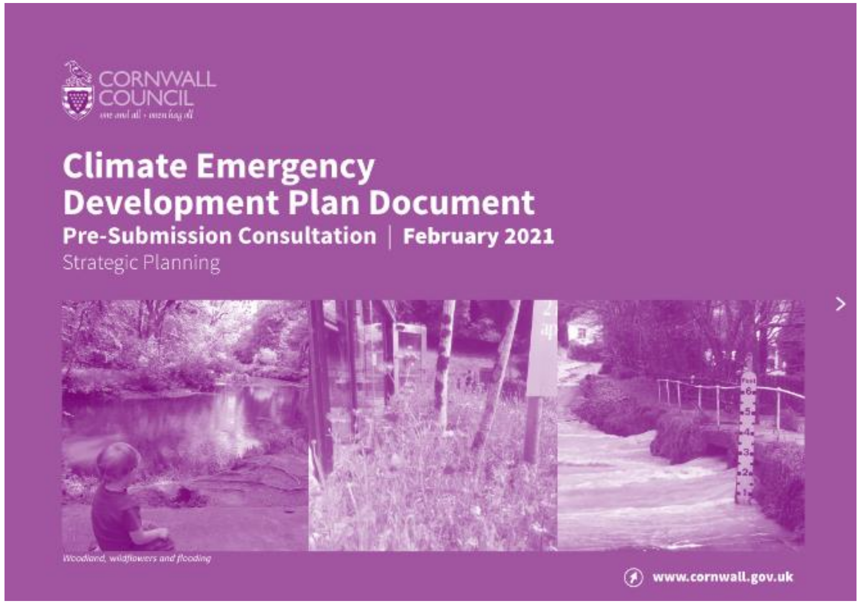
CORNWALL COUNCIL CLIMATE EMERGENCY DPD




# TECHNICAL EVIDENCE BASE FOR POLICY SEC 1 - NEW HOUSING TECHNICAL APPENDICES

July 2021 I Rev G

Currie & Brown

Etude

# Appendix 1

# Modelling Electricity Use (other than space heating and hot water)

This appendix considers how electricity use can be calculated and how this influences policies with total energy use requirements.

## Total energy use requirements and electrical energy use

Total energy use requirements need to include an allowance for all electricity uses in a building. A suitable methodology is required to determine an appropriate allowance, and to provide applicants with the means to consistently assess performance of their buildings against the requirement. If the allowance is too low, applicants will struggle to comply with policy. Conversely, if the allowance is too high the total energy use requirement will be too easy achieve and could fail to deliver the policy objectives.

## Passivhaus Planning Package (PHPP)

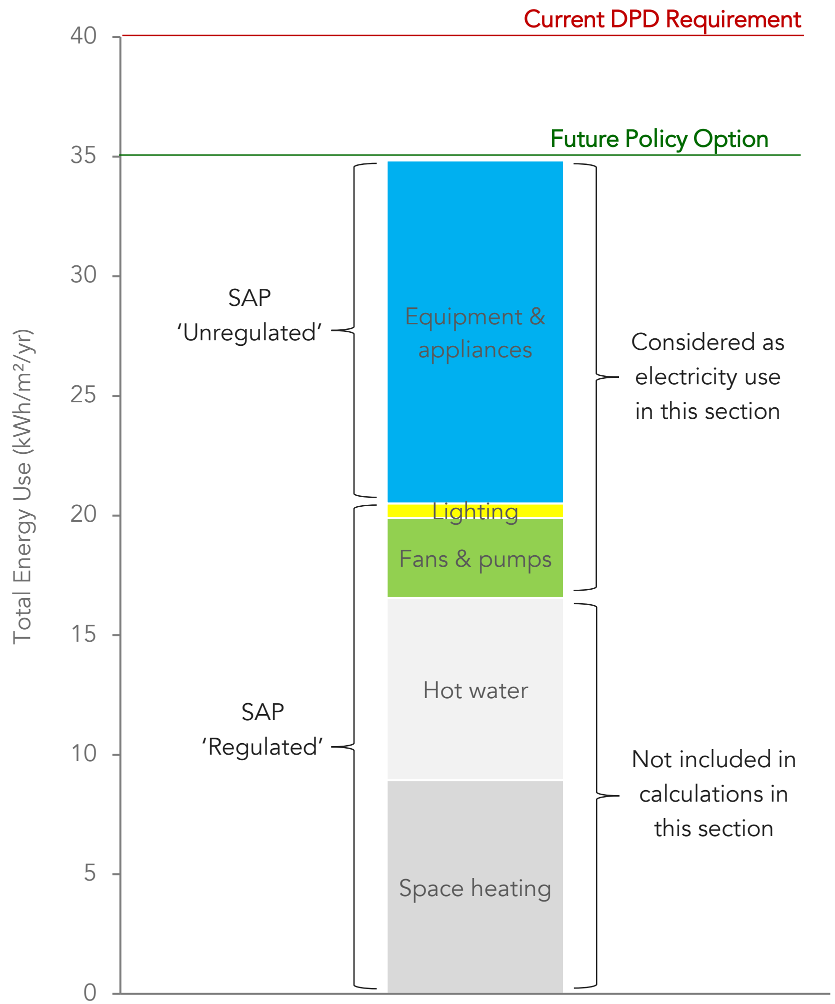
The total energy use requirements used in this report are based on assessment of electricity use using the Passivhaus Planning Package software, which calculates electricity use in detail based on several attributes of the building: the number of occupants, size of the building, ventilation system, appliances, and lighting systems. As the user is allowed to input up to date information on product efficiency, these calculations typically provide a realistic baseline prediction of electricity use.

## SAP

Another methodology to calculate electricity use is to use Part L/SAP calculations. These divide energy use into 'regulated' and 'unregulated', as shown in the graph opposite, splitting electricity use in two. Electricity used for lighting, fans and pumps is classed as 'regulated' and included in standard SAP calculations and outputs. Electricity used for appliances and other equipment is classed as 'unregulated'. It is calculated in Appendix L, and is available as a supplementary output from SAP, but it is not provided as a standard output or factored into cost and carbon calculations.

## Limitations of modelling

In practice, electricity use will vary from what has been modelled due to differences in occupancy, user behaviour and appliance efficiency, relative to what was assumed in the model. Accepting these limitations, energy modelling can still indicate the typical baseline levels of electricity use that can be expected for a new dwelling in a consistent and repeatable way, which enables the use of total energy requirements to deliver more effective policy.




*Graph of total energy use for a typical net zero carbon semi-detached house that is compliant with the current DPD policy. This section considers both 'unregulated' energy use and lighting, fans, and pumps, which SAP classes as 'regulated' energy use. PHPP calculates all these energy uses and does not differentiate between them. Note that Equipment and appliances is typically the largest end use of electricity, and is therefore critical to setting total energy use requirements.*

### Floor area and Specific Electricity Use

Dwelling floor area can have quite a large effect on the *specific* electricity use calculated for assessment against the DPD policy's total energy use requirement. The *specific* electricity use is the electricity use per square meter of Gross Internal Area.

The adjacent diagrams show why this effect occurs: Total electricity use is fairly constant regardless of floor area as appliances and behaviour patterns are likely to be similar, so the dwelling with a smaller floor area has a higher consumption per square meter.

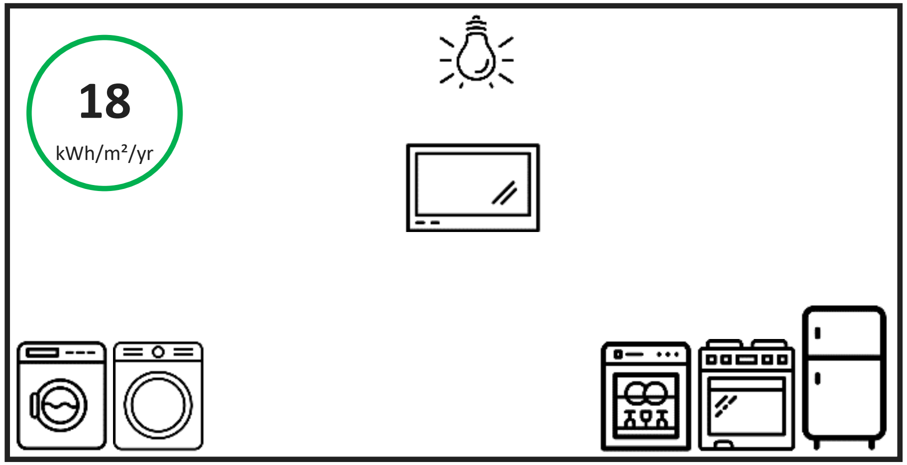
### Floor area and Total Energy Use Requirement

Floor area is not expected to cause a significant issue for compliance with total energy use requirements for dwellings with a gross internal floor area of 80m$^2$ or more. The dwellings modelled for this evidence base had gross internal floor areas ranging from 80m$^2$ for the medium rise flats, to 142m$^2$ for the detached house and all were able to comfortably exceed the DPD requirement for total energy use. The policy requirement for total energy use has built-in flexibility, as smaller dwellings could specify more efficient appliances to achieve compliance.

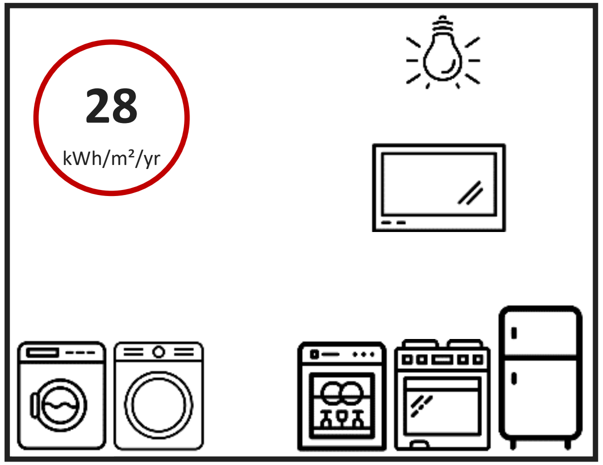
### Average UK Floor Area

To achieve a fair comparison between electricity use modelled in PHPP and in SAP, it is important for the floor area assumed for energy modelling to be representative of the UK average.

The Ministry of Housing, Communities and Local Government's 2018 English Housing Survey reported an average usable floor area of 94m$^2$. This is assumed to be measured in a similar way to Gross Internal Area, which is used for the DPD total energy requirement. Unless otherwise stated, this is the floor area that has been assumed for electrical energy use calculations reported in the appendices.




*PHPP modelling suggests a typical new build home will use around 1,700 kWh of electricity for appliances, lighting, consumer electronics, and fans and pumps. Divided by the average floor area of 94m² GIA, the specific electricity use would be just 18kWh/m²/yr.*




*A smaller home such as a flat would typically use a similar amount of electricity, assuming occupancy is unchanged. Specific electricity use increases for smaller dwellings however, as there is less floor area to divide by. For example, dividing 1,700 kWh by a floor area of 60m² would increase the specific electricity use to 28kWh/m²/yr.*

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## Occupancy and Electricity Use

The number of occupants in a building has a strong influence on the amount of electricity used for equipment and appliances, and to a lesser extent electricity used for lighting, fans and pumps. This is reflected in the table below, which qualitatively ranks the impact of occupancy on different end uses of electricity.

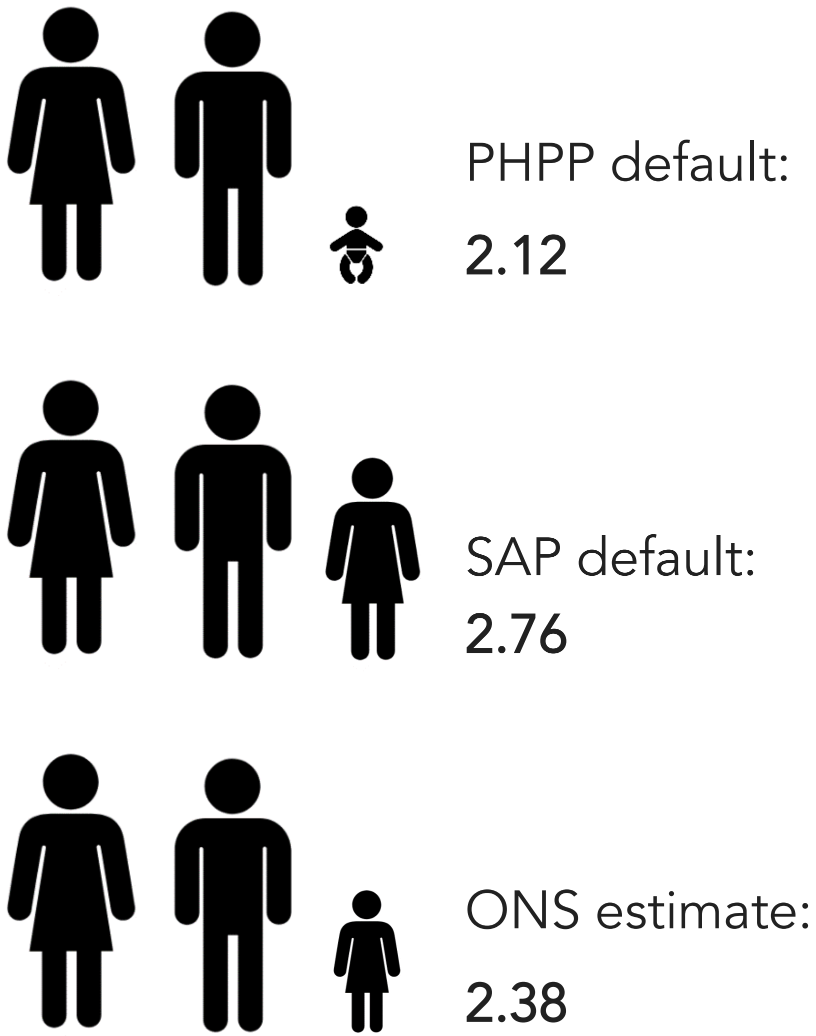
| Electricity End Use | Impact of Occupancy |
|---|---|
| Dishwashing | ***** |
| Clothes Washing | ***** |
| Clothes Drying | ***** |
| Refrigeration | ** |
| Consumer Electronics | ***** |
| Small Appliances | **** |
| Cooking | ***** |
| Lighting | *** |
| Fans and Pumps | * |

## Occupancy in PHPP and SAP calculations

As shown by the adjacent diagram, the 2020 Labour Force Survey produced by the Office for National Statistics estimates that the average occupancy of a UK home is 2.38.

PHPP calculates a default occupancy level of 2.12 for the average size UK home. While this is slightly below the ONS average, the occupancy level in PHPP is used to calculate electricity use for appliances, lighting and ventilation. This increases the accuracy of PHPP calculations for electricity. PHPP occupancy can also be overridden, so it is possible to use the ONS average occupancy to test the accuracy of PHPP against top-down data sets.

SAP calculates a default occupancy level of 2.76 for the average size UK home. While this is above the ONS average and therefore conservative, the Appendix L calculation for energy consumed by appliances does not take occupancy into account. Appendix L calculations only use dwelling floor area as an input.




*For the average size UK home, with a 94m² gross internal area, the default occupancy calculated by PHPP is 2.12 and for SAP it is 2.76. The Office for National Statistics estimated in their 2020 Labour Force Survey that the average UK occupancy was 2.38.*

## General approach

The aim of modelling electricity use is to determine the baseline level of electricity that is required to provide an acceptable standard of living. This is straightforward to achieve and has recently become easier as products have become more efficient, which has reduced the impact of user behaviour on energy consumption.

A typical basket of services that are required to provide a good standard of living includes cooking, refrigeration, laundry, ventilation, lighting, and an allowance for consumer electronics.

## Advantages of modelling electricity use

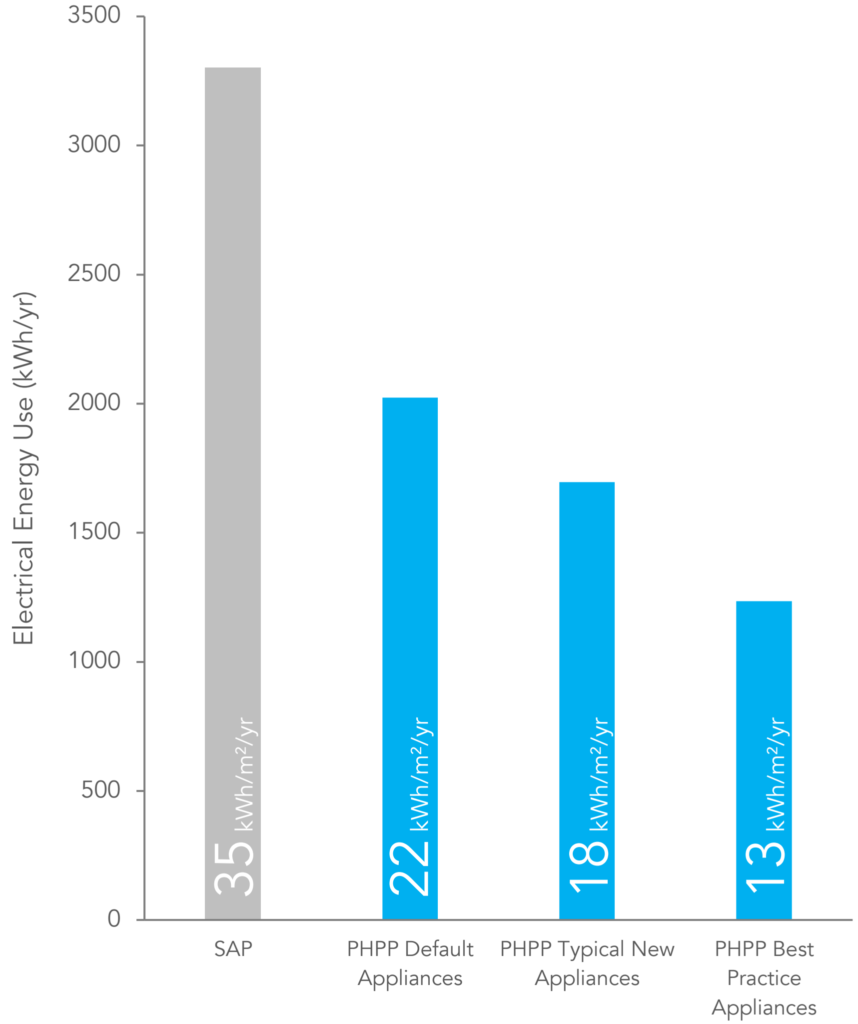
By including the actual performance of electrical devices such as appliances and lighting in energy calculations, it places a value on energy efficiency. This creates an incentive, in some cases, for applicants to ensure lighting and appliances are energy efficient as well as the building's fabric and services. In a net zero home the appliances may be one of the biggest end uses of energy, so this is a significant advantage. If an applicant does not know what devices will be used, conservative assumptions can be used in place of actual performance data, ensuring a route to compliance is always available.

## Part L / SAP

The current version of SAP was originally released in 2012, it is based on use of older less efficient technologies. As a result, electricity use calculated by SAP is typically about twice as high as that calculated by PHPP using up to date data, as shown in the adjacent graph.

## Appliance efficiency

The energy efficiency of household appliances and lighting products has significantly increased over the past decade. PHPP calculations are able to capture these improvements, as shown in the adjacent graph. Electricity use in a typical new home is likely to be about 15% lower than assumed by PHPP's default levels of efficiency, and could be up to 30% lower if using the most efficient products currently available on the market.



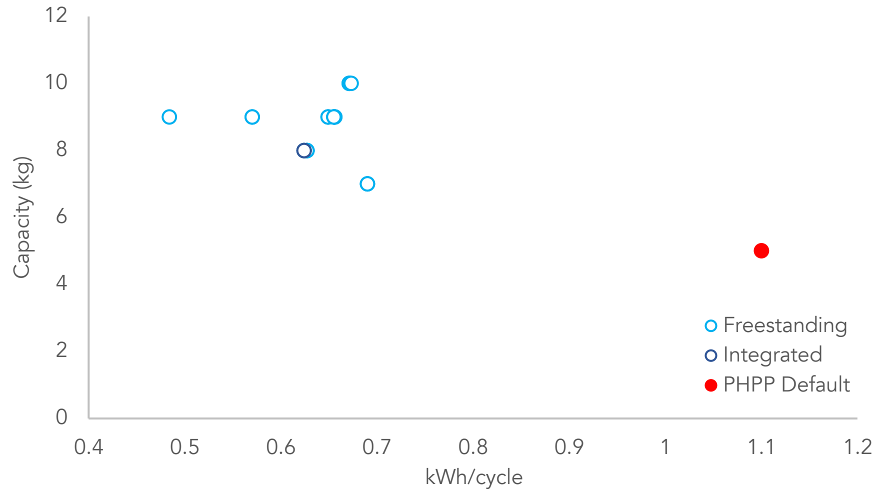

*Electrical energy use calculated by SAP and PHPP for appliances, lighting, fans and pumps. Assumes a dwelling with the UK average floor area of 94m$^2$. PHPP modelling assumes the UK average occupancy of 2.38 estimated by the Office for National Statistics. Energy consumption for 'typical new appliances' and 'best practice appliances' is based on an April 2021 survey of Bosch appliances.*

## PHPP default values in context

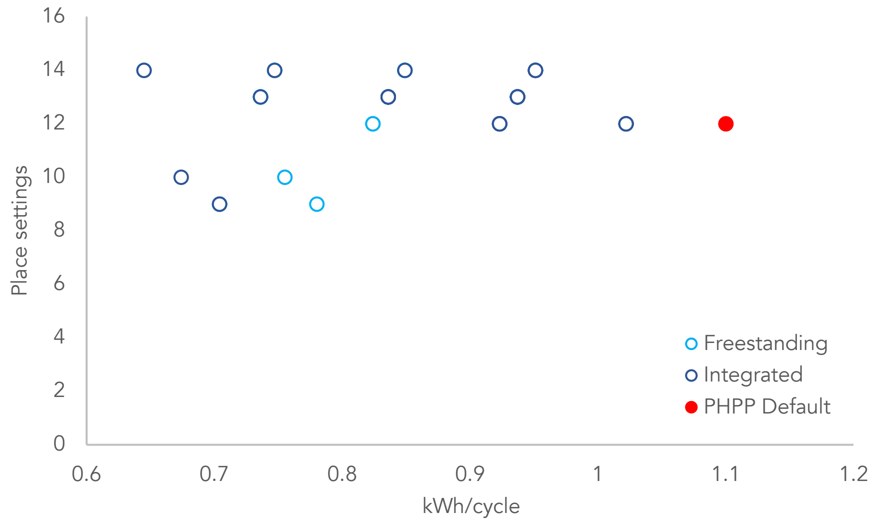
Etude have surveyed the efficiencies of all types of white goods modelled in PHPP that are currently available from one mid-range supplier, Bosch, as of April 2021, based on EU Energy Label data. The graphs on this page show that the default values in PHPP 9.6a are significantly more conservative than even the least efficient appliances currently on the market from this supplier. Spot-checks of other leading manufacturers indicate similar levels of efficiency.

As the previous pages have shown, SAP is even more conservative than PHPP. Even when accounting for higher occupancies and using conservative default efficiencies, calculations of unregulated energy use in PHPP suggests that values of 12-20kWh/m2/yr are plausible.

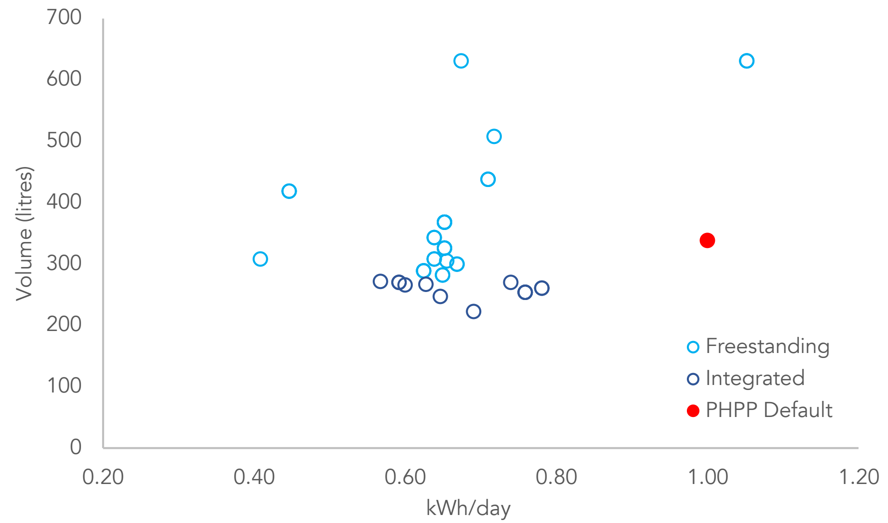
A selection of case studies on the following page provides examples of existing buildings that have exceeded the current DPD requirements and future policy options, indicating these levels of energy use are achievable in practice.




*Energy use of all clothes washers currently available from Bosch, compared to PHPP default value. The PHPP default value is more than twice as high as most clothes washers currently on the market.*




*Energy use of all dishwashers currently available from Bosch, compared to PHPP default value.*




*Energy use of all fridge-freezers currently available from Bosch, compared to PHPP default value. As PHPP does not provide a stated volume, an indicative volume is shown, based on the average of all appliances surveyed.*

# Modelling Electricity Use | Case studies that achieve the DPD total energy use requirement

*Passivhaus Plus block of flats in Seaton, Devon. Reported an EUI of 25 kWh/m²/yr* and solar generation of 18 kWh/m²/yr* from 2019-2020.*

*Passivhaus Plus detached house in Buckinghamshire. Reported an EUI of 25 kWh/m²/yr* and solar generation of 18 kWh/m²/yr* from 2019-2020.*

*Passivhaus Plus detached home in Bristol. Reported an EUI of 30 kWh/m²/yr* and solar generation of 40 kWh/m²/yr* from 2019-2020.*

*Passivhaus detached house in Worcestershire. Reported an EUI of 27 kWh/m²/yr* and solar generation estimated at 19 kWh/m²/yr* in 2017.*

**Energy consumption and generation values reported on this page are in kWh per m² of Passivhaus Treated Floor Area. This is typically 70-80% smaller than the Gross Internal Floor Area measurement used for net zero carbon assessment. Reported consumption and generation is therefore over-estimated.*

# Appendix 2

# Metered Electricity Use (compared to modelled electricity use)

This appendix compares modelled electricity use from PHPP and SAP to key data sets on electricity consumption in the UK.

## Introduction

It is helpful to compare modelled electricity use against metered electricity use, to check the plausibility of the assumptions and methodology used for energy modelling. This appendix compares electricity use calculated in PHPP and SAP with several different sources of metered electricity data.

## Distribution of electricity use

When interpreting domestic metered electricity use data, the statistical distribution of meter data needs to be considered. Distributions of household electricity use are often positively skewed – as demonstrated by the adjacent graphs. A positive skew is exhibited, where the value of the 25th percentile is closer to the median value than the value of the 75th percentile.

Generally, for positively skewed data, the following trend applies to the averages:

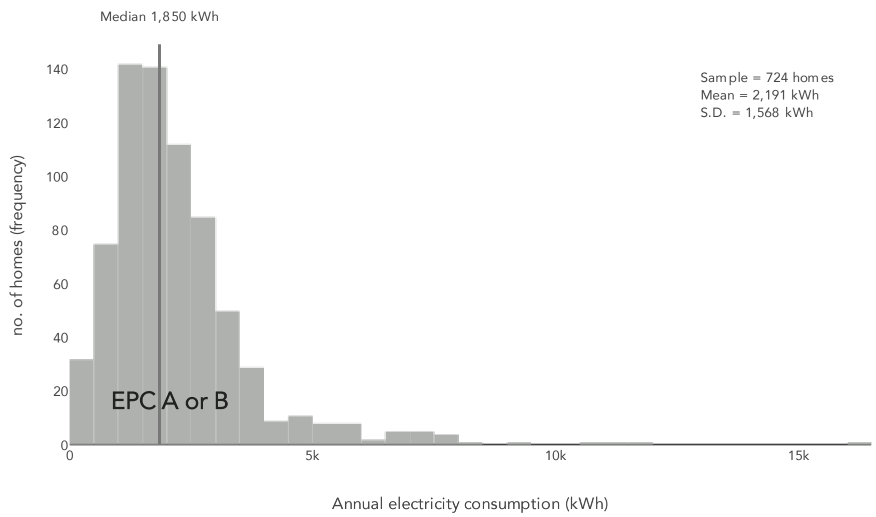
Mean > Median > Mode

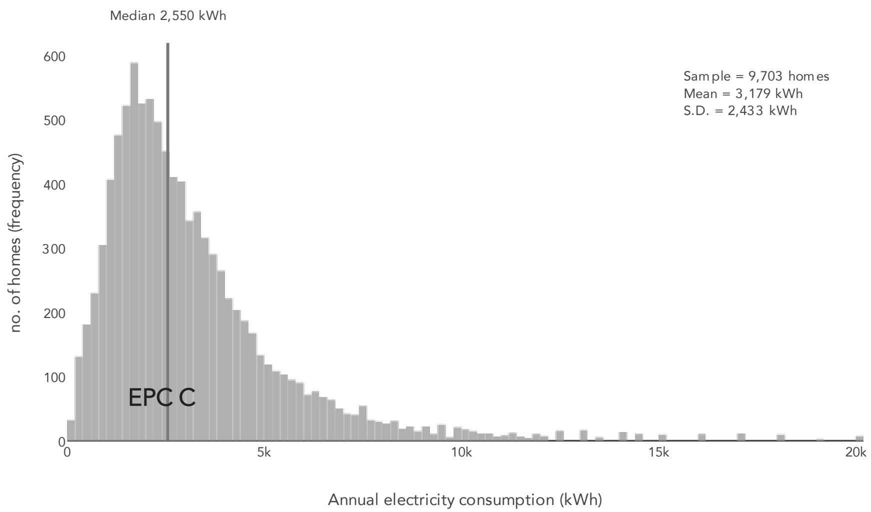
The mean value of domestic electricity use data is often inflated by a small number of high-energy users. These may be homeowners with a large load such as a swimming pool, or they may be data points that have been incorrectly included in the data set, such as non-domestic properties.

Consequently, the mean does not typically offer a reliable average or expected value of electricity use. Many existing indicators of domestic electricity use, such as Ofgem's Typical Domestic Consumption Values, quote the median.

However, the median can also be artificially inflated by high-energy users and erroneous data points. In these cases, the mode may be a better indicator of typical electrical consumption. Use of the modal average should be considered when comparing modelled electricity use for the design of new buildings with metered electricity use.

Distributions may also be negatively skewed by particularly low meter readings caused by partially occupied homes, or outbuildings in the dataset. While these will clearly also affect the average values, the highest resolution data set available (NEED) indicates that positive skew caused by high end outliers is more significant.




*Electricity consumption for two samples of UK homes from the NEED database, based on EPC band. These are fairly typical distribution for residential electricity meter consumption data. Note the median and modal values, which are close to PHPP calculations shown in following pages.*

## OFGEM

Typical Domestic Consumption Values (TDCVs) provided by OFGEM are derived from BEIS' Sub-national Consumption Statistics. BEIS collect annualised MPAN-level electricity consumption data from electricity suppliers.

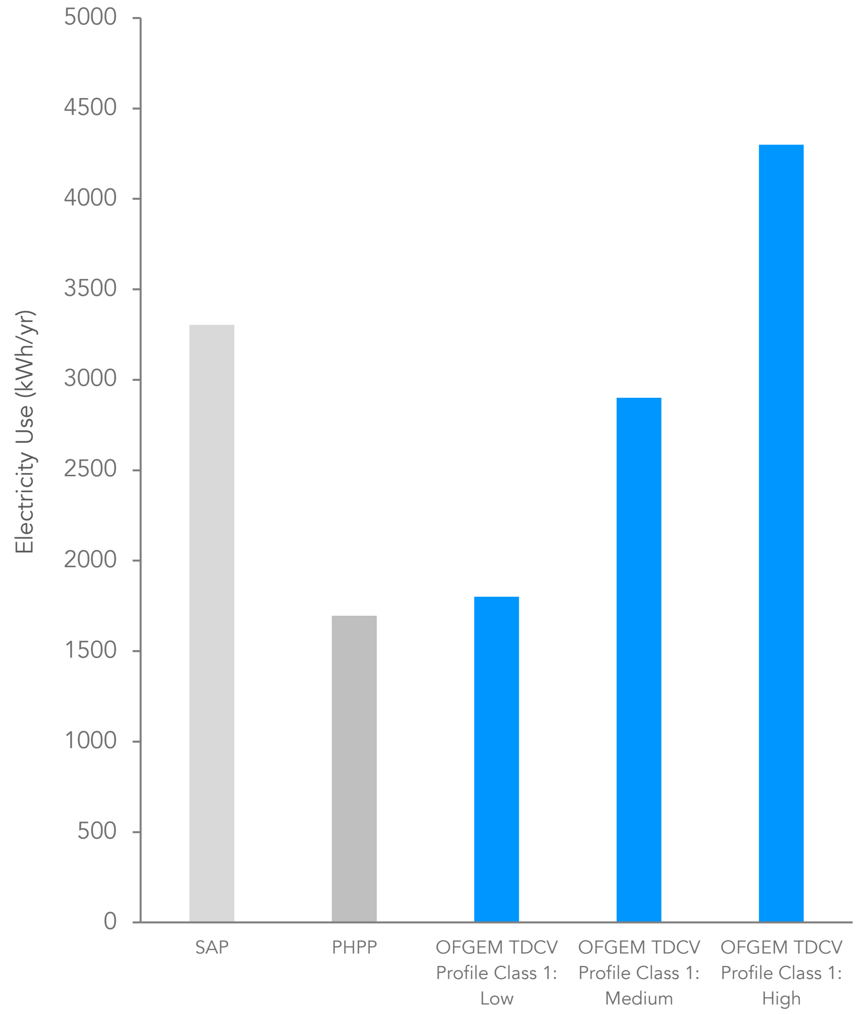
The electricity consumption data is based on non-half hourly (NHH) meters in two profile classes (1 and 2). Class 2 meters charge varying rates depending on the time of day (i.e. Economy 7 meters) and account for 14% of domestic electricity customers. It is believed that households with Class 2 meters are more likely to use electricity to heat their homes. Therefore, this page focuses on Profile Class 1 data.

The median annual electricity consumption (Profile Class 1) is 2,900kWh. 25th percentile and 75th percentile values are also provided by Ofgem, at 1,800kWh and 4,300kWh respectively (published April 2020). These values are shown on the graph to the right, alongside SAP and PHPP calculations for electricity use.

Ofgem recognise that there is a "lack of reliable markers to indicate whether an individual meter is used by a household or small business customer" which may contribute to the positive skew of the data (mean > median).

For electricity, the cut-off point for non-domestic consumption is 100,000 kWh per year. Given the median consumption is 2,900kWh this cut-off point seems high, and could lead to a significant number of non-domestic meters being included in the domestic dataset. This will skew the average level of consumption upward.

Since 2013 the TDCVs have been revised every two years. From these regular reviews OFGEM report that domestic consumption has been "*on a consistent decreasing trend, which may be partly explained by energy efficiency initiatives*". The average appliance efficiency for existing buildings included within the TDCVs data set is no exception and will likely be lower than for a new build home modelled in PHPP using typical modern appliances.




*Comparison of SAP and PHPP calculated electricity use with OFGEM Typical Domestic Consumption values for Profile Class 1. It is possible that the domestic TDCVs include a significant amount of non-domestic electricity data, as well as some homes with direct electric heating. This may inflate the consumption values. The OFGEM 25th percentile (low TDCV value) aligns well with the PHPP prediction.*

## National Energy Efficiency Data Framework (NEED)

The NEED framework was set up to provide an understanding of energy use and energy efficiency in both domestic and non-domestic buildings in Great Britain. The framework matches BEIS sub-national consumption statistics with data about property attributes. Properties are defined as domestic based on the Valuation Office Agency's property attribute database if they have consumption between 100kWh and 25,000kWh.

Metered electricity use is reported for 22.7 million homes. The dataset includes homes with direct electric heating, so an indicative allowance has been added to show how this could skew the data. The allowance is calculated based on the 8.3% of domestic properties reported to be using electric heating in the 2018 English Housing Survey. Allowances of 4,600kWh, 7,200kWh and 10,775kWh per dwelling have been applied to each quartile based on adjusted OFGEM typical domestic consumption values for gas consumption and Class 2 electricity use.

The adjacent graph shows the NEED data compared to electricity use modelled in PHPP and SAP. The PHPP calculation shows good alignment with the lower quartile of the NEED data, however it is about 700kWh lower than the median value. Some difference is to be expected as PHPP assumes typical appliance efficiencies as of April 2021, where as the NEED data is from 2018.

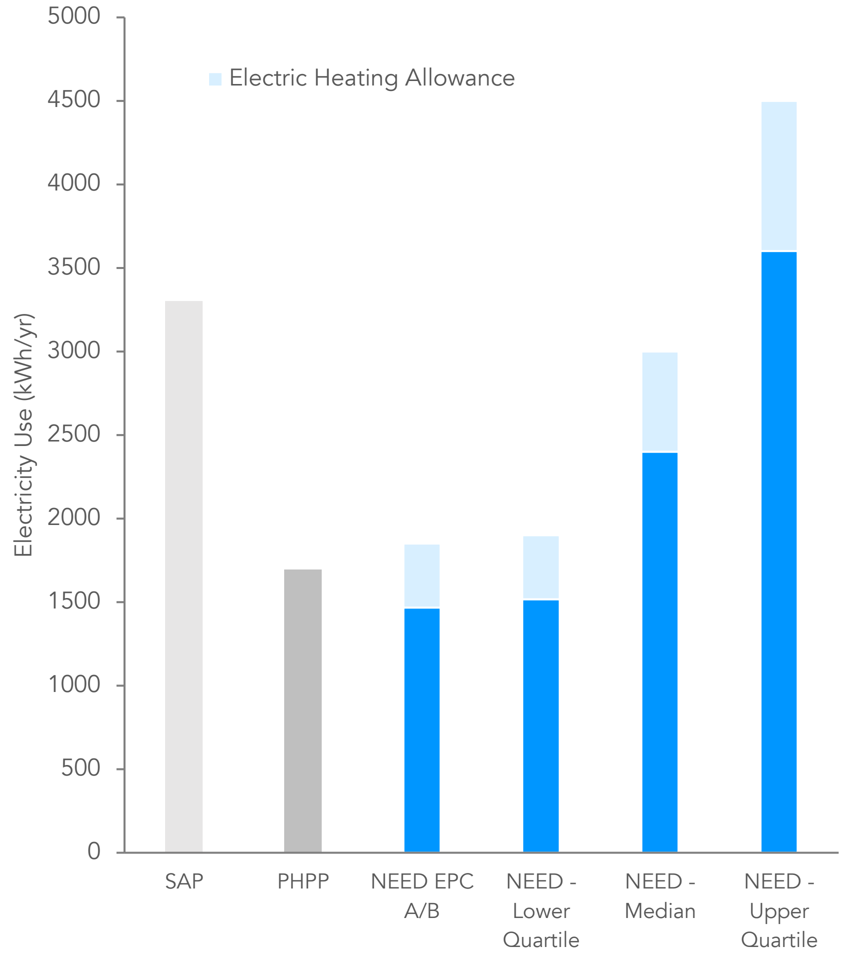
## Project Alpha

A domestic energy database tool was developed by Etude to allow further interrogation of the NEED database for domestic energy consumption:

https://etude-dom-tool.herokuapp.com/

For households with an EPC rating of A or B, data is available for 724 dwellings. The median electricity use sits at 1,850kWh. The mode, or the interval with the highest frequency of households, is substantially lower at 1,000-1,490kWh. Although this is a small subset of the total data it is an indication of electrical use for a property with a similar EPC rating to that delivered under the DPD policy. The extent of electrical heating included in this value is unknown, however an indicative value is shown on the adjacent graph.

It should be noted that the data from the tool is from the years 2005 to 2012, so is already somewhat outdated.




*Comparison of SAP and PHPP calculated electricity use with metered electricity use from the National Energy Efficiency Data Framework database. The 'NEED EPC A/B' category includes data for all properties within EPC bands A or B (years 2005-2012). Both this category and the lower quartile align well with the PHPP calculation and are likely to be representative of new-build homes built to achieve the current DPD policy. An allowance is included for buildings with direct electric heating based on OFGEM data.*

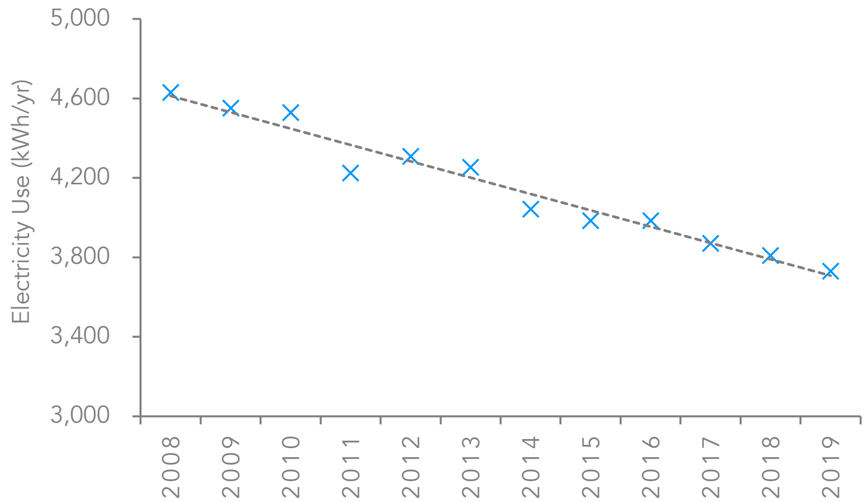
# Metered Electricity Use | Modelled values compared to DUKES/ECUK metered electricity use data

## BEIS Energy Consumption in the UK (ECUK)

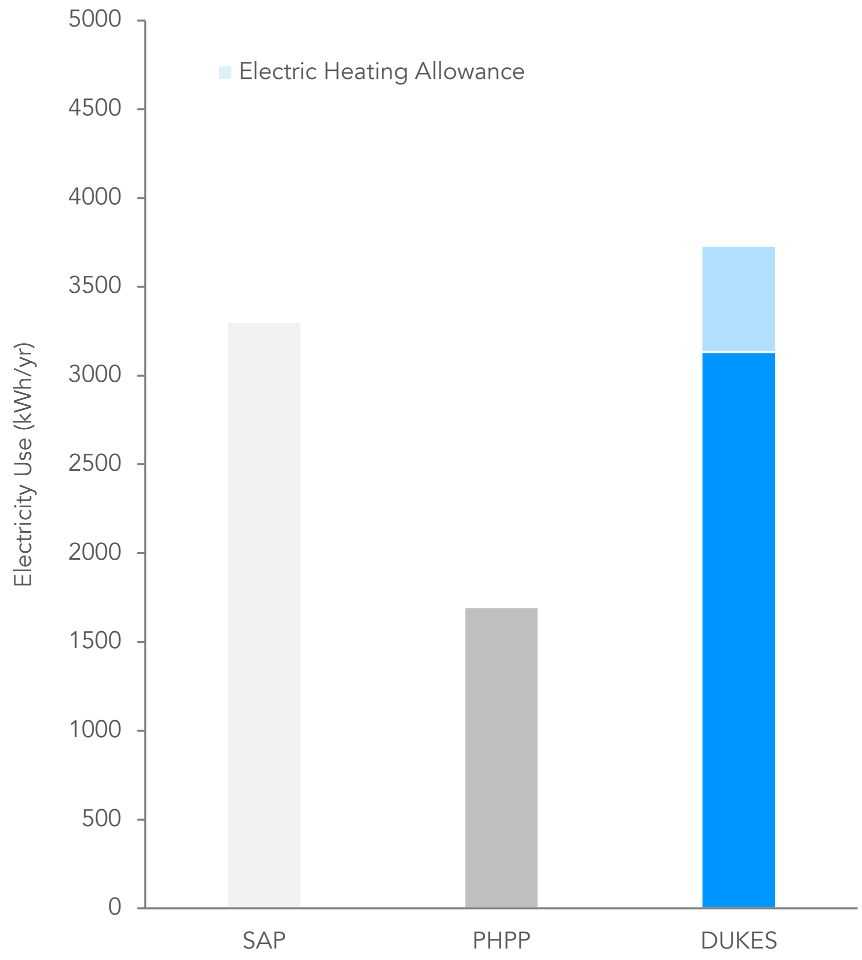
Energy Consumption in the UK is an annual statistical publication by BEIS providing a view of final energy consumption by sector. The energy consumption data is sourced from the Digest of UK Energy Statistics (DUKES). DUKES uses sales statistics gathered by energy companies on a national level. This top-down approach differs from BEIS' subnational dataset created from individual MPAN data.

In 2019 the average domestic electricity consumption, based on 27.8 million households, was reported as 3,731kWh. This figure is the mean value of the dataset and as expected is higher than the other top-down median values. It includes properties that use electricity for direct electric heating.

As a yearly publication, ECUK also highlights trends in energy consumption. The graph below depicts how the DUKES data for domestic electricity consumption has evolved between 2008 to 2019. Domestic electricity consumption is steadily decreasing, at an average rate of 2% a year.




*Domestic average electricity consumption (unadjusted) for 2008-2019: Energy Consumption in the UK, BEIS.*




*Comparison of SAP and PHPP calculated electricity use with DUKES/ECUK domestic average electricity consumption (2019). The DUKES/ECUK data reports the mean value and is therefore easily inflated by high energy users and outliers. It is based on aggregate domestic electricity sales and includes the 8.3% of homes that use direct electric heating.*

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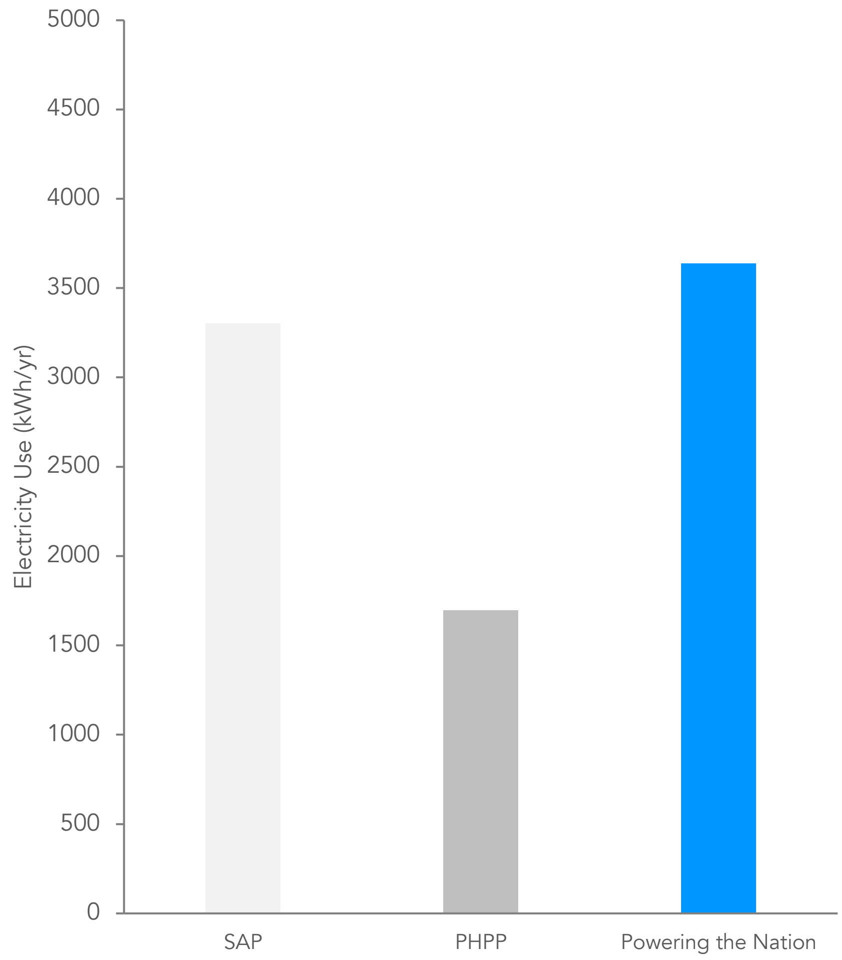
## The Household Electricity Survey

At the time, this survey represented the most detailed monitoring of electricity use in the UK. Electricity consumption was monitored at an appliance level in 250 owner-occupied households across England from 2010 to 2011. This included 26 households for a year, and a further 225 for one month on a rolling basis. The survey produced a range of analysis and data, and two main reports were written summarising the findings. The UKGBC total energy use targets have been developed around levels of electricity use reported by this study.

## Powering the Nation Report

The final survey report was commissioned by DECC and DEFRA, and was released in 2014. It reported annual electricity use ranging from 562 kWh to 14,485kWh, with a mean of 3,638kWh (excluding electric heating). This may be compared to average reported average domestic consumption of 3,300kWh at that time. The mean is more than twice as high as the electricity use predicted by PHPP modelling for a new build home, however it can be explained by:

1. Standby power consumption of 200 kWh/year. This would now be negligible due to EU regulation 1275/2008 on standby and off-mode power consumption.
2. The average age of major white goods was around 6-8 years at the time of the survey. Appliance efficiencies modelled in PHPP for a new build home will be 15-20 years ahead of those captured in the survey. Comparison of reported energy consumption with our 2021 appliance survey confirms that new appliances would be significantly more energy efficient.
3. 70% of light sources were incandescent or halogen, resulting in average lighting energy consumption of 483 kWh. LEDs are now the dominant domestic light source, which use 80-90% less energy.
4. Audio visual and IT technologies have experienced significant improvements in efficiency over the past decade. For example, the survey captured cathode ray tube and plasma televisions.
5. The selection of households was not statistically representative of English or UK households, but was somehwat representative of English owner-occupied households at the time.




*Comparison of SAP and PHPP calculated electricity use with Powering the Nation Report (2014), based on the Household Electricity Survey from 2010-2011. Electricity use calculated by PHPP is less than half of the mean reported by the study, however much of the difference can be explained by improvements in energy efficiency that are captured in PHPP calculations, and above average levels of electricity use by households selected for the study.*

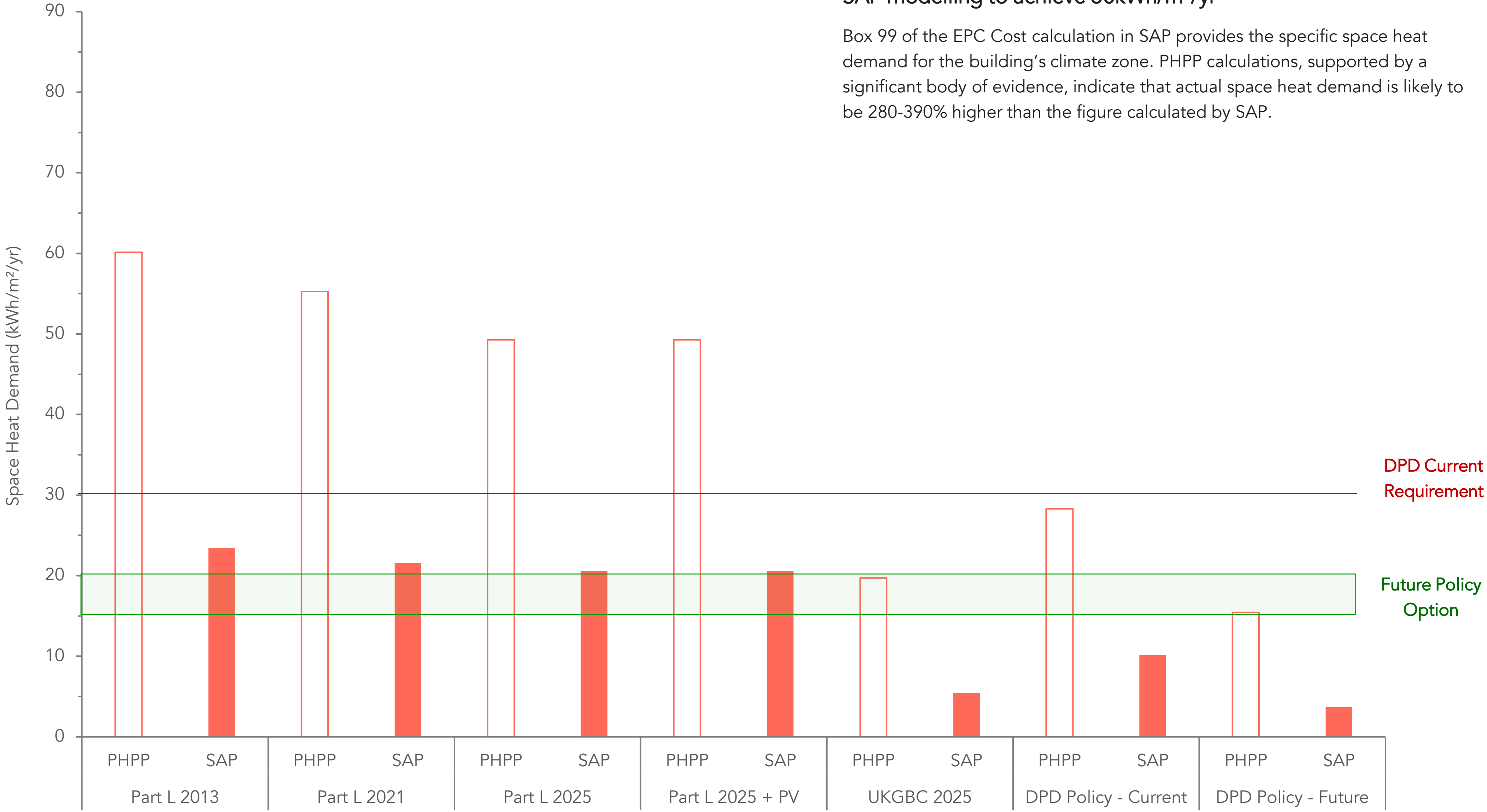
# Appendix 3

## Use of SAP to demonstrate compliance with DPD policy

This appendix investigates the outcome of using SAP calculations to test performance of the six buildings and seven policy scenarios against the core DPD requirements for:

1. Space heat demand
2. Total energy use (EUI)
3. Solar generation to match total energy use

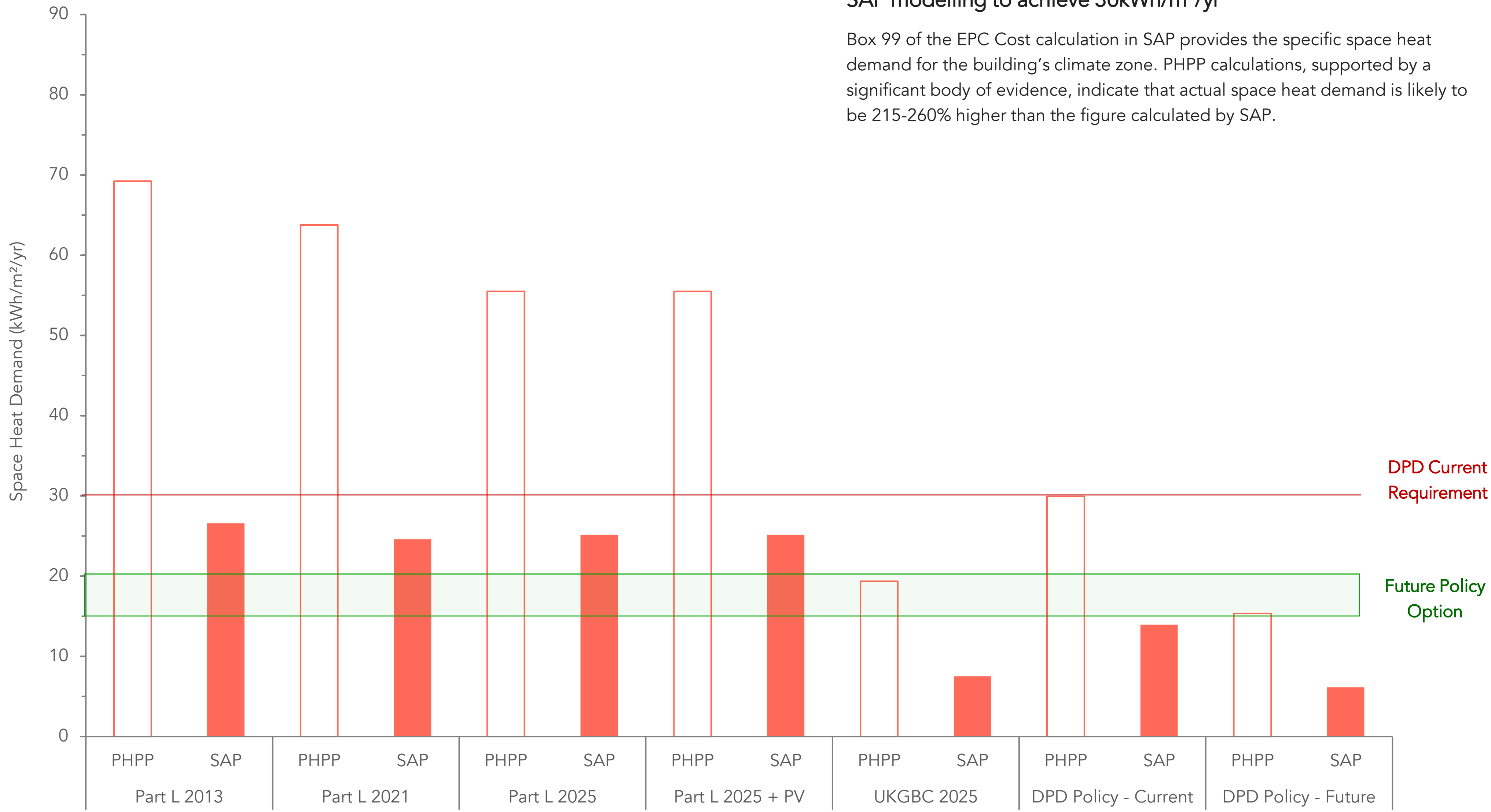
# Energy Modelling | Semi-detached House - DPD requirement for space heating demand




## SAP modelling to achieve 30kWh/m²/yr

Box 99 of the EPC Cost calculation in SAP provides the specific space heat demand for the building's climate zone. PHPP calculations, supported by a significant body of evidence, indicate that actual space heat demand is likely to be 280-390% higher than the figure calculated by SAP.

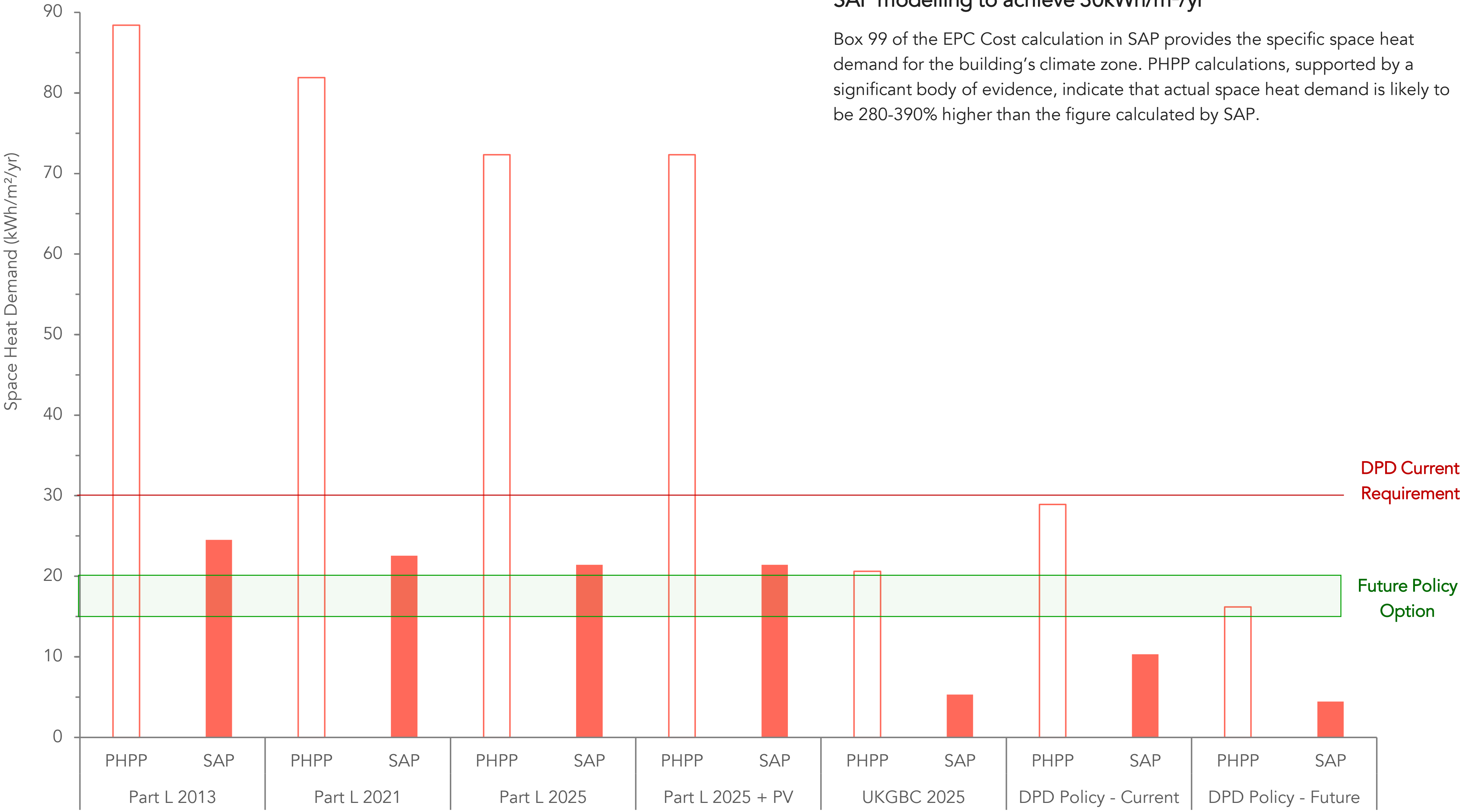
*Space heat demand calculated by PHPP 9.6a and FSAP 2012 for each scenario, compared to the DPD policy requirement. SAP calculations significantly underestimate space heat demand.*




## SAP modelling to achieve 30kWh/m²/yr

Box 99 of the EPC Cost calculation in SAP provides the specific space heat demand for the building's climate zone. PHPP calculations, supported by a significant body of evidence, indicate that actual space heat demand is likely to be 215-260% higher than the figure calculated by SAP.

*Space heat demand calculated by PHPP 9.6a and FSAP 2012 for each scenario, compared to the DPD policy requirement. SAP calculations significantly underestimate space heat demand.*

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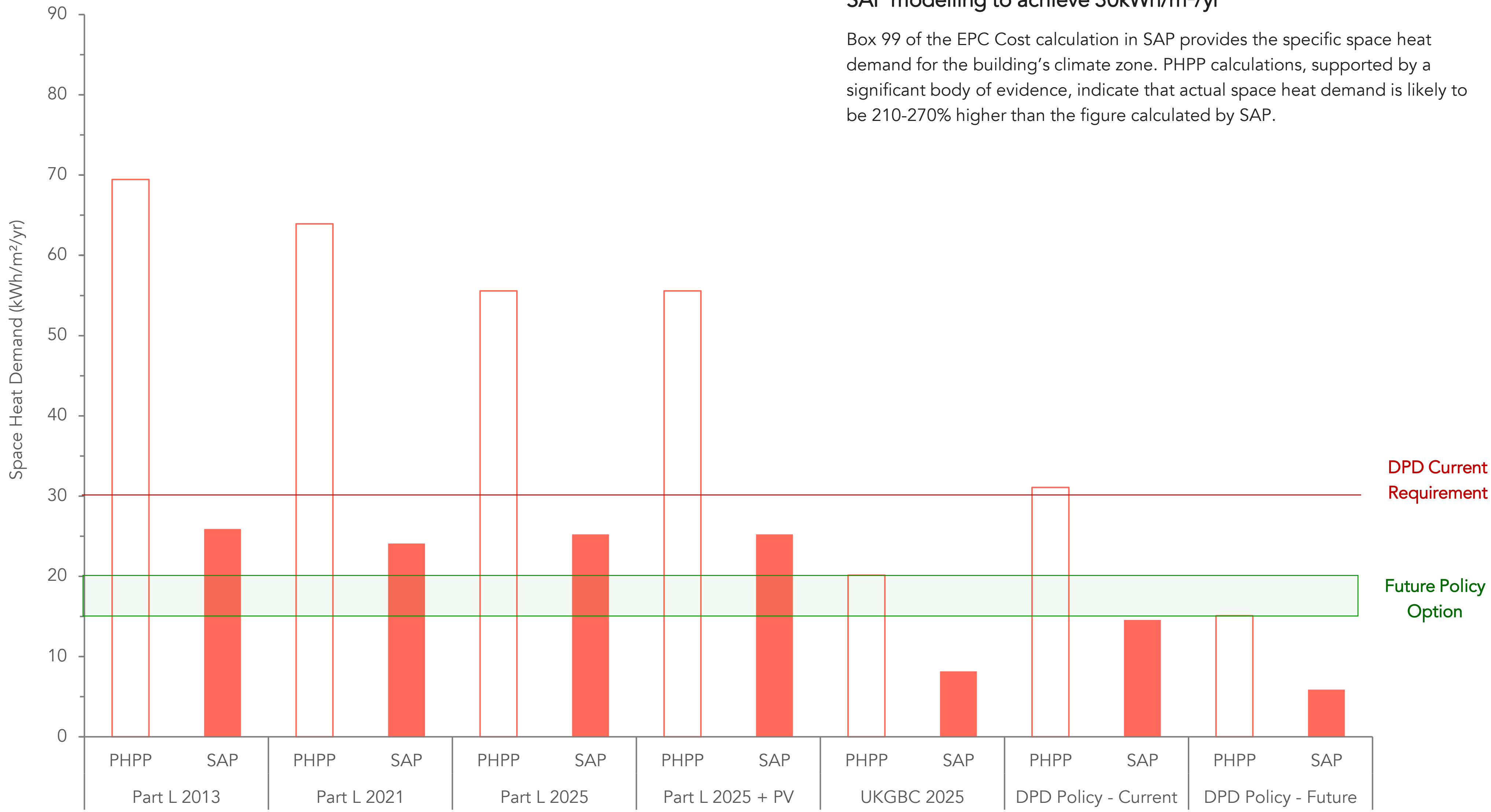
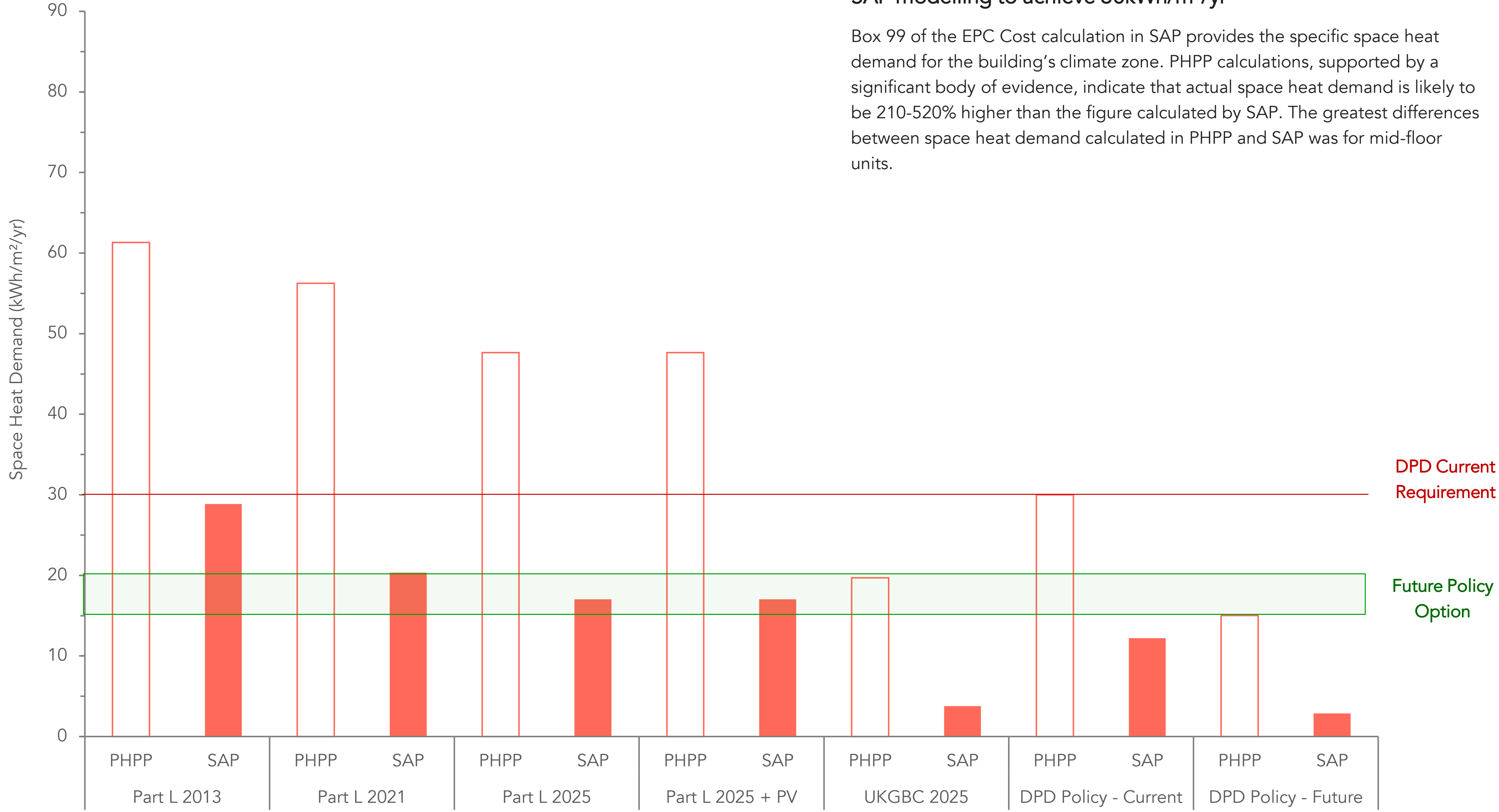



### SAP modelling to achieve 30kWh/m²/yr

Box 99 of the EPC Cost calculation in SAP provides the specific space heat demand for the building's climate zone. PHPP calculations, supported by a significant body of evidence, indicate that actual space heat demand is likely to be 210-270% higher than the figure calculated by SAP.

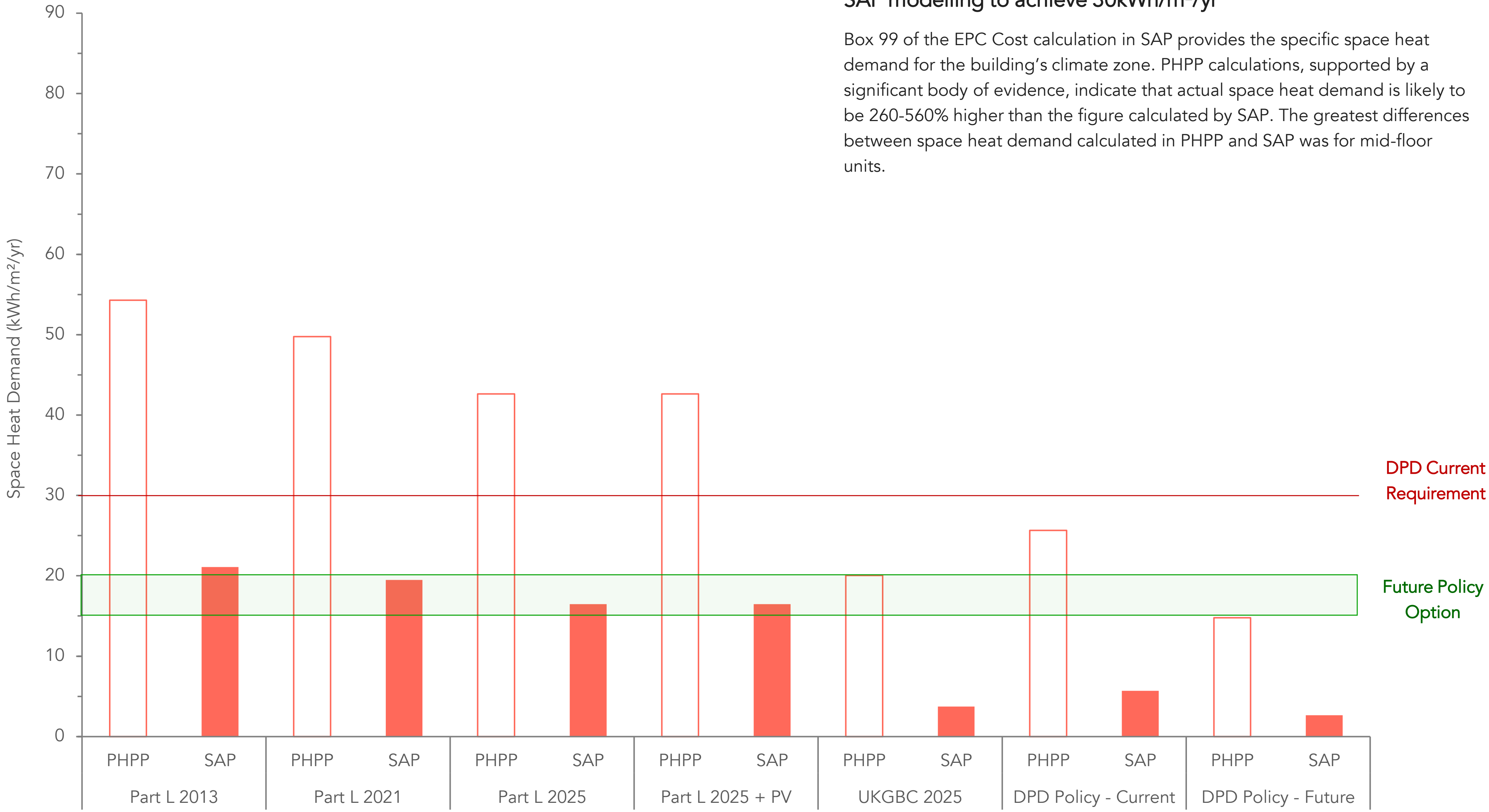
*Space heat demand calculated by PHPP 9.6a and FSAP 2012 for each scenario, compared to the DPD policy requirement. SAP calculations significantly underestimate space heat demand.*




### SAP modelling to achieve 30kWh/m²/yr

Box 99 of the EPC Cost calculation in SAP provides the specific space heat demand for the building's climate zone. PHPP calculations, supported by a significant body of evidence, indicate that actual space heat demand is likely to be 210-520% higher than the figure calculated by SAP. The greatest differences between space heat demand calculated in PHPP and SAP was for mid-floor units.

*Space heat demand calculated by PHPP 9.6a and FSAP 2012 for each scenario. SAP calculations significantly underestimate space heat demand.*

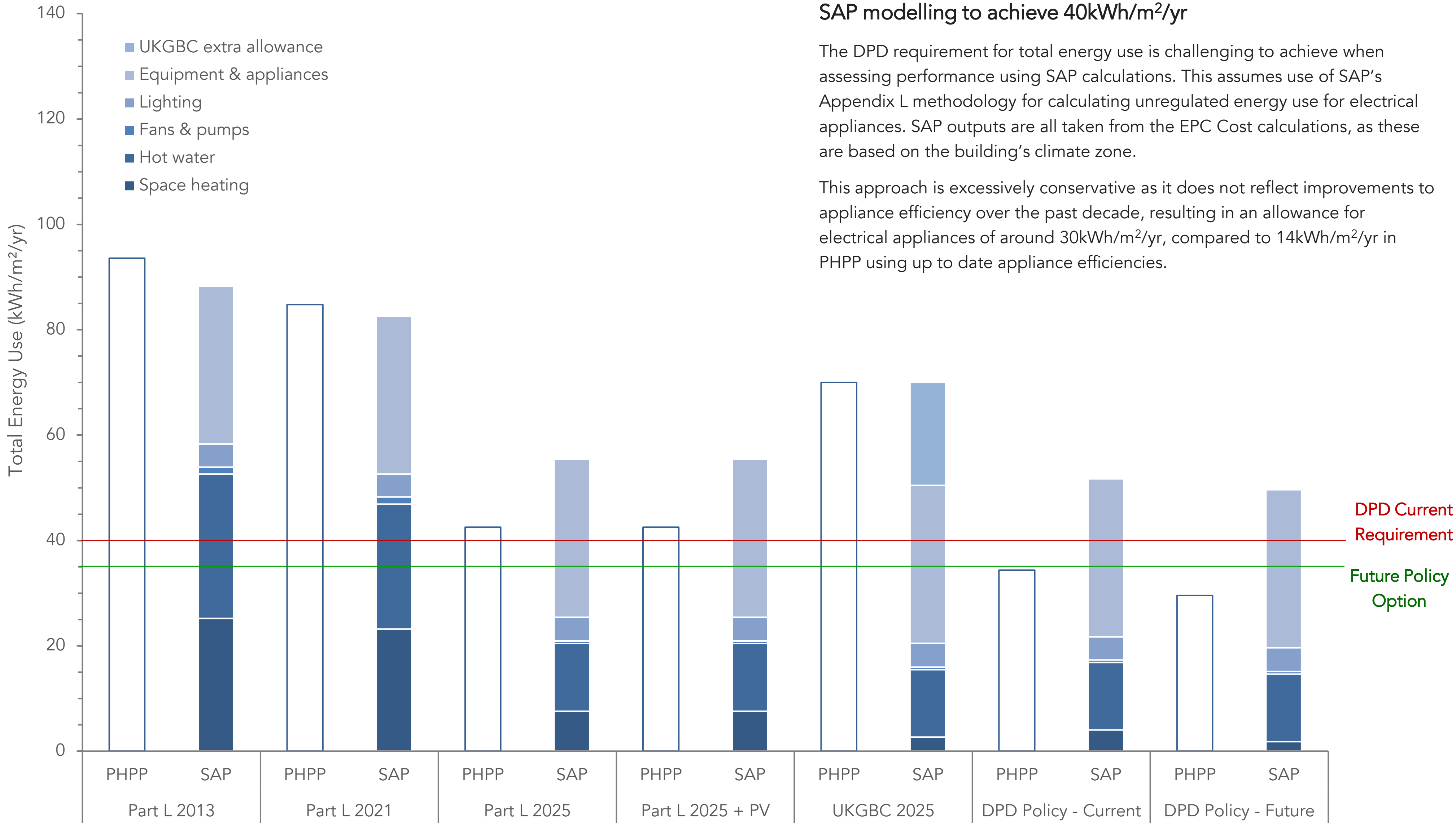



### SAP modelling to achieve 30kWh/m²/yr

Box 99 of the EPC Cost calculation in SAP provides the specific space heat demand for the building's climate zone. PHPP calculations, supported by a significant body of evidence, indicate that actual space heat demand is likely to be 260-560% higher than the figure calculated by SAP. The greatest differences between space heat demand calculated in PHPP and SAP was for mid-floor units.

*Space heat demand calculated by PHPP 9.6a and FSAP 2012 for each scenario, compared to the DPD policy requirement. SAP calculations significantly underestimate space heat demand.*

Etude

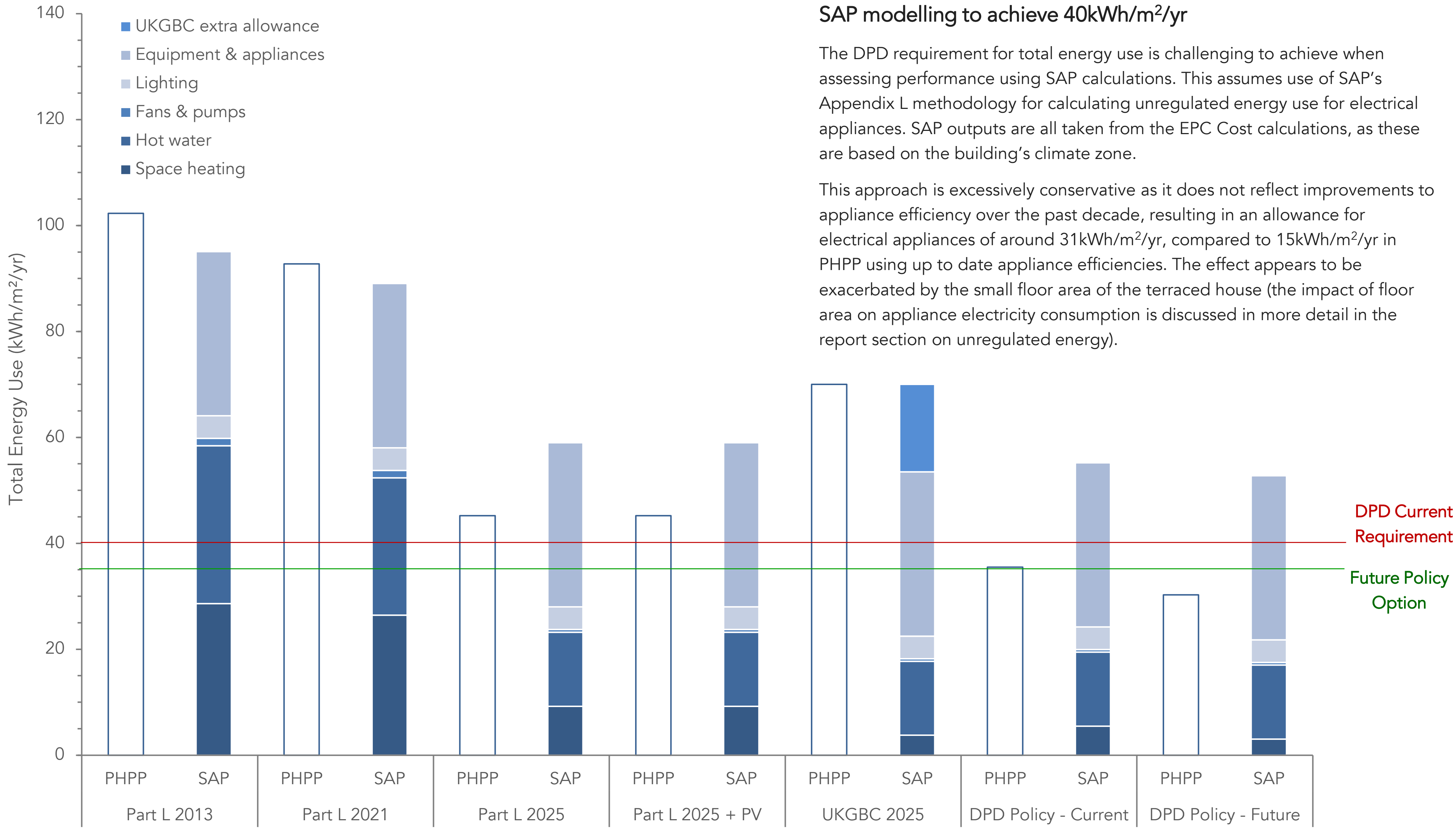



*Total energy use calculated by PHPP 9.6a and SAP for each scenario.*

## SAP modelling to achieve 40kWh/m²/yr

The DPD requirement for total energy use is challenging to achieve when assessing performance using SAP calculations. This assumes use of SAP's Appendix L methodology for calculating unregulated energy use for electrical appliances. SAP outputs are all taken from the EPC Cost calculations, as these are based on the building's climate zone.

This approach is excessively conservative as it does not reflect improvements to appliance efficiency over the past decade, resulting in an allowance for electrical appliances of around 30kWh/m²/yr, compared to 14kWh/m²/yr in PHPP using up to date appliance efficiencies.

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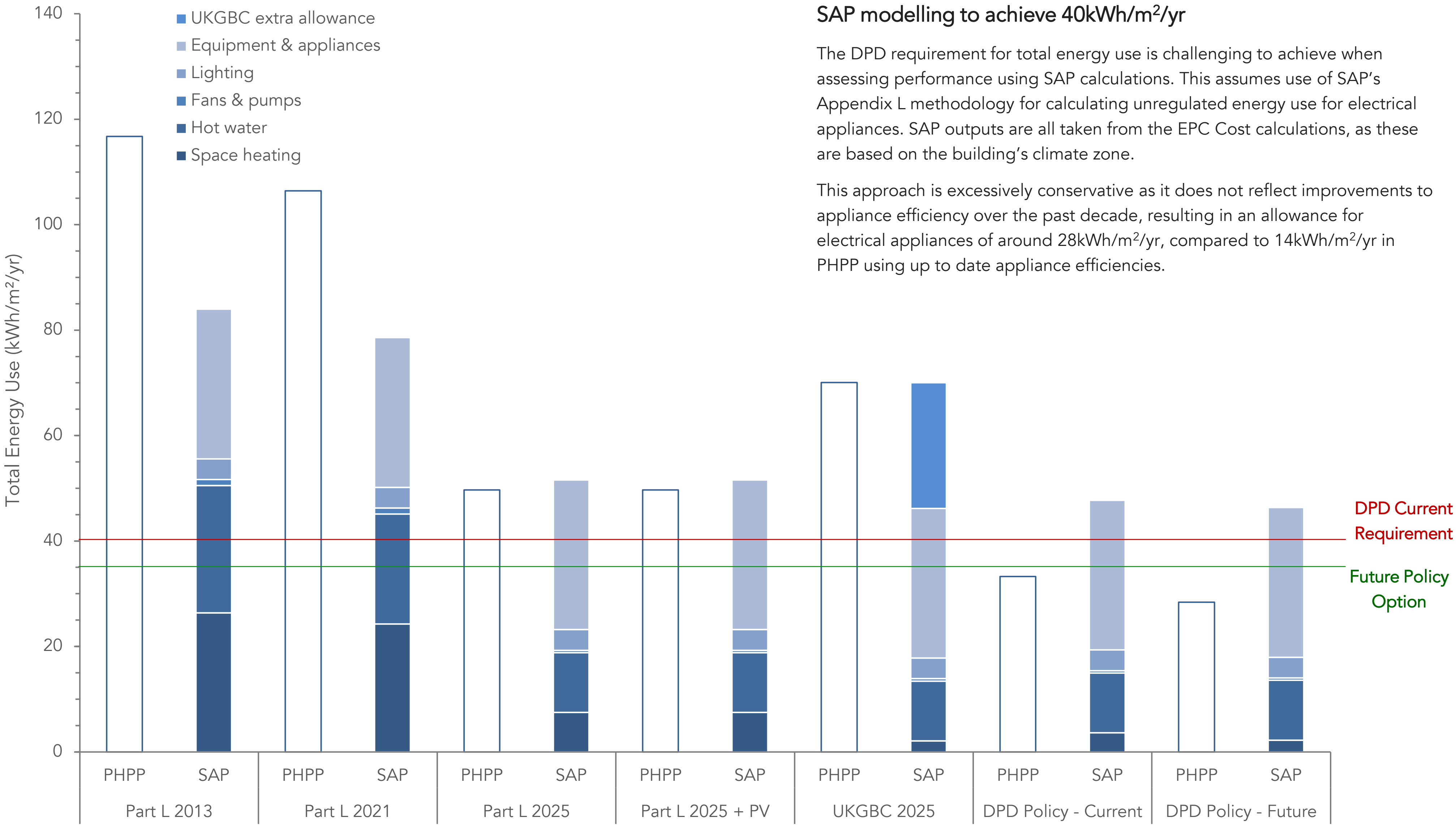
The DPD requirement for total energy use is challenging to achieve when assessing performance using SAP calculations. This assumes use of SAP's Appendix L methodology for calculating unregulated energy use for electrical appliances. SAP outputs are all taken from the EPC Cost calculations, as these are based on the building's climate zone.

This approach is excessively conservative as it does not reflect improvements to appliance efficiency over the past decade, resulting in an allowance for electrical appliances of around 31kWh/m²/yr, compared to 15kWh/m²/yr in PHPP using up to date appliance efficiencies. The effect appears to be exacerbated by the small floor area of the terraced house (the impact of floor area on appliance electricity consumption is discussed in more detail in the report section on unregulated energy).

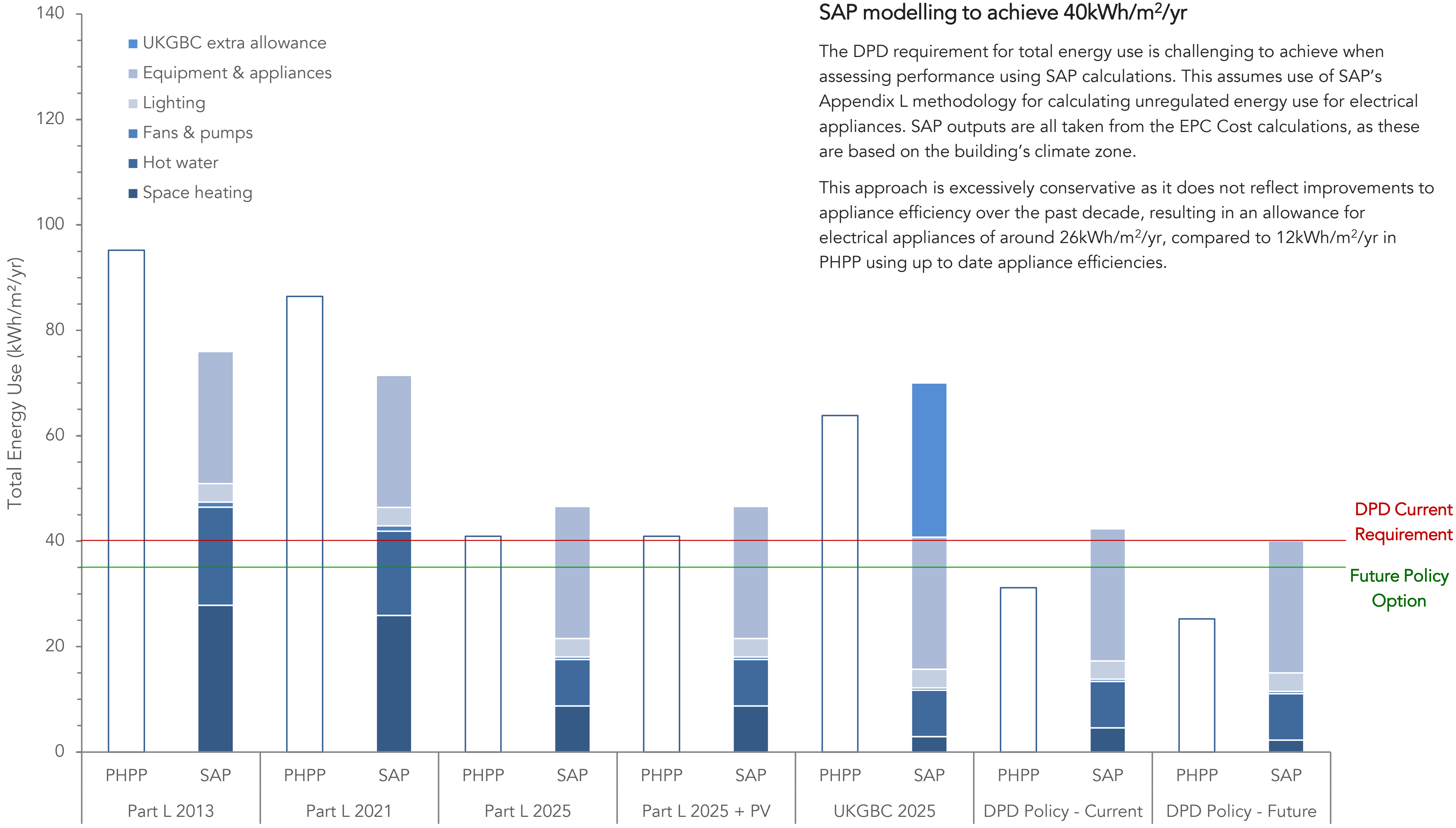



## SAP modelling to achieve 40kWh/m²/yr

The DPD requirement for total energy use is challenging to achieve when assessing performance using SAP calculations. This assumes use of SAP's Appendix L methodology for calculating unregulated energy use for electrical appliances. SAP outputs are all taken from the EPC Cost calculations, as these are based on the building's climate zone.

This approach is excessively conservative as it does not reflect improvements to appliance efficiency over the past decade, resulting in an allowance for electrical appliances of around 28kWh/m²/yr, compared to 14kWh/m²/yr in PHPP using up to date appliance efficiencies.

*Total energy use calculated by PHPP 9.6a and SAP for each scenario.*

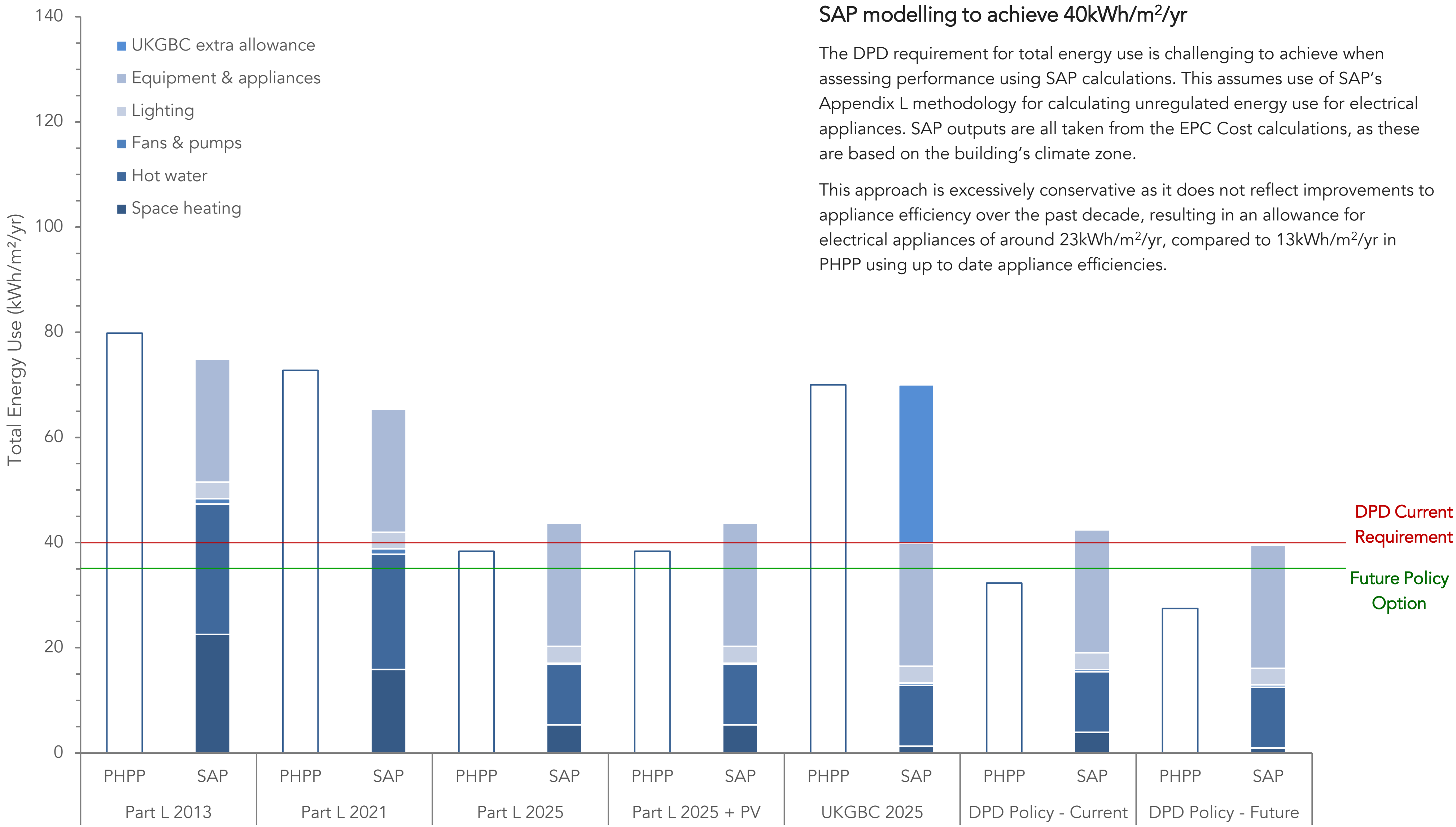



## SAP modelling to achieve 40kWh/m²/yr

The DPD requirement for total energy use is challenging to achieve when assessing performance using SAP calculations. This assumes use of SAP's Appendix L methodology for calculating unregulated energy use for electrical appliances. SAP outputs are all taken from the EPC Cost calculations, as these are based on the building's climate zone.

This approach is excessively conservative as it does not reflect improvements to appliance efficiency over the past decade, resulting in an allowance for electrical appliances of around 26kWh/m²/yr, compared to 12kWh/m²/yr in PHPP using up to date appliance efficiencies.

*Total energy use calculated by PHPP 9.6a and SAP for each scenario.*

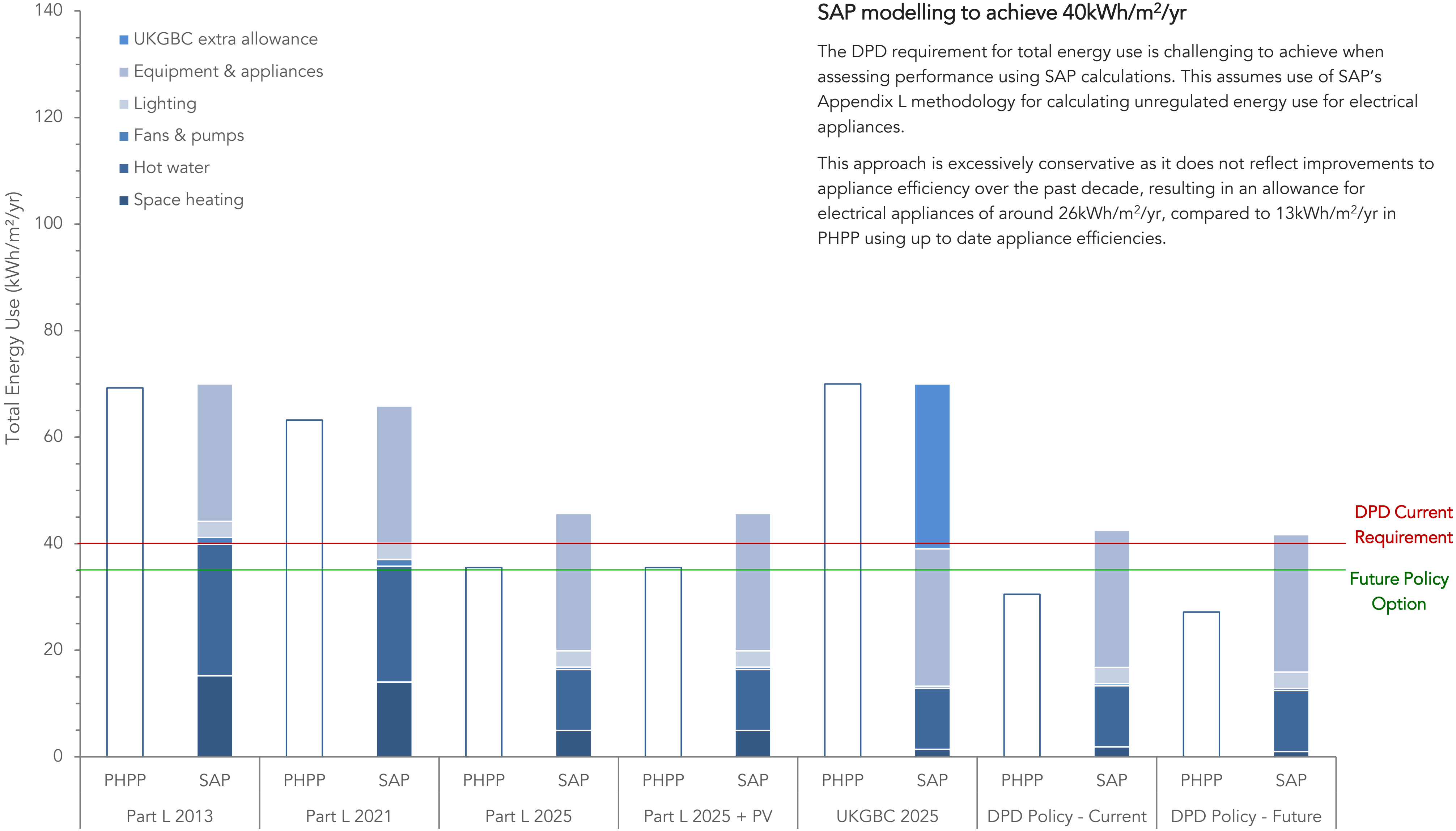



*Total energy use calculated by PHPP 9.6a and SAP for each scenario.*

## SAP modelling to achieve 40kWh/m²/yr

The DPD requirement for total energy use is challenging to achieve when assessing performance using SAP calculations. This assumes use of SAP's Appendix L methodology for calculating unregulated energy use for electrical appliances. SAP outputs are all taken from the EPC Cost calculations, as these are based on the building's climate zone.

This approach is excessively conservative as it does not reflect improvements to appliance efficiency over the past decade, resulting in an allowance for electrical appliances of around 23kWh/m²/yr, compared to 13kWh/m²/yr in PHPP using up to date appliance efficiencies.

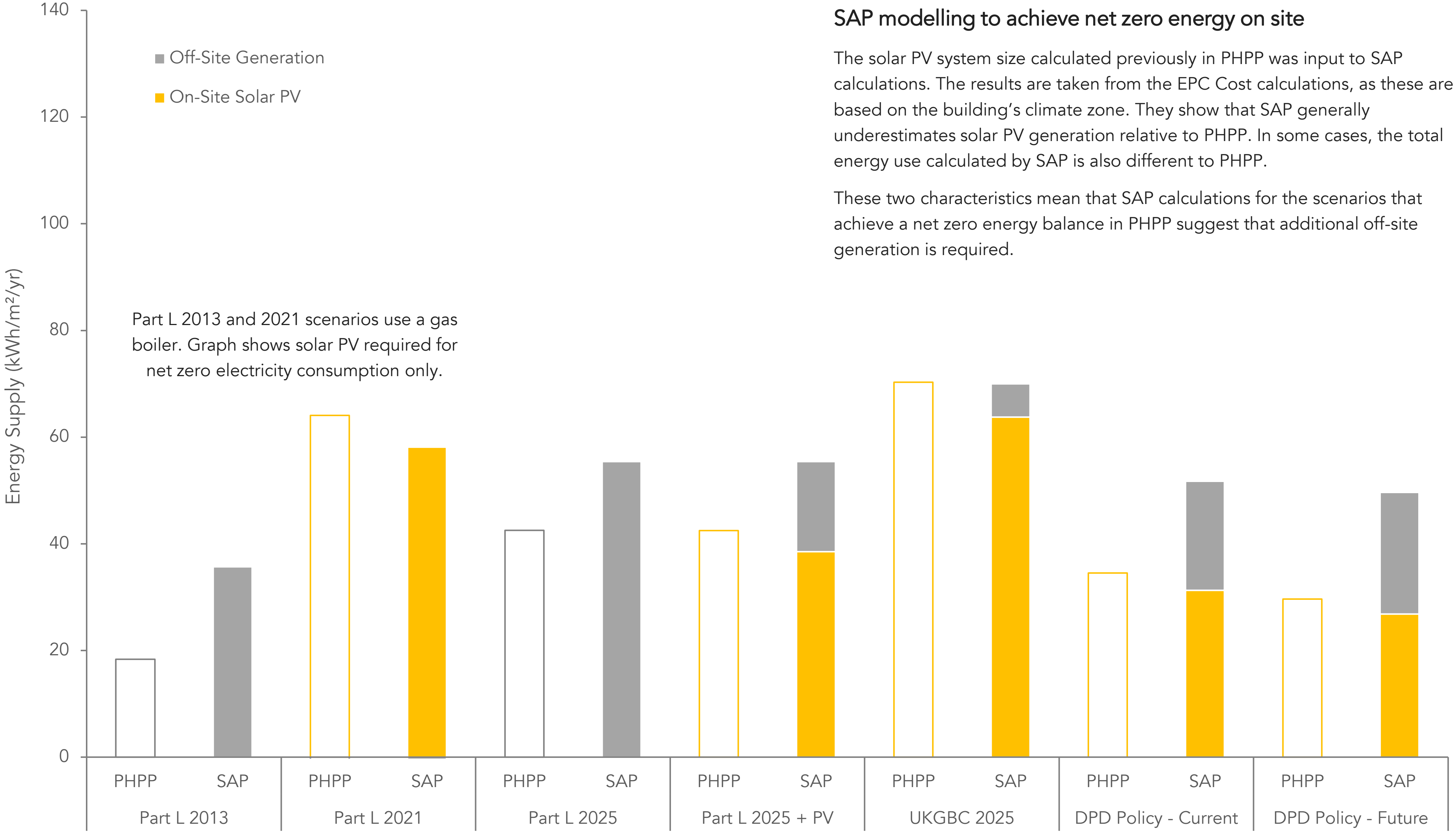



### SAP modelling to achieve 40kWh/m²/yr

The DPD requirement for total energy use is challenging to achieve when assessing performance using SAP calculations. This assumes use of SAP's Appendix L methodology for calculating unregulated energy use for electrical appliances.

This approach is excessively conservative as it does not reflect improvements to appliance efficiency over the past decade, resulting in an allowance for electrical appliances of around 26kWh/m²/yr, compared to 13kWh/m²/yr in PHPP using up to date appliance efficiencies.

*Total energy use calculated by PHPP 9.6a and SAP for each scenario.*




## SAP modelling to achieve net zero energy on site

The solar PV system size calculated previously in PHPP was input to SAP calculations. The results are taken from the EPC Cost calculations, as these are based on the building's climate zone. They show that SAP generally underestimates solar PV generation relative to PHPP. In some cases, the total energy use calculated by SAP is also different to PHPP.

These two characteristics mean that SAP calculations for the scenarios that achieve a net zero energy balance in PHPP suggest that additional off-site generation is required.

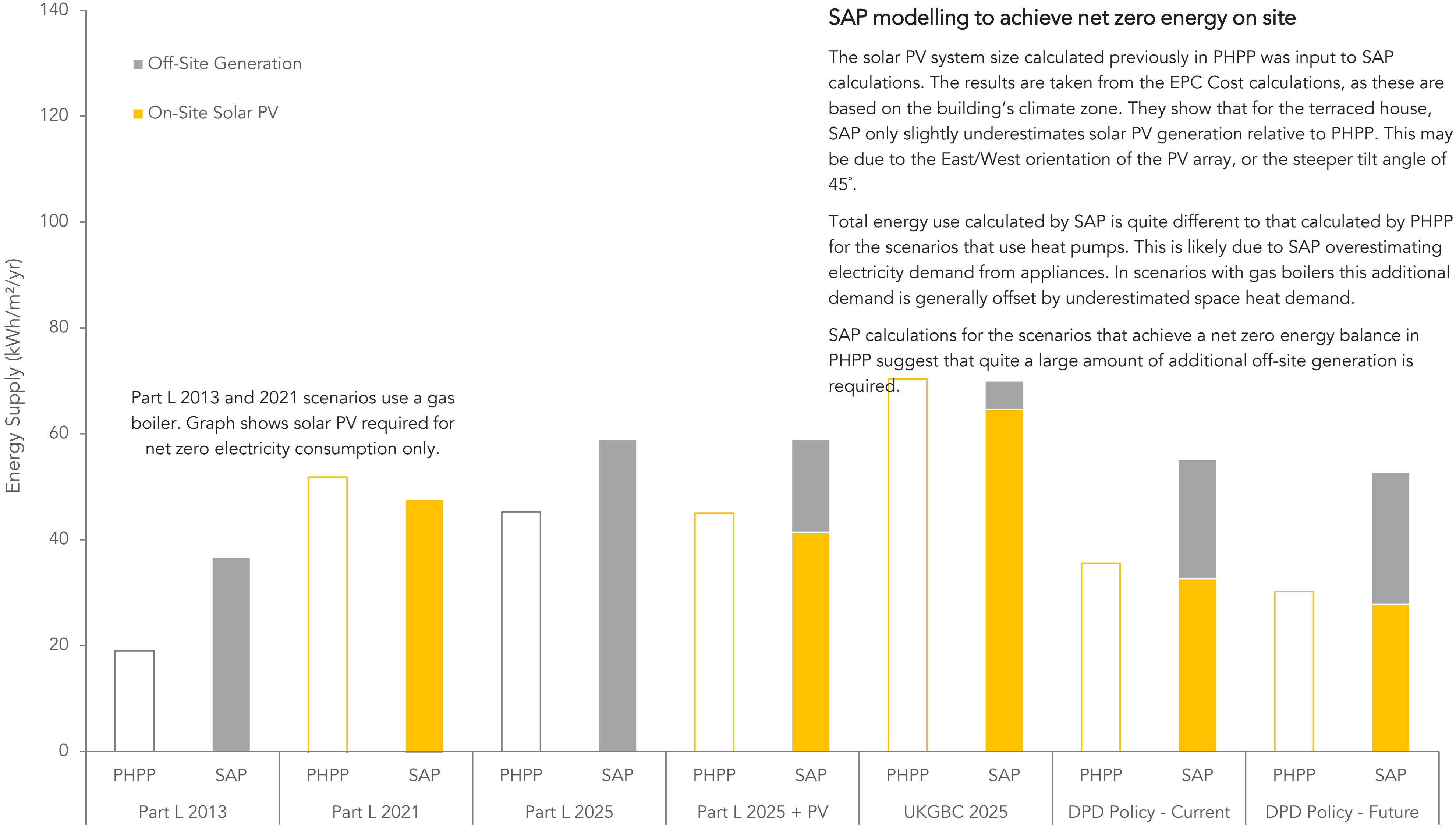
*On-site solar energy generation calculated by SAP for each scenario*

### SAP modelling to achieve net zero energy on site

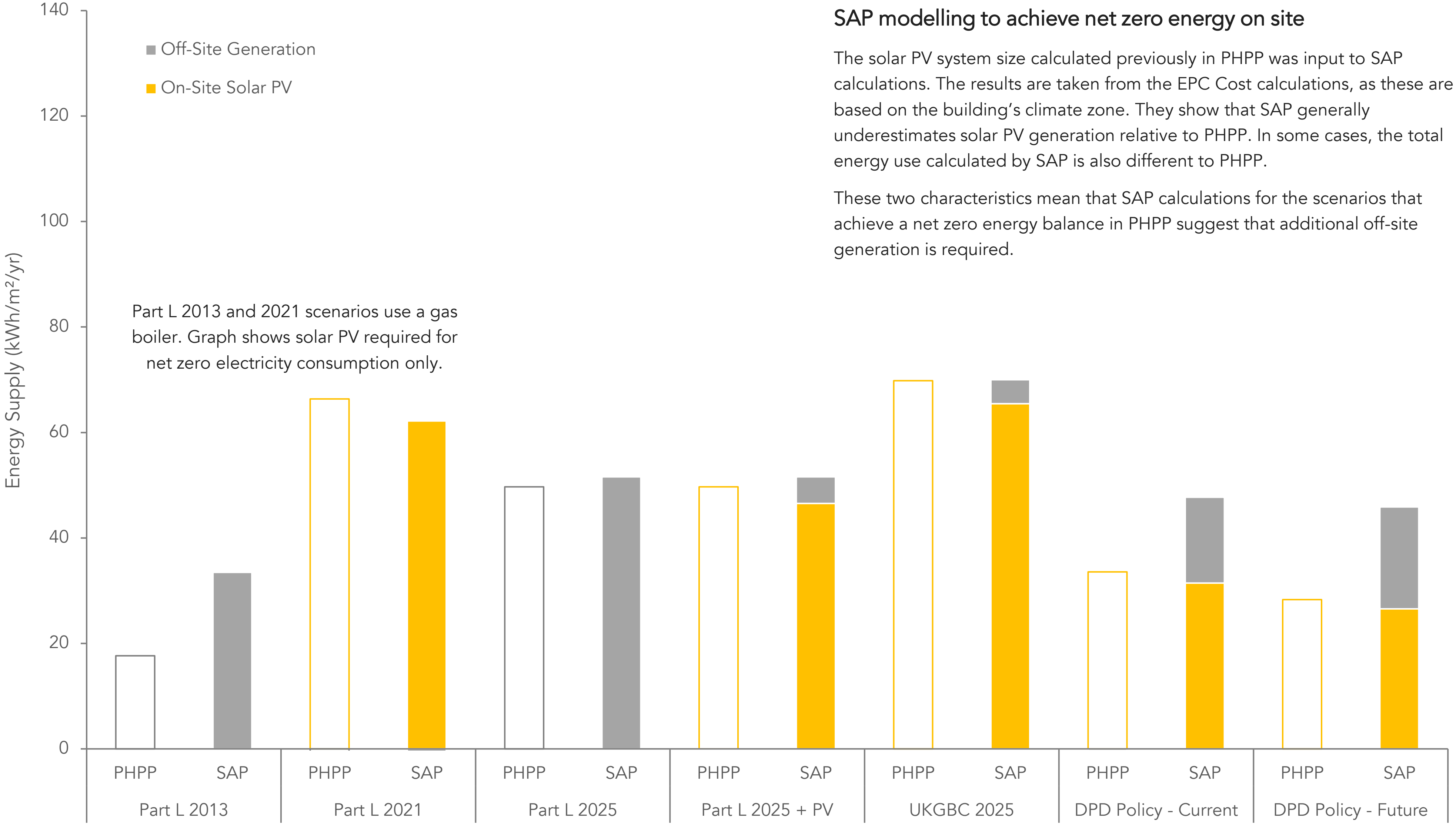
The solar PV system size calculated previously in PHPP was input to SAP calculations. The results are taken from the EPC Cost calculations, as these are based on the building's climate zone. They show that for the terraced house, SAP only slightly underestimates solar PV generation relative to PHPP. This may be due to the East/West orientation of the PV array, or the steeper tilt angle of 45˚.

Total energy use calculated by SAP is quite different to that calculated by PHPP for the scenarios that use heat pumps. This is likely due to SAP overestimating electricity demand from appliances. In scenarios with gas boilers this additional demand is generally offset by underestimated space heat demand.

SAP calculations for the scenarios that achieve a net zero energy balance in PHPP suggest that quite a large amount of additional off-site generation is required.




*On-site solar energy generation calculated by SAP for each scenario*

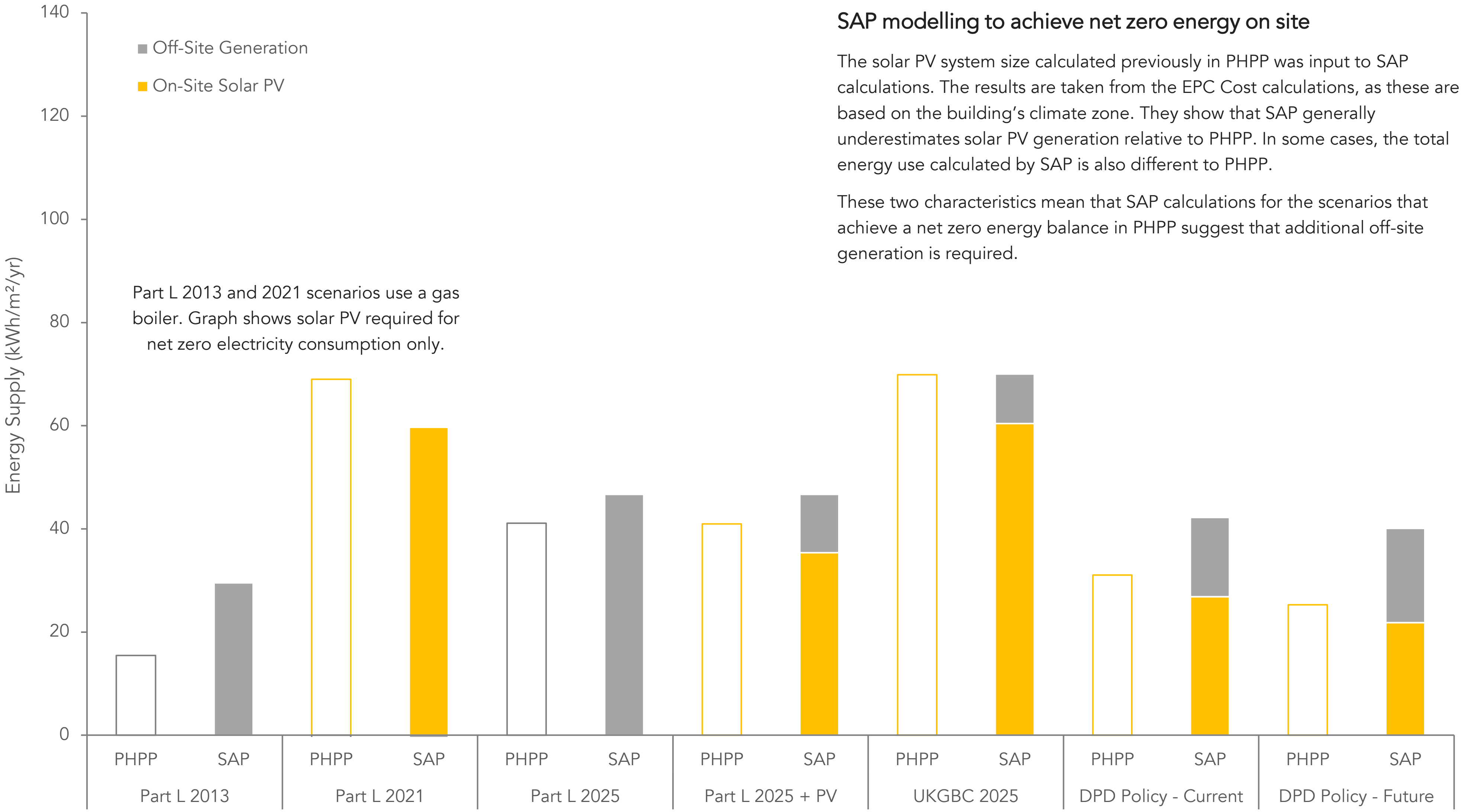



*On-site solar energy generation calculated by SAP for each scenario*

## SAP modelling to achieve net zero energy on site

The solar PV system size calculated previously in PHPP was input to SAP calculations. The results are taken from the EPC Cost calculations, as these are based on the building's climate zone. They show that SAP generally underestimates solar PV generation relative to PHPP. In some cases, the total energy use calculated by SAP is also different to PHPP.

These two characteristics mean that SAP calculations for the scenarios that achieve a net zero energy balance in PHPP suggest that additional off-site generation is required.

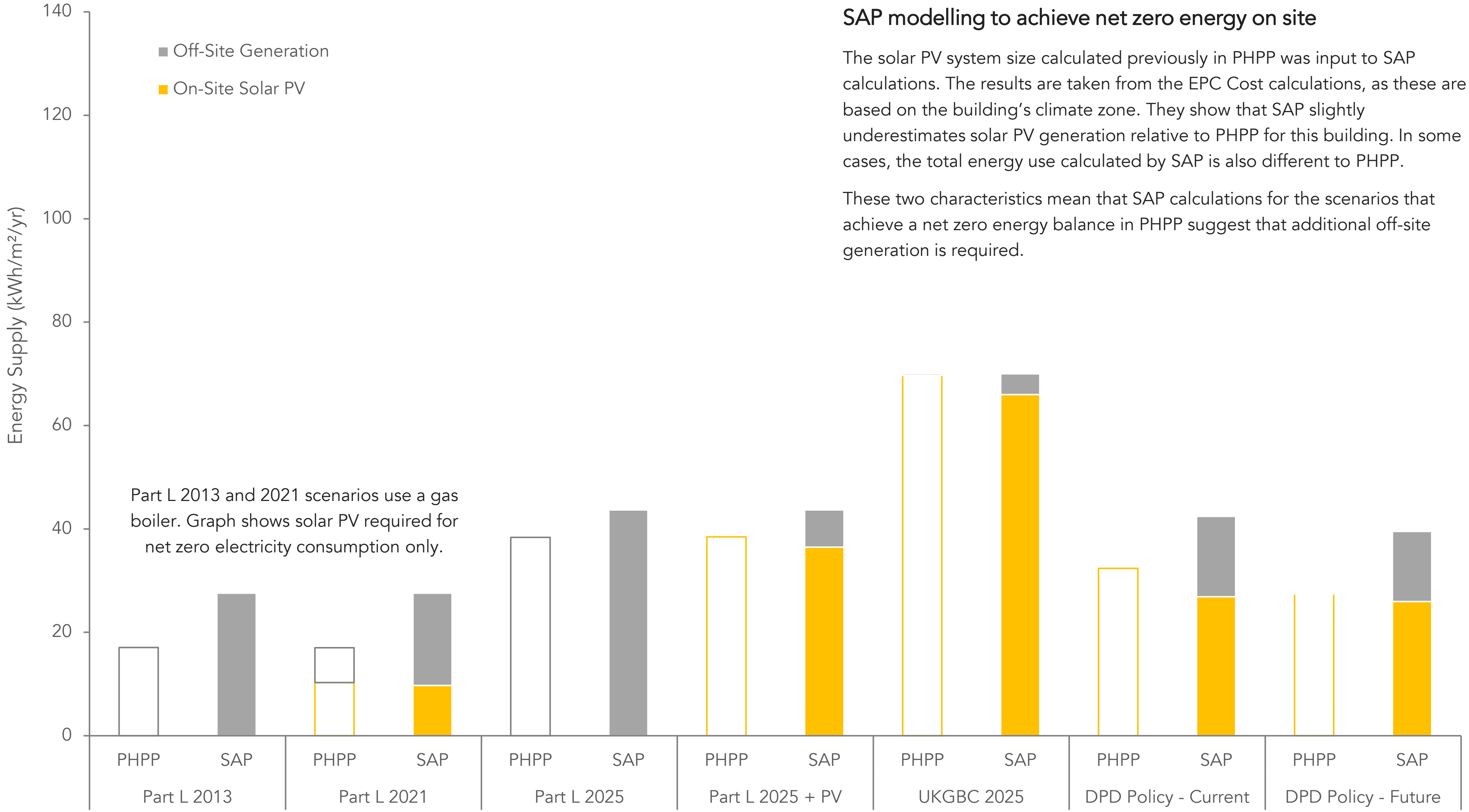



## SAP modelling to achieve net zero energy on site

The solar PV system size calculated previously in PHPP was input to SAP calculations. The results are taken from the EPC Cost calculations, as these are based on the building's climate zone. They show that SAP generally underestimates solar PV generation relative to PHPP. In some cases, the total energy use calculated by SAP is also different to PHPP.

These two characteristics mean that SAP calculations for the scenarios that achieve a net zero energy balance in PHPP suggest that additional off-site generation is required.

*On-site solar energy generation calculated by SAP for each scenario*

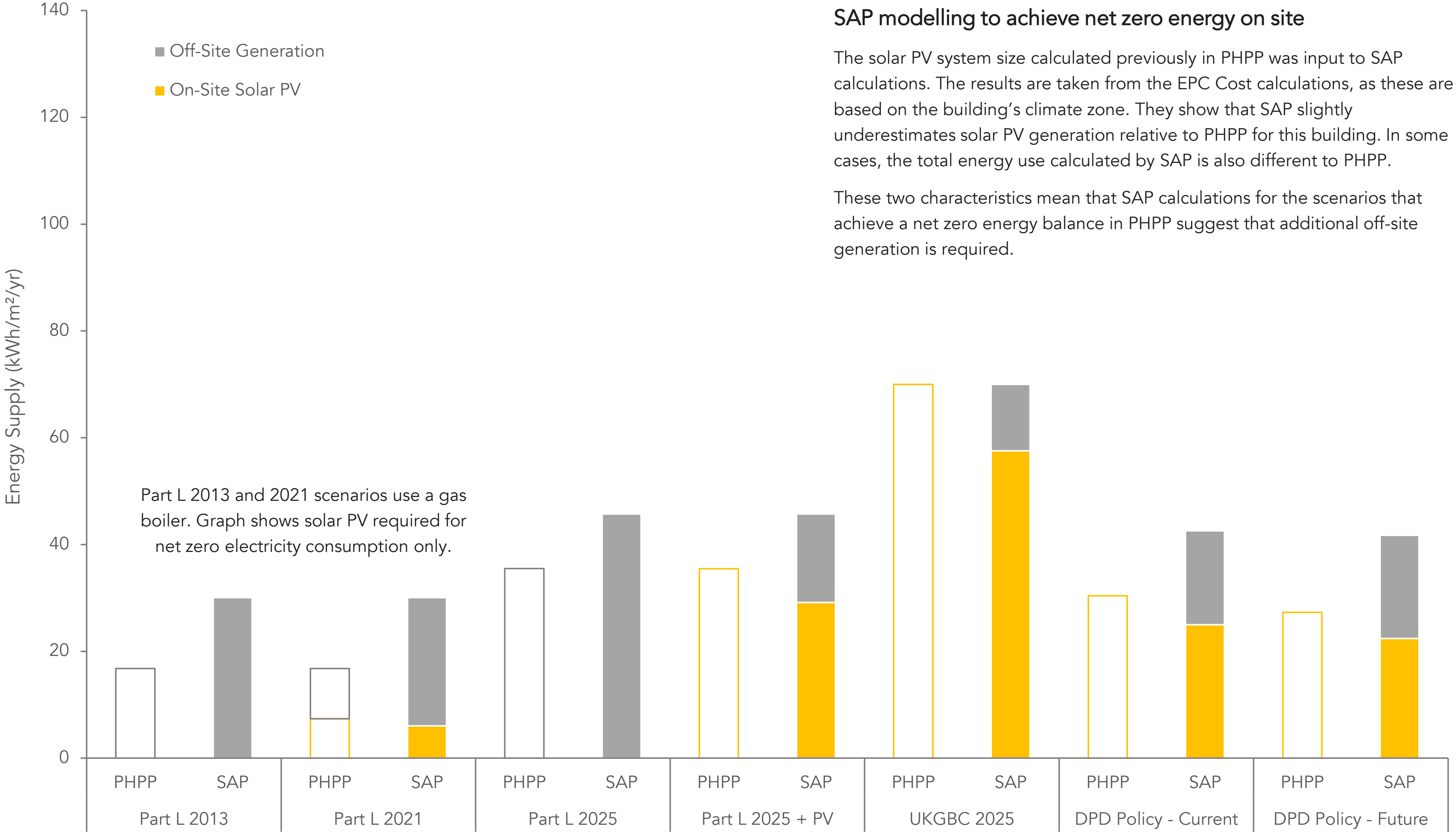



*On-site solar energy generation calculated by SAP for each scenario*

## SAP modelling to achieve net zero energy on site

The solar PV system size calculated previously in PHPP was input to SAP calculations. The results are taken from the EPC Cost calculations, as these are based on the building's climate zone. They show that SAP slightly underestimates solar PV generation relative to PHPP for this building. In some cases, the total energy use calculated by SAP is also different to PHPP.

These two characteristics mean that SAP calculations for the scenarios that achieve a net zero energy balance in PHPP suggest that additional off-site generation is required.




## SAP modelling to achieve net zero energy on site

The solar PV system size calculated previously in PHPP was input to SAP calculations. The results are taken from the EPC Cost calculations, as these are based on the building's climate zone. They show that SAP slightly underestimates solar PV generation relative to PHPP for this building. In some cases, the total energy use calculated by SAP is also different to PHPP.

These two characteristics mean that SAP calculations for the scenarios that achieve a net zero energy balance in PHPP suggest that additional off-site generation is required.

*On-site solar energy generation calculated by SAP for each scenario*

# Appendix 4

## SAP Correction Factors (for space heating and total energy use)

This appendix considers how SAP outputs can be corrected so they are fit to be assessed against the DPD requirements, to ensure the policy achieves its intended outcomes.

# Correction Factors | Space heating demand

## Can this be assessed using SAP?

Our calculations for this evidence base indicate that space heat demand calculated in PHPP (typically close to real world performance) may be anywhere from two to five times as high as the space heat demand calculated by SAP.

This is a well known problem with SAP. The level of variation depends on the type of building and the fabric efficiency. The adjacent graph shows the difference indicated by our calculations for the DPD compliant scenario.

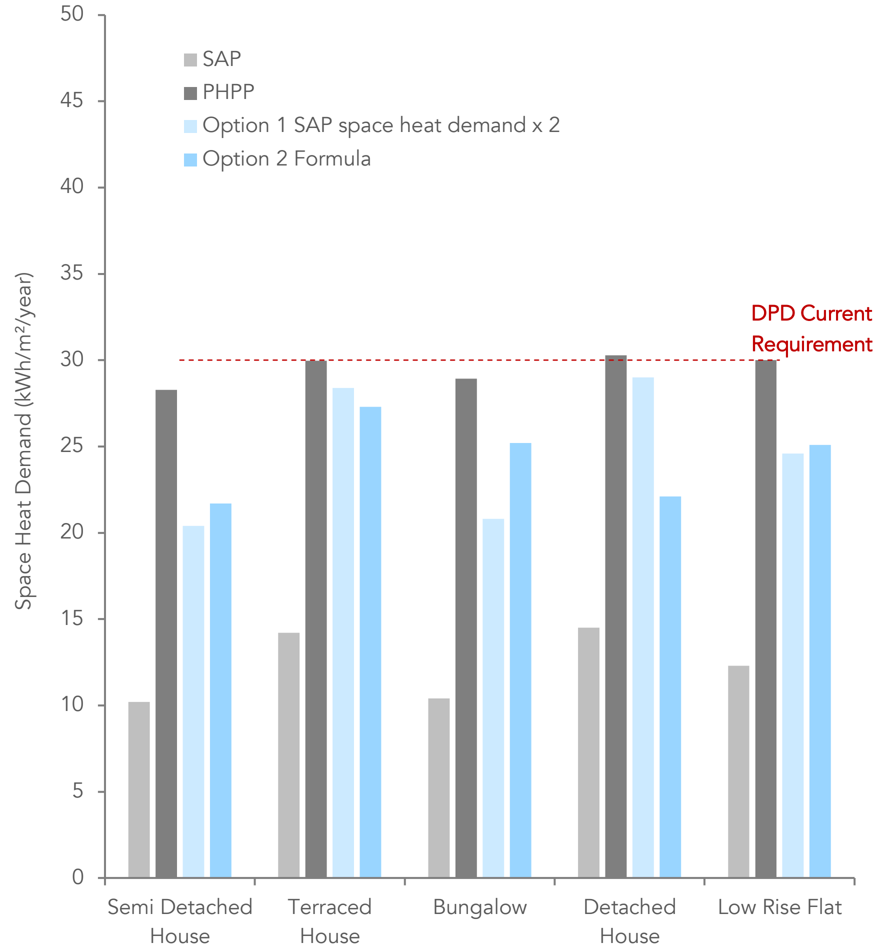
For the DPD policy to achieve its intended outcome, it will be necessary for applicants to convert any space heat demand predicted by SAP into a more realistic figure that can be assessed against the DPD requirement. We have identified two possible approaches to achieve this, by comparing SAP and PHPP space heating demand calculations undertaken for this evidence base:

### Option 1 – Double SAP space heat demand

Doubling the SAP space heat demand provides a straightforward way of bringing the SAP result much closer to the PHPP calculation. A downside of this approach is that it is less accurate for larger homes with lower fabric efficiency, and the smaller homes with better fabric efficiency. It is also unlikely to be effective for single flats with very small heat loss areas.

### Option 2 – Detailed adjustment

A more accurate conversion is possible by adjusting several SAP outputs used to calculate the space heat demand. For example, the transmission losses, ventilation losses, infiltration losses, solar gains and internal heat gains can all be assessed and adjusted separately. This would typically be implemented through a spreadsheet or online calculation tool. A copy of these calculations will be provided by Etude separately.




*Actual SAP and PHPP space heat demand for homes compliant with the current DPD, compared to the results of two different approaches to produce more realistic values from SAP. Option 1 is simple and can work reasonably well, though Option 2 is expected to more reliably produce results more consistent with PHPP calculations.*

## How Options 1 and 2 could work in practice

To obtain the information needed to carry out the SAP conversion in options 1 and 2, developers would need to use a standard output from all SAP software: the EPC Cost Worksheet. An example page from one of these reports is shown across the page. The Cost Worksheet is important as it is the only calculation output from SAP that references local weather data rather than the normalised location used in the other SAP/Part L worksheets.

The report use a numbered box to indicate the calculation steps. These numbers are the same in all the different softwares used for SAP calculations, so provide a common reference point for an online conversion tool.

A total of 11 data references are needed from the Cost Worksheet in order to perform the detailed conversion of space heat demand outlined in option 2. These references allow the calculation of heat gains and losses, based on the climate data for the specific location, as well providing information on the ventilation system, heat loss area, floor area, and indicative information on fabric performance.

Performing this conversion would only require a small amount of manual data entry, and would not require any further calculation by users.

While we believe the proposed approach is robust, as it has drawn upon a reasonably diverse dataset, the analysis could not have covered all possible specification types and buildings. Any homes that significantly differ from the tested data could result in a substantially different result. Further testing of the proposed options is therefore encouraged prior to implementation.

Etude have discussed the option of exporting the required data as a spreadsheet to speed up the process with one of the major SAP software developers. They confirmed that it was not a complicated addition to their software, and they would add it to the development cycle for inclusion in the future. This would likely be the case with other software developers.

**EPC Costs WorkSheet: New dwelling as built**

User Details:

**Assessor Name:** 
**Stroma Number:** 
**Software Name:** Stroma FSAP 2012
**Software Version:** Version: 1.0.5.41

Property Address: DPD - Current

**Address :**

1. Overall dwelling dimensions:

| | Area(m²) | | Av. Height(m) | | Volume(m³) | |
|---|---|---|---|---|---|---|
| Ground floor | 71 | (1a) x | 2.3 | (2a) = | 163.3 | (3a) |
| First floor | 71 | (1b) x | 2.3 | (2b) = | 163.3 | (3b) |
| Total floor area TFA = (1a)+(1b)+(1c)+(1d)+(1e)+.....(1n) | 142 | (4) | | | | |
| Dwelling volume | | | | (3a)+(3b)+(3c)+(3d)+(3e)+.....(3n) = | 326.6 | (5) |

2. Ventilation rate:

| | main heating | | secondary heating | | other | | total | | m³ per hour | |
|---|---|---|---|---|---|---|---|---|---|---|
| Number of chimneys | 0 | + | 0 | + | 0 | = | 0 | x 40 = | 0 | (6a) |
| Number of open flues | 0 | + | 0 | + | 0 | = | 0 | x 20 = | 0 | (6b) |
| Number of intermittent fans | | | | | | | 0 | x 10 = | 0 | (7a) |
| Num[...]nts | | | | | | | | | | |
| Num[...]of flueless[...]res | | | | | | | | x 40 = | | (7c) |

DRAFT

| | | | Air changes[...]hour | |
|---|---|---|---|---|
| Infilt[...] due to ch[...]ys, flu[...]d fans [...]+(6b)+(7a) | | ÷ (5) = | | (8) |
| *If a[...]urisation[...]been ca[...]ut or is inte[...]roceed[...]), otherwise co[...] from [...]16)* | | | | |
| N[...]s in the dw[...] (ns) | | | | (9) |
| Additional infiltration | | [(9)-1]x0.1 = | 0 | (10) |
| Structural infiltration: 0.25 for steel or timber frame or 0.35 for masonry construction | | | 0 | (11) |
| *if both types of wall are present, use the value corresponding to the greater wall area (after deducting areas of openings); if equal user 0.35* | | | | |
| If suspended wooden floor, enter 0.2 (unsealed) or 0.1 (sealed), else enter 0 | | | 0 | (12) |
| If no draught lobby, enter 0.05, else enter 0 | | | 0 | (13) |
| Percentage of windows and doors draught stripped | | | 0 | (14) |
| Window infiltration | | 0.25 - [0.2 x (14) ÷ 100] = | 0 | (15) |
| Infiltration rate | | (8) + (10) + (11) + (12) + (13) + (15) = | 0 | (16) |
| Air permeability value, q50, expressed in cubic metres per hour per square metre of envelope area | | | 1 | (17) |
| If based on air permeability value, then | | (18) = [(17) ÷ 20]+(8), otherwise (18) = (16) | 0.05 | (18) |
| *Air permeability value applies if a pressurisation test has been done or a degree air permeability is being used* | | | | |
| Number of sides sheltered | | | 0 | (19) |
| Shelter factor | | (20) = 1 - [0.075 x (19)] = | 1 | (20) |
| Infiltration rate incorporating shelter factor | | (21) = (18) x (20) = | 0.05 | (21) |

Infiltration rate modified for monthly wind speed

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monthly average wind speed from Table 7 | | | | | | | | | | | | |
| (22)m= | 6.3 | 6 | 5.8 | 5.1 | 5.1 | 4.6 | 4.6 | 4.5 | 4.9 | 5.7 | 5.9 | 6.3 |

Stroma FSAP 2012 Version: 1.0.5.41 (SAP 9.92) - http://www.stroma.com Page 1 of 13

*Example EPC cost output from a SAP calculation*

## Can this be assessed using SAP?

Electricity use calculated by SAP is much higher than in PHPP, and generally too high for the DPD total energy use requirement to be achievable through a SAP calculation. This is because SAP assumes use of older, less efficient appliances and lighting than would be used in a new home for which the DPD requirement has been developed.

We have identified three options to convert the total energy use calculated in SAP to a more reasonable figure that is likely to represent a new home. The graph to the right shows the application of these options relative to the current DPD requirement, and they are explained in more detail below:

### Option 1 – Use an allowance of 12kWh/m²/yr for appliances

$$\frac{12 + \text{Pumps \& Fans} + \text{Lighting} + \text{Cooling} + \text{Heating} + \text{Hot Water}}{\text{SAP floor area}}$$

This approach has the advantage that it changes the energy category least influenced by the developer/designer, however it offers no dependency on occupancy or other dwelling-specific attributes and may not be accurate for large or small dwellings.

### Option 2 - Divide all unregulated energy use by 2

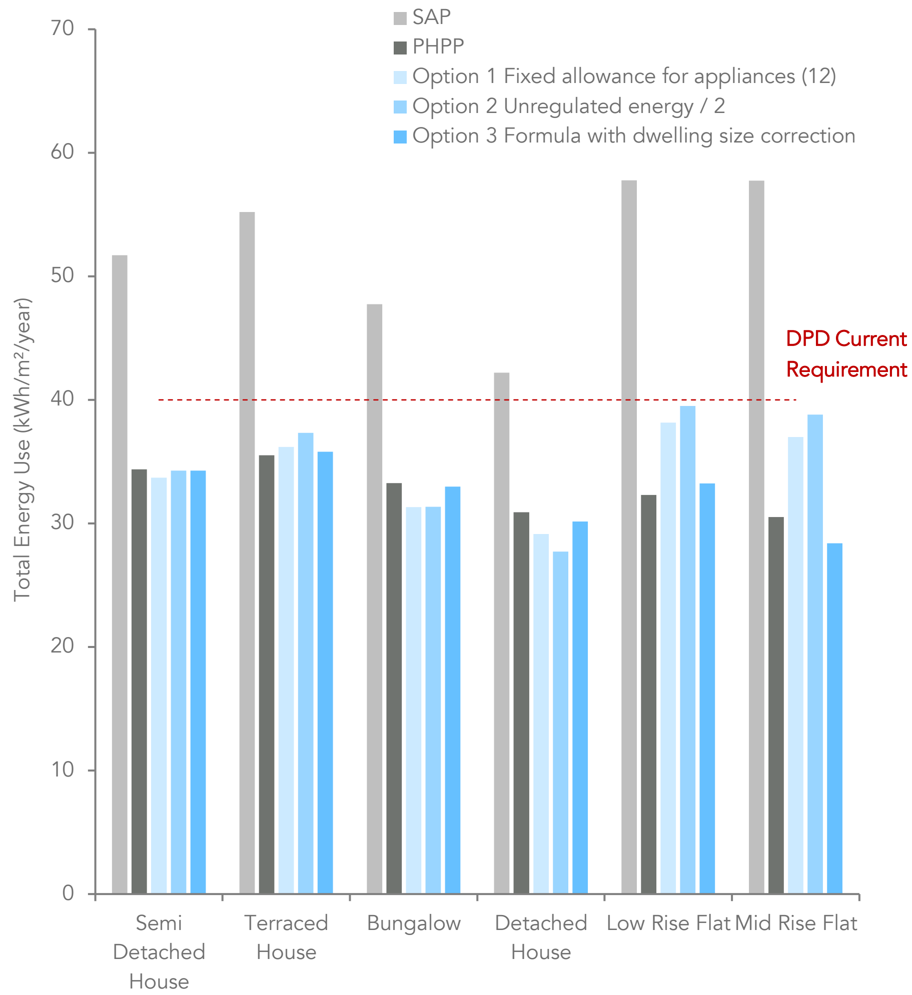
$$\frac{\left[\frac{\text{Appliances} + \text{Pumps \& Fans} + \text{Lighting}}{2}\right] + \text{Cooling} + \text{Heating} + \text{Hot Water}}{\text{SAP floor area}}$$

Advantages of this approach are that it updates the end uses that are the most overinflated, however it is also likely to underestimate energy use for large dwellings and an overestimate for small dwellings.

### Option 3 - Formula with several correction factors

$$\left[\frac{\left[\frac{\text{Appliances} + \text{Pumps \& Fans} + \text{Lighting}}{2}\right] + \text{Cooling} + \text{Heating} \times 2 + \text{Hot Water}}{\text{SAP floor area}}\right] - 2 + Z$$

Use of several correction factors for unregulated energy use, space heating, and dwelling size, results in a value that is much closer to PHPP, particularly for small home such as flats where options 1 and 2 typically overestimate.




*Actual SAP and PHPP total energy use for homes compliant with the current DPD, compared to the results of three different approaches to produce more realistic values from SAP. Options 1 and 2 are simple and do work, though Option 3 produces results more consistent with PHPP calculations. See page 3 for a typical breakdown of dwelling total energy use.*

## How options 1, 2 and 3 could work in practice

Total energy use (in kWh) is not a direct SAP output, however it is straightforward to calculate by combining outputs from the SAP cost worksheet. An example is provided in the adjacent image.

The table below summarises the SAP outputs required to calculate total energy use and their respective locations. Factor Z has been determined by Etude through a comparison of SAP and PHPP total energy use outputs for the buildings and policy scenarios modelled for this evidence base. It is correction factor that improves the accuracy of the calculation even for smaller homes such as flats.

| Energy End Use | Source |
|---|---|
| Electrical appliance energy use | SAP Appendix L [L12] |
| Electricity Pumps Fans | SAP Cost Worksheet [231] |
| Electricity Lighting | SAP Cost Worksheet [232] |
| Space Cooling | SAP Cost Worksheet [221] |
| Heating Fuel | SAP Cost Worksheet [211 + 213 + 215] |
| Water heat Fuel | SAP Cost Worksheet [219] |
| SAP floor area | SAP Cost Worksheet [4] |
| Factor Z* | if SAP floor area < 100 then (SAP floor area - 100)*0.3, otherwise 0. |

**EPC Costs WorkSheet: New dwelling design stage**

| | | | |
|---|---|---|---|
| | Total per year (kWh/year) = Sum(98)1...5,9...12 = | 1326.44 | (98) |
| Space heating requirement in kWh/m²/year | | 25.76 | (99) |

9a. Energy requirements – Individual heating systems including micro-CHP)

**Space heating:**

| | | | |
|---|---|---|---|
| Fraction of space heat from secondary/supplementary system | | 0 | (201) |
| Fraction of space heat from main system(s) | (202) = 1 – (201) = | 1 | (202) |
| Fraction of total heating from main system 1 | (204) = (202) × [1 – (203)] = | 1 | (204) |
| Efficiency of main space heating system 1 | | 93 | (206) |
| Efficiency of secondary/supplementary heating system, % | | 0 | (208) |

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | kWh/year | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Space heating requirement (calculated above) | 285.46 | 225.07 | 175.09 | 83.5 | 31.96 | 0 | 0 | 0 | 0 | 73.46 | 170.04 | 281.86 | | |
| (211)m = {[(98)m x (204)] } x 100 ÷ (206) | 306.95 | 242.01 | 188.27 | 89.78 | 34.36 | 0 | 0 | 0 | 0 | 78.99 | 182.84 | 303.07 | | (211) |
| Total (kWh/year) =Sum(211)1...5,10...12= | | | | | | | | | | | | | 1426.28 | (211) |
| Space heating fuel (secondary), kWh/month = {[(98)m x (201)] } x 100 ÷ (208) (215)m= | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Total (kWh/year) =Sum(215)1...5,10...12= | | | | | | | | | | | | | 0 | (215) |
| **Water heating** Output from water heater (calculated above) | 151.86 | 134.16 | 142.12 | 129.74 | 128.61 | 116.89 | 114.57 | 123.28 | 122.29 | 135.09 | 140.09 | 148.72 | | |
| Efficiency of water heater | | | | | | | | | | | | | 79.9 | (216) |
| (217)m= | 86.22 | 85.94 | 85.18 | 83.57 | 81.73 | 79.9 | 79.9 | 79.9 | 79.9 | 83.19 | 85.14 | 86.23 | | (217) |
| Fuel for water heating, kWh/month (219)m = (64)m x 100 ÷ (217)m (219)m= | 176.14 | 156.11 | 166.86 | 155.24 | 157.37 | 146.3 | 143.39 | 154.3 | 153.05 | 162.39 | 164.54 | 172.46 | | |
| Total = Sum(219a)1...12 = | | | | | | | | | | | | | 1908.14 | (219) |



| **Annual totals** | **kWh/year** | **kWh/year** | |
|---|---|---|---|
| Space heating fuel used, main system 1 | | 1426.28 | |
| Water heating fuel used | | 1908.14 | |
| Electricity for pumps, fans and electric keep-hot | | | |
| mechanical ventilation - balanced, extract or positive input from outside | 15.38 | | (230a) |
| central heating pump: | 30 | | (230c) |
| boiler with a fan-assisted flue | 45 | | (230e) |
| Total electricity for the above, kWh/year — sum of (230a)...(230g) = | | 90.38 | (231) |
| Electricity for lighting | | 241.7 | (232) |
| Electricity generated by PVs | | -688.33 | (233) |
| Total delivered energy for all uses (211)...(221) + (231) + (232)...(237b) = | | 2978.17 | (338) |

10a. Fuel costs - individual heating systems:

Stroma FSAP 2012 Version: 1.0.5.41 (SAP 9.92) - http://www.stroma.com Page 7 of 9

*Example EPC cost output from a SAP calculation*

Etude

# Appendix 5

# Cost modelling results

This appendix contains the results of cost modelling for the different house types and policy scenarios

# Cost modelling results | Summary Tables

| | | Part L 2013 | Part L 2021 | Part L 2025 | Part L 2025 PV | UKGBC 2025 | DPD - Current | DPD - Future |
|---|---|---|---|---|---|---|---|---|
| Semi-detached house | Solar PV | -£5,132 | Baseline costs | -£5,132 | -£1,358 | £392 | -£1,859 | -£2,167 |
| | Heating System | -£881 | Baseline costs | £672 | £672 | £599 | £665 | £552 |
| | Fabric Efficiency | -£1,149 | Baseline costs | £1,056 | £1,056 | £3,775 | £2,390 | £5,405 |
| Terraced house | Solar PV | -£4,376 | Baseline costs | -£4,376 | -£429 | £1,170 | -£1,027 | -£1,368 |
| | Heating System | -£887 | Baseline costs | £665 | £665 | £568 | £648 | £521 |
| | Fabric Efficiency | -£1,360 | Baseline costs | £1,272 | £1,272 | £5,801 | £2,988 | £6,981 |
| Bungalow | Solar PV | -£6,846 | Baseline costs | -£6,846 | -£2,418 | -£1,066 | -£3,497 | -£3,848 |
| | Heating System | -£949 | Baseline costs | £652 | £652 | £431 | £499 | £335 |
| | Fabric Efficiency | -£1,795 | Baseline costs | £2,011 | £2,011 | £10,237 | £5,113 | £10,571 |
| Detached house | Solar PV | -£6,820 | Baseline costs | -£6,820 | -£2,335 | £71 | -£3,133 | -£3,626 |
| | Heating System | -£938 | Baseline costs | £647 | £647 | £496 | £619 | £412 |
| | Fabric Efficiency | -£1,860 | Baseline costs | £1,957 | £1,957 | £6,843 | £3,544 | £10,108 |
| Low rise flats | Solar PV | -£826 | Baseline costs | -£826 | £1,834 | £3,863 | £1,437 | £1,114 |
| | Heating System | -£873 | Baseline costs | £665 | £665 | £617 | £690 | £575 |
| | Fabric Efficiency | -£913 | Baseline costs | £1,106 | £1,106 | £3,814 | £2,533 | £5,009 |
| Medium rise flats | Solar PV | -£471 | Baseline costs | -£471 | £1,586 | £3,536 | £1,300 | £1,125 |
| | Heating System | -£851 | Baseline costs | £675 | £675 | £660 | £693 | £626 |
| | Fabric Efficiency | -£621 | Baseline costs | £738 | £738 | £2,998 | £2,443 | £3,526 |

*Table of cost modelling results for all house types and policy scenarios. Costs are based on typical UK construction costs from Currie and Brown. Local costs of construction and measures required to comply with policy may vary and should not be independently altered. Costs do not factor in anticipated future reductions due to learning rates once policy is adopted.*