in the UK as energy crops intended for the heat and electricity energy markets. To date they have been burnt in power stations, CHP units and heating systems. Official area estimates of Miscanthus and SRC grown in England are available from 2008 in the Defra June survey of Agricultural statistics, and have been summarised by Defra[15].

The largest component of plant biomass is under the form of wood pellets, which are used to generate electricity at several major power plants that have been converted from coal use. Pellets are a form of fuel made of compressed organic matter.

Under the plant biomass heading are also reported sunflower pellets, peanut husks and other types of biomass that are not specified.

Straw

Straw can be burnt in high temperature boilers, designed for the efficient and controlled combustion of solid fuels and biomass to supply heat, hot water and hot air systems; there are large numbers of these small-scale batch-fed whole-bale boilers.

Pre 2014

The estimates for straw used for heat were based on a combination of 1990 information and a survey of straw-fired boilers carried out in 1993-94.

2014 onwards

The end-use of straw was added to the DEFRA Cereal and Oilseed Production survey in 2014[16]. Straw used for heat is calculated by deducting from this straw used for electricity generation, in the form of co-firing and in dedicated straw power stations.

As no time series data are available to amend historic time series data or estimate growth rates, a linear growth rate has been assumed to back-correct to 2008. The same value for 2014 has been maintained.

[15] www.gov.uk/government/statistics/area-of-crops-grown-for-bioenergy-in-england-and-the-uk-2008-2015

[16] www.gov.uk/government/uploads/system/uploads/attachment_data/file/483812/nonfood-statsnotice2014-10dec15.pdf

Wood

Domestic wood

Several methods have been used to estimate domestic wood consumption, with corresponding breaks in the time-series at 2000 and 2008.

Pre-2003:

The annual consumption estimate was based on a survey carried out in 1989[17].

2003-2007:

In 2003, the method was re-examined. From this, domestic wood use figures were based on a 50 per cent growth rate in sales/installations of wood-burning stoves for each 2/3-year period since 2000, supported with anecdotal information from the sources listed below:

- HETAS, the official body recognised by Government to approve solid fuel domestic heating appliances, fuels and services,
- the National Association of Chimney Sweeps, and
- Discussions with a risk assessor acting on behalf of insurance companies.

Estimates from 2003 to 2013 were based on 2002 baseline data that were then extrapolated forward using information from annual discussions with representatives of the associations listed above. The estimates were then peer reviewed by the Forestry Commission prior to publication

Degree-day corrections were added, based on those used for seasonally adjusted and temperature corrected final energy consumption figures for gas, to model increased fuel use during colder weather[18]. These degree-day normalisation factors are based on monthly correction data and are weighted differently to those calculated using annual degree days.

2008-2019 (now superseded)

In 2014 DESNZ commissioned a one-off, large scale, **user survey of domestic wood fuel consumption** in the UK to provide a new baseline. The survey was part of a weekly face to face omnibus survey and was conducted in England, Wales and Scotland. A separate dedicated survey was commissioned in Northern Ireland. A total of 16,046 households were surveyed, with 1,206 (7.5 per cent) confirmed as wood fuel users. Information was collected on number, type and frequency of use of domestic wood fuel appliances and on types and quantities of wood fuels purchased over the previous year.

The survey confirmed that closed stoves and open fires remain the most common wood fuel appliances installed. These appliances are usually used to supply some of the home

[17] ENERGY FROM BIOMASS Volume 3: Converting Wood Fuel to Energy ETSU BM/04/00056/REP/1
[18] www.gov.uk/government/uploads/system/uploads/attachment_data/file/295406/et1_3.xls

heating, although about 12% of wood fuel users use wood as their main fuel. Logs remain the most common form of wood fuel (90% of wood fuel users). The survey indicated a substantial contribution to domestic wood fuel supply from the informal sector including from farmers, garden contractors, self-supply, foraging, and use of discarded wood.

Wood fuel use was estimated from **appliance use data**, rather than quantity estimates in accordance with expert advice that this would produce the most robust estimate. Data were used to estimate total hours of operation in the year and wood fuel use was then calculated using standard data for appliance wood fuel use per hour. The appliance method is indirect in that respondents had to estimate how many hours per week they operated their appliances in winter and summer, and a standard factor for wood use per hour for each appliance type was required.

Further information may be found in the DESNZ publication on the summary of results of the domestic wood use survey[19].

The revised 2014 baseline was back corrected to 2010 using appliance sales figures provided by HETAS and applying a weather correction factor. This methodology was also applied to the 2015 estimate. For 2016, an additional assumption was applied based on new evidence that, given the maturity of the market, some installations would now be replacements rather than new. Accordingly, a 2 per cent replacement rate was applied based on the views of the Renewable Energy Association and Delta Energy and Environment.

2008-present

In December 2020, The Department for the Environment, Food, and Rural Affairs (Defra) published the results of research conducted by Kantar Public to **understand people's domestic burning behaviours**, including an estimate of wood fuel consumption for the residential sector[20].

The scope of Defra's survey, 'Burning in UK Homes & Gardens' was wider than DESNZ' 2014 survey and included outdoor burning and other non-wood fuels, as the policy context was to improve the evidence base on the overall contribution of domestic combustion to air pollution.

A first attempt to compare the outcome of the two surveys was published in March 2021's issue of Energy Trends, as a special article. **Defra's results came out as being quite different from DESNZ'**, estimating consumption for the year 2018 to about 700 ktoe, as opposed to the 2,200 ktoe previously estimated using the 2014 survey. However, both

[19] https://www.gov.uk/government/publications/summary-results-of-the-domestic-wood-use-survey [20] link to Defra's survey results

[20] link to Defra's survey results

surveys used the same typical fuel consumption assumptions for several appliances (to the exclusion of few, niche appliances which had negligible effect on the results) and produce similar estimates for the number of UK indoor wood burners (around 7%).

A key difference between the two methods is that, whilst DESNZ asked respondents to estimate their burning behaviour for an entire calendar year, Defra only prompted respondents to recall whether they had burnt during the preceding week, ensuring non-burning weeks were captured. It is likely that this is the main cause of difference between the two sets of results.

Defra employed a **hybrid methodology** to calculate an energy value for each respondent, whereas DESNZ relied only on hours of operations and appliance assumptions. In fact, Defra asked respondents both to provide hours of operation for their main appliance and to estimate the quantity of fuel they had burnt. Hours of operation were used to produce an energy value for each respondent; this was then apportioned to the energy values of each fuel calculated using fuel quantities. Once energy values were calculated, they were grossed by the number of households and, since the survey only covered the period from April 2018 to February 2019, an uplift factor was applied to the April 2018-February 2019 totals to obtain a full March year estimate; the uplift was based on Heating Degree Days (HDD) on an annual basis.

As DUKES energy balances are compiled on a calendar year, Gross Calorific Value (GCV) basis (Defra used NCVs), Defra supplied estimated figures for monthly fuel weights. Defra’s correction for March 2019 was removed prior to the calendar year estimate, so that a new profile could be estimated for the whole series.

To produce an estimate for the missing months of January-March 2018 and March 2019, a linear regression model was fitted to the aforementioned time series, using monthly Heating Degree Days (HDD) as a predictor. This also enabled to capture the effect of the particularly cold weather that stuck the UK between February and March 2018 (commonly known as ‘the Beast from the East), a period that is excluded from Defra survey.

Using the model’s estimates for the first quarter of 2018 together with survey data for the remaining months of 2018, the new 2018 baseline has increased to 733 ktoe. The new figure has then been incorporated into the energy balances and the series has been back-corrected to 2008, removing the effect of the previous 2015 baseline change.

Note on calorific values of wood fuel

Calorific values depend on the types and composition of the wood mix being burnt. Historically, these were reported on an ''as received' basis for freshly harvested fuels but was not considered typical of that used as fuel which would require seasoning before use. These have now been revised upwards following research into current typical values Gross Calorific Values (GCV) and Net Calorific Values (NCV) are now calculated on an ''as received' basis, based on a GCV for oven dry wood of 20.3 GJ/t (6% H content) and 20%

moisture content. These are in line with those reported by the Forestry Commission's Biomass Energy Centre (BEC) based on more detailed studies of typical wood feedstock compositions. Further information on calorific values is included in Appendix 2.

Non-domestic wood combustion

Use of sawmill residues, furniture manufacturing offcuts etc.as wood fuel (Industrial wood fuel use) has been included as a separate category since 1997. This wood is either used for heat or CHP in-house or is sold as wood fuel. Surveys in 2000 and 2006 showed that the in-house use of wood residues had declined due to the imposition of more stringent emissions controls. Typically, wood fuel is used for space heating and hot water in commercial and public sector properties such as hotels, schools, hospitals, nursing homes, poultry farms, horticulture, and government buildings.

Co-firing of biomass with fossil fuels

Compared with dedicated renewable facilities, co-firing has a relatively low capital cost and is quick to implement. Biomass fuel is usually fed into a conventional power station boiler by means of the existing firing mechanism as a partial substitute for fossil fuel. The pulverised fuel preparation, transport and combustion system of a modern power plant may cope with approximately 5 - 10 per cent substitution without any major mechanical changes. The boiler design and airflows however may permit much higher percentages if the burner systems are modified. Specially designed burners have been introduced on some installations in the UK. Interest in co-firing has now waned as this will no longer be supported under the RO: the last remaining capacity has in fact been dismantled in 2020, with some stations undergoing conversion to dedicated biomass firing.

Heat Pumps

Included technologies

Estimates are made of the renewable heat from:

- Air to water heat pumps (ASHP),
- Ground source heat pumps (GSHP),
- Exhaust air heat pumps and
- Reversible air to air heat pumps (RAAHP)

Methodology

The renewable heat contribution is calculated per the methodology prescribed in the Renewable Energy Directive 2009/28/EC on the promotion of the use of energy from renewable sources. Appendix VII Accounting of energy from heat pumps[21]. The break at 2015 has now been removed by continuing the inclusion of RAAHPs back to 2008. It is internationally recognised that the impact of heat pumps before 2008 was negligible.

Qualification

Prior to 2015 all heat pumps installed after 2008 were assumed to meet the minimum SPF of 2.5 prescribed in the Renewable Energy Directive, and annual hours of operation and Seasonal Performance Factor (SPF) were based on default values proposed by the European Commission in Commission Decision C (2013) 1082 final[22].

In line with advice from EUROSTAT[23], renewable heat from all domestic heat pumps, including those with SPF less than 2.5, should be included in the DUKES/ET statistics.

Heat Generation

Estimates of renewable heat generated are based on sales information from BSRIA on number of heat pumps installed annually since 2008. Sales data are split between small domestic, large domestic and commercial/ industrial ASHP and GSHP. Five per cent of GSHP installations in the commercial/ industrial category are assumed to be industrial.

The average capacity of heat pumps in each category is estimated by DESNZ from data on heat pumps installed under the RHPP and RHI. The allocation of heat pumps to climatic zones is based on the regional data available for schemes installed under the UK RHPP and RHI schemes, and the climate classification in the UK set out by EUROSTAT.[24]

The calculation for heat generated is

$$(C \cdot N_{inst} \cdot h_{\mathrm{HP}}) \cdot (\text{proportion} \geq 2.5\ \text{SPF}) \cdot \left(1 - \frac{1}{\text{SPF}}\right)$$

Where:	C	Average capacity
	N_{inst}.	Number of heat pumps installed
	h_{HP}	hours of operation
	SPF	Seasonal Performance Factor

For DUKES, the proportion of heat pumps meeting the minimum SPF is 10 0 per cent. For reporting progress against the Renewable Energy Directive it is based on research results (if available), or the 100 per cent default assumption as specified.

[21] http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A32009L0028

[22] http://ec.europa.eu/transparency/regdoc/?fuseaction=list&coteId=3&year=2013&number=1082&language=en

[23] Personal communication with Eurostat, April 2016

[24] Shares tool manual 2014. http://ec.europa.eu/eurostat/documents/38154/4956088/SHARES2014manual.pdf/1749ab76-3685-48bb-9c37-9dea3ca51244

2015-2016

Updated information on actual hours of operation and SPF of domestic heat pumps installed in the UK under the Renewable Heat Premium Payments (RHPP) scheme was used to estimate the renewable heat contribution for domestic heat pumps. This is in line with advice from the European Commission in Commission Decision C (2013) 1082 final[25] to utilise country specific information where available and to opt for conservative estimates.

2017

Up until 2017, heat from reversible air to air heat pumps (RAAHPs) was not included in renewable heat; it had been considered that, although they were numerous in the UK, they were used mostly for cooling which is not included in directive reporting. DESNZ commissioned a research project in 2017 to estimate, among other metrics, the number of RAAHPs which could provide heating as well as cooling, and also the proportion of time such heat pumps were operating in heating mode (as opposed to cooling). The full methodology note is available via the following link:

https://www.gov.uk/government/publications/renewable-energy-from-reversible-air-to-air-heat-pumps

Liquid biofuels in transport

Consumption

The primary source of data used are the detailed Department for Transport Biofuels statistics (used for the RTFO), which disaggregate by the various sub-categories of biofuels, which is necessary for the sustainability requirements and adjustments made under the RED (and in DUKES table 6.7). Year 2016 are based on information available from RTFO statistics[26] reports, specifically Y8 report 6 and Y9 report 3.

Due to lags in the above source, as an interim measure, and in table ET 6.2, timelier, but less detailed, data from the HMRC hydrocarbon oils bulletin are used[27]. For the final month in the latest quarter, data from this are not available and so are estimated according to patterns of overall petrol/diesel consumption.

Production and exports

Information on UK biofuels production is collected by means of an annual survey of large-scale biofuels producers, together with an estimate of small scale production. The sampling

[25] http://ec.europa.eu/transparency/regdoc/?fuseaction=list&coteId=3&year=2013&number=1082&language=en

[26] www.gov.uk/government/collections/biofuels-statistics

[27] https://www.uktradeinfo.com/Statistics/Pages/TaxAndDutybulletins.aspx

frame for the survey comprises companies on the RTFO account holders list that produce more than 450,000 litres per annum biofuel.

The survey asks about actual production and production capacity in the calendar year. It also asks about the end market for the biofuel and the feedstocks used in its production. Information is collated in a summary excel workbook and the results are summarised for biodiesel, bioethanol and biogas. Feedstock information is shared with Defra statisticians who use it to help estimate land and crop use for biofuels in the UK. The information on end markets is used to estimate the quantity of biofuels exported.

Small scale production is based on a 2012 estimate which used information from HMRC and industry associations.

Imports

Imports of biofuels are calculated by residual:

Imports = Consumption – (biofuels production – exports).

Quality Assurance

Data validation

Before data are imported into the RESTATS database, several checks are made, including:

- Data cleansing (removing any duplicate or closed sites), utilising GIS
- Cross-checking with other data sources for completeness
- 'Sanity' checks: a) are the load factors in the range expected for type of technology and the current years' seasonal variations for those technologies affected by this; b) are the time-series capacity data meaningful and change in an understandable way.

Duplication of sources

For many technologies, especially electricity, no single data source can provide complete coverage, therefore, several data sources are used. However, between the data sources, there is duplication of data for some sites. Whilst this provides good validation of the primary data source, decisions are made around which data source to use. Generally, survey data is preferred, ahead of administrative data.

Example: MPP v ROCs v NFFO

Typically, due to lags in data, MPP data is expected to exceed ROCs data, which in turn should be higher than NFFO data.

NFFO data therefore provide a good crosscheck with ROCs as these schemes are recorded in both databases. When ROCs first began, there were a few discrepancies primarily related to combustion schemes as the latter required proof of the nature and calorific value of the fuels and would result in a delay in the issuing of certificates. At present, there is usually a good correlation in >99% of the schemes.

Revisions

Where lags in administrative data collection occur and estimates are made, revisions will be made to subsequent publications to reflect that actual data have now replaced the estimates. Additionally, should evidence come to light suggesting previous estimates were incorrect, such as the 2014 domestic wood survey, previous year's data will be revised using back correcting methodologies. This eliminates any possible breaks in the time series.

For DUKES, a decision is made each year as to how many years will be revised; this is a chapter-wide discussion and each chapter lead will contribute to the decision. However, as a rule, every second year will be open for revisions for just two years.

Where data in the tables have been revised, an “r” will appear next to that number to indication a revised value. Any explanation of the revisions will also be discussed in the actual chapter along with the magnitude.

Appendix 1: Conversion Factors

Conversion factors are used to express energy figures in different units. Energy units used are therms, tonnes of oil equivalent (toe – the energy content of one tonne of oil), Megawatt hours (MWh) and Giga-Joules (GJ). The conversion factors used are not the same for each of the combustion technologies and do not convert all the energy released from the fuel into electricity, therefore the conversion factor needs to consider the energy lost during electricity generation.

These data are analysed to **standardised statistical methodologies** and conversion factors in line with International Energy Agency (IEA) and Statistical Office of European Commission (SOEC) definitions.

The conversion factors used are summarised in Table 6 below:

Table 6: conversion factors

Conversion Factors	Technology	Adopted IEA/SOEC Definitions
therms/toe toe/MWh MWh/toe	Standard conversion factors	396.83 0.08598 11.63
MWh_e/toe	Wind	11.63
MWh_e/toe	Hydro (small-scale <5MW)	11.63
MWh_e/toe	Hydro (large-scale ≥5MW)	11.63
MWh_e/toe	Wave Energy	11.63
MWh_e/toe	Tidal Currents	11.63
MWh_e/toe	Biomass electricity conversions, including Others Category, landfill gas + sewage.	3.05[28]
GJ/toe	All Heat Conversions	41.868

[28] This is a two-stage process; multiply by 11.63 to convert from MWh to toe thermal; then multiply by 0.262, the fractional electrical conversion efficiency, to convert from thermal to electrical toe.

Primary electricity contributions from wave, tidal, hydro and wind are expressed in terms of an 'energy-supplied' model.

Further information on conversion factors is available from Annex A in DUKES (this includes a section on calorific values, discussed in Appendix 2):

Digest of UK Energy Statistics (DUKES) - GOV.UK

Figures on fuel use for electricity generation can be compared in two ways. The fuel input basis (after conversion to an oil equivalent unit) is the most appropriate to use for analysis of the quantities of fuels used in electricity generation but it takes no account of how efficiently that fuel is converted into electricity. The output (energy-supplied) basis uses the amount of electricity generated and supplied by each fuel.

While biomass appears to dominate the picture when fuel inputs are being measured, hydroelectricity and wind power together provide a larger contribution when the output of electricity is being measured. This is because, on an energy supplied basis, the inputs are deemed to be equal to the electricity produced for hydro, wind, wave and solar. However, for landfill gas, sewage sludge, municipal solid waste and other renewables, a substantial proportion of the energy content of the input is lost in the process of conversion to electricity.

Appendix 2: Calorific Values for biofuels

Table 6 shows the estimated average Gross Calorific Values (GCV) and Net Calorific Values (NCV) for bioenergy that are used to convert the data from tonnes of fuel processed by the plant to its energy content.

Table 6: Calorific values of biofuels – 2020

Renewable Energy Source	Source		NCV (GJ/te)	GCV (GJ/te)	Moisture Content
Wood fuels[29]					
Domestic Wood	[30]		14.7	16.3	20%
Industrial Wood	[31]		19.0	20.3	0%
Wood pellets	[32]		17.3	18.7	8%
Short Rotation Coppice	[33]		12.6	14.2	30%
Other plant biomass					
Straw	[34]		13.4	15.7	15%

[29] Calculated on an ''as received' basis, based on a GCV for oven dry wood of 20.3 GJ/t (6% H content). These are now in line with those reported by the Forestry Commission's Biomass Energy Centre which was based on data gathered by the team.
[30] NCV and GCV calculated on an ''as received' basis, based on GCV for oven dry wood of 20.3 GJ/t (6% H content) and 20% moisture content. These are now in line with those reported by the Forestry Commission's Biomass Energy Centre which was based on data they gathered.
[31] Based a GCV for oven dry wood of 20.3 GJ/t (6% H content) and 0% moisture content. These are now in line with those reported by the Forestry Commission's Biomass Energy Centre which was based on data they gathered.
[32] Based a GCV for oven dry wood of 20.3 GJ/t (6% H content) and 8% moisture content. These are now in line with those reported by the Forestry Commission's Biomass Energy Centre which was based on data they gathered.
[33] Based a GCV for oven dry wood of 20.3 GJ/t (6% H content) and 30% moisture content. These are now in line with those reported by the Forestry Commission's Biomass Energy Centre which was based on data they gathered.
[34] Straw, Poultry Litter and Energy Crops as Energy Sources ENERGY FROM BIOMASS Volume 5: ETSU BM/04/00056/REP/3

Animal biomass					
Poultry Litter	DESNZ MPP survey		10.0	12.5	20%
Meat and Bone	As above		16.2	18.3	11%
Wastes					
General Industrial Waste	EfW survey		15.2	16.0	5%
Hospital Waste	[35]		13.3	14.0	5%
Municipal Solid Waste	EfW survey		6.8	9.8	30%
Refuse Derived Fuel	[36]		13.0	18.5	30%
Tyres	[37]		30.4	32.0	5%
Transport biofuels					
Biodiesel	[38]		37.2	38.7	4%
Bioethanol	[39]		26.8	29.7	10%
Biogases			**NCV (MJ/m^3)**	**GCV (MJ/m^3)**	
Landfill Gas	[40]		19-23	21-25	
Sewage Gas	" "		19-23	21-25	
Biogas (Anaerobic Digestion - farm/food)	" "		19-24	21-26	

Additionally, a time series for calorific values are published as an Excel spreadsheet and can be accessed via the following link:

[Digest of UK Energy Statistics (DUKES): calorific values - GOV.UK]

[35] Current Practice in Hospital Waste Disposal, Scott P.J., J. Institute of Hospital Engineering, 1989 43 (2). Discussed every 3-4 years against data held by the Environment Agency but considered essentially unchanged
[36] Mitsui Babcock Energy Ltd, Studies on the Thermal Processing of Biomass and Waste Materials. Report No: ETSU B/T1/00358/REP (1997)
[37] The Use of Waste Tyres as a fuel at a Tyre Remoulding Factory. Prepared by NIFES for ETSU acting on behalf of the Energy Efficiency Office ED/194/143 (1988)
[38] Based on data published in BIOGRACE (the EC GHG emissions calculation tool)
[39] Based on data published in BIOGRACE (the EC GHG emissions calculation tool)
[40] Calorific value varies depending on the methane content of the gas

Fuel Calorific Value and Moisture Content

The calorific value (CV) of a fuel is the heat available from that fuel when it is completely burned, expressed as heat units per unit of fuel weight or volume.

The gross, or higher, value (GCV) is determined in the laboratory using a calorimeter. It can be defined as the total heat liberated by the complete combustion of the fuel. It is determined by measuring the heat removed when cooling the products of combustion to a standard reference temperature, and it includes latent heat recovered from condensation of the water vapour component. This water vapour forms either as a by-product of combustion from hydrogen contained within the fuel, or from the vaporisation of any moisture present.

The net, or lower, value (NCV) is determined by calculation[41] and equals the gross calorific value minus the latent heat of the water vapour either formed as a by-product of combustion or present as moisture present in the fuel.

The net value is more representative of the heat available in practice when fuels are burned in equipment such as furnaces and boilers. The latent heat of the water vapour contained in exhaust gases is not normally recoverable, except where low-temperature heat recovery involving condensation is used.

Calorific values for the biomass fuels above are usually quoted on an **"as received" basis** which includes the effect of the moisture in the fuel. Other bases are used such as dry, air-dried, oven-dried etc., for particular purposes[42].

The Biomass Calorific Value Calculator (advanced) developed by the New Zealand Forest Research Institute Limited is very useful for use with wood and it is recommended that such tools are used to gain a more meaningful insight [43]

The calorific value of **used poultry litter**, and the effects of moisture content, was investigated as part of the independent monitoring of the Energy Power Resources (formerly Fibropower) Eye power litter-fired power station commissioned by the former DTI[44].

On an as received basis, the moisture content typically ranges from 25 - 50% throughout the season. The Net Calorific Value (NCV) is variable but typically in the range 10-12 GJ/te. Its variation with moisture content is shown in Figure 1.

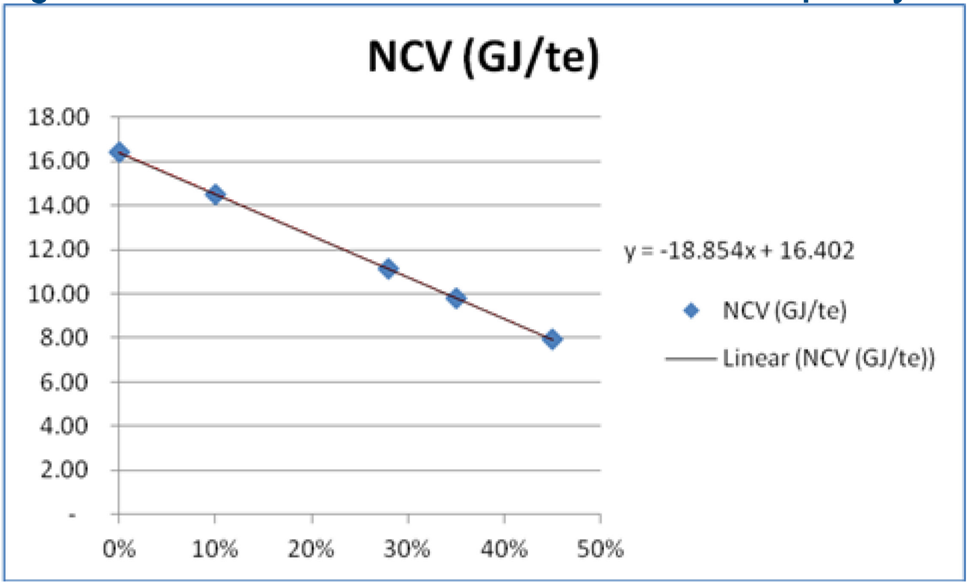
[41] http://www.biodat.eu/pages/FuelSpecificationCalculation.pdf

[42] http://p29596.typo3server.info/fileadmin/Files/Documents/05_Workshops_Training_Events/Taining_materials/english/D19_6_EN_Solidbiofuels_properties.pdf

[43] http://www.eecabusiness.govt.nz/wood-energy-resources/biomass-calorific

[44] Use of Poultry Litter for Power Generation - Monitoring of 'Eye' Power station. FEC Ltd. ETSU B/FW/00235/REP Crown Copyright (1995)
Available via the British Lending Library

Figure 1: Net calorific value and moisture content of poultry litter



Appendix 3: Combined Heat and Power (CHP)

A CHP plant is an installation where useful heat and power (usually electricity) are supplied from a single generation process. Some CHP installations are fuelled either wholly or partially by renewable fuels. The main renewable fuels currently used in CHP are sewage gas, biomass, municipal solid and industrial waste and anaerobic digestion from farm/food waste feedstocks.

Chapter 7 of this Digest summarises information on the contribution made by CHP to the UK's energy requirements using the results of annual studies undertaken to identify all CHP schemes (CHPSTATS). Included in Tables 7.1 to 7.9 of that chapter is information on the contribution of renewable sources to CHP generation in each year from 1996 onwards. There are occasionally differences in the numbers reported by CHPSTATS compared with RESTATS that are primarily attributed to whether the electricity is considered to come from 'good quality' CHP (further details on 'good quality' CHP are provided in Chapter 7). In addition, there are oddities with some CHP facilities where both biomass and fossil fuels are burnt (though not always as co-firing). The total installed capacity recorded for the site under CHPSTATS can cover multiple generators, some of which only handle fossil fuels (e.g., gas turbines). As it would be misleading to record the entire capacity reported in RESTATS as being potentially available for renewables generation, only the appropriate capacity figures are recorded.

Appendix 4: Renewable Energy Directive

The Renewable Energy Directive (RED), which came into EU law in April 2009, is designed to help Member States progress towards meeting the EU 2020 target of 20% energy derived from renewable sources. As the UK has left the EU in 2020, reporting the UK progress against the target is no longer a legal requirement. For the year 2020, a final report has been published in DUKES. The target for the UK was 15% of **final energy consumption** calculated on a net calorific basis[45]. Reporting for RED has a major impact on the contribution from biomass which historically has been calculated based on the energy content of the fuel. In addition, 10% of energy used in transport had to be renewable. This has resulted in changes to the methodology required to provide data to monitor progress to this target. Data were reported annually to Eurostat, with comparative statistics on progress for all member states[46].

The RED uses different measures of both renewables and overall energy from those elsewhere in the Digest. The renewable numerator in the calculation uses 'normalised' wind and hydro generated electricity – combined with other actual electricity generated from other sources, energy for heating and cooling by final consumers, as well as the use of energy for transport purposes. Gross final energy consumption (which is calculated on a net calorific value basis) also includes consumption of electricity by power generators, consumption of heat by heat generators, transmission and distribution losses for electricity, and transmission and distribution losses for distributed heat. Normalised generation is calculated by applying an average load factor to current capacity. For wind, the load factor is calculated as the average of the past five years (including the present one), with current capacity taken as an average of the start and end of year capacity. For hydro, the load factor is the average of the past 15 years, applied to capacity at the end of the current year. The generation figures obtained from this procedure replace the actual generation figures for wind and hydro in the Directive calculation. The energy generated by heat pumps is also calculated differently; only heat pumps which meet a minimum Seasonal Performance Factor (SPF) of 2.5 are included as prescribed by the Commission's guidance for calculating renewable energy from heat pumps[47].

[45] Renewable Energy Directive http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:EN:PDF
[46] http://epp.eurostat.ec.europa.eu/portal/page/portal/energy/other_documents
[47] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32013D0114

Additionally, the Directive includes a cap on the proportion that air transport can contribute to the total; this cap is currently 6.18 per cent. Certain fuels also receive a higher weighting in the calculation, with full details being set out in the Directive[48].

In the UK, energy balances are usually published on a gross calorific value basis. However, to facilitate comparisons with international statistics, the balances are also available on a net calorific basis in table I1[49].

When measuring the contribution of transport biofuels for the Renewable Energy Directive, only those meeting sustainability criteria count. The data referred to above do not contain sustainability information, including those which carry a higher weighting (mostly sourced from waste), and the table which does, is usually not a complete data set for the time DUKES is published. This is due to the RTFO allowing suppliers to make claims for RTFCs up to August after the obligation period (to allow suppliers to optimise their supply chain verification processes), as well as, allowing sufficient time for DfT to make necessary compliance checks before applications are processed. An estimate of the proportion of compliant bio liquids and the proportion meeting the double credited criteria (mostly those from waste sources) is also reported.

[48] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:EN:PDF

[49] www.gov.uk/government/statistics/energy-chapter-1-digest-of-united-kingdom-energy-statistics-dukes