# UK Historical Energy Dataset

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**for the National Infrastructure Commission (NIC)**

**to accompany the NIC's UK Historical Energy Dataset**

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# 1. The Project and its Aims

Effective energy provision has been fundamental to economic activity and development in the United Kingdom since before the Industrial Revolution. During the nineteenth and twentieth century, the expansion of and improvements in infrastructure to supply energy have been critical to the reductions in the costs of heating, transportation and powering firms and households across the country (Fouquet 2008). In the twenty-first century, pressures to create a sustainable and inclusive energy system impose new demands on the United Kingdom's infrastructure.

With this in mind, the National Infrastructure Commission (NIC) has sought to improve its understanding of the long run development of the United Kingdom energy system through the creation of a historical energy dataset. To begin this task, the NIC hired Dr Roger Fouquet at the London School of Economics to collate relevant historical energy statistics. This pilot project aimed to provide time series data on historical energy consumption, energy prices and carbon dioxide emissions in the United Kingdom. This dataset was accompanied by this report outlining (i) the data, including the temporal and geographical dimensions, (ii) the units of measurement, (iii) the data sources, including the methodology of indicator measurement, such as any assumptions made and notes on data characteristics, (iv) data quality assurance and (v) potential extensions to the dataset. This report ends with a reference section with an additional reading list of publications for a richer understanding of the data and the history of energy system in the United Kingdom.

# 2. The Value of Historical Energy Infrastructure Data

The study of the history of energy data has the potential to offer many valuable insights of relevance for today's energy markets and climate policy. For instance, historical energy transitions have been associated with major phases of infrastructure development in order to supply new energy sources. Without these major infrastructural expansions, these energy transitions would not have been possible and would have been important barriers to the transition. Thus, knowledge of the factors that accelerate or hinder the expansion of energy infrastructure is critical to assisting any future energy transitions.

Central to generating this type of knowledge is the data on past experiences. Researchers are increasingly exploring and refining the rich vein of information associated with the history of energy, and have unearthed more data than might perhaps have been expected. Many in previous generations, including often meticulous local government and other responsible officials and employees, kept relatively good records of transactions relating to energy infrastructure, capacity and supply. Certainly, from the mid-nineteenth century, official government statistics on energy production were produced, in the Coal Statistical Tables (British Parliamentary Papers) up to 1913 and in the various editions of the Statistical Digests of the Ministry of Fuel and Power and of the Digests of United Kingdom Energy Statistics (known as DUKES) published annually by the Department of Trade and Industry (DTI) and later the Department of Energy and Climate Change (DECC) and now the Department for Business, Energy & Industrial Strategy (BEIS).

While some of this historical data is collected in a unified way, much of it is in disparate sources. It is of great benefit to energy analysts to have this historical data accessible from a single source. An exciting precedent that can be learned from is the Bank of England's (2017) effort to bring together historical economic statistics under a single roof, through its A Millennium of Macroeconomic Data, which can be accessed at https://www.bankofengland.co.uk/statistics/research-datasets. Thus, a longer term ambition would be develop an equivalent for historical energy statistics.

# 3. The Dataset

### (i) The Spreadsheet and its Variables (including Temporal and Geographical Dimensions)

This dataset focuses on national historical energy consumption, energy prices and carbon dioxide emissions.

The section of worksheets on energy consumption is separated into eight main categories:

1.1. Primary energy consumption (1700-2018)
1.2. Final user energy consumption (1700-2018)
1.3. Coal consumption (1700-2018)
1.4. Manufactured solid fuel consumption (1900-2018)
1.5. Oil consumption (1870-2018)
1.6. Gas consumption (1820-2018)
1.7. Electricity consumption (1895-2018)
1.8. Electricity generated from renewable sources (1920-2018)

The section of worksheets on energy prices are separated into three main categories:

2.1. Domestic energy prices (1700-2019)
2.2. Transport fuel prices (1902-2020)
2.3. Coal Consumption (1700-2018)

The third section of worksheets is on carbon dioxide emissions (1700-2018)

Each category has a first worksheet ending in the suffix LR to denote the long run series for this category (e.g. 1.3.1 CoalLR). This LR worksheet brings together data from other worksheets (with names ending with 1, 2 or 3 (e.g. 1.3.2 Coal1, 1.3.3 Coal2, 1.3.4 Coal3)), often relating to different historical periods. The best way to identify these interlinkages for specific variables in particular years is to click on particular cells, and see from which worksheet the values come. Thus, the first worksheet (which ends in LR) is the main table for each category and the other tables indicate the original data source.

To provide a usable time series, in certain places, linear interpolation has been used to fill gaps in the time series. This linear interpolation involves estimating a new value by connecting two known values with a straight line. To help identify these interpolations, they are in light blue, when they have been done specifically for this data set; in green, if the calculations are done for this study; and in red, if assumptions are made.

As mentioned above, the dataset presents national values. One problem facing any effort to collect long run data is the definition of geographical boundaries. For much of the statistics, the information relates to Great Britain (i.e., England, Scotland and Wales) until 1882, the United Kingdom including Ireland from 1883 to 1920, and the current United Kingdom (that is, England, Wales, Scotland and Northern Ireland) afterwards.

### (ii) The Units of Measurement

Energy is a physical concept bringing together what once were considered separate phenomena, such as heat and power. Different units have been used to measure energy. While under different physical conditions the conversion of those units varies, some standard conversion factors can be presented and will be adequate for the nature of this dataset. These will also be useful for the reader possibly more familiar with different units of energy from those employed in this dataset. Indeed, the approach followed in the dataset is to use the units of measurements used by the Digest of United Kingdom Energy Statistics (BEIS 2019) and, therefore, particularly for the section on energy consumption, this

means using ‘thousands of tonnes of oil equivalent’. Below, the basic conversion factors are provided - for instance, to convert one tonne of oil equivalent into therms, kilojoules (KJ), Gigajoules (GJ) or kWh. More information can be found in the Digest of United Kingdom Energy Statistics (BEIS 2019).

| | | | |
|---|---|---|---|
| 1 tonne of oil equiv (toe) | = | 7.5 | barrels |
| | = | 425 | therms |
| | = | 12700 | GWh of electrical energy |
| | = | 42000 | cu ft natural gas |
| | = | 1200 | cu m natural gas |
| | = | 41,870,000 | KJ |
| | = | 46.2 | GJ per tonne of average petroleum |

**(iii) The Data Sources**

It is important to note that this dataset builds on the many statistical digests from the various government agencies that represented the energy industries since 1948, when the first Digest of United Kingdom Energy Statistics (DUKES). Also, the dataset benefits from DECC’s digitisation of a number of the statistical tables in celebration of the 60th anniversary of the first DUKES. These tables are updated on annual basis by BEIS and are included as the official and most reliable source. Thus, the main exercise here is to build on BEIS’s or DUKES current tables (using the same format) and push the statistics further back in time, either by using additional official statistics or quantitative information provided by historians. It is hoped that maintaining the same variables and formatting will make this historical data particularly user-friendly and valuable to readers.

**Primary Energy Consumption** (Table 1.1.1 PrimEnLR):

Primary energy consumption measures the total energy demand of a country. It covers consumption of the energy sector itself, losses during transformation (for example, from oil or gas into electricity) and the distribution of energy, and the final consumption by end users. In the dataset, primary energy consumption is separated by energy sources, including fossil fuels (coal, petroleum and natural gas), nuclear power and renewables (hydro, wind, solar, geothermal/heat pumps and bioenergy).

Back to 1970, the latest Digest of United Kingdom Energy Statistics (DUKES) provides the necessary information (BEIS 2019a). Before that, the Ministry of Power (1961) has statistics back to 1923, which can be extended back to 1913 with the Ministry of Fuel and Power’s (1951) data, which marks the end of the direct annual estimates of fuel consumption.

Before 1913, official statistics were produced about the amount of “coal available for home consumption”. This was estimated by calculating the level of coal production after subtracting exports and bunkers for steamships; the calculations should also include year-on-year differences in stocks, but these are not available. Between 1873 and 1912, this information can be found in the Mines and Quarries Statistical Tables (BPP 1914), and from 1858 to 1872, official estimates are presented as evidence for a Select Committee Report on the Scarcity and Dearness of Coal (BPP 1873). The first official estimates of coal production were in 1854 by Hunt (Church 1987). Church (1989) presents coal production figures back to 1830, explaining that the official estimates prior to 1874 and Pollard’s (1980) estimates for 1750–1850 were underestimates, because of omissions of certain regions and collieries. The estimates presented below, therefore, use Church’s (1989) more reliable production estimates along with the official statistics on exports (back to 1858) and Mitchell’s (1988 p.252) figures from 1816 to 1857 and Church’s (1987) estimates of coal bunkers back to the 1830s – before then, there were no steamships.

Estimates of coal production before 1830 have not been produced on an annual basis. The two sources of estimates between 1800 and 1830 are from Pollard (1980) and Flinn (1984). Since Church (1989) suggests Pollard's figures are underestimates and Flinn uses Pollard's along with other estimates to present figures for 1800, 1815 and 1830, the latter is considered more reliable and is used for linear interpolations. United Kingdom coal exports in Mitchell (1988) go back to 1816. Flinn (1984) presents figures for most years between 1800 and 1815, which have been used, as well as estimates back to 1700.

**Final User Energy Consumption** (Table 1.2.1 FinUserLR):

Final energy consumption measures the total energy consumed by end users, such as domestic or residential consumers, industry, transport and other users. This variable focuses on the energy reaching the final consumer and excludes the amount of energy used by the energy sector itself.

This can be seen as the pivotal energy statistical table, receiving inputs from Tables 1.3.1-1.7.1. Thus, in the worksheets there are links between these tables and Table 1.2.1.

The data sources are similar to the ones for primary energy consumption. The Ministry of Fuel and Power (1950) and Ministry of Power (1961) statistical digests push back in time the data on final user energy consumption table. , which is the main table, incorporating all the other consumption tables, at least back to 1950 (before it was 1970), and in some cases much further back. Fouquet (2008) provides a great deal of additional data. Detailed discussion of the sources for these is available in a lengthy data appendix.

**Coal Consumption** (Table 1.3.1-1.3.4 CoalLR, Coal1, Coal2, Coal3):

Much of this information is explained above in the section on primary energy consumption. BEIS (2019b) offers statistics on coal consumption back to 1943. Stone (1954) and Prest (1955) present a detailed breakdown of estimates between 1900 and 1938. Before this, back to 1830, Chruch (1986) splits consumption into the main final user and energy industry sectors.

**Manufactured Solid Fuels Consumption** (Table 1.4.1-1.4.3 MSFLR, MSF1, MSF2):

Manufactured solid fuels are secondary fuels often derived from coal. Coke and breeze are two common manufactured fuels, frequently used in industrial processes to produce heat with minimal impurities.

BEIS (2019c) provides the key information on the use of coke, breeze, coke over gas and other manufactured fuels back to the 1940s. Prior to this, Stone (1954) and Prest (1955) offer estimates of sectoral coke consumption. One challenge for both the manufactured fuels and coal was that one of the key sources for nineteenth century data, Church (1986), combines coal and 'manufactured solid fuels' for the period 1830-1913 under the label 'coal'. Attempts were made to separate the Church (1986) data into these two categories. Since Stone (1954) and Prest (1955) separate the categories, it is possible to estimate, back to 1830, the consumption by assuming a similar ratio of coal to manufactured fuels in each sector as in 1900.

**Oil Consumption** (Table 1.5.1 OilLR):

BEIS (2019d) offers key information on petroleum consumption back to the 1870s, separated by products to the early twentieth century. However, it separates by fuel types rather than sectors, making the link with final user Table 1.2.1 constrained. Back to the late 1930s, this is not a problem as it possible to attribute the products to sectors (for instance, motor spirit and derv are for transportation). The Ministry of Power (MoP 1961) indicates the share of motor spirit used by both between 1938 and 1960. King (1952) helps estimate motor spirit and derv for passenger and freight road transport were estimated back to 1910.

**Gas Consumption** (Table 1.6.1 GasLR, Gas1, Gas2):

Natural gas or methane has been used since the late 1960s. Before that, town gas was used to provide heating and initially lighting. BEIS (2019e) presents the statistics on natural and town gas consumption, with detailed evidence back to 1882. Before then, estimates of gas consumption for London are available from 1822 (Fouquet 2008). They have been extrapolated to represent the whole country (using the 1881 ratio between London and country consumption as an anchor, which was one-third, and increasing the share of London consumption going back to 1822.

**Electricity Consumption** (Table 1.7.1-1.7.3 ElecLR, Elec1, Elec2):

BEIS (2019f) provides similar detailed information for electricity back to 1920. Fouquet (2008) uses information in Hannah (1979) and Byatt (1979) to construct the evidence from 1895.

**Renewable Energy Consumption** (Table 1.8.1-1.8.3 RenElLR, RenHLR, RenPTLR):

BEIS (2019a) offers information about renewable energy sources back to 1990. This coincides with the advent of the development and expansion of modern renewable energy sources, including power from onshore and offshore wind, wave and tidal, solar photovoltaic, small scale and large scale hydroelectric dams, and a range of bioenergy-related sources (e.g., landfill gas, sewage sludge digestion, energy from waste combustion, animal and plant biomass, anaerobic digestion, and co-firing with fossil fuels). Before the 1990s, there was very limited consumption of modern renewable energy in the United Kingdom.

However, there was an earlier era of renewable energy sources, which pre-dates the First Industrial Revolution starting in the eighteenth century. Indeed, the economy into the nineteenth century needed renewable energy sources. In 1700, almost 30% of the energy came from renewable sources. By 1800, renewables contribution had fallen to 10%. In 1900, it was down to 3%, and less than 2%, in 2000. In 2018, the contribution of renewable energy sources to primary energy consumption had risen to 13% (see Table 1.1.1).

Efforts have been made to include traditional energy sources. Just like most developing economies, information available about the production and consumption of traditional biomass-based fuels, like wood, charcoal and crop ‘residues’, such as straw or stalks, is very limited. Fouquet and Pearson (2003) show the possible consumption after 1500, as does Warde (2007). Fouquet (2008) builds on these two endeavours, combining both to generate an integrated time series of woodfuel consumption, with a separation into domestic, iron and steel (based on Hammersley 1987, King 2005), and other industries.

Similarly, the amount of animal power used back to the eighteenth century was provided by Fouquet (2008). It builds on estimates of the horse population in the nineteenth century in Thompson (1976), which separates them by end uses. This information was combined with the trends in transport services (Chartres and Turnbull 1983) to estimate the variation in energy consumption related to transport. From the estimates of horse population, an estimate of the amount of provender or fodder could be calculated based on the appetite of horses (Thompson 1976). The energy provided by hay and oats could be converted into its tonnes of oil equivalent (Smil 1994).

Trends in wind power use for sailing ships were measured in Fouquet (2008). Using information in Mitchell (1988) and statistics in annual British Parliamentary Papers of the time on the volume (that is, the weight lifted) of goods that entered and left ports for trade, it was possible to estimate the tonnes of freight carried and required wind power to move these tonnes in the United Kingdom during the eighteenth and nineteenth centuries.

Quantitative evidence on water and wind mills in Britain were constructed in Fouquet (2008). Mill capacity was interpolated between Langdon’s (2005) estimate for 1540 and Kanefsky’s (1979a)

implied values (that is, dividing capacity by the number of mills) for 1760, then with greater detail in Kanefsky (1979a, 1979b). Based on the type of mill and its energy capacity, it was possible to construct estimates of power provided by water and wind mills. While the quantity of power generated by water mills appears small, given its symbolic role in stimulating the Industrial Revolution, the estimates seem broadly correct. For instance, Kanefsky (1979a) indicates that the water mill capacity was less than 0.2GW at its peak in 1870; in 2018, it was more than 54GW (BEIS 2019a) – roughly 250 times greater. The power generated in 1870 by water mills was equivalent to 35 thousand tonnes of oil and in 2018 by renewable energy sources was equivalent to 15,800 thousand tonnes of oil (toe) – roughly 440 times greater. Given the probable greater efficiency of modern renewable power generators than nineteenth century water mills, the estimates seem relatively reliable.

**Domestic/Residential fuel prices** (Table 2.1.1.-2.1.2 PricesLR, Prices ONS):

This set of worksheets present data on consumer/retail prices (i.e. after tax), principally for domestic/residential consumers.

ONS (2020) provides information on the retail price index series for fuel and light back to 1947, and separated by energy source to 1987. This can be extended back to 1700 using two alternative sources. One estimate of the average energy prices is based on a component (the 'fuel & light' price series - the source does not provide individual fuel price series) of a classic cost-of-living series produced by Phelps-Brown and Hopkins (1955, 1981), which goes from the thirteenth century to 1954. The data is presented from 1700 to 1947, and linked it to the ONS data to bring it to the present.

Similarly, the dataset includes Fouquet (2011) average energy price series, which uses some more up-to-date data (principally Clark (2007) and Allen (2007) data), and then linked it with the ONS data from 1947. The worksheet also presents the data for each energy source from 1300 to 2000. It is reassuring that since 1987, Fouquet (2011) and ONS (2020) series follow the same trajectories. Also, the Phelps-Brown-Hopkins and Fouquet (2011) series broadly follow the same direction since 1700, with just a few divergences.

Except where stated (i.e. nominal prices), all prices presented are in real terms (that is, in £(2000) or £(2015) money). The ONS (2020) provides the general consumer and retail price index and the Bank of England Millenium Data set (2017) also builds a series back to the thirteenth century. Thus, albeit with substantial reservations about whether price indexes have captured adequately the quality improvements that have flowed from technological change, the costs of using different energy sources and technologies are broadly comparable across time.

**Transport fuel prices** (Table 2.2.1-2.2.2 Prices RoadLR, Prices Road1): The price of motor spirit and derv (diesel for road vehicles) is available back to 1954 from BEIS (2020a), and data from the Institute of Petroleum back to 1902. The real price of motor spirit remained broadly flat between the early 1920s and late 1980s, with a subsequent rise – no doubt, due to government's duty of transport fuels.

**Industrial energy prices** (Table 2.3.1-2.3.3 Prices IndLR, Prices Ind1, Prices Ind2): BEIS (2020b) offers statistics on industrial fuel prices back to 1970. DTI 's Energy Demand Modelling documents related to EP65 (Miller 1994), includes individual industrial fuel prices back to 1955. Fuel prices that relate to the industrial sector were found in an early Digest of Energy Statistics prepared by the Ministry of Fuel and Power (1951). This included the price of electricity in factories back to 1924 and fuel oil prices, which was the oil price Miller (1994) used, back to 1921. Industrial town gas prices and coal prices were not available. For coal, the average pithead price is used as the trend back to 1900 and linked to the industrial coal price value in 1955. This approach would ignore any changes in the costs of transport to the factory between 1900 and 1955. The cost of railway freight did not change very much over this period (Supple 1987).

**Carbon dioxide emissions** (Table 3.1.1-3.1.2 CO2LR, CO21): It is possible to measure carbon dioxide emissions by recording the emissions at source or by estimating the amount emitted using the amount of fuel used and applying conversion factors that take account of the calorific content of energy sources and the associated emission factors for particular energy sources. This latter approach is the most commonly used method.

BEIS (2019g) presents carbon dioxide emissions between 1990 and 2018 broken down by primary energy source. These can compared and link with Marland et al (2008), which produce estimates at a similar level of aggregation (i.e. primary coal, oil, gas, ..) from 1751-2014. BEIS (2019h) provides information on carbon dioxide emissions from up to 300 sources between 1990 and 2018. The figure shows that the trends track very closely, but the actual levels are different. This suggests that the differences in trends are associated with conversion factors used to convert fossil fuels consumed into carbon dioxide emissions.

It is also worth noting that there are two ways of estimating carbon dioxide emission – as carbon dioxide or as the carbon content in carbon dioxide. As the worksheet explains, to convert carbon content into carbon dioxide, it is necessary to multiply by the ratio of the molecular weight of carbon dioxide to that of carbon (44/12). BEIS (2019g) uses the carbon dioxide emissions and BEIS (2019h) use the carbon content, as does the CDIAC and the estimates produced directly from the primary energy consumption (Table 1.1.1).

**(iv) Quality Assurance**

Quality control of the data was an integral part of this project and took place during the data collection, data entry and digitisation, and data checking. For instance, during data collection, the researcher ensured that the data recorded or digitised was the actual values in the original documents. Indeed, it is important to note that old documents with uncommon fonts do not digitise well. With the objective of quality assurance in mind, every effort has been made to replicate the data as represented in the original documents.

**(v) Potential Extensions to the Dataset**

This exercise could be seen as a pilot project in a greater endeavour to collect historical energy data. Data on the following additional variables could be collected:

- Energy production
- Energy imports and exports
- Employment in energy production
- Investment in energy infrastructure
- Physical energy infrastructure (e.g., estimated coal, oil and gas reserves; number of coal mines; oil rigs; number of refineries; number and capacity of power stations; length of electricity network; and length of pipeline)
- Energy consumption at more frequent intervals (e.g. quarterly, monthly and weekly).
- Energy consumption by industry (e.g. iron and steel; non-ferrous metals; Metal products, machinery and equipment; chemicals, etc..)
- Energy consumption by end-use (e.g., heating, refrigeration, computing and lighting)
- Energy services generated (e.g., levels of heating, refrigeration, computing and lighting generated)
- Regional energy consumption
- Regional energy prices

An additional valuable service related to this dataset is the scanning of and open-access to old copies of DUKES. The first (official) digest was from 1948, and there were parliamentary papers before then. From 2000, they are available online (see Appendix A for links). However, older copies are not

accessible. Crown copyright expires 50 years after the end of the year of publication (National Archives 2017). So, there would be the potential to include pre-1970 digests. This would be a valuable resource for enabling researchers and analysts to find additional data.

Ultimately, this pilot project could be the foundation of a larger collaboration with the NIC. For instance, an ambition could be to undertake a longer data collection process using historical documents and accompany the richer data set of historical energy infrastructure with a report on the drivers and barriers to major phases of infrastructure development in British history with a perspective to provide lessons for the future.

## References and Related publications

Below are a list of references and additional readings of potential interests and relevance to users of the historical energy data set:


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BEIS (2019b) Historical coal data: coal production, availability and consumption 1853 to 2018.

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BEIS (2019c) Historical coke and breeze data: coal carbonized and coke and breeze produced at coke ovens 1920 to 2018.

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BEIS (2019e) Historical gas data: gas production and consumption and fuel input 1920 to 2018

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BEIS (2019f) Historical electricity data: 1920 to 2018

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**Appendix A: Archival links to Digests of United Kingdom Energy Statistics (post-1999)**

The archive links can be found at the following online addresses:

2000

http://webarchive.nationalarchives.gov.uk/20001219211500/http://www.dti.gov.uk/epa/digest.htm

2001

http://webarchive.nationalarchives.gov.uk/frame/20020124145649/http://www.dti.gov.uk/epa/digest01/contents01.htm

2002

http://webarchive.nationalarchives.gov.uk/20021129080728/http://www.dti.gov.uk/energy/inform/dukes/dukes2002/index.shtml

2003

http://webarchive.nationalarchives.gov.uk/20031220221849/http://www.dti.gov.uk/energy/inform/dukes/dukes2003/index.shtml

2004

http://webarchive.nationalarchives.gov.uk/20050302180025/http://www.dti.gov.uk/energy/inform/dukes/dukes2004/index.shtml

2005

http://webarchive.nationalarchives.gov.uk/20060715170620/http://www.dti.gov.uk/energy/statistics/publications/dukes/page19311.html

2006

http://webarchive.nationalarchives.gov.uk/20070603181728/http://www.dti.gov.uk/energy/statistics/publications/dukes/page29812.html

2007

http://webarchive.nationalarchives.gov.uk/20080610183636/http://www.berr.gov.uk/energy/statistics/publications/dukes/page39771.html

2008

http://webarchive.nationalarchives.gov.uk/20090203183605/http://www.berr.gov.uk/whatwedo/energy/statistics/publications/dukes/page45537.html

2009 http://webarchive.nationalarchives.gov.uk/20100104211000/http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx

2010

http://webarchive.nationalarchives.gov.uk/20101209110222/http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx

2011

http://webarchive.nationalarchives.gov.uk/20120403141252/https://www.decc.gov.uk/assets/decc/11/stats/publications/dukes/2312-dukes-2011--full-document-excluding-coverpages.pdf

2012

http://webarchive.nationalarchives.gov.uk/20130627075100/https://www.gov.uk/government/organisations/department-of-energy-climate-change/series/digest-of-uk-energystatistics-dukes

2013 onwards https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes