SAP 10 Technical Paper

S10TP-15

CO_2 AND PRIMARY ENERGY FACTORS FOR SAP

Version 1.1

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TABLE OF CONTENTS

1. INTRODUCTION

The Government's Standard Assessment Procedure (SAP) is used for assessing the energy performance of dwellings. The SAP outputs include an Environmental Impact (EI) rating, Dwelling CO_2 Emission Rate (DER) and Dwelling Primary Energy Rate (DPER). These reflect the CO_2 emissions and primary energy associated with space heating, water heating, ventilation and lighting within the dwelling. The EI rating is expressed on a scale of 1 to 100; the higher the number the better the standard. The DER and DPER are used for the purpose of demonstrating compliance with building regulations. They are equal to the annual CO_2 emissions and primary energy per unit floor area for space heating, water heating, ventilation and lighting, less the emissions saved by energy generation technologies, expressed in $kgCO_2e/m^2$/year and kWh/m^2/year.

SAP calculates the energy consumption for space heating, water heating, ventilation and lighting for a dwelling under standardised occupancy conditions. The actual demand for energy services is likely to differ because individual actual occupancy and behavioural patterns of real households affect usage, e.g., the operation hours, internal gains, ventilation rates, etc., and hence impact on the energy consumption.

In order to calculate the CO_2 and primary energy impacts associated with this energy use, emission factors and primary energy factors are determined and applied to each fuel type.

This paper presents carbon emission factors and primary energy factors which are to be used in SAP 10.1 and also for SBEM (the compliance calculation tool for non-domestic buildings)[1]. It identifies the data sources used and describes the calculation methodology and the underlying rationale.

[1] In most instances the factors for SAP and SBEM are identical. Exceptions are house coal and non-domestic coal, and domestic and non-domestic manufactured solid fuels.

2. SCOPE

As the purpose of these factors is to reflect the environmental impact of the energy used by a building, it is desirable to adopt as wide a scope as possible in order to accurately reflect these impacts. However, in practice the scope is limited by data availability and uncertainties, particularly regarding combustion conditions and changes in energy supply chains. This section describes the scope of the SAP 10.1 emission and energy factors and outlines the rationale behind it. The scope that has been adopted attempts to balance the desire for completeness and accuracy with the practicalities of obtaining data and inherent uncertainties associated with available data. The scope of emissions and energy consumption sources included for SAP 10.1 is the same as for SAP 2012. A more detailed technical paper which accompanied the 2012 SAP Consultation exercise provides a more detailed description of the rationale behind the scope.[2]

2.1 Emissions from combustion and fugitive emissions of CO_2, CH_4 and N_2O, measured as CO_2e[3] (CO_2 equivalent) are included.

Carbon dioxide (CO_2) is one of the main products of fuel combustion but it is not the only greenhouse gas that is emitted. Nitrous oxide (N_2O) and methane (CH_4) are also released as a result of energy consumption. N_2O is a side product of the fuel combustion process as the heat produced causes the oxidation of nitrogen in the surrounding air.

In addition to being generated directly from the combustion of fuels, greenhouse gases are also released directly from the energy supply chain. In particular nitrous oxide is released from the cultivation of soils which form part of the production process for bio-fuels and methane can be released directly into the air at various points along the energy supply chain including oil and gas exploration, natural gas leakage from gas pipelines and coal mines and also that which arises from incomplete combustion.

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[2] STP11/CO204: Proposed Carbon Emission Factors and Primary Energy Factors for SAP 2012, BRE, December 2011

[3] CO_2e is calculated based on the GWP (Global Warming Potential) values from the Intergovernmental panel on Climate Change's (IPCC) Second Assessment Report, where CH_4 = 21 and N_20 = 310, which is consistent with reporting under the Kyoto Protocol.

Both N_2O and CH_4 are more potent greenhouse gases than CO_2. Although the global warming impact of CH_4 and N_2O from energy use is generally small compared to that of CO_2 for most fossil fuel energy sources, they can make up a significant proportion of the emission impact, in particular for fuels from biomass sources. Therefore including CH_4 and N_2O in addition to CO_2 provides a more accurate reflection of the impacts of energy use.

2.2 Energy and emissions associated with the following upstream energy production activities are included:

- **Planting of biofuel sources**
- **Cultivation of biofuel sources**
- **Extraction of fuels (fossil, nuclear, etc)**
- **Processing of fuels (e.g. cleaning, grading)**
- **Transformation of fuels (e.g. electricity generation, oil refining)**
- **Transportation of raw and refined products**
- **Transmission and distribution losses (electricity, gases, etc.)**

The system boundary is deemed to start when production begins: for fossil fuels this will be extraction, and for fuels derived from biomass this will be cultivation. For waste products this will be transportation from the location where the waste is produced. The final stage included within the boundary is energy use in the building; subsequent disposal of any waste arising is not included. The system boundary for emissions from energy use in SAP is shown in the following diagram.

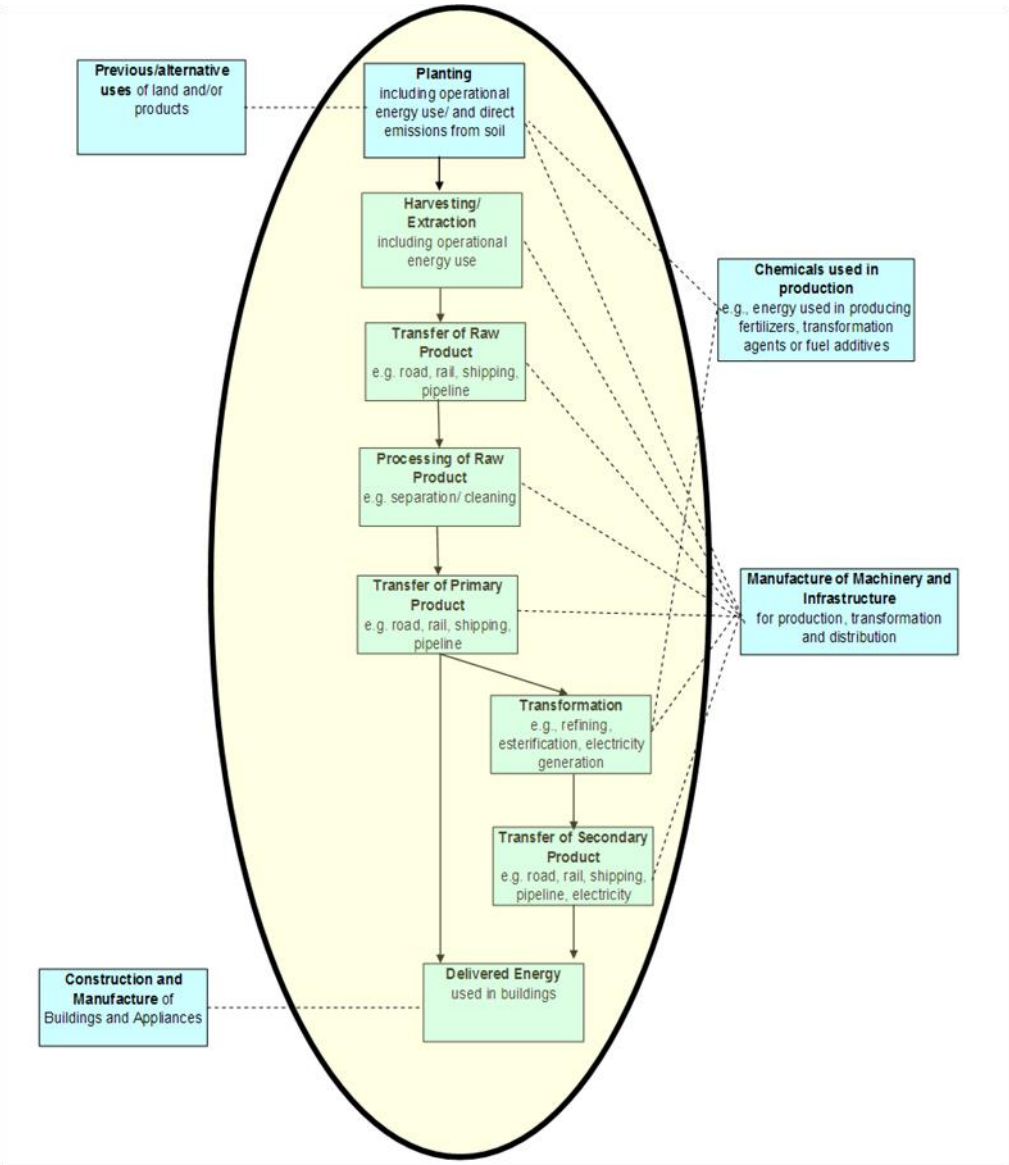

Figure 1: System Boundary for Greenhouse Gas Emissions from Delivered Energy Use

2.3 Upstream emissions and energy use that occur outside of the UK are included (in so far as data availability permits.)

This is particularly important where the supply chain and production methods are different compared to UK produced fuels. For example, for imports of liquefied natural gas, where upstream emissions from compression and shipping are significant, and for imported electricity, where the electricity generation mix may be very different.

2.4 Carbon dioxide arising from the combustion of fuels derived from biomass sources are not included in the emission factors[4]

This is because carbon dioxide emissions that arise directly from the combustion of bio-genic materials (provided they are derived from sustainable biomass sources) form part of the carbon cycle and so do not lead to a net increase in atmospheric CO_2 emissions when viewed over the long term. Thus, excluding carbon dioxide emissions arising directly from combustion of bio-genic carbon is justified and in line with major end-user carbon accounting methodologies, e.g. GHG reporting protocol[5].

2.5 Energy and emission factors are based on average values for energy sources supplied in the UK over the expected compliance period.

Weighted average UK values for energy sources are appropriate because the SAP calculation:

- does not take account of specific fuel choices made by occupiers for appliances that can be fuelled by more than one energy source[6]
- does not take account of local variations in energy supply chains and distribution networks
- is independent of the geographical location of the building

Using projected five-year average values takes into account changes in the UK energy supply chain that are expected to occur over the expected life of the particular Part L Amendment to which a specific version of SAP applies.

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[4] However direct emissions of CH_4 and N_2O from combustion and all other non-bio-genic upstream GHG emission sources are included.

[5] The GHG Protocol for Project Accounting, World Business Council for Sustainable Development/World Resources Institute, 2004

[6] E.g., for solid fuel appliances which can burn coal or wood, the energy and emission factors are based on the average UK mix of these fuels used in the domestic sector.

The issue of timescale is important for electricity and possibly for mains gas. However, for most other energy sources the carbon impacts are not expected to change significantly over the period of the Part L Amendment, so for other fuels the current emission factors are taken to represent projected values.

2.6 Energy and Emissions for grid supply electricity are system average values (rather than marginal values)

System average values reflect the primary energy and emissions associated with grid supply electricity in the UK and are appropriate for measuring and reporting energy and carbon impacts. In contrast, marginal emission factors are appropriate for measuring the effect of changes in demand compared to a normal or baseline situation.

2.7 The system average value for grid supply electricity is applied to electricity exports and electricity generated using CHP

System average values are also applied to electricity generated by the building (generally from renewable sources) which is exported to the grid. This reflects the fact that each kWh of electricity generated by a building displaces a kWh of electricity which would have otherwise had to be generated by the grid.

For CHP, the SAP calculation uses the power station displacement method to allocate emissions between electricity and heat outputs[7] so it is appropriate to apply the system average grid value.

2.8 Time of day/month averaging

Unlike other fuels, the factors for electricity are variable due to the constantly changing mix of inputs to the electricity grid. For example, in the summer, there will be increased PV generation and, in the winter, when demand is higher, there may be increased

[7] The convention assumes that the electricity generation by CHP displaces electricity generated by the grid taking into account transmission and distribution losses.

generation from gas power stations. To reflect this in the SAP electricity factors, a monthly set of factors has been calculated based on the actual generation mix at different times of the day and at different times of the year. For each tariff and for each month, a factor has been calculated based on this actual mix profile. For more details on the calculation of these factors, see SAP 10 Technical Paper S10TP-17.

2.9 Primary Energy Factors

A set of primary energy factors for fuels used in SAP and SBEM are also provided. These factors are used to convert the delivered (or final user) energy consumption of different fuels, as calculated by the tools, into primary energy, which includes energy used for production, processing and transporting fuels. The primary energy factors are calculated using the same methodological scope and timescales as for the CO_2 emission factors.

The definition of primary energy used to calculate the SAP 10.1 factors is the same as that used for the SAP 2012 values; in particular, primary energy covers both renewable and non-renewable energy sources. This definition is consistent with EPBD Art. 2(5) which states “primary energy’ means energy from renewable and non-renewable sources", and in accordance with EN 15316-4-5 which states ".... Waste heat, surplus heat and regenerative heat sources are included by appropriate primary energy factors.”

Renewable energy sources such as solar, natural flow hydro and wind generation are capturing abundant natural energy sources. To treat the electricity generated by these sources as primary energy a statistical convention assigns these a primary energy factor of 1 at the point of generation. Any subsequent energy use associated with the distribution of energy from renewable sources and losses should be included in the primary energy factor. Biomass sources and waste used to produce energy should be assigned a primary energy factor of 1 with any subsequent energy use or losses that occur prior to delivery added.

Electricity generated from nuclear sources is a more complex issue as it is often derived from plutonium which is not naturally occurring and is therefore classed as a secondary energy source. So, the primary energy factor for nuclear electricity also takes account of any energy use associated with nuclear fuel processing as well as thermal losses that occur during steam generation and the subsequent generation and supply of electricity.

3. METHODOLOGY FOR CO_2 EMISSION FACTORS

This section outlines the data sources and assumptions that have been used to determine the carbon emission factors in line with the scope outlined in the previous section.

In instances where the scope of emissions for SAP coincides with those of emission factors provided in the Government's conversion factors for company reporting, the appropriate values have been selected from the most recent conversion factors. Where a suitable match was not identified, the additional data sources, assumptions and calculations used to derive the values are described.

The data sources, assumptions and calculation procedures used to derive the Government's factors are identified based on the methodology paper which accompanies the conversion factors[8]. It is important to note that the methodology paper acknowledges that it is not exhaustive and does not provide a detailed explanation of every calculation performed. However, the key data sources and methodological approach are provided.

The Government's conversion factors provide a number of different values for each fuel which cover the various emission sources (or *Scopes* in GHG protocol terminology – See box 1 for definitions), the GHGs covered, and whether they apply to net or gross calorific value energy data.

For SAP, emission factors with gross calorific values in terms of $kgCO_2e$ are used. For fossil fuels and biomass energy the SAP factors will be the sum of the (scope 1) conversion factor plus the upstream (scope 3) conversion factor (referred to as "well to tank" (WTT) factors in the Government Conversion Factors).

[8] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2017

Description of Greenhouse Gas Protocol Corporate Standard Scopes

> ***Scope 1 (Direct emissions):*** *Emissions from activities owned or controlled by your organisation. Examples of Scope 1 emissions include emissions from combustion in owned or controlled boilers, furnaces, vehicles; emissions from chemical production in owned or controlled process equipment.*
>
> ***Scope 2 (Energy indirect):*** *Emissions released into the atmosphere associated with your consumption of purchased electricity, heat, steam and cooling. These are indirect emissions that are a consequence of your organisation's energy use but which occur at sources you do not own or control.*
>
> ***Scope 3 (Other indirect):*** *Emissions that are a consequence of your actions, which occur at sources which you do not own or control and which are not classed as Scope 2 emissions. Examples of Scope 3 emissions are business travel by means not owned or controlled by your organisation, waste disposal which is not owned or controlled, or purchased materials or fuels. Deciding if emissions from a vehicle, office or factory that you use is Scope 1 or Scope 3 may depend on how you define your operational boundaries. Scope 3 emissions can be from activities either upstream or downstream from your organisation.*

3.1 Fossil Fuels

For most fossil fuels the emission factors for SAP are taken from the Government's conversion factors, specifically, the sum of "Fuel" value in terms of $kgCO_2e/kWh$ on a gross calorific value plus the equivalent WTT emission factor for that fuel. It is necessary to sum the two values because the "Fuel" value only includes direct emissions from fuel combustion at the point of use (Scope 1), whilst the WTT value covers the upstream emissions that occur during extraction, processing, transformation and transportation of fuels and correspond to Scope 3 emissions.

In the absence of a specific UK-based set of fuel lifecycle emissions factors, many of the WTT emissions are taken from a preeminent European study[9] which covers conventional

[9] "Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context" Version 4, July 2013. Report EUR 26028 EN – 2013. http://iet.jrc.ec.europa.eu/about-jec/

and alternative road transport fuels and other fuels/energy carriers including coal, natural gas, naphtha, heating oil and (EU) electricity. For fuels where no lifecycle emissions were provided in the JEC WTT these were estimated based on similar fuels.

The direct and WTT values selected from the Government conversion factors and the primary data sources for these are shown in the following table.

SAP fuel type	Government conversion factors fuel type	Direct (Scope 1)	Upstream (Scope 3)	$kgCO_2e$ /kWh	Primary data sources/Assumptions
LPG	LPG	0.2145	0.0262	0.2415	Government GHG Conversion Factors 2018
Domestic heating oil (burning oil/kerosene)	Burning oil	0.2467	0.0513	0.2980	Government GHG Conversion Factors 2018
Gas oil (diesel)	Gas oil	0.2765	0.0589	0.3354	Government GHG Conversion Factors 2018
Fuel oil	Fuel oil	0.2683	0.0508	0.3191	Government GHG Conversion Factors 2018
House coal	Coal (domestic)	0.3447	0.0507	0.3954	Government GHG Conversion Factors 2018
Anthracite	Coal (domestic)	0.3447	0.0507	0.3954	Government GHG Conversion Factors 2018
Coal (non-domestic) (For use in SBEM)	Coal (industrial)	0.3248	0.0507	0.3755	Government GHG Conversion Factors 2018
Natural Gas	Natural Gas	0.1840	0.0256	0.2095	Government GHG Conversion Factors 2018

Table 1: Fossil fuel emission factors and primary data sources and assumptions

The Government's conversion factors for direct emissions are the default values from the UK GHG Inventory and are activity weighted values. For solid fuels sector specific factors are provided which take account of:

- the difference is the mix of grades of fuel used,
- the extent to which combustion is complete, and

- how N_2O and CH_4 emissions vary depending on the typical combustion conditions in each sector[10].

However, for liquid and gaseous fossil fuels it is appropriate to use the UK sector weighted average values as there are no significant differences between sectors.

Conversions between different energy units and between gross and net calorific value were made using information provided in the Digest of UK Energy Statistics (DUKES)[11].

Natural Gas

The "natural gas" factors in the Government emission factors refers to mains gas delivered via the grid based on the 2017 grid mix of piped natural gas and liquefied natural gas in mains supply gas[12]. The emission factor for piped natural gas was back calculated from the 2017 grid supply mix (9% LNG) and the LNG emission factor.

SAP fuel type	Government conversion factors fuel type	Direct (Scope 1)	Upstream (Scope 3)	$kgCO_2e$ /kWh	Primary data sources/Assumptions
-	Natural gas (2019 mains supply)	0.1840	0.0256	0.210	Government GHG Conversion Factors 2018 (Determined from 2017 mix of LNG and piped natural gas)
LNG	LNG	0.1840	0.0635	0.2475	Government GHG Conversion Factors 2018
Mains gas	-	0.1840	0.02225	0.2064	Value for piped natural gas calculated from 2019 grid supply mix and LNG conversion factor with 8% LNG (2017 mains supply %)

Table 2: Natural gas emission factors

[10] It would be possible to provide specific factors for the domestic and non-domestic sectors for other fossil fuels, but in most cases the differences are small (~1%) and using these would mean that the SAP emission factors would differ from the "official" Defra conversion values.

[11] https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes

[12] It was assumed that the Defra natural gas emission factor referred to piped natural gas rather than mains supply gas.

The natural gas (piped) and LNG factors were subsequently used to calculate the average projected emission factor for mains supply gas for the period 2020-2024. See section 3.2 for more details.

Solid Manufactured Fuels

The Government's conversion factors do not provide values for solid manufactured fuels, so these are derived from primary source documents. The NAEI (National Atmospheric Emissions Inventory) data gives direct emissions for domestic and non-domestic smokeless solid fuel per tonne. These were converted to kgCO_2e/kWh based on the gross calorific value for manufactured solid fuel from the Digest of United Kingdom Energy Statistics.

In addition to direct emissions, three upstream emission sources are added to the direct emission factor. These are:

- Emissions from the solid manufactured fuel production process – fugitive methane emissions and emissions from coal used during the production process (from the 2012 NAEI)
- Upstream emissions from the input fuels that are transformed during the production process, specifically coal and petroleum coke (from the Government's WTT factors for industrial coal and petroleum products), and
- Estimated emissions for transporting solid manufactured fuel to the final user (based on an average 200km journey 80% by rail, 20% by road and calculated using transport factors for the Government's emission factors).

The emission values and primary data sources are shown in Table 3.

SAP fuel type	Direct (Scope 1)	Upstream (Scope 3) - input fuels	Upstream (Scope 3) - SSF production	Upstream (Scope 3) - transport	kgCO_2e /kWh	Sources
Domestic Manufactured Solid Fuel	0.3775	0.0473	0.0013	0.0055	0.4317	Direct - UK NAEI 2012, Upstream input fuels = JEC 2013 WTT coal + petroleum coke (weighted average 2013 input fuels DUKES) Upstream SSF production = UK NAEI emissions from coal used in SSF production + fugitive methane SSF production 2013, Upstream transport = UK Govt factors for rail + road transport (average laden rigid diesel truck), distance = 200km, 80% rail, 20% road
Non-Domestic Manufactured Solid Fuel	0.3534	0.0473	0.0013	0.0055	0.4076	

Table 3: Solid Manufactured Fuel Emission Factors

3.2 Grid supply energy

UK mains supply gas

The projected UK mains gas emission factor for 2020-2024 has been estimated based on the projected mix of LNG and piped natural gas[13] provided in the National Grid's Gas Ten Year Statement[14] and the emission factors for LNG and for piped natural gas.

The gas supply projections indicate that the proportion of LNG in the UK supply will be 8% over the period 2020-2024.

The piped natural gas was back calculated from the 2018 Defra conversion values for grid supplied natural gas as described in Section 0.

The emission factor for mains gas is then calculated from the SAP emission factors as follows:

%LNG*SAP LNG factor + (1-%LNG)*SAP natural gas factor

SAP fuel type	kgCO_2e /kWh	Sources
Mains gas supply	0.2095	SAP 2018 factors for LNG & natural gas + projected grid supply mix 2020-2024 from Gas Ten Year Statement 2017

Table 4: Mains gas supply emission factor and data sources

[13] Includes biogas from GHG

[14] http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/Gas-Ten-Year-Statement/

UK mains supply electricity

The system average annual emission factors were calculated for each year based on the projected UK electricity generation mix, the efficiency of generation for each fuel type and the emission factor for each fuel type. The total annual emissions arising from energy generation were calculated as follows:

$$\sum_{\text{all fuels}} \text{kWh electricity generated} / \text{efficiency of generation} * \text{fuel emission factor}$$

The UK projected electricity generation mix is taken from BEIS's Updated Energy and Emissions Projections (UEEP)[15]. Annex J gives total annual electricity generation by source.

The generation efficiency for each fuel type was taken from DUKES (Table 5.6) as "net supplied (gross)" [16] divided by "fuel used" for all generating companies as follows:

- Coal generation 33%
- Gas generation 47%
- Oil generation 23%
- Other thermal 19%

The proportion of UK electricity that is imported from France is not included in the UK projections. The amount of electricity imports varies from year to year so a three year average value (2015-2017) from DUKES Table 5.1 2018 (6%) was used.

The emission factors applied to the power station consumption and their sources are shown in the Table 5.

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[15] https://www.gov.uk/government/collections/energy-and-emissions-projections

[16] The "net supplied (gross)" is net of electricity "used on works", but not net of electricity "used in pumping" (for pumped storage)

SAP fuel type	Government conversion factors fuel type	Direct (Scope 1/2)	Upstream (Scope 3)	$kgCO_2e$ /kWh	Sources
Power station coal	Coal power stations	0.31112	0.05066	0.3618	Government GHG conversion factors 2018
Power station oil	Fuel oil	0.2683	0.0508	0.3191	Government GHG conversion factors 2018
Power station gas	Mains gas	0.18396	0.02557	0.2095	Government GHG conversion factors 2018
Imports	French electricity	0.00382[17]	0.02736[18]	0.0411	RTE dataset 2017

Table 5: Electricity generation fuels emission factor and data sources

The total emissions are then divided by the total projected electricity supply[19] from BEIS's Updated Energy and Emissions Projection[20] to provide an emission factor for gross electricity supply in the UK.

This electricity generation emission factor was then adjusted to take account of UK transmission and distribution losses that occur before reaching the final user.

Transmission and distribution losses were calculated from the average losses for the public distribution system from DUKES Table 5.2 as follows:

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[17] This factor is for CO_2 only and is from the 2017 RTE dataset. https://www.rte-france.com/eco2mix/telecharger-les-indicateurs

[18] This includes both WTT emissions from inputs fuels and transport and distribution losses within France and is from the 2018 conversion factors.

[19] This is equivalent to electricity "supplied net" in DUKES Table 5.5 which is net of electricity used on works and electricity used in pumping and so these losses are already taken into account.

[20] https://www.gov.uk/government/collections/energy-and-emissions-projections

("Transmission losses" + "Distribution losses") / "Total demand" = 7.6%

This was then applied to the electricity generated emission factor to generate the final user emission factor as follows:

$kgCO_2e/[kWh(generated) * (1 + T\&Dlosses)] = kCO_2e/kWh(delivered)$

The SAP 10.1 emission factor is taken as the average value over 2020 - 2024, see Table 6.

Period	2020	2021	2022	2023	2024	SAP 10.1
$kgCO_2e/kWh$	0.161	0.135	0.124	0.129	0.129	0.136

Table 6: Projected annual emission factor for UK grid electricity 2020-2024

This is also broken down into monthly factors, which are detailed in a separate technical paper entitled *S10TP-17 - Monthly factors for CO_2 emissions and primary energy*.

3.3 Biofuels

For most biofuels the emission factor for SAP are taken from the Defra conversion factors, specifically, the sum of "Bioenergy" value in terms of $kgCO_2e/kWh$ on a gross calorific value basis, plus the equivalent WTT emission factor for that fuel. It is necessary to sum the two values because the "Bioenergy" value only includes direct emissions from fuel combustion at the point of use (Scope 1)[21], whilst the WTT value covers the upstream emissions that occur during extraction, processing transformation and transportation of fuels (Scope 3).

The direct and WTT values selected from the Government conversion factors and their sources are shown in Table 7.

[21] Direct scope 1 emissions are from CH_4 and N_2O only, as CO_2 arising from the combustion of fuels derived from biomass sources is not included (See section 2 for explanation)

SAP fuel type	Government conversion factors fuel type	Direct (Scope 1)	Upstream (Scope 3)	$kgCO_2e$ /kWh	Sources
Biogas	Biogas	0.00022	0.02405	0.0243	Government GHG conversion factors 2018
FAME (biodiesel)	Biodiesel	0.00376	0.03404	0.0378	Government GHG conversion factors 2018
Bioethanol	Bioethanol	0.0015	0.1038	0.1053	Government GHG conversion factors 2018
Wood logs	Wood logs	0.01506	0.01277	0.0278	Government GHG conversion factors 2018
Wood pellets	Wood pellets	0.01506	0.03744	0.0525	Government GHG conversion factors 2018
Wood chips	Wood chips	0.01506	0.00792	0.0230	Government GHG conversion factors 2018
Biomass	Grass/straw	0.01314	0.01604	0.0292	Government GHG conversion factors 2018
Waste vegetable oil	Biodiesel (from used cooking oil)	0.0389	-	0.0389	Government GHG conversion factors 2018

Table 7: Biofuel emission factors and data sources

The GHG document uses the Ofgem calculator[22] to find the emission factors for UK biogas, wood pellets and wood chips. This data includes energy-related and fugitive emissions arising during fuel production as well as combustion emission. The methodology used in the calculator is in accordance with EU requirements for calculating life cycle greenhouse gas emissions under the Renewables Obligation and includes the following upstream processing stages:

- Crop production
- Harvesting
- Drying and storage
- Biomass/biogas transportation
- Biomass/biogas processing
- Storage

[22] https://www.ofgem.gov.uk/publications-and-updates/uk-solid-and-gaseous-biomass-carbon-calculator

For biodiesel and bioethanol the UK average values are derived from RTFO (Road Transport Fuel Obligation) statistics and provide a breakdown of the feedstock used, and the country of origin, for biofuels supplied under the RTFO[23]. The statistics also include the upstream emission factors for each feedstock and country. This data is used to calculate a weighted average value for the UK biofuels. However, RTFO emission factors do not include direct methane and nitrous oxide produced at the point of use therefore values for an equivalent fossil fuel are substituted[24].

The Defra conversion factor for wood is based on data from the Biomass Energy Centre (BEC) which is a research agency managed by the UK Forestry Commission. The emission factor is a representative value for the UK which takes account of full lifecycle emissions.

For appliances that can use a combination of fuel types, e.g. wood and coal or heating oil and FAME (biodiesel), the fuel ratios and data sources for dual fuel appliances are shown in Table 8. This table also includes values for BK30 and BD30 which are specific blends of biofuels. These blends are not currently commercially available and the emission for these blends should only be used for appliances which are designed to run exclusively on these fuel blends.

[23] Although the calculator is specifically for road transport fuels supplied under the RTFO, as road transport fuels account for the vast majority of liquid biofuel use in the UK, these values should be applicable to biofuels used in buildings.

[24] Direct scope 1 emissions are from CH_4 and N_2O only, as CO_2 arising from the combustion of fuels derived from biomass sources is not included (See section 2 for explanation)

Dual Fuels/Specific blends	Ratio	kgCO_2e /kWh	Data Sources/Assumptions
Domestic heating oil and FAME (liquid biofuel)	100:1	0.2978	Government statistics show no evidence of significant amounts of biodiesel being used for heating in the UK25
Gas oil and FAME (liquid biofuel	100:1	0.3255	Government statistics show no evidence of significant amounts of biodiesel being used for heating in the UK26
Solid mineral fuel and wood	21.02%	0.1080	UK ratio of coal and wood logs used in the domestic sector DUKES 2015 table 1.1 and 6.1, respectively27
BK30	30:70	0.2293	30% FAME biodiesel, 70% burning oil
BD30	30:70	0.2488	30% FAME biodiesel, 70% gas oil

Table 8: Emission factors for dual fuel and fuel blends and data sources

3.4 Other Energy Sources

Waste heat from power stations requires power stations to produce heat at a higher temperature than would otherwise be the case. This results in a reduction in electricity generation when a power station is producing heat at a high enough temperature to provide district heating. The SAP emission factor is based on the assumption of a 1kW reduction in electricity output for each 9kW of heat generated. Therefore, the emission factor for waste heat is 1/9th of the emission factor for grid generated electricity.

[25] The majority of FAME/biodiesel use in the UK is for transport to meet the RTFO (Renewable Transport Fuels Obligation. In 2014/2015 biofuels accounted for 3.73% of total road and non-road machinery fuel (RTFO Statistics, Department for Transport)

[26] The majority of FAME/biodiesel use in the UK is for transport to meet the RTFO (Renewable Transport Fuels Obligation. In 2014/2015 biofuels accounted for 3.73% of total road and non-road machinery fuel (RTFO Statistics, Department for Transport)

[27] It is assumed that manufactured smokeless fuel will only be used in the smokeless zones (because it is more expensive than coal) and therefore the ratio of solid mineral fuel to wood is based for coal only and that wood pellets and wood chips require fuel specific appliances.

Heat from Geothermal sources requires energy to pump the heat up from the ground. The SAP emission factor is based on metered data for the electricity used to pump heat from a single deep geothermal district heating system[28]

The emission factor for heat generated from waste incineration is derived from data extracted from Defra's Biomass Environmental Assessment Tool (BEAT)[29], which includes GHG emissions from the following process stages.

- Pre-treatment
- Fairport process
- Road transport for inert waste disposal
- Inert waste disposal to landfill
- Density separation
- Pelletisation
- Transport to heating plant
- Combustion and heat production

Table 9 summarises the emission factors for these fuels.

SAP fuel type	Direct (Scope 1)	Upstream (Scope 3)	kgCO2e /kWh	Data Sources/Assumptions
Waste heat from power stations	0	0.0442	0.0442	11.1% grid supply electricity
Geothermal heat	0	0.0312	0.0312	7.83% grid supply electricity
Waste incineration	0.0086	0.0655	0.072	BEAT Municipal solid waste39

Table 9: Emission factors for other energy sources and data sources

[28] Private communication from Simon Woodward, Utilicom

[29] BEAT (Biomass Environmental Assessment Tool) Life Cycle Greenhouse Gas Emissions for Production of Heat by Combustion of High Biomass Refuse Derived Fuel (RDF) from Muncipal Solid Waste using the Fairport Process http://www.biomassenergycentre.org.uk/portal/page?_pageid=74,153193&_dad=portal&_schema=PORTAL

The emission factor for electricity or heat generated directly from the following is zero: solar energy, wind energy, geothermal energy, hydro power.

4. METHODOLOGY FOR PRIMARY ENERGY FACTORS

This section outlines the data sources and assumptions that have been used to determine primary energy factors in line with the scope outlined in Section 2.

Although the Government does publish some energy statistics in terms of primary energy, these are at an aggregated level and do not include upstream energy use outside of the UK. In the absence of a set of UK primary energy factors the values for SAP and SBEM are derived from other data sources. The main sources used are the JEC WTT study[30], which provides EU primary energy factors for some fuels and DUKES which provides the UK energy flows for different fuels. Wherever possible the source data is the same as that used for the CO_2 emission factors.

The primary energy factor is calculated as 1 plus the sum of energy use for all process stages divided by the energy content of the final delivered fuel[31]:

$$Primary\ energy\ factor = 1 + \frac{\sum_{all\ process\ staages} Energy\ Use}{Energy\ content\ of\ delivered\ fuel}$$

For most fuels the primary energy factor will be close to 1 and to simplify the calculation procedure this approximation is adopted when calculating upstream energy inputs[32]. However, for electricity this is not the case and so the primary energy factor for electricity is applied when calculating the primary energy factor of other fuels.

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[30] "Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context" Version 4, July 2013. Report EUR 26028 EN – 2013. http://iet.jrc.ec.europa.eu/about-jec/

[31] Energy use/Energy content of delivered fuel is referred to as the energy use ratio.

[32] The alternative would be to carry out complex iterative calculations which would make very little difference to the values obtained.

The data sources and assumptions used to generate the primary energy factors for each type of fuel are shown and described in the remainder of this section.

4.1 Coal

For coal, the primary energy factor includes energy used in coal extraction and for transportation. The specific data sources and assumptions used to generate the coal primary energy factor are described below.

Coal Extraction

For the UK, this is calculated as the sum of energy use provided in the DUKES "Commodity Balance" tables for all fuels where coal extraction is included under the "Energy Industry Use" heading. Dividing the energy use for extraction by the energy content of the coal extracted gives the coal extraction contribution to primary energy.

The majority of coal imported to the UK is from Russia and the US and in the absence of readily available data on energy use for coal extraction in these countries, the UK value is assumed for coal extraction for imported coal.

$$\textit{Coal extraction energy ratio} = 0.0367 kWh_{energy\ use}/kWh_{production}$$

Coal transport

In the absence of readily available information about the distances and modes of transport used to move coal from the extraction site to the final user in the UK, nominal transport distances were assumed for both land transport within the UK and overseas, with the sea transport distances being estimated based on distances between an appropriate port in the country of origin and Portsmouth for the UK[33]. These assumptions are summarised in Table 13.

[33] Distances were calculated using http://www.sea-distances.org/

Distance (km)	UK rail	UK road	Port	sea	other country rail	other country road
UK	160	40				
European Union	160	40	Gdansk	1,055	400	100
Australia	160	40	Abbot Point	11,316	400	100
Canada	160	40	Argentina	2,167	400	100
China	160	40	Amoy	9,725	400	100
Colombia	160	40	Barranquilla	4,288	400	100
Republic of South Africa	160	40	Cape Town	5,947	400	100
Russia	160	40	Lomonosov	1,480	400	100
USA	160	40	Baltimore	3,443	400	100
Other countries	160	40	Average other countries	4,928	400	100

Table 13: Assumed distances in km for coal transport by mode and country of origin plus ports of origin for sea transport

The amount of UK coal that is produced domestically was taken from DUKES table 2.1 (Commodity Balance Coal), and imported coal by country of origin was provided from coal imports data from Energy Trends[34] and is shown in Table 14.

Coal imports	Thousand tonnes
European Union	356
Australia	749
Canada	36
China	75
Colombia	731
Republic of South Africa	50
Russia	3,883
USA	2,351
Other countries	267
Total all countries	**8,498**

Table 14: UK Coal imports by country of origin

Transport energy factors for different modes of transport were derived from information provided in the Government's Conversion Factors as shown in Table 15.

[34] Table ET 2.4, https://www.gov.uk/government/collections/energy-trends

Transport mode	Conversion factor for	kgCO2e/ km.tonne	Fuel	Fuel kgCO2e/kWh	kWh/ tonne.km
Road	average HGV rigid diesel average laden	0.26414	diesel	0.30601	0.86317
Rail	rail	0.04107	diesel	0.30601	0.13420
Bulk shipping	average bulk carrier - fuel oil	0.00422	fuel oil	0.31907	0.01324
Crude/products tanker	average crude/products tanker - fuel oil	0.00546	fuel oil	0.31907	0.01711
LNG tanker	average LNG tanker	0.01378	fuel oil	0.31907	0.04320

Table 15: Derivation of energy factors for transport of fuels

The energy use for transport of UK produced coal is calculated as the sum of the distances travelled by mode of transport multiplied by the appropriate transport energy factor, divided by the energy content of UK produced coal.

The energy use for transport of imported coal is calculated in a similar way but using a weighted average distance for the distance travelled by sea.

$$\textit{Transport energy ratio UK production} = 0.0072\ kWh_{energy\ use}/kWh_{production}$$

$$\textit{Transport energy ratio imports} = 0.0349\ kWh_{energy\ use}/kWh_{production}$$

The figure for UK supply is calculated based on the ratio of UK produced to imported coal which is provided in DUKES table 2.1, Commodity Balances - UK production/(Total supply + Stock change) = 1:5.709

$$\textit{Transport energy ratio UK coal supply} = 0.02726\ kWh_{energy\ use}/kWh_{production}$$

Primary energy factor = 1+ extraction ratio + UK supply transport UK ratio = 1.064

4.2 Mains Supply gas

In the UK the majority of mains supply gas is from piped natural gas and the remainder is imported as liquefied natural gas by sea. This section describes the derivation of the primary energy factor for piped natural gas, LNG and UK mains supply gas.

Piped Natural gas

For piped natural gas the primary energy factor comprises energy used in oil and gas production and gas distribution. The specific data sources and assumptions used to generate the piped natural gas primary energy factor are described below.

Oil and gas production

For the UK, this is calculated as the sum of energy use provided in the DUKES "Commodity Balance" tables for all fuels where oil and gas production is included under the "Energy Industry Use" heading. Dividing the energy use for extraction by the energy content of the oil and gas extracted gives the gas and oil production contribution to primary energy.

The majority of piped gas in the UK is from Norway and is piped to the UK from the North Sea. In the absence of readily available data on energy use for oil and gas production for Norway, the UK value is assumed for imported gas.

$$\textit{Oil and gas energy ratio} = 0.0982\ kWh_{energy\ use}/kWh_{production}$$

Gas distribution

For the UK, this is calculated as the sum of energy use provided in the DUKES "Commodity Balance" tables for all fuels where gas distribution is included under the "Energy Industry Use" heading. Dividing the energy use for distribution by the energy content of the gas distributed gives the contribution to primary energy.

$$\textit{Gas distribution energy ratio} = 0.0077\ kWh_{energy\ use}/kWh_{production}$$

Gas distribution losses are also taken into account by dividing the losses identified in the DUKES "Commodity Balance" table for gas distribution.

$$\textit{Losses} = 0.77\%$$

The primary energy factor for natural gas is 1 + the sum of the energy use for each of these process steps

Piped natural gas primary energy factor = 1.1135

LNG

For natural gas imported in the form of liquefied natural gas, there is significant additional energy use associated with compression, transportation (by sea in a tanker) and decompression before the gas is injected into the UK supply network. The energy use for this is provided in the JEC WTW study.

$$LNG\ energy\ ratio = 0.2018\ kWh_{energy\ use}/kWh_{production}$$

The primary energy factor for natural gas imported as LNG is equal to the primary energy factor for piped natural gas plus energy use associated with LNG.

Primary energy factor for LNG imports = 1.3153

Natural gas (mains supply)

The primary energy factor for UK mains gas is determined by the projected gas mix for 2020-2024 which contains 8% LNG (See section 7 for data sources), 1% Biogas and the primary energy factors for piped and LNG imports.

Primary energy factor UK mains gas supply = 1.1303

4.3 Petroleum products

For all petroleum products, the primary energy factor includes energy use for oil and gas production, transportation of crude oil to refineries, energy use at refineries and transport of petroleum products to the final user.

Energy use ratio for oil and gas production = 0.0982 $kWh_{energy\ use}/kWh_{production}$

The energy use ratio for oil and gas production is described in Section 5.2

Energy use for transport of crude oil to refineries and distribution of petroleum products was taken from JEC WTW analysis.

Energy use ratio for transport = 0.0216 $kWh_{energy\ use}/kWh_{production}$

For the UK, energy use in refineries is calculated as the sum of energy use provided in the DUKES "Commodity Balance" tables for all fuels where refineries are included under the "Energy Industry Use" heading. Dividing the energy use for refineries by the energy content of the petroleum products gives the refineries contribution to primary energy. In the absence of readily available data sources the same energy use is assumed for imported petroleum products.

Energy use ratio for refineries = 0.0606 $kWh_{energy\ use}/kWh_{production}$

For the UK supply of LPG, a proportion is extracted directly along with natural gas rather than being produced in a refinery[35]. Accordingly, the refinery energy use is applied to the same proportion of LPG production.

Primary energy factor for LPG = 1+(extraction ratio + transport ratio + 0.3*refinery ratio) = 1.14

Primary energy factor for other petroleum products = 1 + (extraction ratio + transport ratio + refinery ratio) = 1.18

[35] DUKES Table 3.2 shows that 30% of LPG (Propane and butane) is from sources other than refinery outputs.

4.4 Manufactured Smokeless Fuel

For manufactured smokeless fuel, the primary energy factor includes net energy losses during the manufacturing process plus transport energy use[36].

The net energy losses during manufacture are calculated from the difference in the energy content of the input fuels (coal and petroleum coke)[37] and manufactured smokeless fuel output[38] divided by the energy content of the output fuel.

Net energy losses manufactured solid fuel production = 26%

The energy use ratio for transporting the product to the final user was estimated using the same assumptions for coal (See section 5.1). In the absence of readily available data, the same assumption was used to estimate transport of the input fuels to the manufacturing plant.

Transport energy ratio manufactured solid fuel = 0.02726

Primary energy factor for Manufactured Solid Fuels = 1+ (losses + transport ratio) = 1.261

4.5 Biofuels and waste

For biofuels, the primary energy factor can vary considerably depending on the production route. In instances where the production process used to generate biofuels in the UK is not available, average values for all production routes are used.

[36] No additional energy use is assigned to energy industry use for manufactured solid fuel, so no energy use is assigned to production.

[37] From DUKES, table 1.1 Aggregate energy balance

[38] From DUKES, table 1.2 Commodity balance Manufactured Fuels

Biogas

For biogas, the primary energy factor is the average value for all EU production routes for biogas and synthetic methane[39] and includes energy use for transporting raw materials, biogas production and distribution, but excludes energy use for compression and CNG dispensing which is only relevant when biogas is being used as a transport fuel.

Primary Energy Factor for biogas = 1.286

Bioethanol

For bioethanol, the primary energy factor is the average value for all EU production routes for ethanol from organic sources[40] and includes energy use for cultivation of feedstock, transporting feedstock, ethanol production and distribution and dispensing at the retail site.

Primary Energy Factor for bioethanol = 1.472

Biodiesel

For biodiesel the primary energy factor is from a 2003 project report[41] for biodiesel from rapeseed oil.

Primary Energy Factor for biodiesel = 1.4370

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[39] JEC Well to Wheel Study 2014 Appendix 4 v4a

[40] JEC Well to Wheel Study 2014 Appendix 4 v4a

[41] Carbon and Energy Balances for a range of Biofuel Options, Resources Research Unit, Sheffield Hallam University, M A Elsayed, R Matthews and N D Mortimer. http://www.forestry.gov.uk/pdf/fr_ceb_0303.pdf/$FILE/fr_ceb_0303.pdf

Waste Vegetable Oil

For waste vegetable oil, the only energy use that will contribute to the primary energy factors will be any energy use for filtering and cleaning the oil plus transport to the final user. In the absence of available data on these, a nominal value was calculated based on a calorific value of 45 GJ/tonne (similar to fuel oil) and 25 km transport by road (See section 4.1 Table 15 for transport energy factors).

Primary energy factor waste vegetable oil = 1.042

Wood, biomass and waste

Primary energy factors for wood were derived from the life cycle greenhouse gas emissions for the generation of heat for a variety of biofuels provided in the BEAT tool[42]. The energy inputs occurring at all production stages were extracted from each data set and the following categories were included: cultivation, harvesting, primary processing, primary transport, drying and storage, secondary processing and secondary transport. The specific life cycles used to determine the SAP primary energy factors for these fuels are shown below.

Wood logs

Combustion of long logs

Primary energy factor wood logs = 1.046

Wood chips

Average value for the following processes:

- Wood Chips from Wood Processing Waste
- Wood Chips Derived by Combined Harvesting and Chipping of Short Rotation Coppice
- Wood Chip Derived from Short Rotation Coppice (obtained by stick harvesting)
- Wood Chip from UK Forest Residues

[42] BEAT v2

- Wood Chip from Forest Residues (overseas source)
- Shredded Medium Density Fibreboard Offcuts
- Shredded Chipboard Offcuts

Primary energy factor wood chips = 1.046

Wood pellets

Average for the following processes:

- Wood Pellets Derived by Combined Harvesting and Chipping of Short Rotation Coppice
- Wood Pellets Derived from Short Rotation Coppice (obtained by stick harvesting)
- Wood Pellets from Wood Processing Waste
- Wood Pellets from UK Forest Residues
- Pelletised Medium Density Fibreboard Offcuts
- Combustion of Wood Pellets from Forest Residues (overseas source)

Primary energy factor wood pellets = 1.325

Biomass

Combustion of Straw Bales

Primary energy factor for biomass = 1.2857

Waste

High Biomass Refuse Derived Fuel (RDF) from Municipal Solid Waste using the Fairport Process

Primary energy factor for waste = 1.1689

4.6 Grid electricity

The primary energy factor for grid electricity is calculated from the primary energy of the input fuels, the projected electricity generation mix and the transmission and distribution losses. The method is very similar to that described for emissions factors in section 3.2 but using the primary energy factors of the constituent inputs as found earlier in this section

(See section 7 for data sources). As with the emissions factor, this can be summarised as total electricity generation divided by total demand. For the SAP factor, an average for 2020-2024 has been taken.

Period	2020	2021	2022	2023	2024	SAP 10.1
kWh/kWh	1.578	1.498	1.464	1.483	1.481	1.501

Table 16: Projected annual primary energy factor for UK grid electricity 2020-2024

Primary energy factor for grid supply electricity = 1.501

This is also broken down into monthly factors, which are detailed in a separate technical paper entitled *S10TP-17 - Monthly factors for CO_2 emissions and primary energy*.

4.7 Renewable energy

Energy from renewable sources (not derived from biomass) are allocated a primary energy factor of 1. This applied to all heat and electricity generated from solar, wind, nuclear, hydro or geothermal sources.

Primary energy factor renewable energy = 1

5. CO2 EMISSIONS FACTORS TABLE

Table 17 summarises the emission factors for SAP and SBEM for all types of fuel commonly used in the UK in terms of $kgCO_2e/kWh$ gross calorific value, alongside the equivalent value for SAP 2012.

$kgCO_2/kWh$	**SAP 2012**	**SAP 10.1**
Gas:		
mains gas	**0.216**	**0.210**
bulk LPG	**0.241**	**0.241**
bottled LPG	**0.241**	**0.241**
bottled LPG (no contract)	**0.241**	**0.241**
LPG subject to Special Condition 18	**0.241**	**0.241**
biogas (including anaerobic digestion)	**0.098**	**0.024**
Liquid fuel:		
heating oil	**0.298**	**0.298**
biodiesel from any biomass source	**0.123**	**0.038**
biodiesel from vegetable oil only	**0.083**	**0.018**
appliances able to use mineral oil or biodiesel	**0.298**	**0.298**
B30K	**0.245**	**0.220**
bioethanol from any biomass source	**0.140**	**0.105**
Solid fuel:		
house coal	**0.394**	**0.395**
anthracite	**0.394**	**0.395**
manufactured smokeless fuel	**0.433**	**0.366**
wood logs	**0.019**	**0.028**
wood pellets (in bags for secondary heating)	**0.039**	**0.053**
wood pellets (bulk supply for main heating)	**0.039**	**0.053**
wood chips	**0.016**	**0.023**
dual fuel appliance (mineral and wood)	**0.226**	**0.087**
Electricity:		
standard tariff	**0.519**	**0.136**
7-hour tariff (high rate)	**0.519**	**0.136**
7-hour tariff (low rate)	**0.519**	**0.136**
10-hour (high rate)	**0.519**	**0.136**
10-hour (low rate)	**0.519**	**0.136**
18-hour (high rate)	**0.519**	**0.136**
18-hour (low rate)	**0.519**	**0.136**
24-hour heating tariff	**0.519**	**0.136**
electricity exported to grid	**0.519**	**0.136**
electricity, any tariff	**0.519**	**0.136**
Community heating schemes:		
heat from boilers - mains gas	**0.216**	**0.210**
heat from boilers - LPG	**0.241**	**0.241**
heat from boilers - oil	**0.331**	**0.335**
heat from boilers that can use mineral oil or biodiesel	**0.331**	**0.335**
heat from boilers using biodiesel from any biomass source	**0.123**	**0.038**
heat from boilers using biodiesel from vegetable oil only	**0.083**	**0.018**
heat from boilers - B30D	**0.269**	**0.269**
heat from boilers - coal	**0.380**	**0.375**
heat from electric heat pump	**0.519**	**0.136**
heat from boilers - waste combustion	**0.047**	**0.074**
heat from boilers - biomass	**0.031**	**0.029**
heat from boilers - biogas (landfill or sewage gas)	**0.098**	**0.024**
waste heat from power station	**0.058**	**0.015**
geothermal heat source	**0.041**	**0.011**
heat from CHP	**as above**	**0.011**
electricity generated by CHP	**0.519**	**0.136**
electricity for pumping in distribution network	**0.519**	**0.136**

Table 17: CO2 Emission Factors for SAP and SBEM

6. PRIMARY ENERGY FACTORS TABLE

Table 18 summarises the primary energy factors for SAP for all types of fuel commonly used in the UK, alongside the equivalent value for SAP 2012.

kWh primary/kWh delivered	SAP 2012	SAP 10.1
Gas:		
mains gas	**1.22**	**1.130**
bulk LPG	**1.09**	**1.141**
bottled LPG	**1.09**	**1.141**
bottled LPG (no contract)	**1.09**	**1.141**
LPG subject to Special Condition 18	**1.09**	**1.141**
biogas (including anaerobic digestion)	**1.10**	**1.286**
Oil:		
heating oil	**1.10**	**1.180**
biodiesel from any biomass source	**1.06**	**1.437**
biodiesel from vegetable oil only	**1.01**	**1.042**
appliances able to use mineral oil or biodiesel	**1.10**	**1.180**
B30K	**1.09**	**1.257**
bioethanol from any biomass source	**1.08**	**1.472**
Solid fuel:		
house coal	**1.00**	**1.064**
anthracite	**1.00**	**1.064**
manufactured smokeless fuel	**1.21**	**1.261**
wood logs	**1.04**	**1.046**
wood pellets (in bags for secondary heating)	**1.26**	**1.325**
wood pellets (bulk supply for main heating)	**1.26**	**1.325**
wood chips	**1.12**	**1.046**
dual fuel appliance (mineral and wood)	**1.02**	**1.049**
Electricity:		
standard tariff	**3.07**	**1.501**
7-hour tariff (high rate)	**3.07**	**1.501**
7-hour tariff (low rate)	**3.07**	**1.501**
10-hour (high rate)	**3.07**	**1.501**
10-hour (low rate)	**3.07**	**1.501**
18-hour (high rate)	**3.07**	**1.501**
18-hour (low rate)	**3.07**	**1.501**
24-hour heating tariff	**3.07**	**1.501**
electricity exported to grid	**3.07**	**1.501**
electricity, any tariff	**3.07**	**1.501**
Community heating schemes:		
heat from boilers - mains gas	**1.22**	**1.130**
heat from boilers - LPG	**1.09**	**1.141**
heat from boilers - oil	**1.10**	**1.180**
heat from boilers that can use mineral oil or biodiesel	**1.10**	**1.180**
heat from boilers using biodiesel from any biomass source	**1.06**	**1.437**
heat from boilers using biodiesel from vegetable oil only	**1.01**	**1.042**
heat from boilers - B30D	**1.09**	**1.090**
heat from boilers - coal	**1.00**	**1.064**
heat from electric heat pump	**3.07**	**1.501**
heat from boilers - waste combustion	**1.23**	**1.169**
heat from boilers - biomass	**1.01**	**1.037**
heat from boilers - biogas (landfill or sewage gas)	**1.10**	**1.286**
waste heat from power station	**1.34**	**1.063**
geothermal heat source	**1.24**	**1.051**
heat from CHP	**as above**	**1.051**
electricity generated by CHP	**3.07**	**1.501**
electricity for pumping in distribution network	**3.07**	**1.501**

Table 18 Primary Energy Factors for SAP and SBEM

7. DATA SOURCES

Document Title	Sources
Updated energy and emissions projections	https://www.gov.uk/government/collections/energy-and-emissions-projections#updated-energy-and-emissions-projections
Greenhouse gas reporting: conversion factors.	https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting
DUKES chapter 1: statistics on overall energy production and consumption.	https://www.gov.uk/government/statistics/energy-chapter-1-digest-of-united-kingdom-energy-statistics-dukes
DUKES chapter 2: statistics on supply and demand for coal and manufactured solid fuels.	https://www.gov.uk/government/statistics/solid-fuels-and-derived-gases-chapter-2-digest-of-united-kingdom-energy-statistics-dukes
DUKES chapter 3: statistics on supply and demand for petroleum.	https://www.gov.uk/government/statistics/petroleum-chapter-3-digest-of-united-kingdom-energy-statistics-dukes
DUKES chapter 4: statistics on supply and demand for natural gas.	https://www.gov.uk/government/statistics/natural-gas-chapter-4-digest-of-united-kingdom-energy-statistics-dukes
DUKES chapter 5: statistics on electricity from generation through to sales.	https://www.gov.uk/government/statistics/electricity-chapter-5-digest-of-united-kingdom-energy-statistics-dukes
DUKES chapter 6: statistics on energy from renewable sources.	https://www.gov.uk/government/statistics/renewable-sources-of-energy-chapter-6-digest-of-united-kingdom-energy-statistics-dukes
Dukes A.1 -A.3: Estimated average calorific values of fuels 2019	https://www.gov.uk/government/statistics/dukes-calorific-values
Energy Trends section 2.4	https://www.gov.uk/government/statistics/solid-fuels-and-derived-gases-section-2-energy-trends

RTE eCO2mix indicators.	https://www.rte-france.com/eco2mix/telecharger-les-indicateurs
Gas Ten Year Statement (GTYS)	https://www.nationalgrid.com/uk/gas-transmission/insight-and-innovation/gas-ten-year-statement-gtys
"Well-to-Wheels Analysis of Future Automotive Fuels and Powertrains in the European Context" Version 4, July 2013. Report EUR 26028 EN – 2013.	http://iet.jrc.ec.europa.eu/about-jec/

APPENDIX A: DESCRIPTION OF FUEL TYPES AND THEIR APPLICATION IN SAP

A description of the fuel types and the circumstances under which each of the factors should be used is provided below.

Natural gas: Gas that has been piped directly from gas fields before being introduced into the UK mains supply system. (Not a SAP emission factor - provided for information only.)

LNG (Liquefied Natural Gas): Gas that has been liquefied and shipped to the UK before entering the UK mains supply system.

Mains gas: Gas that is piped into dwellings is a mixture of natural gas, LNG and biogas. Factors for mains gas would be used in most cases where the fuel is gas as this represents the grid mix.

LPG (Liquid Petroleum Gases): Used for appliances that use propane or butane. It is generally only used where mains supply gas is not available. LPG is derived from oil and pressurised into liquid for distribution and may be bulk supply (stored in tanks) or supplied in reusable cylinders.

Bio-gas: Use for appliances that exclusively use methane that has been generate from bio-genic sources. Sources of bio-gas include landfill sites and fermentation of animal waste and vegetable matter. This factor should only be used where appliances are directly connected to a bio-gas supply source.

Domestic heating oil/burning oil/kerosene (28 sec oil): Use with appliances that are designed to use domestic heating oil. Domestic heating oil is a low viscosity refined petroleum product predominantly used as a heating fuel in domestic scale appliances.

Gas oil/diesel (35 sec oil): Use with appliances that are designed to use gas oil/diesel. Gas oil is a medium viscosity refined petroleum product predominantly used as heating fuel in commercial scale appliances.

Fuel oil: Use with appliances that are designed to use fuel oil. Fuel oil is a high viscosity refined petroleum product predominantly used as a heating fuel in large industrial scale applications.

Bio-diesel from any biomass source: Use with appliances that are designed to run exclusively on bio-diesel. Bio-diesel is derived from vegetable oil or animal fats and consists of long-chain alkyl (methyl, propyl or ethyl) esters and is sometimes referred to as FAME (fatty acid methyl esters). The emissions associated with this fuel can vary greatly depending on the biomass source and production methods and the distribution chain. The emission factor provided here is based on the current mix of bio-fuels used in the UK and excludes direct CO_2 emissions from fuel combustion which are of bio-genic origin.

Vegetable oil: Use for appliances designed to run exclusively on vegetable oil. Vegetable oil used as a fuel may be derived from virgin sources or from used vegetable oil.

Domestic heating oil or liquid bio-fuels (Dual Fuel Appliances): Use for appliances that can use either domestic heating oil or liquid bio-fuels. Currently there are very few appliances available that are known to run on domestic heating oil or bio-diesel. Therefore, the amount of liquid bio-fuels (bio-diesel or vegetable oils) that are used in appliances that can also use domestic heating oil will be very small. In the absence of statistical information, it is assumed that the ratio of domestic heating oil to liquid bio-fuel is 100%. Hence the emission factor for domestic heating oil represents the current UK fuel mix for these appliances. This situation may change in the future.

Gas oil or liquid bio-fuels (Dual Fuel Appliances): This factor should be used for appliances that can use either gas oil or liquid bio-fuels. Currently there are very few appliances available that are able to run or known to run on gas oil or bio-diesel. Therefore, the amount of liquid bio-fuels (bio-diesel or vegetable oils) that are used in appliances that can also use gas oil will be very small. In the absence of statistical information, it is assumed that the ratio of gas oil to liquid bio-fuel is 100%. Hence the emission factor for gas oil represents the current UK fuel mix for these appliances. This situation may change in the future.

Fuel oil or liquid bio-fuels (Dual Fuel Appliances): Use for appliances that can use either fuel oil or liquid bio-fuels. Currently there are very few appliances available that are able to run or known to run on fuel oil or bio-diesel. Therefore, the amount of liquid bio-fuels (bio-diesel or vegetable oils) that are used in appliances that can also use fuel oil will be very small. In the absence of statistical information, it is assumed that the ratio of fuel oil to liquid bio-fuel is 100%. Hence the emission factor for fuel oil represents the current UK fuel mix for these appliances. This situation may change in the future.

Bio-ethanol from any biomass source: Use for appliances that exclusively run on bio-ethanol. Bio-ethanol is ethanol that has been derived from vegetable oil or animal fats. The emission factor excludes direct CO_2 emissions from fuel combustion as it is bio-genic in origin.

House coal: Use for domestic appliances that are designed to use coal and are outside of smoke control zones. The factor given represents an average value for bituminous coal supplied to the domestic sector.

Anthracite: Use for appliances that are designed to run on anthracite which is permitted inside smoke control zones. Anthracite is a purer, more compressed form of coal which contains minimal hydrocarbons and tars and generally has high heat content compared to other types of coal and can be used in smokeless zones.

Coal (non-domestic): For use in SBEM not SAP. The factor given is an average value for coal supplied to the non-domestic sector.

Manufactured smokeless fuel (domestic): Use for appliances that are designed to run on smokeless solid fuels which are permitted inside smoke control zones. Smokeless solid fuels covers coke produced for domestic/commercial use such as Coalite, and briquetted fuels such as Phurnacite and Homefire.

Manufactured smokeless fuel (non-domestic): For use in SBEM not SAP. Use for appliances that are designed to run on smokeless solid fuels which are permitted inside smoke control zones. Smokeless solid fuels covers coke produced for

domestic/commercial use such as Coalite, and briquetted fuels such as Phurnacite and Homefire.

Wood logs: Use for appliances designed exclusively for burning wood logs and should only be used for buildings where adequate storage is provided for wood logs. The emission factor excludes direct CO_2 emissions from fuel combustion as it is bio-genic in origin.

Wood pellets: Use for appliances designed exclusively for burning wood pellets. This emission factor excludes direct CO_2 emissions from fuel combustion as it is bio-genic in origin.

Wood chips: Use for appliances designed exclusively for burning wood chips. This emission factor excludes direct CO_2 emissions from fuel combustion as it is bio-genic in origin.

Mineral or wood solid fuels (Dual Fuel Appliances): Use for solid fuel appliances that are designed to burn both wood and mineral solid fuels. This emission factor is based on the UK average mix of solid fuels used in the domestic sector.

Electricity: Use for all electrical appliances. The factor given is based on projected system average values over the stated period.

Electricity exported to the grid: Use for any electricity generated from onsite renewables which is exported to the grid. The factor given is based on projected system average values over the stated period.

Geothermal heat sources: Use for district heating supplied from geothermal sources.

Biomass used to generate heat or heat and power: This includes raw biomass sources other than wood, e.g., grasses and straw. This factor should be used for district heating schemes fired by these biomass sources. Direct CO_2 emissions are excluded as they are of bio-genic origin

Waste used to generate heat or heat and power: Use for appliances that use waste to generate either heat or heat and power. Direct CO_2 emissions from the proportion of waste that is derived from bio-genic sources are excluded, but direct CO_2 emissions from plastic are included as they are derived from fossil fuel sources.

Waste heat from power stations: Use for district heating supplied by waste heat from power stations.

Electricity generated by CHP: Use for all electricity generated by CHP regardless of the generation fuel. The factor given is based on projected system average values over the stated period.

Electricity for pumping in distribution network: Use for electricity used for pumping for district heating schemes regardless of the fuel used to generate heat.