Consultation Paper: CONSP:07

CO_2 AND PRIMARY ENERGY FACTORS FOR SAP 2016

Version 1.0

DOCUMENT REVISIONS

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DOCUMENT REVISION LOG

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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) and Dwelling CO_2 Emission Rate (DER). These reflect the CO_2 emissions associated with space heating, water heating, ventilation and lighting within the dwelling. The Environmental Impact rating is expressed on a scale of 1 to 100; the higher the number the better the standard. The DER is used for the purposes of compliance with building regulations. It is equal to the annual CO_2 emissions per unit floor area for space heating, water heating, ventilation and lighting, less the emissions saved by energy generation technologies, expressed in $kgCO_2e/m^2/year$.

SAP calculates the energy consumption for space heating, water heating, ventilation and lighting for a dwelling under standardised occupancy conditions. The 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 impacts associated with this energy use emission factors are determined and applied to each fuel type. To comply with the EPBD (Energy Performance of Building Directive) the energy impacts must also be calculated in terms of primary energy which encompasses upstream energy use.

This paper presents provisional carbon emission factors and primary energy factors which are to be used in the 2016 versions of SAP and also for SBEM (the compliance calculation tool for non-domestic buildings)[1]. It identifies the data sources used and describes the calculation methodology used and the underlying rationale. It is intended that a final version will be produced later which takes account of any updated information which subsequently becomes available. This paper highlights instances where updates may lead to a significant change to the values presented here.

[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.

It is important to bear in mind that, whilst the same method will be used, the factors will need to be updated again shortly before SAP is published to bring them into line with the latest data available at the time. Therefore these are not the final figures which will be included in SAP 2016.

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 with regard to combustion conditions and changes in energy supply chains. This section describes the scope of the SAP 2016 energy and emission 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 2016 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.

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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.

In addition to being generated directly from 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.

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 activities 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.

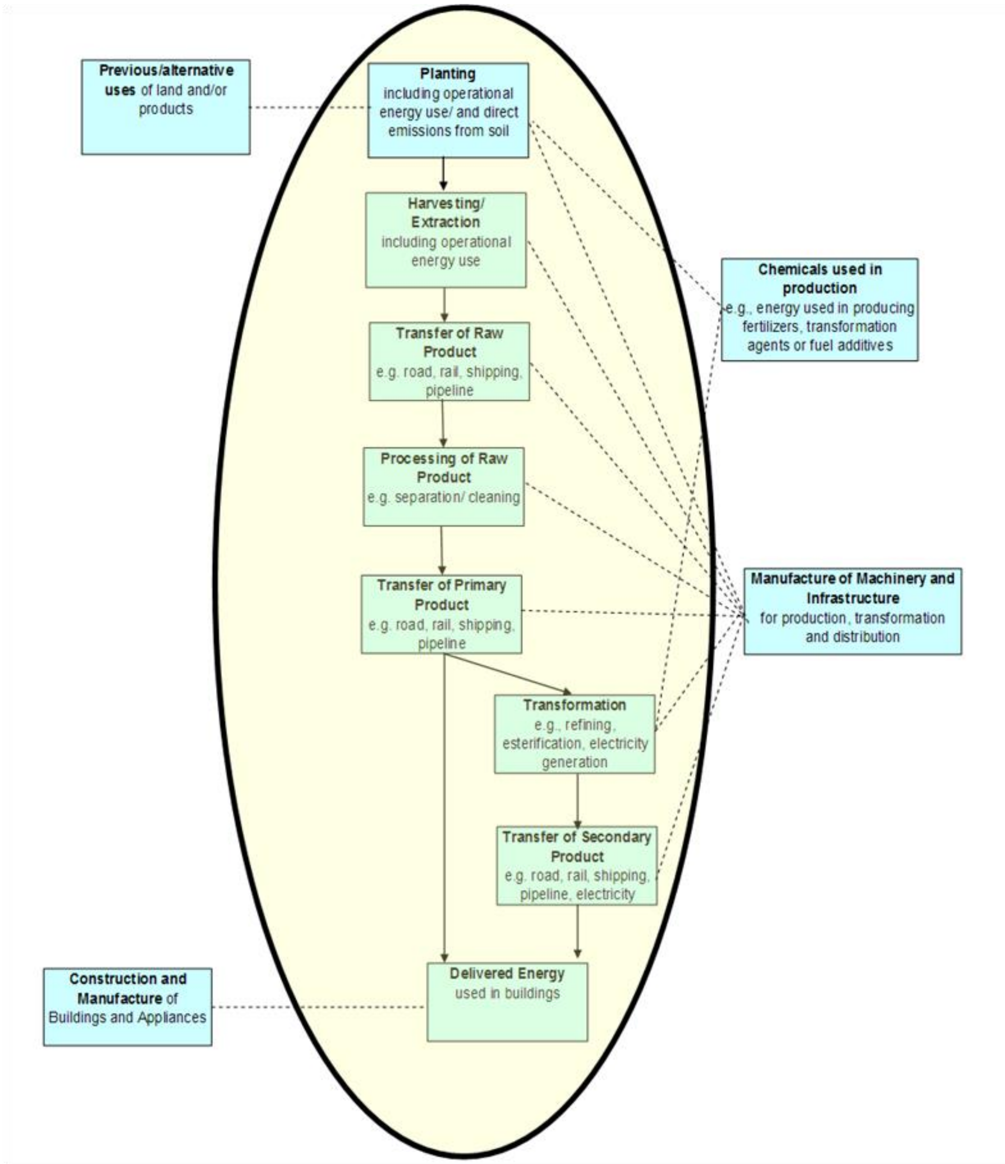

Figure 1: System Boundary for Greenhouse Gas Emissions from Delivered Energy Use

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 proposed three year 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, and*
- *is independent of the geographical location of the building.*

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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.

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

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 (as against 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.*

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

2.8 Primary Energy Factors

In order to comply with the EPBD (Energy Performance of Building Directive) the energy impacts must also be calculated in terms of primary energy which encompasses upstream energy use. Accordingly 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 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 2016 SAP 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.”

For 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. Similarly biomass sources and waste used to produce energy should also 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 should also take 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 (2015) 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 2015 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 where possible.

The Government's conversion factors for 2015 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 for use 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)

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[8] 2015 Government GHG Conversion Factors for Company Reporting: Methodology Paper for Emission Factors Final Report
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/507942/Emission_Factor_Methodology_Paper_-_2015.pdf

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" (well to tank) emission factor for that fuel.[9] 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.

[9] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2015

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[10] which covers conventional 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 2015 Government conversion factors and the primary data sources for these are shown in the following table[11].

SAP fuel type	Government conversion factors fuel type	Direct (Scope 1)	Upstream (Scope 3)	$kgCO_2e$ /kWh	Primary data sources/Assumptions
LPG	LPG	0.2147	0.0270	0.2417	2015 Government GHG Conversion Factors 2015
Domestic heating oil (burning oil/kerosene)	Burning oil	0.2466	0.0511	0.2976	Government GHG Conversion Factors 2015
Gas oil (diesel)	Gas oil	0.2710	0.0545	0.3255	Government GHG Conversion Factors 2015
Fuel oil	Fuel oil	0.2680	0.0505	0.3185	Government GHG Conversion Factors 2015
House coal	Coal (domestic)	0.3659	0.0503	0.4162	Government GHG Conversion Factors 2015
Anthracite	Coal (domestic)	0.3659	0.0503	0.4162	Government GHG Conversion Factors 2015
Coal (non-domestic) (For use in SBEM)	Coal (industrial)	0.3285	0.0503	0.3788	Government GHG Conversion Factors 2015

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

[10] "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/

[11] Values for smokeless solid fuel will be included in the final version of this paper

The Government's conversion factors for direct emissions are the default values from the UK GHG Inventory and are activity weighted values for 2015. 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[12].

However, for liquid and gaseous fossil fuels it is appropriate to use the UK sector weighted average value as there are no significant difference in emission factors between sectors for these fuels.

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) 2015[13].

3.1.1 Natural Gas

The "natural gas" factors in the Government emission factors refers to mains gas delivered via the grid based on the 2013 grid mix of piped natural gas and liquefied natural gas in mains supply gas[14,15]. This source also provides a factor for LNG (Liquefied Natural Gas). The emission factor for piped natural gas was back calculated from the 2013 grid supply mix (12.07% LNG) and the LNG emission factor.

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[12] It would be possible to provide specific factors for the domestic and non-domestic sectors for other fossil fuels. However, in most instances the differences are small (circa 1%) and using these would mean that the SAP emission factors would not appear to be consistent with the "official" Defra conversion values.

[13] Digest of United Kingdom Energy Statistics 2015, DECC, July 2015.

[14] For SAP 2012 it was assumed that the Defra natural gas emission factor referred to piped natural gas rather than mains supply gas.

[15] The amount of biogas injected into the grid from small producers is currently too small to register in the National Grid projections, but may become significant in the future.

SAP fuel type	Government conversion factors fuel type	Direct (Scope 1)	Upstream (Scope 3)	$kgCO_2e$ /kWh	Primary data sources/Assumptions
-	Natural gas (2013 mains supply)	0.1845	0.02483	0.2093	Government GHG Conversion Factors 2015 (Determined from 2013 mix of LNG and piped natural gas)
LNG	LNG	0.1845	0.0682	0.2527	Government GHG Conversion Factors 2015
Natural gas (piped)	-	0.1845	0.01852	0.2030	Value for piped natural gas calculated from 2013 grid supply mix and LNG conversion factor and proportion of LNG in 2013 mains supply (12.07%)

Table 2: Natural gas emission factors

The natural gas (piped) and LNG factors were subsequently used to calculate the average projected emission factor for mains supply gas for the period 2016-18. See section 3.2 for more details.

3.1.2 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 2014.

In addition to the 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 2013 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	0.3622	0.0466	0.0754	0.0055	0.4897	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	0.3453	0.0466	0.0754	0.0055	0.4728	

Table 3: Solid Manufactured Fuel Emission Factors

3.2 Grid supply energy

3.2.1 UK mains supply gas

The projected UK mains gas emission factor for 2016-2018 has been estimated based on the projected mix of LNG and piped natural gas provided in the National Grid's Gas Ten Year Statement[16] 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 9% over the period 2016-2018[17]. This is considerably lower than the 25% that was projected for 2013-2015 for SAP 2012.

The piped natural gas was back calculated from the Defra 2014 value for grid supplied natural gas as described in Section 3.1.1

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	0.2077	SAP 2016 factors for LNG & natural gas + projected grid supply mix 2016-2018 from Gas Ten Year Statement 2014

Table 4: Mains gas supply emission factor and data sources

3.2.2 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 fuel type and the

[16] Gas Ten Year Statement 2014, National Grid, December 2014 http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/Gas-Ten-Year-Statement/ Download of GTYS 2014 Charts

[17] This is an average for two of the scenarios which are presented in the report using the "no progress" and "carbon lifetime" scenarios.

emission factor for each fuel type. The total annual emissions arising from energy generation were calculated as follows:

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

The UK projected electricity generation mix is taken from DECC's Updated Energy and Emissions Projections (UEEP) 2014[18]. Annex J gives total annual electricity generation by source.

The generation efficiency for each fuel type was taken from DUKES 2014 (Table 5.5) as "net supplied (gross)" [19] divided by "fuel used" for all generating companies for 2013 as follows:

- Coal generation 34%
- Gas generation 46%
- Oil generation 28%
- Other thermal 21%

The proportion of UK electricity that is imported from France is not included in the UK projections. The amount of electricity imports vary from year to year so a three year average value (2011-2013) from DUKES Table 5.1 2014 (4%) has been assumed for the period 2016 – 2018.

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

[18] Updated energy and emissions projections 2014: projections of greenhouse gas emissions and energy demand 2014 to 2030, October 2014, DECC

[19] The "net supplied (gross)" is net of electricity "used on works", but not of 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	0.3099	0.0503	0.3602	Government GHG conversion factors 2015
Power station oil	Fuel oil	0.2680	0.0505	0.3185	Government GHG conversion factors 2015
Power station gas	Mains gas	0.1845	0.0191	0.2036	Government GHG conversion factors 2015
Imports	French electricity	0.0586[20]	0.0141[21]	0.0728	Government GHG conversion factors 2014/2015

Table 5: Electricity generation fuels emission factor and data sources

The total emissions are then divided by the total projected electricity supply[22] from DECCs Updated Energy and Emissions Projection 2014[23] 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.

[20] This factor is for CO_2 only and is from the 2014 Government GHG conversion factors (values for imported electricity were not provided in the 2015 dataset.)

[21] This includes both WTT emissions from inputs fuels and transport and distribution losses within France and is from the 2015 dataset.

[22] 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.

[23] Updated energy and emissions projections 2014: projections of greenhouse gas emissions and energy demand 2014 to 2030, October 2014, DECC

Transmission and distribution losses were calculated from the average losses for the public distribution system 2011-2013 from DUKES 2014 Table 5.2 as follows:

(“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 2016 emission factor is taken as the average value over 2016-2018, see Table 6.

Period	2016	2017	2018	SAP 2016 value
$kgCO_2e/kWh$	0.4157	0.3983	0.3790	0.3985

Table 6: Projected annual emission factor for UK grid electricity 2016-2016

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)[24], 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 2015 Government conversion factors and their sources are shown in Table 7.

[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)

SAP fuel type	Government conversion factors fuel type	Direct (Scope 1)	Upstream (Scope 3)	$kgCO_2e$ /kWh	Sources
biogas	Biogas	0.0002	0.0392	0.0395	Government GHG conversion factors 2015
FAME (biodiesel)	Biodiesel	0.0022	0.0676	0.0698	Government GHG conversion factors 2015
Bioethanol	Bioethanol	0.0009	0.1173	0.1182	Government GHG conversion factors 2015
wood logs	Wood logs	0.0132	0.0128	0.0260	Government GHG conversion factors 2015
wood pellets	Wood pellets	0.0132	0.0322	0.0454	Government GHG conversion factors 2015
wood chips	Wood chips	0.0132	0.0166	0.0298	Government GHG conversion factors 2015
biomass	Grass/straw	0.0250	0.0197	0.0447	Government GHG conversion factors 2015
Waste vegetable oil	Waste oils	0.0009	-	0.0009	Government GHG conversion factors 2015

Table 7: Biofuel emission factors and data sources

The Government emission factors use data from the Ofgem calculator[25] was used to calculate 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

25 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[26]. 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 is substituted[27].

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.

The 2015 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 ratio of each fuel type used within buildings. 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 a 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.

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[26] 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.

[27] 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 UK[28]
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 UK[29]
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, respectively[30]
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 that 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

[28] 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)

[29] 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)

[30] 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 metering data for the electricity used to pump heat from a single deep geothermal district heating system[31]

The emission factor for heat generated from waste incineration is derived from data extracted from Defra's Biomass Environmental Assessment Tool (BEAT)[32], 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)	$kgCO_2e$ /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 waste[39]

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

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[31] Private communication Simon Woodward, Utilicom

[32] 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. PROPOSED NEW FACTORS

Table 10 summarises the provisional 2016 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. **Remember that these will be updated again shortly before SAP is published, so these do not represent the final figures that will be in SAP 2016.**

kgCO2/kWh	SAP 2012	SAP 2016	% change
mains supply gas	0.216	0.208	-4%
natural gas (1)	0.204	0.203	-1%
LNG (1) (2)	0.250	0.253	1%
LPG	0.241	0.242	0%
biogas (3)	0.098	0.039	-60%
Liquid Fuels:			
domestic heating oil (burning oil/kerosine)	0.298	0.298	0%
gas oil (diesel)	0.331	0.325	-2%
fuel oil	0.319	0.319	0%
appliances that specifically use FAME (biodiesel) (3)	0.123	0.070	-43%
appliances that specifically use waste vegetable oil (3)	0.083	0.050	-40%
domestic heating oil and liquid biofuels (dual fuel appliance)	0.298	0.298	0%
gas oil and liquid biofuels (dual fuel appliance)	0.331	0.325	-2%
B30K (4)	0.245	0.229	-7%
B30D (4)	0.269	0.249	-7%
Bioethanol from any biomass source (3)	0.140	0.118	-16%
Solid fuel:			
house coal	0.394	0.416	6%
anthracite	0.394	0.416	6%
coal (non-domestic) (5)	0.345	0.379	10%
manufactured smokeless fuel (domestic)	0.433	0.490	13%
manufactured smokeless fuel (non-domestic) (5)	0.433	0.473	9%
wood logs (3)	0.019	0.026	37%
wood pellets (3)	0.039	0.045	16%
wood chips (3)	0.016	0.030	89%
dual fuel appliance (mineral and wood)	0.226	0.108	-52%
Electricity:			
electricity consumption (6)	0.519	0.398	-23%
electricity exported to the grid (6)	0.519	0.398	-23%
Community heating and CHP: Fuels used to generate heat or heat and power			
mains supply gas	0.216	0.208	-4%
coal	0.380	0.379	0%
LPG	0.241	0.242	0%
domestic heating oil (burning oil/kerosine)	0.298	0.298	0%
gas oil (diesel)	0.331	0.325	-2%
fuel oil	0.319	0.319	0%
electricity	0.519	0.398	-23%
waste	0.047	0.074	56%
biomass	0.031	0.045	44%
biogas (3)	0.098	0.039	-60%
waste heat from power stations	0.058	0.044	-23%
geothermal heat sources	0.041	0.031	-23%
appliances that specifically use FAME (biodiesel) (3)	0.123	0.070	-43%
appliances that specifically use vegetable oil (3)	0.083	0.050	-40%
domestic heating oil (including appliances that are able to use liquid biofuels or liquid biofuel/fuel oil blends)	0.298	0.298	0%
gas oil (including appliances that are able to use liquid biofuels or liquid biofuel/fuel oil blends)	0.331	0.325	-2%
B30K (4)	0.245	0.229	-7%
B30D (4)	0.269	0.249	-7%
Bioethanol from any biomass source (3)	0.140	0.118	-16%
Electricity generated by CHP (6)	0.519	0.398	-23%
Electricity for pumping in distribution network (6)	0.519	0.398	-23%

Table 10: Proposed 2016 Emission Factors for SAP and SBEM

(1) These values are provided for information only and are not for use in SAP calculations

(2) Liquefied Natural Gas imports to the UK grid supply gas

(3) Data sourced from a more recent source (Government GHG conversion factors)

(4) To be used for appliances that are only able to use the fuel blends specified.

(5) For use in SBEM only

(6) The observed decrease is primarily due to changes in the projected generation mix over the relevant periods (2013-2015 and 2016-2018)

DISCUSSION CO_2 EMISSION FACTORS

These emissions factors have been generated using the most recent data sources available. Where possible the current official set of government emissions factors (Defra conversion factors for company reporting 2015) are used and the underlying source data and any assumptions made are identified.

These provisional factors are based on information that is currently available and will be updated when revised data becomes available, but the calculation methodology is not expected to change. It is anticipated that the following key data sources will become available as indicated below:

- Government's conversion factors – June 2016
- Digest of United Kingdom Energy Statistics – July 2016
- DECCs Updated Energy and Emissions Projection – September 2016

For most fossil fuels the changes in emission factors are small and result primarily from variations in the average composition for each fuel type. For biofuels there have been some significant decreases in the emission factors compared to the 2012 values this is because factors based on more recent data are now provided in the Government GHG conversion factors.

The factors for grid supply energy sources (mains gas and grid supply electricity) can vary considerably from year to year depending on the generation mix and the fuel sources used.

For electricity the provisional emission factor for SAP 2016 is 23% lower than the 2012 value. This is due to two key changes:

- An increase in the proportion of conventional (thermal) electricity generated from natural gas compared to coal arising from anticipated lower price of gas relative to coal
- An increase in the amount of renewable energy in the generation mix

Over the relevant periods (2013-2015 for SAP 2012 and 2016-2018 for SAP 2016) the proportion of electricity generated from coal is predicted to fall from 53% to 30%, whilst the proportion of natural gas is expected to increase from 27% to 44% and renewable generation from 8% to 14%.

For natural gas there has been a small decrease in the emission factor. This arises from an anticipated reduction in LNG in mains supply mix compared to previous years and also from a mistaken assumption in SAP 2012 that the Defra "natural gas" referred to piped natural gas rather than mains supply gas.

There have been significant changes in the emission factors for biofuels compared to the SAP 2012 values. Emissions from biofuels are more variable than those for other fuels because emissions upstream in the supply chain account for a much larger proportion of the carbon impacts and there is a much greater variation in the supply chain itself with respect to production and processing methods and also transport modes and distances. In addition more complete/newer data sources have become available which will also lead to differences between the two periods. In particular:

- The addition of direct (Scope 1) conversion factors for methane (CH_4) and nitrous oxide (N_2O) for biodiesel and bioethanol
- Upstream (Indirect/Scope 3) emissions for biomass and biogas have been update from a new data source.

4.1 Changes in Electricity Emission Factors

For electricity the emission factor for SAP 2016 is 23% lower than the 2012 value due to significant changes in the projected electricity generation mix between the two periods which the factors cover (2013-2015 and 2016-2018), see Figure A below.

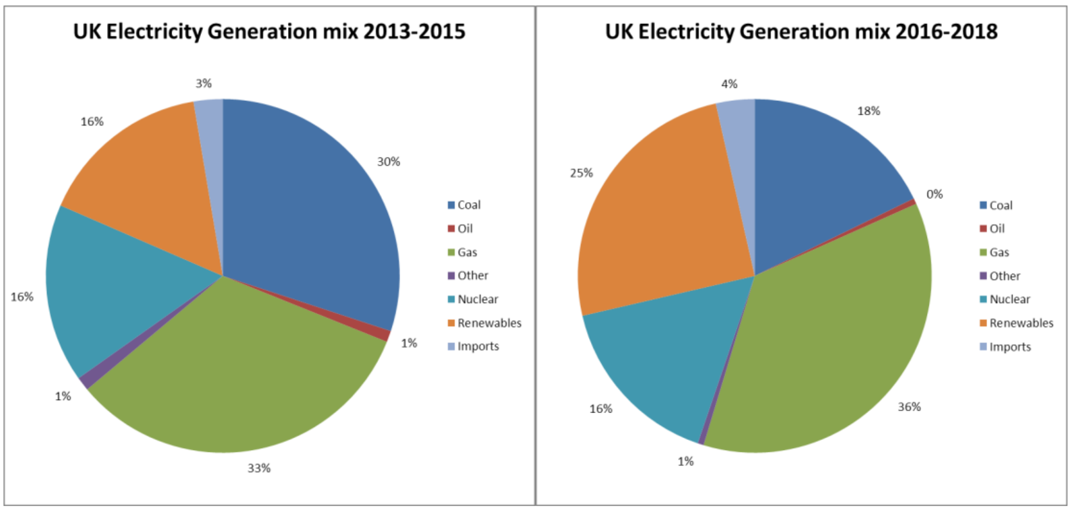

Figure A: UK electricity generation mix for SAP 2012 (left) and SAP 2016 (right)

It can be seen from the above chart that there are two main reasons for the observed decrease in the SAP 2012 electricity factor compared to the SAP 2016 one.

1) An increase in the renewable generation capacity leading to a decrease in electricity generated from conventional combustion generation plant.

    For renewable energy generation plant, once built, the marginal cost of operating it is negligible in comparison and so renewable energy generators will tend to operate whenever possible.

2) A reduction in the price of gas compared coal leading to more gas fired generating plant tending to operate in favour of coal fired generation.

    For conventional combustion plant fuel costs comprise the majority of operation costs, therefore changes in the relative price of fuels can lead to large shifts in the types of plant that are operating when generation capacity exceeds demand[33].

[33] At peak demand most plant will need to be operating regardless of cost

This will make a significant contribution to the observed reduction in the emission factor because as well as having a lower emission factor than coal natural gas also has a higher average generation efficiency (45% compared to 33%).

In addition, changes in the average generation efficiency, transmission and distribution losses and in the proportion of electricity imported via the French interconnector may also alter the emission factor .However, no significant changes in these values are anticipated between the two periods, so they have not contributed to the observed change in electricity emission factor.

The SAP emission factors are based on projected estimates of the generation mix which are based on assumptions surrounding the overall demand for electricity, the capacity and availability of generation plant and the price of generation fuels. The following chart shows the actual electricity emissions factor to 2013 and the projected values to 2035 based on the central scenarios from the 2014 UEP.

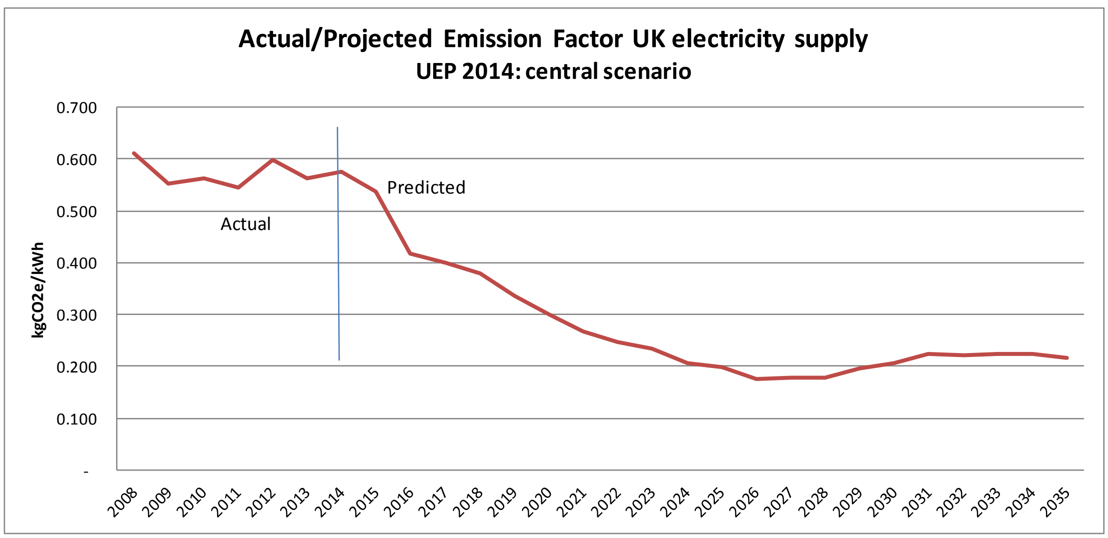

Figure B: Actual and projected electricity emission factors 2035

Table 11 shows the projected system average electricity emission factors for current and future periods (coinciding with anticipated revisions of Part L of the Building Regulations). This provided an indication of the likely trajectory, but the emission factor for future years may be different.

2013-2015	2016-2018	2019-2021	2022-2024	2025-2027
0.558	0.399	0.302	0.229	0.183

Table 11: Projected system average emission factors for UK electricity kgCO_2e/kWh

Comparing the projected value for 2016-2018 for SAP 2016 of 0.399 kgCO_2/kWh which is based on the 2014 updated energy projections with the projected value for the same period based on the 2011 updated energy projections (which were used to inform the SAP 2012 factors) show that the SAP 2012 factor was 7% below the actual value over the period (2013-2015), see Table 12.

Average projected kgCO_2e/kWh	2013-2015
2011 UEP	0.519
2014 UEP	0.558
% change	-7%

Table 12: Comparison of the electricity emission factor for SAP 2012 based on the 2011 energy projections compared to the 2014 projections.

5. 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[34], which provides EU primary energy factors for some fuels and DUKES 2015 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.

[34] JEC study

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[35]

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

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[36]. 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.

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

5.1 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.

5.1.1 Coal Extraction

For the UK this is calculated as the sum 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 but the energy content of the coal extracted gives the coal extraction contribution to primary energy.

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

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

The majority of coal imported from the UK 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.

$$\textit{Coal extraction energy ratio} = 0.0242\ kWh_{energy\ use}/kWh_{production}$$

5.1.2 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 where 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[37]. These assumptions are summarised in Table 13.

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 for coal transport by mode and country of origin plus ports of origin for sea transport

The amount UK coal that is produced domestically was taken from DUKES table 2.1 2015 (Commodity Balance coal), and imported coal by country of origin was provided from coal imports data from Energy Trends June 2015[38] and is shown in Table 14.

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

[38] Table ET 2.4, Energy Trends, June 2015, DECC

Coal imports	Thousand tonnes
European Union	895
Australia	1,919
Canada	434
China	43
Colombia	10,840
Republic of South Africa	391
Russia	18,521
USA	11,231
Other countries	681
Total all countries	**44,954**

Table 14: UK Coal imports for 2014 by country of origin

Transport energy factors for different modes of transport were derived from information provided in the Governments Conversion Factors as shown in Tables 15.

Transport mode	Conversion factor for	$kgCO_2e$/ km.tonne	Fuel	Fuel $kgCO_2e$/kWh	kWh/ tonne.km
Road	average HGV rigid diesel average laden	0.30180	diesel	0.30065	1.00383
Rail	rail	0.03433	diesel	0.30065	0.11419
Bulk shipping	average bulk carrier - fuel oil	0.00418	fuel oil	0.37054	0.01127
Crude/products tanker	average crude/products tanker - fuel oil	0.00540	fuel oil	0.37054	0.01456
LNG tanker	average LNG tanker	0.01363	fuel oil	0.37054	0.03677

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.

$$\textit{Transport energy ratio UK production} = 0.0137\ kWh_{energy\ use}/kWh_{production}$$

$$\textit{Transport energy ratio imports} = 0.0466\ kWh_{energy\ use}/kWh_{production}$$

The figure for UK supply is calculated based on the ratio of UK produced to imported coal which is provided in DUKES 2015 table 2.1, Commodity Balances - UK production/(Total supply + Stock change) = 1:3.996

Transport energy ratio UK coal supply = 0.0400 $kWh_{energy\ use}/kWh_{production}$

Primary energy factor = 1+ extraction ratio + UK supply transport UK ratio = 1.080.

5.2 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 sections describes the derivation of the primary energy factor for piped natural gas, LNG and UK mains supply gas

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

Oil and gas energy ratio = 0.09726 $kWh_{energy\ use}/kWh_{production}$

Gas distribution: For the UK this is calculated as the sum 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.

Gas distribution energy ratio = 0.00878 $kWh_{energy\ use}/kWh_{production}$

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

Losses = 0.879%

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 = 1.1039

5.2.2 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 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 = 1.3166

5.2.3 Natural gas (mains supply)

The primary energy factor for UK mains gas is determined by the projected gas mix for 2016-2019 which contains 9.5% LNG (See section X for data sources) and the primary energy factors for piped and LNG imports.

Primary energy factor UK mains gas supply = 9.5%*1.3166+90.5%*1.1039=1.1340

5.3 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 = 0.0973 $kWh_{energy\ use}/kWh_{production}$

The energy use ratio for oil and gas production is described in Section 6.2

Energy use for transport of crude oil to refineries and distribution of petroleum products was taken from JEC WTW analysis[39]

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

For the UK energy use in refineries is calculated as the sum energy use provided in the DUKES 2015 “Commodity Balance” tables for all fuels where refineries is included under the “Energy Industry Use” heading. Dividing the energy use for refineries but 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 = 0.0798 $kWh_{energy\ use}/kWh_{production}$

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[39] JEC 2015 Well to Wheel Study Appendix Version 4a COD1 (Diesel Fuel) Crude oil transport + Distribution (post refinery)

For UK supply of LPG a proportion is extracted directly along with natural gas rather than being produced in a refinery[40]. Accordingly the refinery energy use is applied to the same proportion of LPG production.

Primary energy factor for LPG = 1+(extraction ratio + transport ratio + 0.28*refinery ratio) = 1.1753

Primary energy factor for other petroleum products = 1 + (extraction ratio + transport ratio + refinery ratio) = 1.1977

5.4 Manufactured Smokeless Fuel

For manufactured smokeless fuel the primary energy factor includes net energy losses during the manufacturing process plus transport energy use[41].

The net energy losses during manufacture is calculated from the difference in the energy content of the input fuels (coal and petroleum coke)[42]- and manufactured smokeless fuel output[43] divided by the energy content of the output fuel.

Net energy losses manufactured solid fuel production = 9%

The energy use ratio for transporting the product to the final user was estimated using the same assumptions for coal (See section 6.1). In the absence of readily available data the same assumption was used to estimate transport of the input fuels to the manufacturing plant.

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[40] DUKES 2015 Table 3.2 shows that 28% of LPG (Propane and butane) is from sources other than refinery outputs.

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

[42] from DUKES 2015, table 1.1 Aggregate energy balance

[43] from DUKES 2015, table 1.2 Commodity balance Manufactured Fuels

Transport energy ratio manufactured solid fuel = 0.0275

Primary energy factor for Manufactured Solid Fuels = 1+(losses + transport ratio) = 1.256

5.5 Biofuels and waste

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

5.5.1 Biogas

For biogas primary energy factor is the average value for all EU production routes for biogas and synthetic methane JEC WTW[44] study 2014 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 = 1.846

5.5.2 Bioethanol

For bioethanol primary energy factor is the average value for all EU production routes for biogas and synthetic methane JEC WTW[45] study 2014 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 = 1.4609

5.5.3 Biodiesel

[44] JEC Well to Wheel Study 204 Appendix 4 v4a

[45] JEC Well to Wheel Study 204 Appendix 4 v4a

For biodiesel the primary energy factor is from a 2003 project report[46] for biodiesel from rapeseed oil

Primary Energy Factor for biodiesel = 1.4370

5.5.4 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 X for transport energy factors)

Primary energy factor waste vegetable oil = 1.0020

5.5.5 Wood, biomass and waste

Primary energy factors for wood were derived life cycle greenhouse gas emission for the generation of heat for a variety of biofuels provided in the BEAT tool.[47] 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 2016 primary energy factors for these fuel are shown below.

Wood logs

Combustion of long logs

Primary energy factor wood logs = 1.0579

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[46] 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

[47] BEAT v2

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

Primary energy factor wood chips = 1.1744

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 = 1.3201

Biomass

Combustion of Straw Bales

Primary energy factor for biomass = 1.1389

Waste

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

Primary energy factor for waste = 0.3541

5.6 Grid electricity

The primary energy factor for grid electricity is calculated from the primary energy of the input fuels, the projected electricity generation mix for 2016-2019 and the transmission and distribution losses (See section 3.2 for data sources).

Primary energy factor for grid supply electricity = 2.364

5.7 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 = 1.0000

6. PROPOSED NEW PRIMARY ENERGY FACTORS

Table 16 summarises the 2016 primary energy factors for SAP for all types of fuel commonly used in the UK, alongside the equivalent value for SAP 2012.

$kgCO_2/kWh$	**SAP 2012**	**SAP 2016**	**% change**
Gas:			
mains gas	1.112	1.127	1%
natural gas (1)	1.026	1.108	8%
LNG (1) (2)	1.416	1.310	-7%
LPG	1.068	1.166	9%
biogas (3)	1.340	1.846	38%
Liquid Fuels:			
domestic heating oil (burning oil/kerosine)	1.068	1.189	11%
gas oil (diesel)	1.068	1.189	11%
fuel oil	1.068	1.189	11%
appliances that specifically use FAME (biodiesel) (3)	1.300	1.437	11%
appliances that specifically use waste vegetable oil (3)	1.120	1.014	-9%
domestic heating oil and liquid biofuels (dual fuel appliance)	1.068	1.189	11%
gas oil and liquid biofuels (dual fuel appliance)	1.068	1.189	11%
B30K (4)	1.137	1.264	11%
B30D (4)	1.137	1.264	11%
Bioethanol from any biomass source (3)	1.340	1.461	9%
Solid fuel:			
house coal	1.009	1.079	7%
anthracite	1.009	1.079	7%
coal (non-domestic) (5)	1.009	1.079	7%
manufactured smokeless fuel (domestic)	1.175	1.265	8%
manufactured smokeless fuel (non-domestic) (5)	1.175	1.265	8%
wood logs (3)	1.050	1.058	1%
wood pellets (3)	1.200	1.320	10%
wood chips (3)	1.070	1.174	10%
dual fuel appliance (mineral and wood)	1.027	1.062	3%
Electricity:			
electricity consumption (6)	3.069	2.364	-23%
electricity exported to the grid (6)	3.069	2.364	-23%
Community heating and CHP: Fuels used to generate heat or heat and power			
heat generated on site from renewable sources	1.000	1.000	0%
mains gas	1.112	1.127	1%
coal	1.009	1.079	7%
LPG	1.068	1.166	9%
domestic heating oil (burning oil/kerosine)	1.068	1.189	11%
gas oil (diesel)	1.068	1.189	11%
fuel oil	1.068	1.189	11%
electricity	3.069	2.364	-23%
waste	1.280	1.354	6%
biomass (3)	1.070	1.354	27%
biogas (3)	1.340	1.354	1%
waste heat from power stations	1.229	1.151	-6%
geothermal heat sources	1.162	1.107	-5%
appliances that specifically use FAME (biodiesel) (3)	1.300	1.437	11%
appliances that specifically use vegetable oil	1.080	1.014	-6%
domestic heating oil (including appliances that are able to use liquid biofuels or liquid biofuel/fuel oil blends)	1.120	1.189	6%
gas oil (including appliances that are able to use liquid biofuels or liquid biofuel/fuel oil blends)	1.068	1.189	11%
B30K (4)	1.068	1.264	18%
B30D (4)	1.137	1.264	11%
Bioethanol from any biomass source (3)	1.340	1.461	9%
Electricity generated by CHP (4)	3.069	2.364	-23%
Electricity for pumping in distribution network (4)	3.069	2.364	-23%

Table 16: Proposed Primary Energy Factors for SAP and SBEM

(1) These values are provided for information only and are not for use in SAP calculations

(2) Liquefied Natural Gas imports to the UK grid supply gas

(3) Data sourced from a more recent source (Government GHG conversion factors)

(4) To be used for appliances that are only able to use the fuel blends specified.

(5) For use in SBEM only

(6) The observed decrease is primarily due changes in the projected generation mix over the relevant periods (2013-2015 and 2016-2018)

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.

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 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 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 able to run and 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: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/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: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/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: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.