Passivhaus Trust
The UK Passive House Organisation

Future Homes Hub contender specifications for the FHS

Passivhaus Trust position paper

June 2023

> *"I was working as a physicist. I read that the construction industry had experimented with adding insulation to new buildings and that energy consumption had failed to reduce. This offended me – it was counter to the basic laws of physics. I knew that they must be doing something wrong. So I made it my mission to find out what, and to establish what was needed to do it right."*
>
> — Prof. Dr. Wolfgang Feist

Thanks to our Patron members

The Passivhaus Trust Patron Members provide additional support to the Passivhaus Trust, including funding for technical research and publications.

http://bit.ly/PHTpatronmembers

Contents

Figures

Tables

Acknowledgements

Author:
Rachel Mitchell Passivhaus Trust

Editorial team:
Laura Soar Passivhaus Trust

Technical review:
Jon Bootland Passivhaus Trust
Sarah Lewis Passivhaus Trust
Alan Clarke
Nick Grant Elemental Solutions

Thanks also to the Passivhaus Trust Technical Steering Group for additional peer review

About

This position paper responds to the report *Ready for Zero: Evidence to inform the 2025 Future Homes Standard – Task Group Report*, published by the Future Homes Hub on 28 February 2023.

Recommendations

1. Decisions on the Future Homes Standard (FHS) should be based on more accurate modelling such as PHPP 10, and/or measured performance data, because SAP 10 cannot accurately model heat demand in very low energy buildings.

2. PHPP should be accepted as an alternative tool for compliance as it is proven to accurately reflect performance in use.

3. Passivhaus Classic is equivalent to or better than the proposed Future Homes Hub Contender Specifications up to CS3 and CS4 and significantly outperforms reference buildings 2021 & 2025 (England & Wales) plus Section 6 2023 (Scotland) as well as providing many other benefits, and should therefore be considered as *deemed to satisfy* these levels.

4. The capital cost uplift associated with Passivhaus Classic is more like 4% compared to current Building Regulations, rather than the 19% figure quoted in the Future Homes Hub report.

Introduction

This position paper responds to the report *Ready for Zero: Evidence to inform the 2025 Future Homes Standard – Task Group Report*, published by the Future Homes Hub on 28 February 2023[1].

In the report, five contender specifications (CS1- CS5) are proposed for the new Future Homes Standard (FHS). There is no equivalent to Passivhaus Classic (PH) within this report, as photovoltaics (PVs) are included in each CS level; however, Passivhaus Classic could be considered as an alternative to CS3 – see more below. CS4 is superficially approaching the Passivhaus Plus (PH Plus) standard, although the actual CS4 space heating demand is likely to be significantly higher and does not give the same comfort and health benefits that are associated with the Passivhaus quality assurance and Certification process. A detailed summary of the contender specifications used in this report can be found in Appendix 1.

Using the same FHH end of terrace reference building, we have modelled Ref 2021 (Part L1A 2021), Ref 2025, CS2, CS3, CS4, Passivhaus Classic (PH) and Passivhaus Plus (PH Plus) and well as Section 6 2023 of Scottish Building Regulations in both SAP 10 and PHPP 10, to compare the standards in both assessment methods. Outputs are shown in Appendix 2 and we report on space heating demand, regulated energy demand, carbon emissions and costs.

Our modelling shows that space heating demand is predicted to be much lower in SAP 10, up to a factor of almost 500% compared to PHPP 10, which is proven to be an accurate measuring tool in post occupancy evaluations.[2]

In our calculations (see Appendix 2), CS3 when modelled in PHPP will have a higher space heating demand than Ref 2021 modelled in SAP 10. Wrongly assuming low energy demand can drive decisions to allow direct electric heating in flats, which may lead to much higher energy costs than expected for occupants, or to prioritise photovoltaics over building fabric, which depends on there being sufficient roof area and suitable orientation and does not work in tall buildings.

Figure 1 shows the percentage difference between predicted space heating demand from both models.

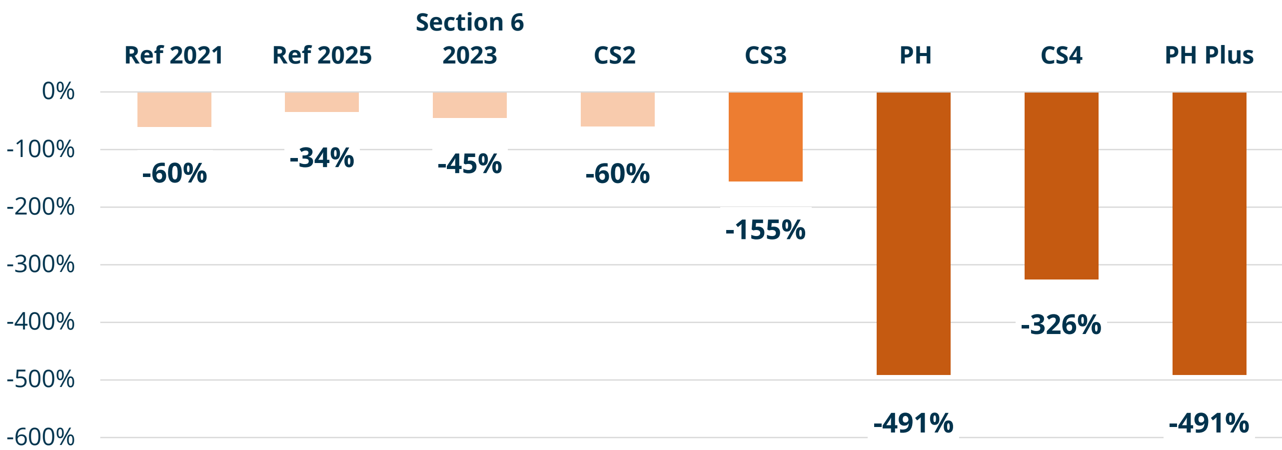


Figure 1: *Percentage difference in space heating demand between SAP 10 and PHPP 10*

We can see that as homes become more energy efficient, the difference between space heating demand predictions from SAP 10 and PHPP 10 increases, and once you reach the Passivhaus standard, that difference is nearly 500%.

SAP 10 should not be used as a compliance tool for very low energy buildings. Therefore, we have based our findings on PHPP 10 modelling, rather than SAP 10, which also does not adequately address summer overheating, local climate, altitude etc.

1 *Ready for Zero: Evidence to inform the 2025 Future Homes Standard – Task Group Report*, Future Homes Hub (2023). Available online via futurehomes.org.uk: https://irp.cdn-website.com/bdbb2d99/files/uploaded/Ready for Zero - Evidence to inform the 2025 Future Homes Standard -Task Group Report FINAL- 280223- MID RES.pdf

2 Rachel Mitchell and Sukumar Natarajan, 'UK Passivhaus and the energy performance gap', *Energy and Buildings* (2020). Available online: https://doi.org/10.1016/j.enbuild.2020.110240

Regardless of the modelling method, a Passivhaus Classic or Passivhaus Plus building would have lower space heating demand than any FHH proposal up to level CS5. Investing in the building fabric locks the energy reductions into the lifetime of the building, rather than relying on building services which can degrade over time and have no guarantee of being replaced to maintain the energy savings over time.

In addition, building to the Passivhaus Classic or Passivhaus Plus standard will deliver the following benefits compared to the other specifications.

	Ref 2021	Ref 2025	Section 6 2023	CS3	CS4	PH	PH Plus
Lowest space heating demand	-	-	-	-	-	√	√
Effectively eliminating the performance gap	-	-	-	-	-	√	√
Low energy bills	-	-	-	√	√	√	√
Summer comfort	?	?	?	?	?	√	√
Winter comfort	-	-	-	-	√	√	√
Good internal air quality	-	-	-	?	?	√	√
Protection against condensation and mould	-	-	-	?	?	√	√
Better quality components	-	-	-	-	-	√	√
Better build quality	-	-	-	-	-	√	√
No future retrofit	-	-	-	-	√	√	√
Lowest peak demand on the grid	-	-	-	-	-	√	√
Responsive to local climate	-	-	-	-	-	√	√

Table 1: *Benefits of building to Passivhaus*

The benefits of Passivhaus are examined in more detail in *Passivhaus Benefits* (Passivhaus Trust, 2021).[3]

3 *Passivhaus Benefits*, Passivhaus Trust (2021). Available online: https://pht.guide/benefits

Performance predictions

The performance gap between design and in use energy performance is well documented[4] and, conservatively, is found to result in a 60% increase in space heating demand. While it is recognised that as part of the uplift to Part L1A 2021, an additional compliance report is required to show that insulation measures are correctly installed, windows are properly specified and building services perform as designed, there is, to date, no evidence that these measures will significantly reduce the performance gap. Therefore a 40% performance gap for space heating demand, reduced to reflect the above, is included in all options except PH and PH Plus. Ref 2021 is based on a gas boiler and all other specifications are based on a 3.5 kW air source heat pump.

SPACE HEATING DEMAND

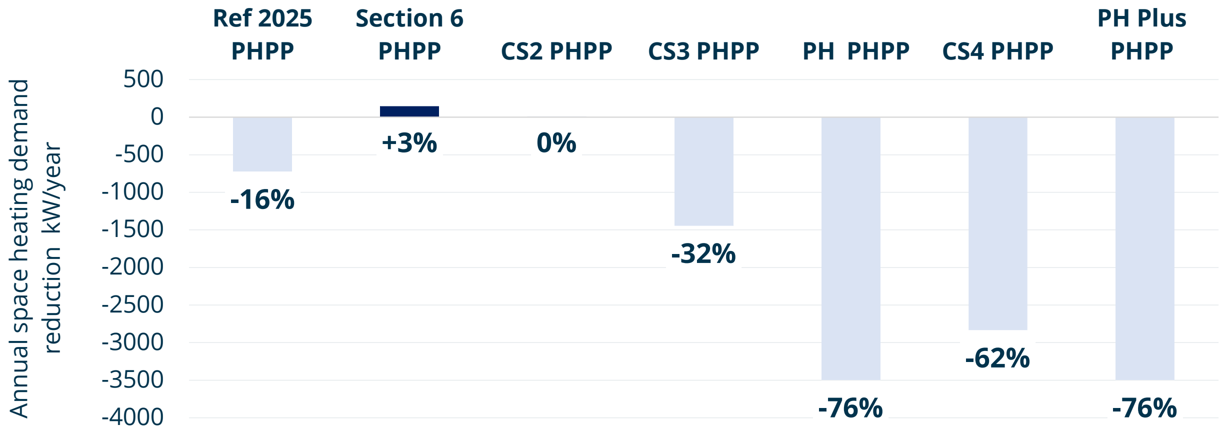


Figure 2: *Delivered space heating demand reduction compared to Ref 2021*

Both PH and PH Plus give the greatest delivered space heating demand reductions. For the other specifications, an increase in predicted space heating demand as a result of more accurate modelling and accounting for the performance gap may result in a larger heat pump being specified, which will impact on both emissions and costs, and may affect compliance.

CARBON EMISSIONS

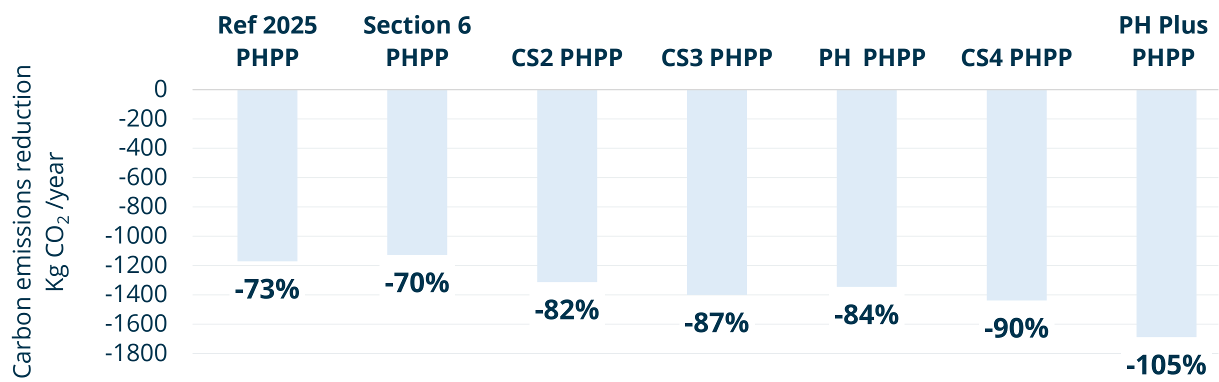


Figure 3: *Predicted reduction in carbon emissions compared to Ref 2021*

PH Plus gives the greatest reduction in carbon emissions, and PH compares well to CS2, CS3 and CS4, which rely on PV to reduce energy demand and emissions. All perform better than Ref 2021 which is based on a gas boiler.

4 See, for example, David Johnston et al., 'Quantifying the domestic building fabric "performance gap"', *Building Services Engineering Research & Technology* (2015). Available online: https://doi.org/10.1177/0143624415570344

ENERGY USE COSTS

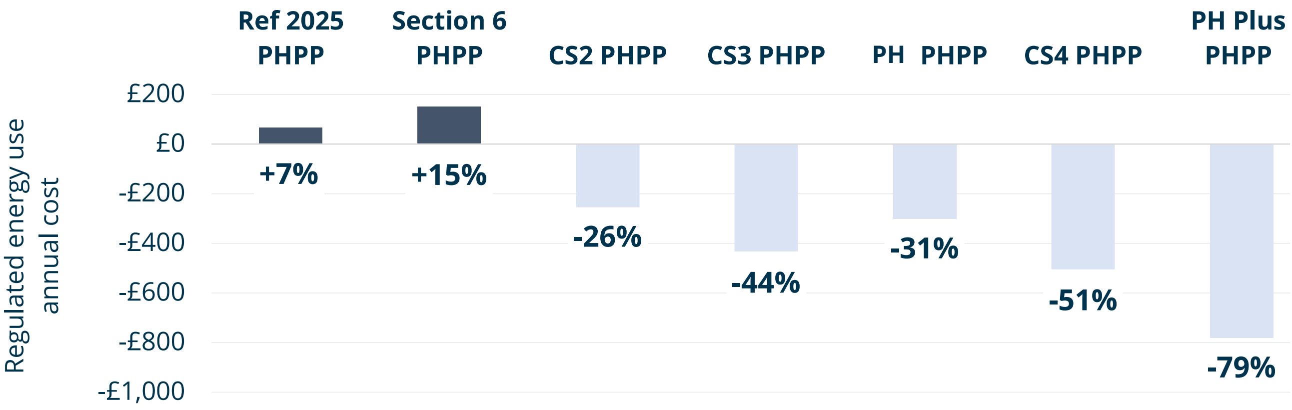


Figure 4: *Predicted regulated energy costs reduction compared to Ref 2021*

PH Plus gives the greatest reduction in regulated energy cost compared to Ref 2021 as it has the largest PV array as well as improved building fabric performance. As above, CS2, CS3 and CS4 also rely on PV to reduce energy demand and therefore costs. This philosophy works on this building typology; however, flats will have less roof area per dwelling, and therefore the taller the building, the less energy will be generated for each dwelling – it will not be sufficient to offset costs in the same way. In addition, if direct electric heating is chosen and space heating is higher than predicted, energy costs will increase disproportionally for dwellings with a lower building fabric performance.

This is not the case for PH, which uses building fabric improvements alone to reduce costs. As the number of storeys increase, a tipping point will be reached when PH achieves the same regulated energy cost savings or better than both CS3 and CS4.

Full details of these findings can be found in Appendix 3.

BUILD COSTS

There is an area of uncertainty within the FHH *Ready for Zero* report regarding build costs, and the disagreements are acknowledged. We strongly dispute the costing figures given there, on the basis of data from multiple sources including delivering real-life Passivhaus projects. Table 2 below presents a range of cost uplifts to meet CS4 type standards for building fabric (i.e. before the addition of renewables), which are much less than suggested in the FHH report.

	Cost uplift against Part L1A 2013
PHT best practice	**9%**
PHT experienced practitioner	**8%**
PHT projection of costs when delivered at scale	**4%**
Currie and Brown 2019	**4%**
***Building for 2050* fabric only**	**1 – 2.5%**
AVERAGE	**4% uplift**

Table 2: *Summary of uplift to CS4 type fabric standards*

The sources for these costs are given below in Appendix 4.

The cost uplifts above are referenced against Part L 2013, and therefore would be even less if referenced against Ref 2021. However, even if this conservative average cost uplift (4%) for CS4 type building fabric is applied to CS4 (with renewables also included) and to PH, then the cost and percentage uplift is much less than shown in the FHH report. Using the FHH methodology, we see no cost uplift from Ref 2025 to PH.

	CS4	PH
Average uplift from Part L 2013 / Ref 2021	£8,562 **+8%**	£4,550 **+4%**
Average uplift from Ref 2025	£2,870 **+2%**	£0 **0%**

Table 3: *Revised capital cost uplift for CS4 and PH*

In addition, transitioning a domestic space heating demand peak load from natural gas to electricity has the potential to create a considerable infrastructure cost. As recognised in both the FHH *Ready for Zero* report and the BEIS research paper *Building for 2050*[5], reducing space heating demand reduces peak load, and therefore has a beneficial impact on the level of energy generation and energy infrastructure needed to deliver this transition. There will be significant costs unless the construction sector and energy services sector work better together to reduce peak load and allow for load shifting and variable pricing.

Full details of these cost calculations can be found in Appendix 4 and 5.

5 *Building for 2050: Low cost, low carbon homes*, BEIS (2022). Available online: https://www.gov.uk/government/publications/building-for-2050

APPENDIX 1

Comparison of specifications

	Ref 2021	Ref 2025	CS2	CS3	CS4	PH	Section 6 2023
Wall U-value	0.19	0.15	0.19	0.15	0.13		0.15
Roof U-value plane	0.11				0.10		0.11
Floor U-value	0.15	0.11	0.15	0.11	0.10		0.15
Glazing	Double	Triple	Double		Triple		Double
Window U-value/ centre pane g-value	1.3/0.73	0.8/0.57	1.3/0.73	1.2/0.53	0.8/0.53		1.4/0.73
Front door U-value	1.2	1.0	1.2	1.0	0.8		1.2
Half glazed door U-value	1.3	1.0	1.3	1.0	0.8		1.2
Thermal bridge Psi-value	0.035	0.05	0.035	0.028			0.07
Air permeability q_{E50} ($m^3/hr.m^2$)	4.5-5.0	5.0	4.5-5.0	3	1	0.4 *equivalent to 0.6 ACH n_{50}**	5.00
Ventilation	dMEV	Nat vent + extract fans	dMEV	MVHR			dMEV
Heating emitter type	Radiators 55ºC flow	Radiators 45ºC flow					
Heating	Gas boiler + compensator	ASHP					
Domestic hot water (DHW)	Gas boiler + compensator	ASHP					
Wastewater heat recovery (WWHR)	No		Yes			No	
Shower flow rate	8 l/min						
PV philosophy	To pass Part L 2021	None	40% of roof area in plan capped at 3.68 kWp			None	
PV installed (kWp)	1.68	0.0	2.68			n/a	
PV diverter	No		Yes			No	
Battery	No						

** The Passivhaus airtightness criterion of 0.6 ACH is equivalent to 0.4 $m^3/hr.m^2$ air permeability for this particular house form*

Table 4: *Summary of specifications Ref 2021, Ref 2025, CS2, CS3, CS4, PH, and Section 6 2023 for end of terrace house*

APPENDIX 2

SAP 10 and PHPP 10 space heating demand outputs

The end terrace house used in the FHH report has been modelled in SAP 10 and PHPP 10 against the standards for Ref 2012, Ref 2025, Section 6 2023, CS3, PH, CS4 and PH Plus. The outputs from the space heating demand calculations for both models are shown in Figure 5 below. This shows that SAP 10 is underestimating space heating demand, and the greater the fabric improvements, the greater the difference between the two models.

As it is known that PHPP accurately models space heating demand, based on in use monitoring, it is reasonable to assume the inaccuracy lies within SAP 10.

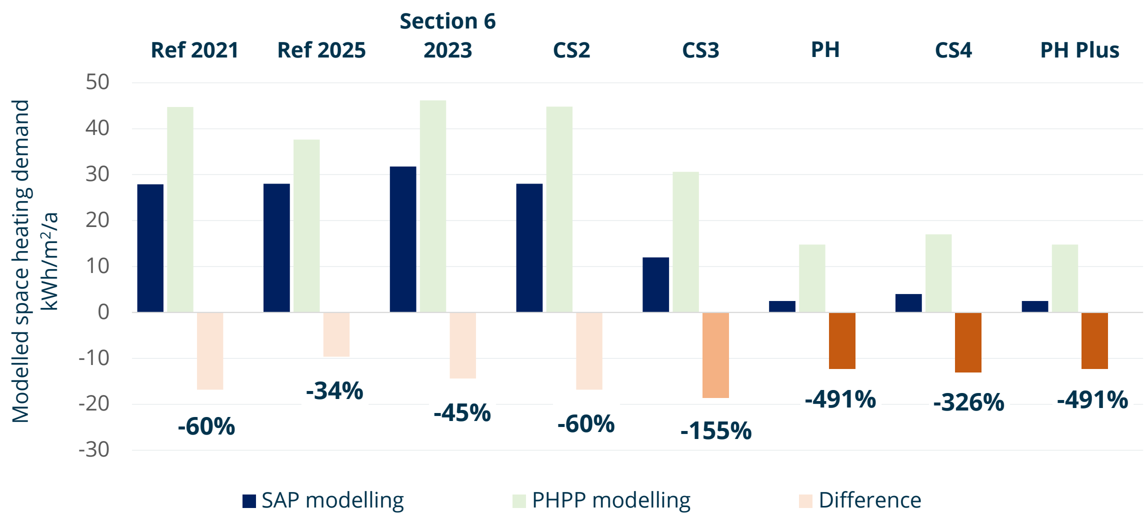


Figure 5: *Differences in space heating demand modelled in SAP 10 and PHPP 10*

APPENDIX 3

Building performance

To demonstrate the differences between Passivhaus Classic (PH), CS3, CS4 and Section 6 2023, the same SAP 10 modelling exercise used in the FHH report has been undertaken to show space heating demand, regulated energy demand, carbon emissions and costs for an end terrace house. While it is recognised that as part of the uplift to Part L1A 2021 an additional compliance report is required to show that insulation measures are properly installed, windows are correctly specified and building services perform as designed, there is, to date, no evidence that these measures will reduce the performance gap. Therefore a 40% performance gap for space heating demand is included in all options except PH.

The same specifications were then modelled in PHPP 10, which is proven to be an accurate measuring tool in post occupancy evaluations.

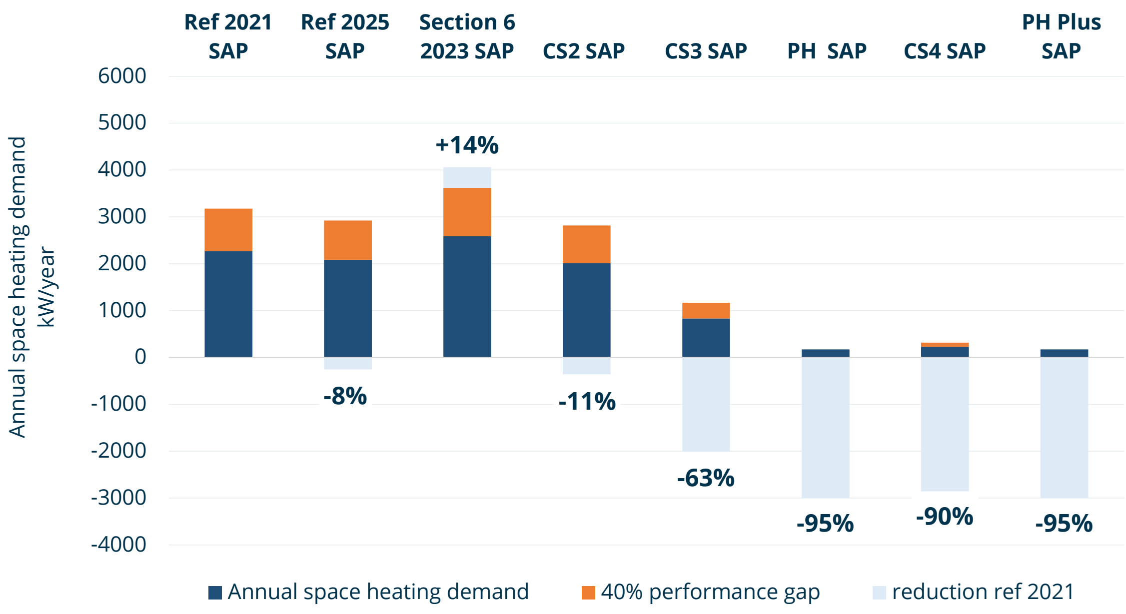
The main differences between SAP 10 and PHPP 10 inputs are as follows:

1. PHPP by default assumes lower occupancy levels, and these have been adjusted to match SAP 10 assumptions.
2. PHPP 10 by default assumes lower hot water heating demand, and this has been adjusted to reflect the assumptions in SAP 10, which are higher, to allow better comparison.
3. Losses from the hot water distribution system can be considerable and the rationalised heat distribution network of a Passivhaus will reduce these losses.
4. SAP 10 is sensitive to the choice of heat pump. With the greater space heating demand modelled, PHPP 10 predicts that Ref 2025 and Section 6 2023 will require a 5 kW heat pump.
5. PHPP uses local climate data. In our examples all the dwellings have been located in East Pennines to match SAP 10, with the exception of Section 6 2023 which is located in Glasgow.

In our PH example, wastewater heat recovery is included as this is a low cost option to reduce hot water costs. In addition, heat losses from the hot water distribution network have been reduced in line with research from both Currie and Brown and Grant and Clarke.[6]

6 Nick Grant and Alan Clarke, 'The importance of hot water system design in the Passivhaus', *14th International Passive House Conference Proceedings* (2010)

SPACE HEATING DEMAND



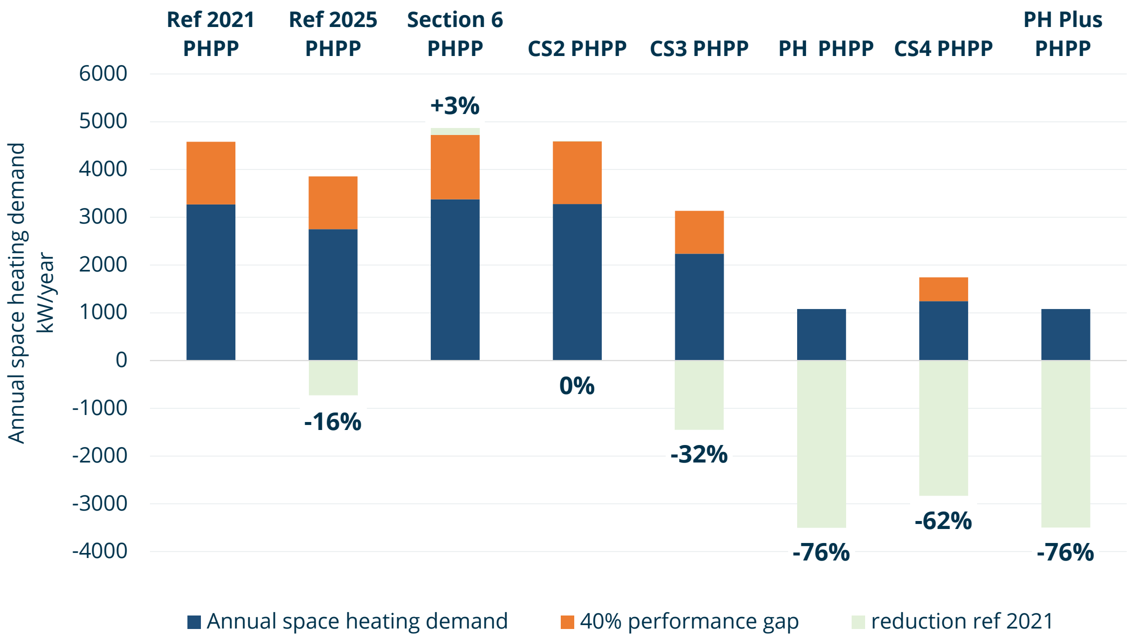
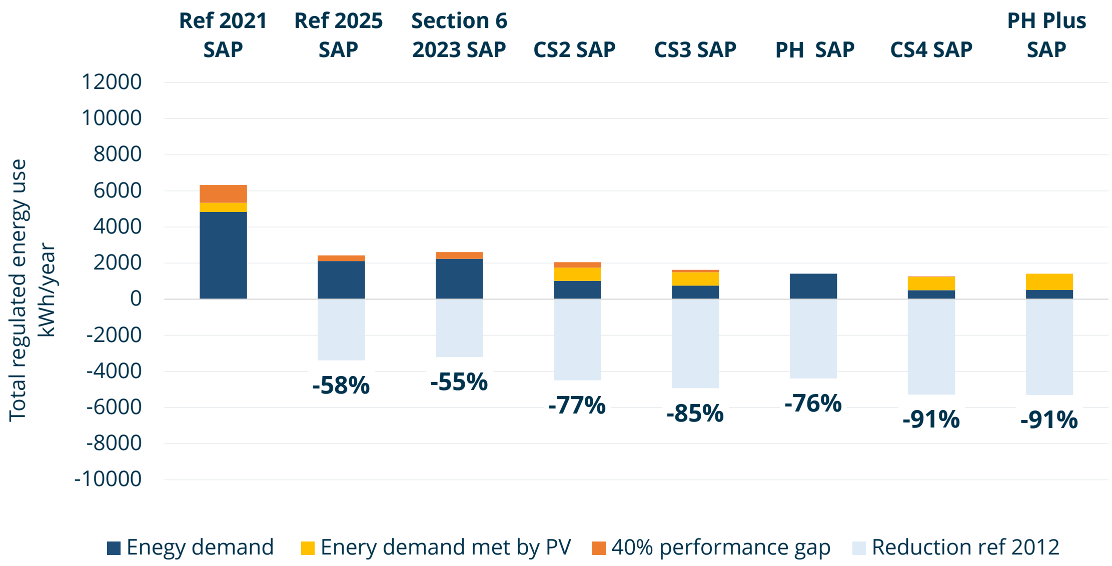


Figure 6: *Space heating demand reduction (with 40% performance gap), SAP 10 and PHPP 10 methodologies*

PHPP 10 predicts a higher space heating demand compared to SAP 10, and as predictions from PHPP have been verified as accurate in post occupancy evaluations, are therefore a more reliable predictor of demand. Based on both the SAP and PHPP modelling, PH and PH Plus will have the greatest reduction in space heating demand (95% and 76% respectively) compared to the other specifications because of the improved building fabric. This difference in space heating demand is further enhanced when the energy performance gap is included in the assessment.

REGULATED ENERGY USE



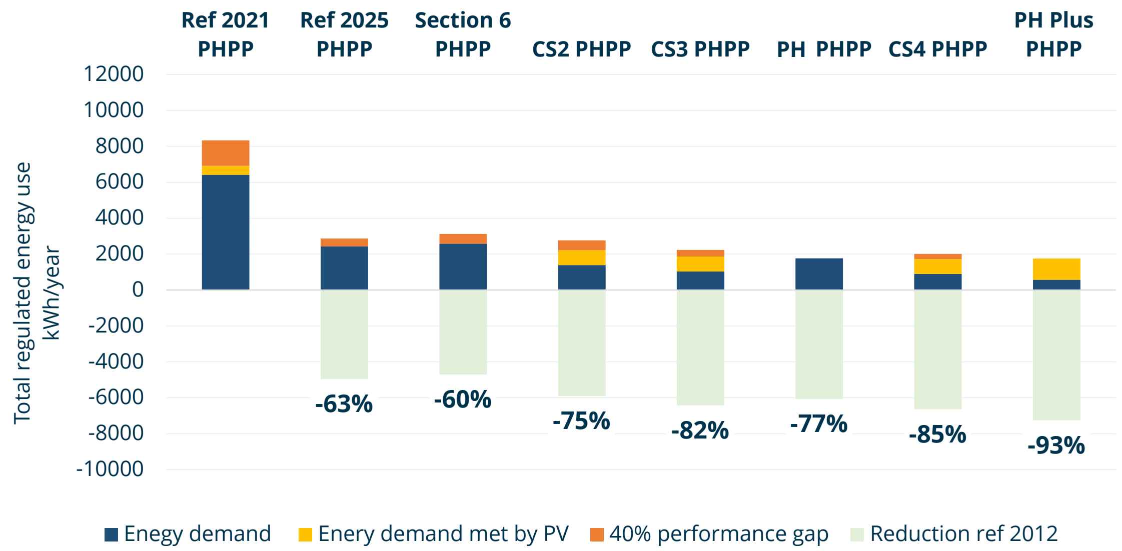
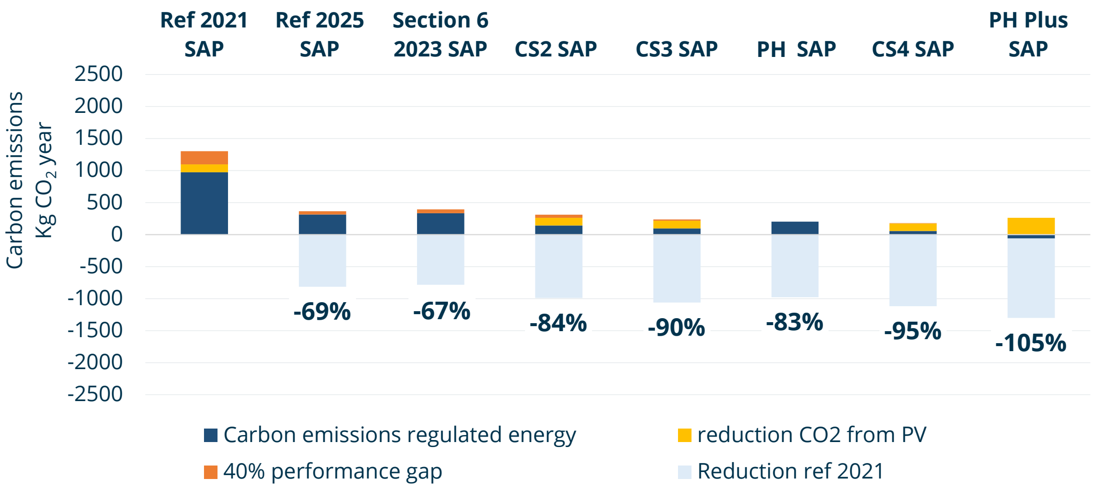


Figure 7: *Regulated energy use, SAP 10 and PHPP 10 methodologies*

As PHPP 10 predicts a greater space heating demand, total regulated energy demand also increases for all the specifications using this assessment. Regulated energy use is offset in CS2, CS3, CS4 and PH Plus with photovoltaics, which means these specifications mostly perform better than PH. However, regulated energy use in PH is still reduced by 76-77% compared to Ref 2021, is similar to CS2, CS3 and CS4 and photovoltaics can be added at any time to achieve the reductions shown in PH Plus.

CARBON EMISSIONS

All options were modelled using SAP 10 emissions factors to allow comparison. Ref 2021 is modelled with a gas boiler; all other specifications are based on a 3.5 kWh ASHP.



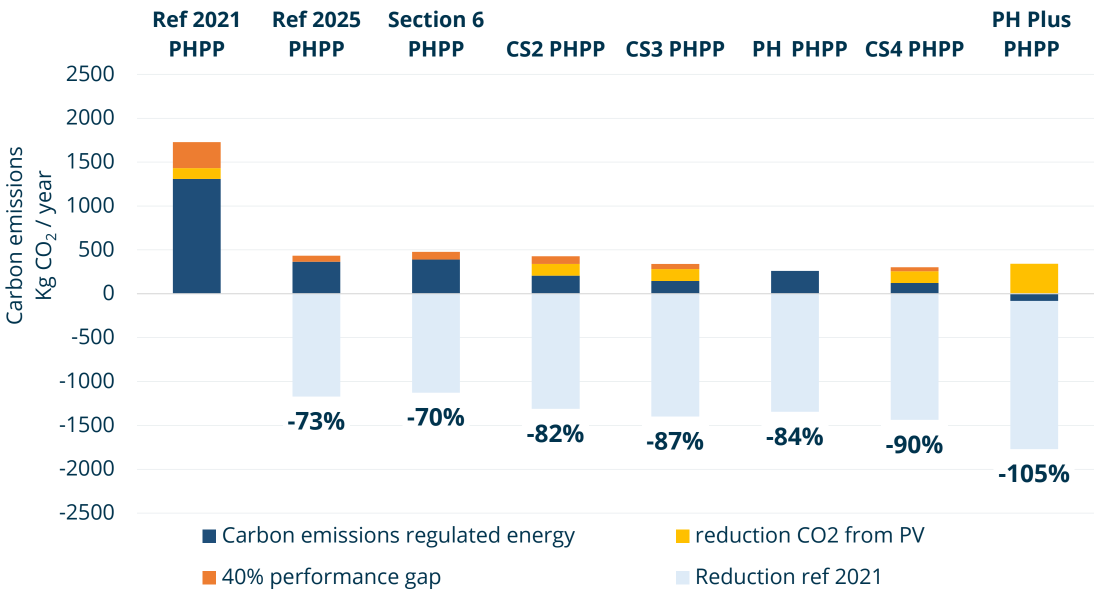
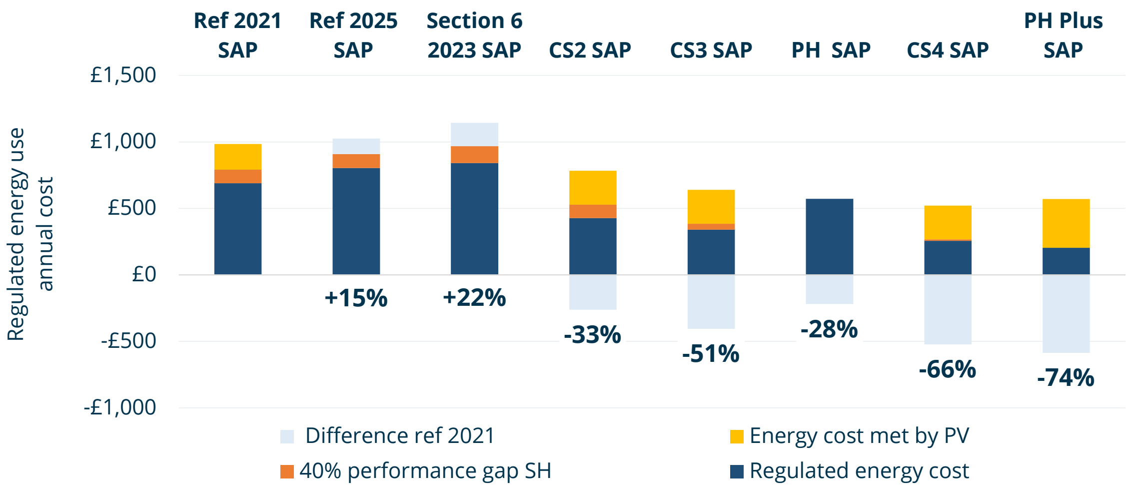


Figure 8: *Summary of carbon emissions, SAP 10 and PHPP 10 methodologies*

As with regulated energy use, CS2, CS3 and CS4 have reduced emissions, and PH Plus is net zero for regulated energy, because of the photovoltaics. However, even without this additional technology, PH still shows an 83-84% reduction in carbon emissions compared to Ref 2021 and is comparable to CS3 and CS4. In addition, these emission reductions are locked into the lifetime of the building fabric, whereas CS2, CS3 and CS4 rely heavily on photovoltaics.

ENERGY USE COSTS



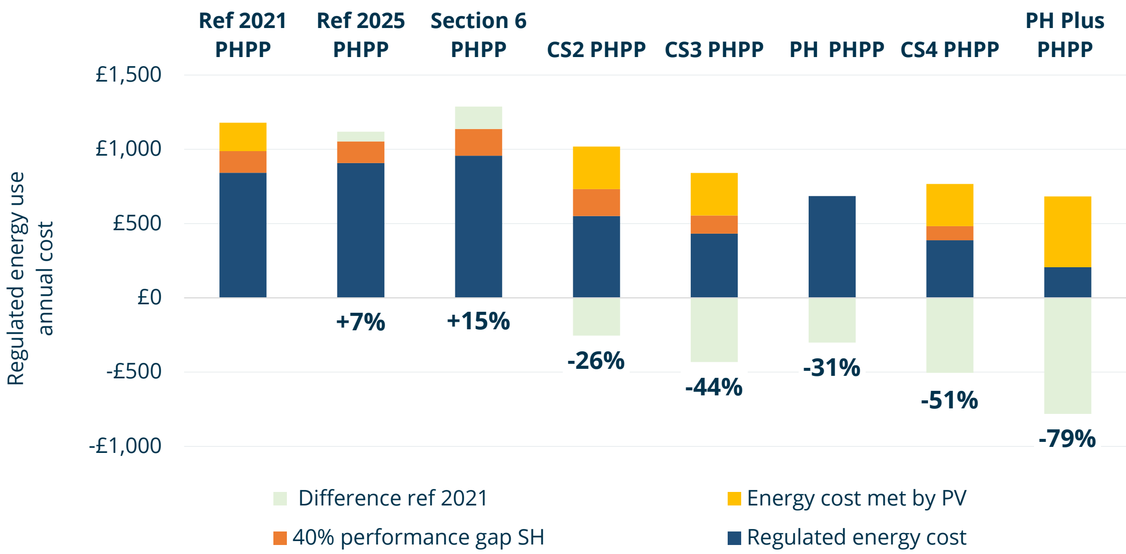


Figure 9: *Summary of regulated energy costs, SAP 10 and PHPP 10 methodologies*

For CS3 and CS4, using the SAP methodology, half of the regulated energy costs are met by the photovoltaics, either by generating energy for use in the home or from the income received by exporting electricity to the grid. The percentage contribution from PV is less using the PHPP methodology as space heating costs are higher. Even without PV, PH will cost considerably less to run than Ref 2025 and again, PV can be added at any stage to achieve the reductions shown in PH Plus.

FLATS

The FHH report specifies direct electric heating for CS2, CS3 and CS4 and a hot water only heat pump. Using this specification for PH and PH Plus, and assuming that 40% of the roof area is available for PV and it is orientated south, PHPP predicts the following energy use costs for a three-storey block of nine 60m² flats. It is assumed that there are individual heat pumps for Ref 2025 and Section 6 2023.

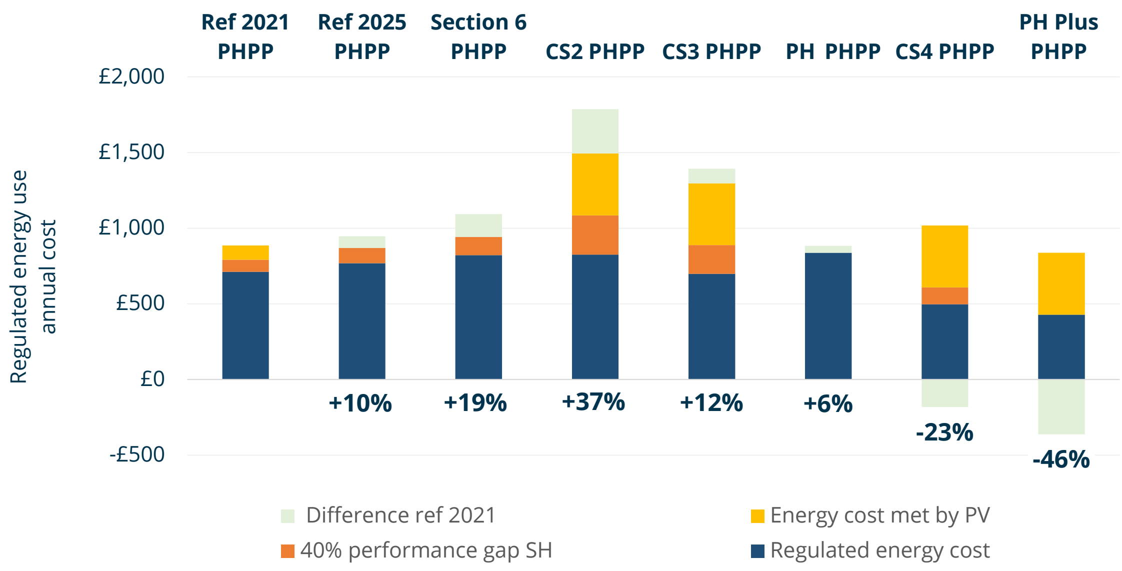


Figure 10: *Predicted regulated energy use costs for a three storey block of flats, PHPP 10*

As space heating in these flats is met by direct electric and the hot water only heat pump is less efficient, costs rise until the impact of reduced demand overtakes the higher price per unit of demand. PH performs better than CS2 and CS3 in this scenario, with PH Plus being the best performing specification.

OTHER CONSIDERATIONS – LOCAL CLIMATE AND ALTITUDE

PHPP allows for the use of more localised climate data and can make adjustments for altitude, whereas SAP 10 does not, all of which affects heat loss calculations. For CS3 this can result in a variation in space heating demand of ±10 kWh/m².a, depending on location.

APPENDIX 4

Capital cost uplift

In the FHH *Ready for Zero* report, all the contender specifications have been applied to the same end terrace house, costed by Arcadis and then benchmarked against Ref 2021 and Ref 2025. Table 6 below gives a summary of the FHH proposed cost uplifts for all the contender specifications compared to these two reference buildings.

	Ref 2025	CS1	CS2	CS2A	CS3	CS4	CS5
Uplift from Ref 2021 (Arcadis)	£5,690 **+5%**	£2,580 **+2%**	£7,960 **+7%**	£11,620 **+10%**	£17,070 **+15%**	£21,800 **+19%**	£19,170 **+17%**
Uplift from Ref 2025 (Arcadis)	–	£3,110 **-3%**	£2,270 **+2%**	£5,930 **+5%**	£11,380 **+9%**	£16,110 **+13%**	£13,480 **+11%**

Table 5: *Summary of the cost uplift from 'Ready for Zero: Evidence to inform the 2025 Future Homes Standard'*

This paper challenges the cost assumptions for CS4 (the closest to PH) by:

1. Examining the existing evidence on cost uplifts from delivered schemes specified to higher building standards similar to CS4
2. Revising the FHH cost calculations considering this actual cost evidence.

Table 7 below shows the FHH proposed relative cost uplifts for Ref 2025 and CS4; the same costs for CS4 have then been applied to PH. Photovoltaics are not required to meet the Passivhaus standard and therefore this cost element has been removed.

	Ref 2025	CS4	PH
Uplift from Ref 2021 (Arcadis)	£5,690 **+5%**	£21,800 **+19%**	£17,790 **+16%**
Uplift from Ref 2025 (Arcadis)	–	£16,110 **+13%**	£12,100 **+10%**

Table 6: *CS4 costs plus PH (equivalent to CS4 without renewable energy and wastewater heat recovery)*

PASSIVHAUS COST RESEARCH

Three papers which provide cost evidence on delivered schemes to either Passivhaus or similar low energy building standards have been reviewed.

1. Passivhaus construction costs[7] published in 2019 by the Passivhaus Trust. The report identified the following cost uplifts in different scenarios when comparing actual costs with SPONS UK average and the Baker Ruff Hannon average.

	Cost uplift against Part L1A 2013
Best practice	**+9%**
Experienced practitioner	**+8%**
Projection of costs when delivered at scale	**+4%**

Table 7: *Summary of cost uplifts identified in 'Passivhaus construction costs', PHT (2019)*

2. The costs and benefits of tighter standards for new buildings[8]. This report was produced in 2019 by Currie & Brown and AECOM on behalf of the Climate Change Committee. Using the example of a semi-detached house with an ASHP and a space heating demand of 15 kWh/m².a (similar to PH), the predicted uplift in costs is £4,800 or 3.9%, which is in line with the Passivhaus Trust's projected costs at scale (see above).

The report concludes that ultra-high energy efficiency standards alongside an air source heat pump represent a 1-4% cost uplift relative to a home built to current regulations (Part L1A 2013).

3. Building for 2050: Low cost, low carbon homes[9]***.*** Published in 2022 by BEIS, this research paper gives the results from a five-year project looking at low carbon housing. Part of the objective is to identify additional capital costs of low carbon homes and how best to minimize these to aid delivery at scale.

Four sites were studied in depth and the findings showed the cost uplift to a building standard similar to CS4 ranged from a 1-2.5% uplift for fabric only and a 9-18% uplift with photovoltaics and battery storage, and more complex heat networks. When building fabric alone is considered, the uplift is 1-2.5% (£3,200 - £5000 extra cost per dwelling).

The report concludes that there is a perception within the construction industry that building to higher energy standards will result in increased capital costs, which reduce the viability of a scheme. However, in a well-planned, well-constructed low carbon development, the capital cost uplift is minimal and wider uptake would likely further reduce these costs.

LEARNING FROM EXPERIENCE

Exeter City Council has been building Passivhaus projects since 2010 and has seen capital uplifts on build costs reduce by 25% over this period to 4%. This has been achieved by using the following:

- Simplified form and generic house types
- Generic details i.e., reducing repetition
- Similar building systems
- Experienced trade teams
- Maturing supply chain

The key findings from Exeter are also echoed in the *Building for 2050* report in terms of the key elements to reduce capital costs.

7 *Passivhaus construction costs*, PHT (2019). Available online: https://pht.guide/costs

8 *The costs and benefits of tighter standards for new buildings*, Currie & Brown and AECOM for the CCC (2019). Available online: https://www.theccc.org.uk/publication/the-costs-and-benefits-of-tighter-standards-for-new-buildings-currie-brown-and-aecom/

9 *Building for 2050: Low cost, low carbon homes*, BEIS (2022). Available online: https://www.gov.uk/government/publications/building-for-2050

PROPOSED REVISED COSTINGS

The 4% uplift identified above is for PH against Part L1A 2013 rather than 2021. Obviously the Part L1A 2021 standard is better than the 2013 version, so the actual uplift to PHC from Part L 2021 should be less than 4%. However, in the absence of any data about the actual cost uplift from Part L1A 2013 to 2021, we have assumed the worst-case scenario in our proposed revised costs and have therefore applied a 4% increase to Ref 2021.

Even given this worst-case assumption, we propose the more accurate increase in cost would be as shown in Table 10.

	CS4	PH
Uplift from Ref 2021	£8562 **+8%**	£4,550 **+4%**
Uplift from Ref 2025	£2870 **+2%**	£0 **0%**

Table 8: *Revised capital cost uplift for CS4 and PH*

Therefore, we are proposing that the cost uplift for PH should, in a worst-case scenario, be 4% from the 2021 reference building and +0% compared to the 2025 reference building. With the additional inclusion of renewable technologies, the uplift to CS4 from the 2021 reference building should be closer to 8%, and from the 2025 reference building should be 2%.

	Ref 2021	Ref 2025		CS4	
	Specification	Specification	Cost uplift Ref 2021	Specification	Cost uplift Ref 2021
Wall U-value	0.19	0.15	**+£1100** *50 mm insulation*	0.13	**+£4270** *70 mm insulation plus steel ties, VCL and lintels*
Internal walls			No change	VCL to party wall	**+£730**
Roof U-value plane	0.11	0.11	No change	0.10	**+£630** *50 mm insulation plus VCL*
Floor U-value	0.15	0.11	**+£800** *700 mm insulation*	0.10	**+£1440** *(PIR instead or ESP) plus 150 mm excavation*
Glazing	Double	Triple	**+£960** *doors and windows*	Triple	**+£1510** *enhanced door U-value + airtightness measures*
Window U-value/ centre pane g-value	1.3/0.73	0.8/0.57		0.8/0.53	
Front door U-value	1.2	1.0		0.8	
Half glazed door U-value	1.3	1.0		0.8	

continues over

	Ref 2021	Ref 2025		CS4	
	Specification	Specification	Cost uplift Ref 2021	Specification	Cost uplift Ref 2021
Thermal bridges	0.035	0.05		0.028	
Air permeability	4.5-5	5.0		1	**+£100** *gaskets for penetrations*
Ventilation	dMEV	Nat vent plus extract fans		MVHR	**+£3700** *unit and ducting minus extract fans*
Heating emitter type	Radiators 55ºC flow	Radiators 45ºC flow		Radiators 45ºC flow	
Heating	Gas boiler + compensator	ASHP	**+£4370**	ASHP	**+£4370**
DHW	Gas boiler + compensator	ASHP		ASHP	
WWHR	No	No		Yes	**+£750**
Shower flow rate	8 l/min	8 l/min		8 l/min	
PV philosophy	To achieve Part L to pass	None		40% of roof area in plan	
PV installed (kWp)	1.68	0.0	**-£2190** *from 2021 baseline*	2.68	**+£1820** *3 x panels plus diverter*
PV diverter	No	No		Yes	
Battery	No	No		No	
Main contractor prelims			**+£470**		
Testing			**+£180** *T and C ASHP*		**+£270** *MVHR*
General					**+£2,210** *higher spec + airtightness coordination*
TOTAL uplift from 2021			**£5690**		**£21,800**

Table 9: *Cost uplift from Ref 2021 to Ref 2025 and CS4*

APPENDIX 5

Other considerations

Building typologies CS3 and CS4 rely on photovoltaics to reduce energy demand, emissions and costs. On houses and low rise flats, there is usually sufficient roof space to allow for enough PV panels to give sufficient reductions. As buildings become taller, the area of roof space relative to the number of units becomes less, and therefore proportionally less PV can be generated for each unit. The approach proposed for the contender specifications based on PV to reduce running costs and emissions is not compatible with medium to high rise buildings. A point is reached where a PH would have lower running costs compared to CS3 and CS4.

	Ref 2021	Ref 2025	Section 6 2023	CS3	PHC	CS4	PH Plus
Terrace house	£1,157	£1,182	£1,204	£528	£715	£464	£276
3 storey block of flats	£1,004	£1,025	£1,120	£615	£703	£536	£460
6 storey block of flats	£889	£902	£934	£672	£687	£603	£440

Table 10: *Average regulated energy cost difference between low and high rise buildings*

At six storeys, the estimated regulated energy costs of CS3 and PH are the same, as the contribution to each flat from PV reduces.

The Passivhaus Trust is an independent, non-profit organisation that provides leadership in the UK for the adoption of the Passivhaus standard and methodology.

Passivhaus is the leading international low energy design standard, backed with over 30 years of building performance evidence. It is a tried & tested solution that enables a meaningful transition to net-zero now. Over 65,000 buildings have been certified to this standard worldwide. The Trust promotes Passivhaus as a robust way of providing high standards of occupant comfort and health AND slashing energy use and carbon emissions from buildings in the UK.

Please find us on Twitter, Linkedin, Instagram, & Facebook @PassivhausTrust. Keep up to date with all things Passivhaus by joining our mailing list.

www.passivhaustrust.org.uk

Passivhaus Trust

The UK Passive House Organisation