

Briefing Note – Derivation and use of Primary Energy factors in SAP

Introduction

The purpose of this briefing note is to summarise the method used to derive the primary energy factors published in SAP. This anticipates likely increased interest in this topic during and following consultation on changes to UK building regulations which are expected to put greater emphasis on the calculated primary energy figures produced by SAP calculations.

The definition of primary energy used here is ‘*energy from renewable and non-renewable sources which has not undergone any conversion or transformation process*’¹. For example, the chemical energy contained in fossil fuels is a source of primary energy. However, a unit of electricity generated by burning that fossil fuel would not be considered primary energy because it has gone through a conversion process.

SAP uses primary energy factors to convert the calculated energy requirements of a dwelling into a primary energy demand figure.

Method and sources

This section outlines the process used to derive the primary energy factors in SAP. A more detailed description can be found in the SAP 2016 consultation paper, CONSP-07².

The key information required to calculate primary energy factors is that describing the upstream activities involved in the production of the fuel. These may include:

- Planting of biofuel sources
- Cultivation of biofuel sources
- Extraction of fuels
- Processing of fuels (e.g. cleaning, grading)
- Transformation of fuels
- Transportation of raw and refined products
- Transmission and distribution losses

The Government’s Digest of UK Energy Statistics (DUKES)³ provides this information for most of the fuels used in SAP. Tables in this dataset provide information on how much of each fuel, and therefore how much energy, is used in the production of another fuel. To find the primary energy factor for a given fuel, the following formula is used:

$$\text{Primary energy factor} = 1 + \sum_{\text{All process stages}} \left(\frac{\text{Energy use}}{\text{Energy content of delivered fuel}} \right)$$

For example, the extraction of oil requires gas and oil to be used. Similarly, the transport and refining processes associated with producing heating oil also require other fuels to be used. The energy content of the fuels used in these processes are summed and compared to the chemical

¹ Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018

² https://www.bre.co.uk/filelibrary/SAP/2016/CONSP-07---CO2-and-PE-factors---V1_0.pdf

³ <https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes>

energy content of the heating oil that is produced to find the primary energy factor for oil. A summarised calculation is given in Appendix A. A similar process is used for other fossil fuels.

In the case of electricity, the Updated Energy & Emissions Projections Annex J⁴ provides Government projections of the electricity grid mix. Having found the primary energy factors for the fuels that are used in the production of electricity, a weighted average using these projections gives the primary energy factor for electricity. A significant portion of UK electricity is now generated using renewable sources, like wind and solar energy. Due to these sources being abundant, a statistical convention of assigning these renewables a primary energy factor of 1 at the point of generation has been adopted for the calculation of the electricity primary energy factor.

For fuels not covered by DUKES, such as biomass and bioethanol, other sources including JEC WTW⁵, BEATv2⁶ and Ofgem's Biomass Calculator⁷ are used. These tools and sources are used to carry out similar analyses to the above to find primary energy factors for these fuels.

The primary energy factors for all fuels used in SAP are published in Table 12 of the SAP specification document. The factors used in SAP 10.1 are given in Appendix C of this document.

Primary energy factors in the SAP calculation

The primary energy factors in Table 12 are used as follows (which is identical to the way the CO₂ emissions factors from the same table are applied). First, the SAP calculation is carried out to find the energy demand of the dwelling for each of the uses specified, for example space heating, water heating and lighting. As the fuel type used to meet each of these requirements can be different, each energy demand is then multiplied by the appropriate primary energy factor for the fuel being used to meet it. Summing the primary energy figures associated with each purpose then gives the total primary energy demand of the dwelling. Example calculations can be found in Appendix B. The calculated primary energy of the dwelling can then be used for regulatory purposes, e.g. by comparison to a target rate.

⁴ <https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2016>

⁵ <https://ec.europa.eu/jrc/en/jec>

⁶ <https://www.forestresearch.gov.uk/tools-and-resources/biomass-energy-resources/reference-biomass/documents-downloads/beat/>

⁷ <https://www.ofgem.gov.uk/publications-and-updates/uk-solid-and-gaseous-biomass-carbon-calculator>

Appendix A – Example calculation for the primary energy factor of oil⁸

$$\begin{aligned}\text{Extraction factor} &= \text{Energy used in extraction} / \text{Energy content of extraction output} \\ &= 58,247 \text{ kWh} / 651,624 \text{ kWh} \\ &= 0.09816 \text{ kWh/kWh}\end{aligned}$$

$$\begin{aligned}\text{Refinery factor} &= \text{Energy used in refineries} / \text{Energy content of refinery output} \\ &= 46,238 \text{ kWh} / 808,860 \text{ kWh} \\ &= 0.06063 \text{ kWh/kWh}\end{aligned}$$

$$\text{Transport factor} = 0.0216 \text{ kWh/kWh}^9$$

$$\begin{aligned}\text{Oil PE factor} &= 1 + \text{Extraction factor} + \text{Refinery factor} + \text{Transport factor} \\ &= 1 + 0.09816 + 0.06063 + 0.0216 \\ &= 1.18 \text{ kWh/kWh}\end{aligned}$$

Appendix B – SAP example calculations of primary energy

The following examples show how this would apply for some technologies using only main heating demands for simplicity.

Dwelling A with a 90% efficient gas boiler has a heating demand of 10,000 kWh. The PE factor for mains gas is 1.130 kWh/kWh. The associated primary energy would be $(10,000 \text{ kWh} / 0.90) \times 1.130 = 12,556 \text{ kWh}$.

Dwelling B with a 300% efficient electric heat pump has a heating demand of 10,000 kWh. The PE factor for electricity is 1.501 kWh/kWh. The associated primary energy would be $(10,000 \text{ kWh} / 3.00) \times 1.501^{10} = 5,003 \text{ kWh}$.

Dwelling C with 100% efficient electric panel heaters has a heating demand of 10,000 kWh. The associated primary energy would be $(10,000 \text{ kWh} / 1) \times 1.501 = 15,010 \text{ kWh}$.

Dwelling D has the same heating system and demand as Dwelling C but also has PV panels producing 2,500 kWh of electricity. 1,500 kWh of this is used within the dwelling and 1,000 kWh exported to the grid. The primary energy would be $((10,000 \text{ kWh} - 1,500 \text{ kWh}) / 1) \times 1.501 - (1,000 \text{ kWh} \times 0.501) = 12,759 \text{ kWh} - 501 \text{ kWh} = 12,258 \text{ kWh}$.

⁸ The sources used for this and all other calculations to find primary energy factors are from March 2019 or earlier to ensure consistency throughout MHCLG's analysis in preparation for the consultation of Building Regulations.

⁹ From JEC WTW study Version 4a

¹⁰ For these examples, annual demands and primary energy factors have been used for simplicity; but in SAP 10.1 this would be a monthly calculation with monthly primary energy factors.

Appendix C – Primary energy factors for fuels in SAP 10.1

Fuel	Primary energy factor
Gas:	
mains gas	1.130
bulk LPG	1.141
bottled LPG (for main heating system)	1.141
bottled LPG (for secondary heating)	1.133
LPG subject to Special Condition 11F	1.163
biogas (including anaerobic digestion)	1.286
Oil:	
heating oil	1.180
biodiesel from any biomass source	1.437
biodiesel from vegetable oil only	1.042
appliances able to use mineral oil or biodiesel	1.180
B30K	1.257
bioethanol from any biomass source	1.472
Solid fuel:	
house coal	1.064
anthracite	1.064
manufactured smokeless fuel	1.261
wood logs	1.046
wood pellets (in bags for secondary heating)	1.325
wood pellets (bulk supply for main heating)	1.325
wood chips	1.046
dual fuel appliance (mineral and wood)	1.049
Electricity:	
standard tariff	1.501
7-hour tariff (high rate)	1.501
7-hour tariff (low rate)	1.501
10-hour tariff (high rate)	1.501
10-hour tariff (low rate)	1.501
18-hour tariff (high rate)	1.501
18-hour tariff (low rate)	1.501
24-hour heating tariff	1.501
electricity sold to grid, PV	0.501
electricity sold to grid, other	0.501
electricity displaced from grid	1.501
electricity, any tariff	1.501
Heat networks:	
heat from boilers – mains gas	1.130
heat from boilers – LPG	1.141
heat from boilers – oil	1.180
heat from boilers that can use mineral oil or biodiesel	1.18
heat from boilers using biodiesel from any biomass source	1.437
heat from boilers using biodiesel from vegetable oil only	1.042
heat from boilers – B30D	1.090
heat from boilers – coal	1.064
heat from electric heat pump	1.501
heat from boilers – waste combustion	1.169
heat from boilers – biomass	1.037
heat from boilers – biogas (landfill or sewage gas)	1.286
waste heat from power station	1.063
geothermal heat source	1.051
heat from CHP	1.051
electricity generated by CHP	1.501
electricity for pumping in distribution network	1.501