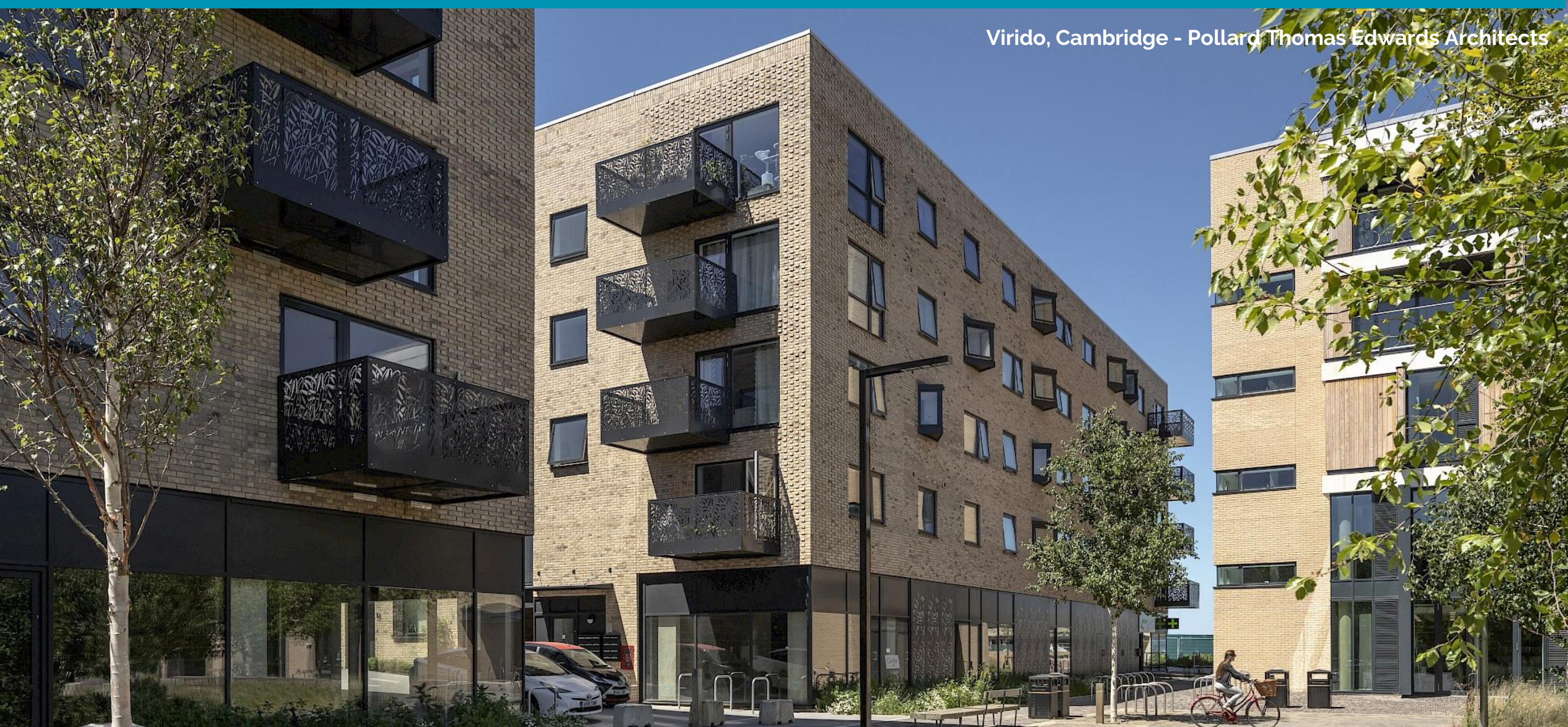
BUILDING STANDARDS COMPARISON

2020 BUILDING STANDARDS COMPARED TO A NET ZERO OPERATIONAL TARGET



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October 2020 **v1.2**

Building Standards Comparison

2020 Building Standards Compared to a Net Zero Operational Target

This paper was commissioned by the Good Homes Alliance and Woodknowledge Wales to understand the outcomes and consequences between low energy building standards for new homes, when comparing them to a net zero (operational) outcome target in 2020 through to 2050. The paper seeks to illustrate clearly how the choice of selecting a building standard affects the amount of renewable energy generation that is required to comply with a net zero operational outcome. The report does not take into account embodied energy/carbon. All energy and carbon modelling is illustrative but based upon real archetypes.

The work was carried out by John Palmer of the Passivhaus Trust in August 2020.

INTRODUCTION AND METHODOLOGY

How do our homes use energy?

Before trying to compare different energy standards, it is useful to have a common model to explain how dwellings use energy and also take into account the impact of different types of heating technology and changing carbon factors.

If we start with the dwelling itself, energy use can be broken down into 4 distinct areas:

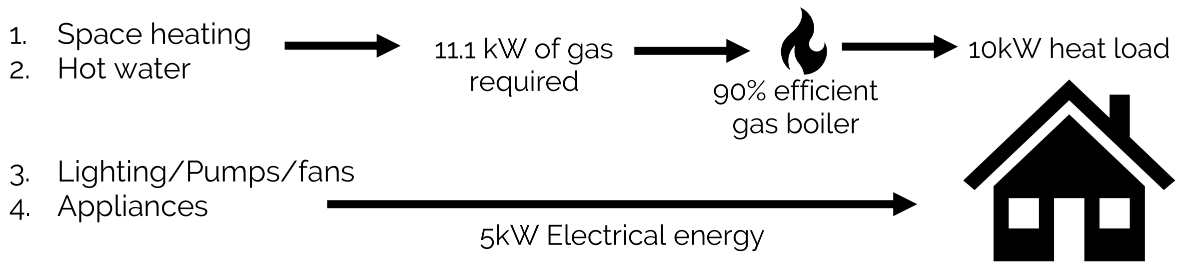
1. Space heating
2. Hot water
3. Lighting and Pumps/fans (usually associated with the heating and hot water systems)
4. Appliances (also known as plug loads or **Unregulated** energy)

All this energy is the actual amount of energy used by the occupants in the home and is called **final energy**. For example, this might include 1kW of heat energy emitted by a radiator.

The type of energy used in items 3 and 4 will always be electrical, whereas items 1 and 2 will vary from dwelling to dwelling – but is most often natural gas in the UK.

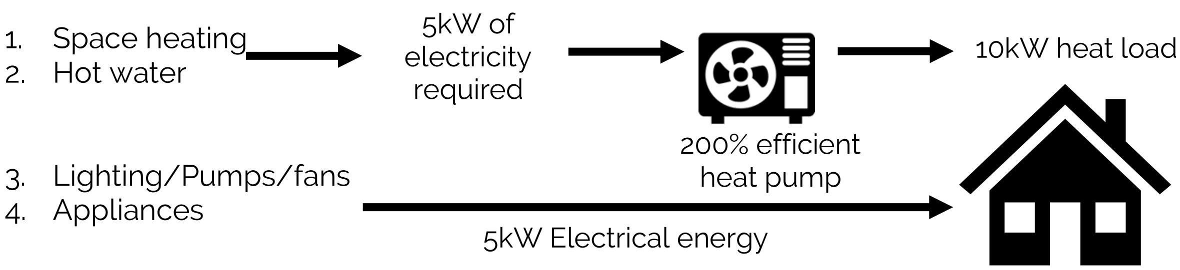
Once delivered to a home, electrical energy used directly is 100% efficient – e.g. 1kW of electrical energy delivered to an electric panel heater will emit 1kW of heat. However, the heating mechanism for other fuels is not 100% efficient and so there will be losses, meaning that additional energy needs to be delivered to the home to provide the same amount of final energy output. This is known as the **delivered energy.**

For example, if a home needs 10 kW of heating and hot water on a winter's day and uses a gas boiler which is 90% efficient, then 11.1 kW of gas will need to be delivered to the property. It may also need say 5kW for lighting, appliances and pumps etc.



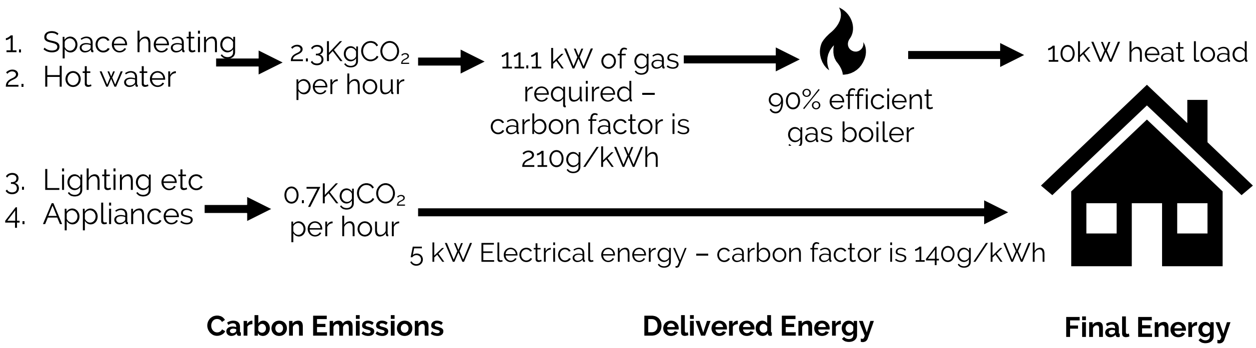
If we were to use a heat pump instead of a gas boiler, then this is the same principle, but the heat pump uses electrical energy not gas. However, it also extracts energy from the air or ground and so is able to provide more heat energy than the electrical energy it consumes. In effect, a heat pump is more than 100% efficient. A heat pump's level of efficiency is known as it's Coefficient of Performance or COP. For example, a heat pump with a COP of 2 will produce 2kW of heat energy for every 1kW of electrical energy.

Thus, our model now becomes:



Each of these different forms of energy has different carbon factors – i.e. the amount of CO_2 emissions that result from each unit of energy consumed. For a gas boiler this will be fairly consistent over time as you are simply combusting a fossil fuel. For electrical energy this changes constantly as more or less renewable energy is introduced to our national electricity grid – solar and wind energy is not that predictable. We can estimate the average carbon factor for electricity for the next few years, but in the long term, it is difficult to predict exactly what will happen. In 2020 the annual average carbon factor for electricity is around 140g of CO_2 per kWh and for gas, it is 210g[1]. Currently, the carbon factor in use within SAP[2] is 519g.

This means we can work out how much CO_2 is being emitted per hour on average.



In looking at the long-term efficiency of buildings, it is important to consider how the various components of our model might change. As we have already seen, the carbon factor for electricity in particular will vary both in the short and long term. Over the next 30 years the carbon intensity of our national grid will depend on a range of factors, technologies and government policies – so is impossible to predict with absolute accuracy.

Our heat generation technologies will also change. The typical lifetime of a gas boiler or heat pump is around 20 years. At that point it will need to be replaced with perhaps a more efficient device, or something different such as hydrogen boiler or fuel cell. This new device will have a completely different efficiency and thus change the amount of delivered energy required.

However, the final energy required is likely to remain more consistent over the lifetime of the building. For heating, the final energy required is related in most part to the fabric performance of the building – the insulation in its walls, floors and roofs, its window performance, ventilation system and airtightness. All these are set at the point of construction and are expected to perform consistently throughout the building's life. The demand for hot water is related in most part to the number of occupants and their living habits and so is not affected by the technology. Finally, appliance load is again related to occupancy habits, but it is also likely that future appliances will be more efficient, thus reducing the demand.

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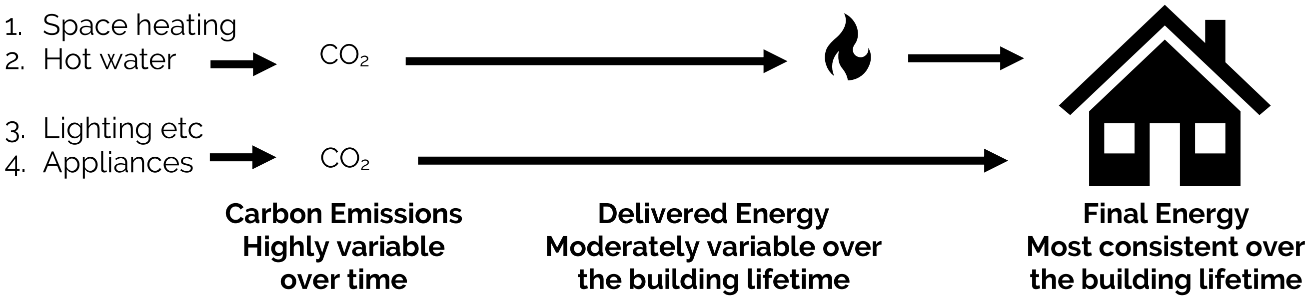
[1] Proposed SAP 10.1 carbon factors – see https://www.bregroup.com/wp-content/uploads/2019/10/SAP-10.1-01-10-2019.pdf table 12d

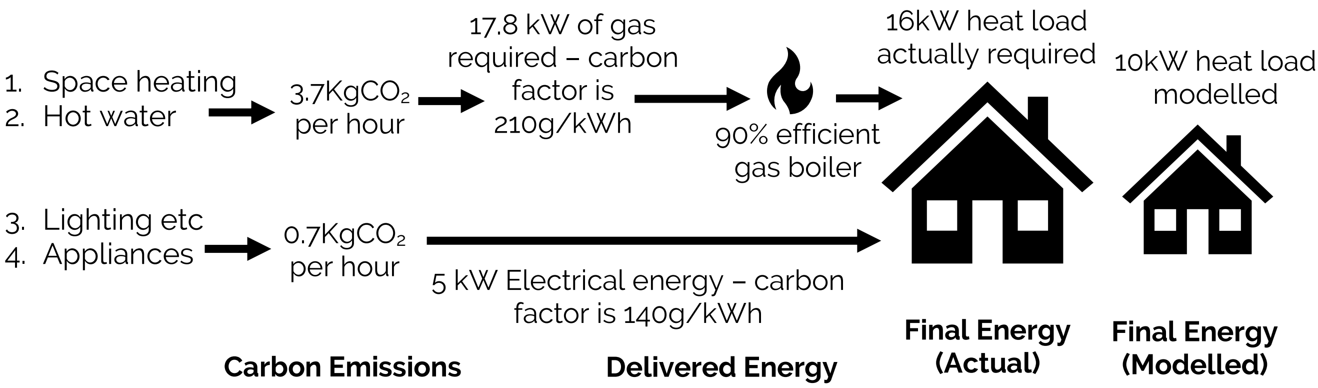
[2] The Standard Assessment Procedure (SAP) is the methodology used by the government to calculate building energy and carbon use. The current edition is 2012, version 9.92.



Thus, to get a true picture of the actual energy efficiency of buildings, as well as their impact on climate change over time, we must look at all aspects of the chain of delivery of energy to the building.

The Performance Gap

Whilst energy models are useful to predict energy demand, we must also consider the evidence from monitoring of actual buildings in use. This data indicates that a typical building regulations standard home will require, on average, at least 60% more energy for heating than is predicted[3]. Whilst the causes of this performance gap are beyond the scope of this paper, it is important that it is included in our considerations as otherwise we will make inaccurate comparisons and draw incorrect conclusions. The performance gap, in the main, impacts the space heating demand of a building as it primarily relates to the fabric performance of the building[4]. Thus, our model becomes:



A performance gap has been assumed or derived for each standard. How each has been determined is detailed in annex A and is summarised in the table below:

Standard	SAP 2012	SAP 10.1	SAP 2012 Wales	London Plan	Energiesprong	AECB	Passivhaus LEB	LETI	Passivhaus Classic	Passivhaus Plus	Passivhaus Premium
Fabric Performance Gap (%)	60%	60%	60%	60%	0%	20%	0%	30%	0%	0%	0%

[3] Passivhaus: The Route to Zero Carbon? Passivhaus Trust, March 2019, Appendix 2
[4] See, for example, http://www.zerocarbonhub.org/current-projects/performance-gap

Generation and Net Zero

To get to a net zero position on-site (i.e. just considering our individual building), we must generate sufficient renewable energy over the course of a year to match the energy consumed by the building – i.e. the delivered energy. Note that this definition of net zero is independent of changing carbon factors. However, we must also consider what type of energy we are dealing with. Our renewable generation, both locally and at scale, will nearly always take the form of electricity[5]. Thus, we can use this to match any electrical load. Generation which can't be used on-site (e.g. when there is not enough demand) will be fed into the grid and used elsewhere, so it is still being used.

In contrast, burning gas will result in immediate emissions at the point of use. These cannot be offset by electrical generation – the CO_2 has been emitted. The energy we gain from gas boilers cannot therefore be considered in the same way as electrical energy.

As this analysis will show, generating sufficient energy on site to get to a net zero position is not always possible. Particularly in high density housing. However, high density buildings are still a very efficient way of building. It is therefore important to consider where you wish to place your net zero boundary.

For example, is a large detached dwelling with sufficient photovoltaic generation to be net zero preferable to a three-storey building containing 12 apartments with a very efficient fabric which has also funded additional renewable generation capacity within the local area?

Methodology

In comparing different energy standards it is important to ensure that we are able to make a like-for-like comparison. This is not always straightforward as different standards use different metrics and mechanisms to generate their targets. For the purposes of this analysis, we will attempt to express each standard in terms of final energy broken down into the categories that we have outlined above:

- Heating demand
- Hot water demand
- Lighting, pumps and fans
- Appliances (Unregulated)

We will then apply a performance gap uplift to each standard. The size of this uplift will relate to how effective the standard has been shown to be in closing the performance gap.

We will then translate this into a delivered energy demand for different types of heat source (e.g. gas boiler, heat pumps etc) and finally use the forecast electricity grid carbon factors from the Treasury Green Book 2020 to indicate lifetime carbon emissions.

When comparing energy demand and carbon emissions, we will express the results mostly in $kWh/m^2.year$ – i.e. the amount of energy needed per m^2 of the building over the course of one year. This enables us to compare buildings of varying size.

Additional modelling parameters used are included at annex D.

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[5] Renewable energy can also take the form of heat – e.g. solar thermal. However, the vast majority of sources of renewable energy result in electrical energy (photovoltaic, wind, tidal, wave)

Building archetypes

The analysis will also demonstrate how the standards perform for 5 different building archetypes:

Arche-type	Gross Internal Floor Area (m2)	Bedrooms	Occupancy	No. Storeys	Form	No. Mixer Showers	No. Baths	Total dwellings in the building
1	50	1	2	3	Flat	1	0	12
2	61	2	3	2	Flat	1	1	8
3	84	3	4	2	Semi	1	1	1
4	84	3	4	2	Terraced	2	1	1
5	110	5	6	2	Detached	2	1	1

In order to allow an equitable comparison between standards, the standard calculated occupancy for each archetype will be used rather than the given occupancy listed above.

Standards to be compared

The standards that have been compared are:

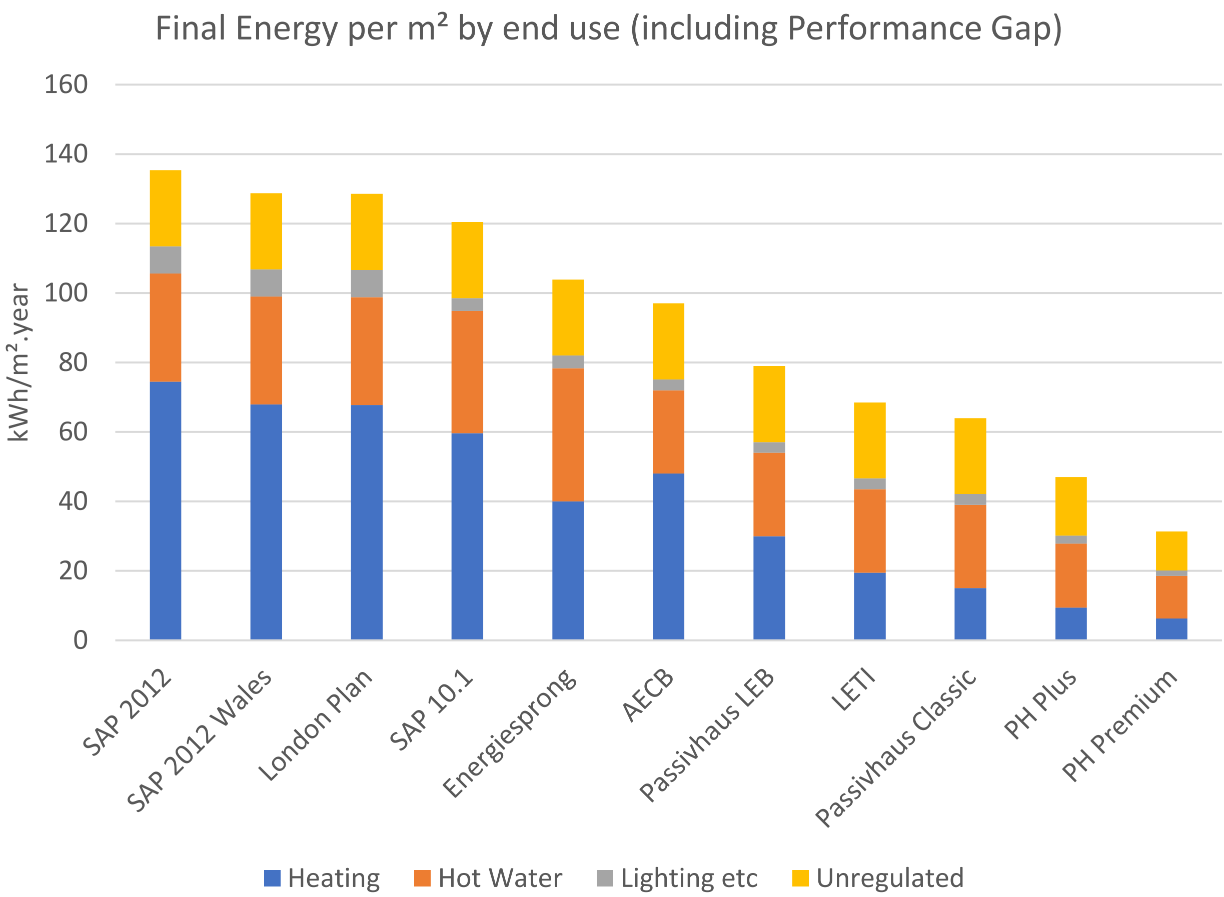
- SAP 2012/ Part L - Current English building regulations standard
- SAP 2012/ Part L – Current Welsh building regulations standard
- SAP 10.1 / Part L – proposed improvement in English standards
- Energiesprong New Build
- Passivhaus Classic
- Passivhaus Low Energy Building
- AECB Standard
- London Plan
- LETI Net Zero Operational Carbon standard
- Passivhaus Plus
- Passivhaus Premium

A detailed discussion of how the results for each standard have been obtained is in annex A.

Comparison of Standards

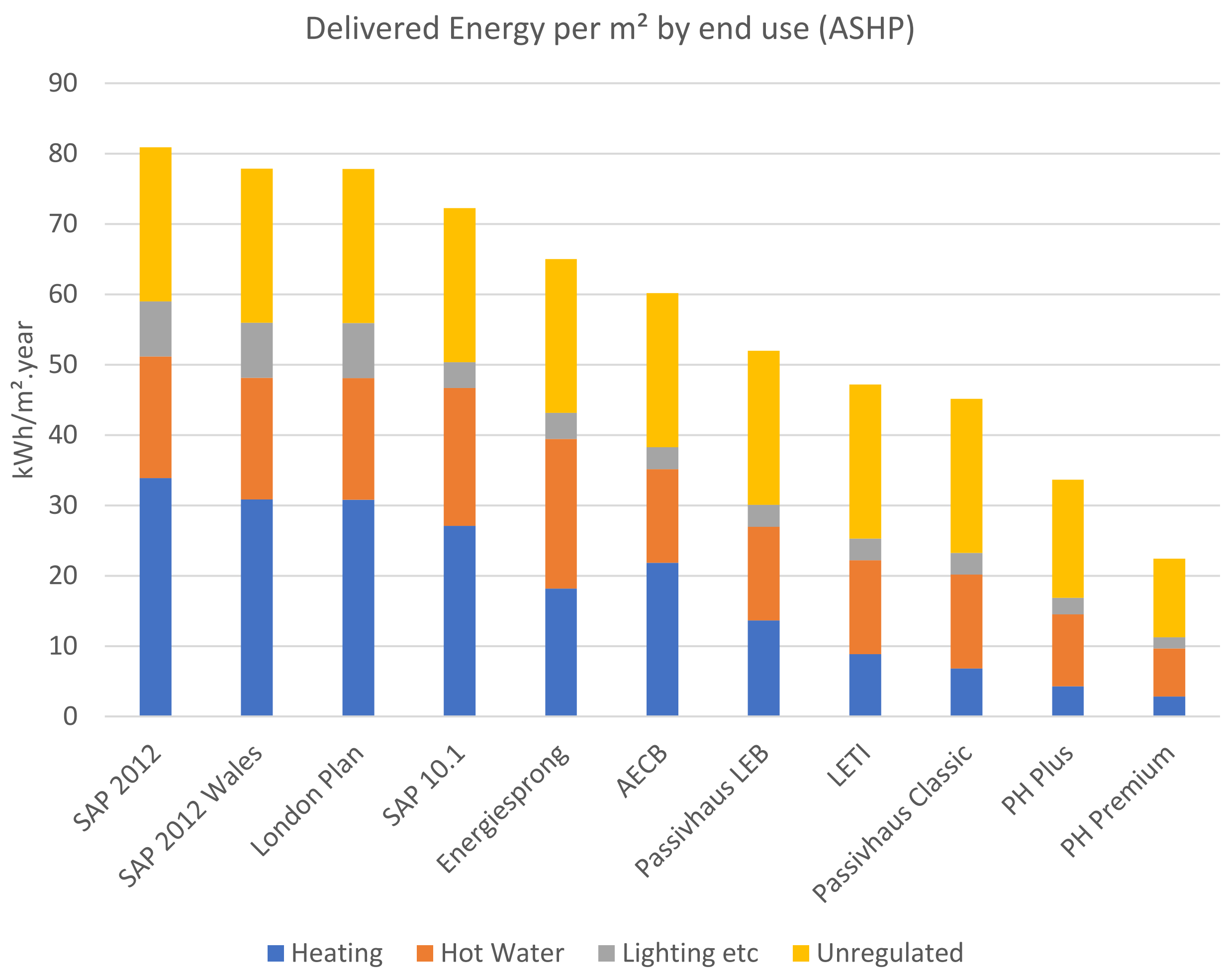
Final Energy (Actual)

The first comparison shows the final energy (including the performance gap) per m² and broken down into end uses. This part of the analysis is independent of the choice of heating and hot water systems. The data shown is for archetype 3.

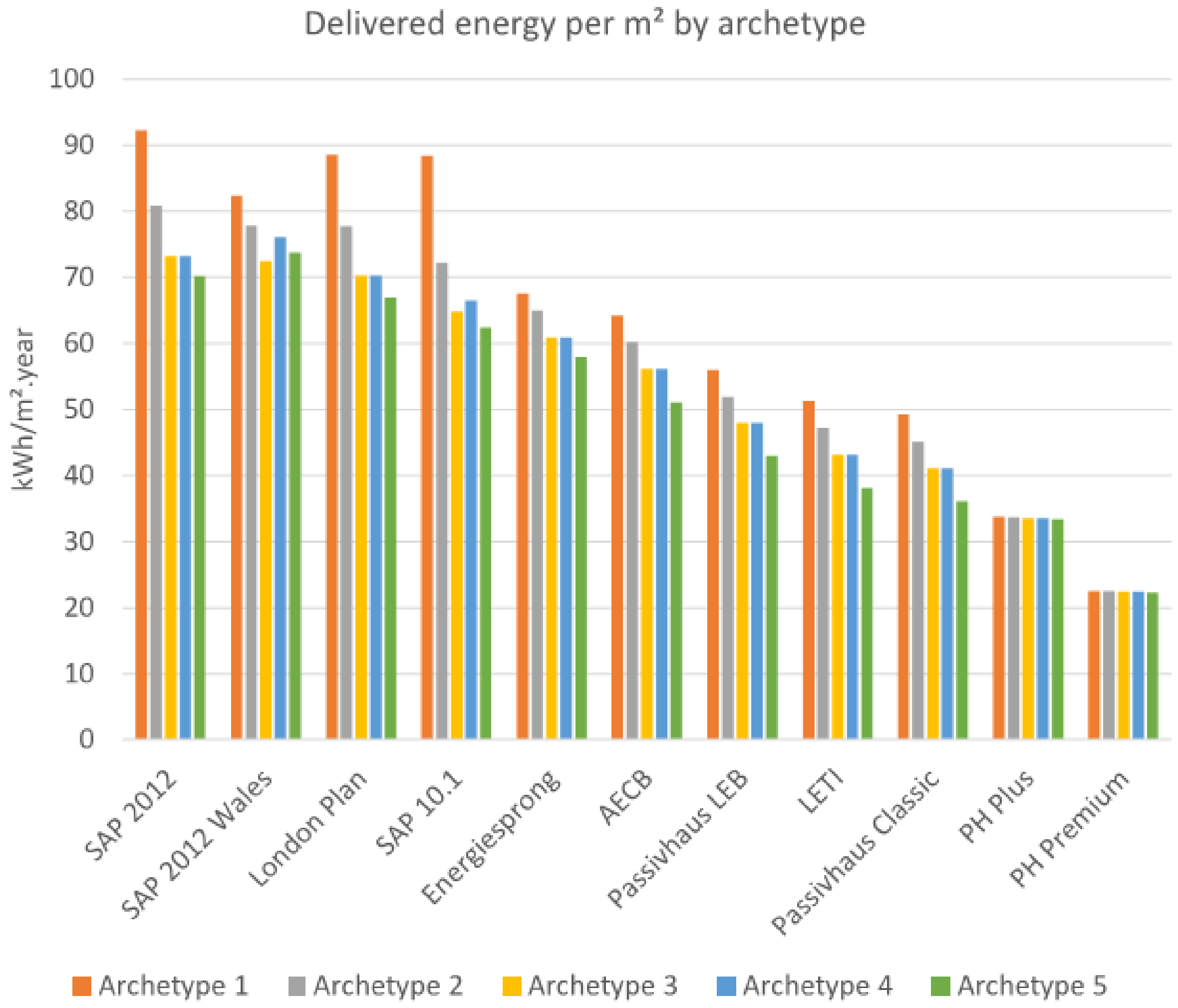


Delivered Energy

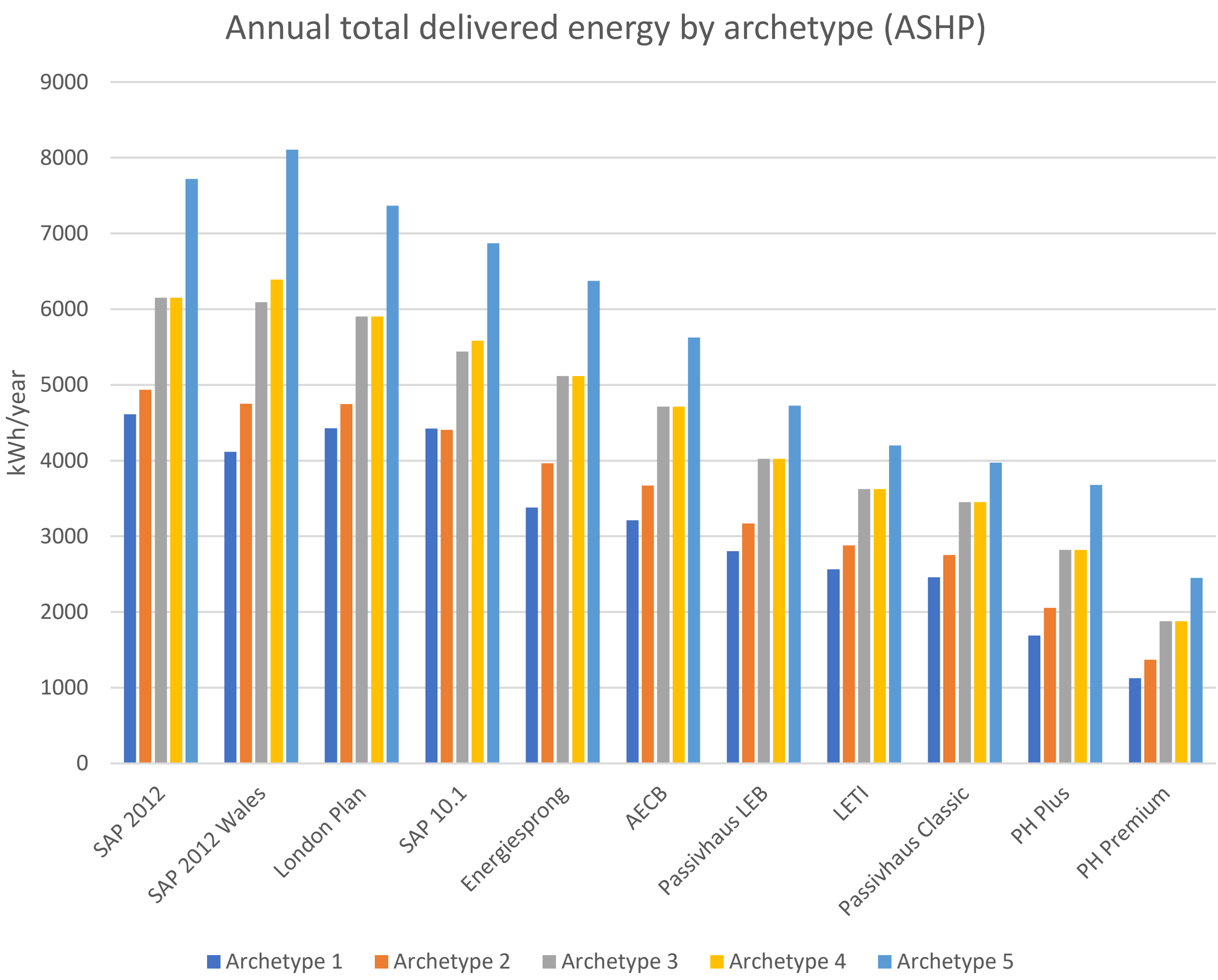
The next comparison shows the delivered energy (including the performance gap) per m² and broken down into end uses for archetype 3 and assuming an Air Source Heat Pump as the heat source for heating and hot water. Note that the proportion of energy needed for heating and hot water has reduced because of the Coefficient of Performance of the heat pump. The energy needed for lighting and unregulated uses has not changed.



The next comparison shows the delivered energy per m² for all archetypes, again using an ASHP.

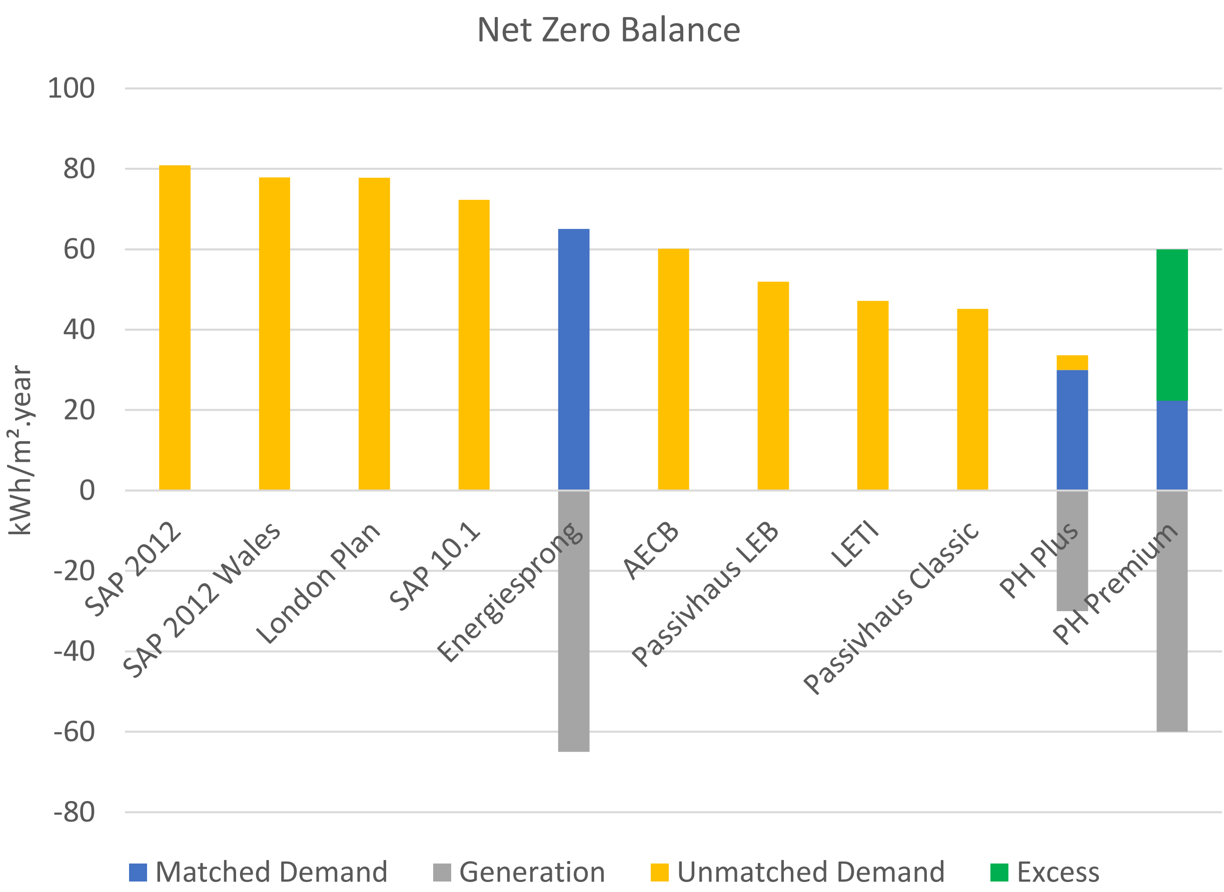


Finally, the annual delivered energy per archetype is shown – i.e. total energy required, rather than per m². As expected, this shows that the larger dwellings will use more energy.

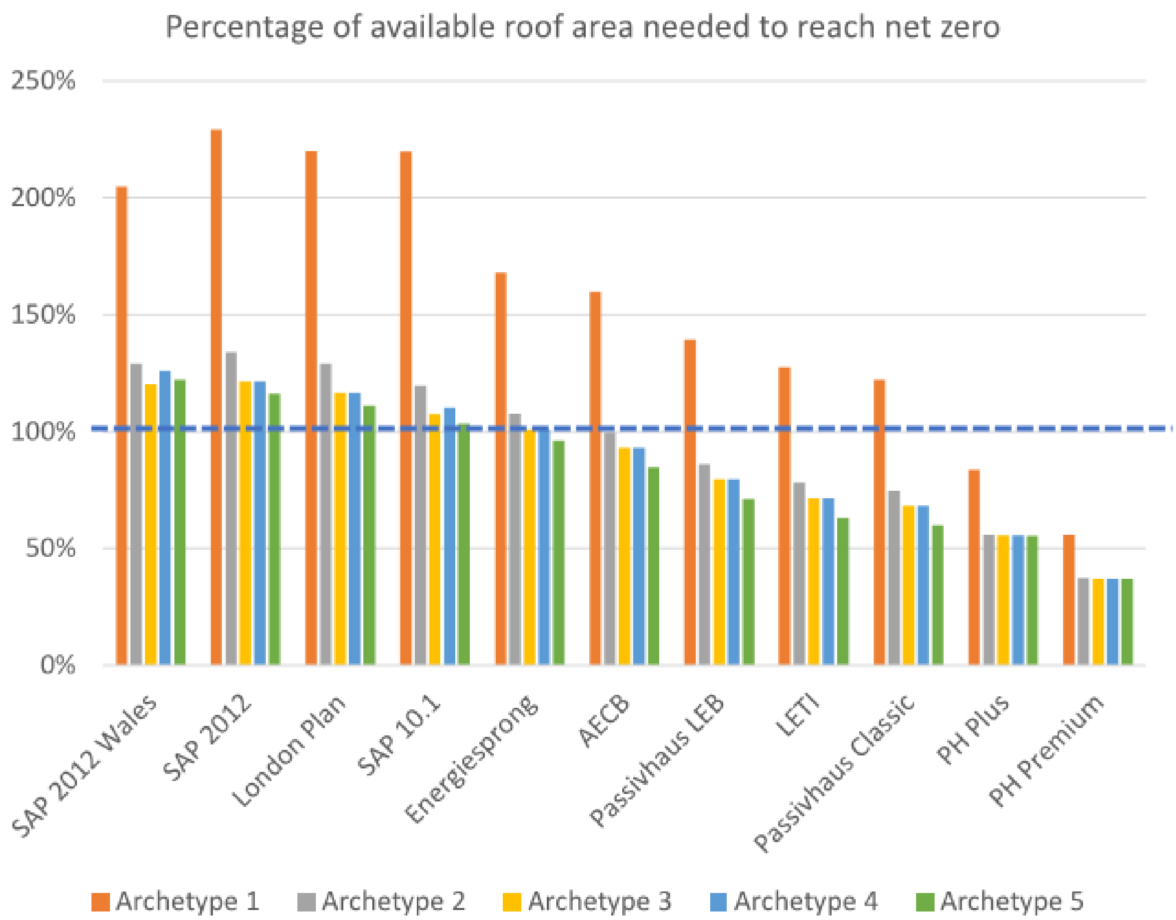


Net Zero Comparison

The next comparison is the net zero balance of the building on site, again for archetype 3, and assuming an Air Source Heat Pump for heating and hot water. Those standards that have a generation requirement are shown as matching a proportion of the dwelling's demand. However, it should be noted that generation can be applied to any of the standards, so the key issue becomes how much generation is needed to get to a net zero position. The amount of generation that is feasible is linked primarily to the available roof area and thus it will not always be possible to achieve this – particularly for medium and high density housing. For example, for archetype 3, the generation requirement for the Energiesprong standard would require 108% of the available roof space.

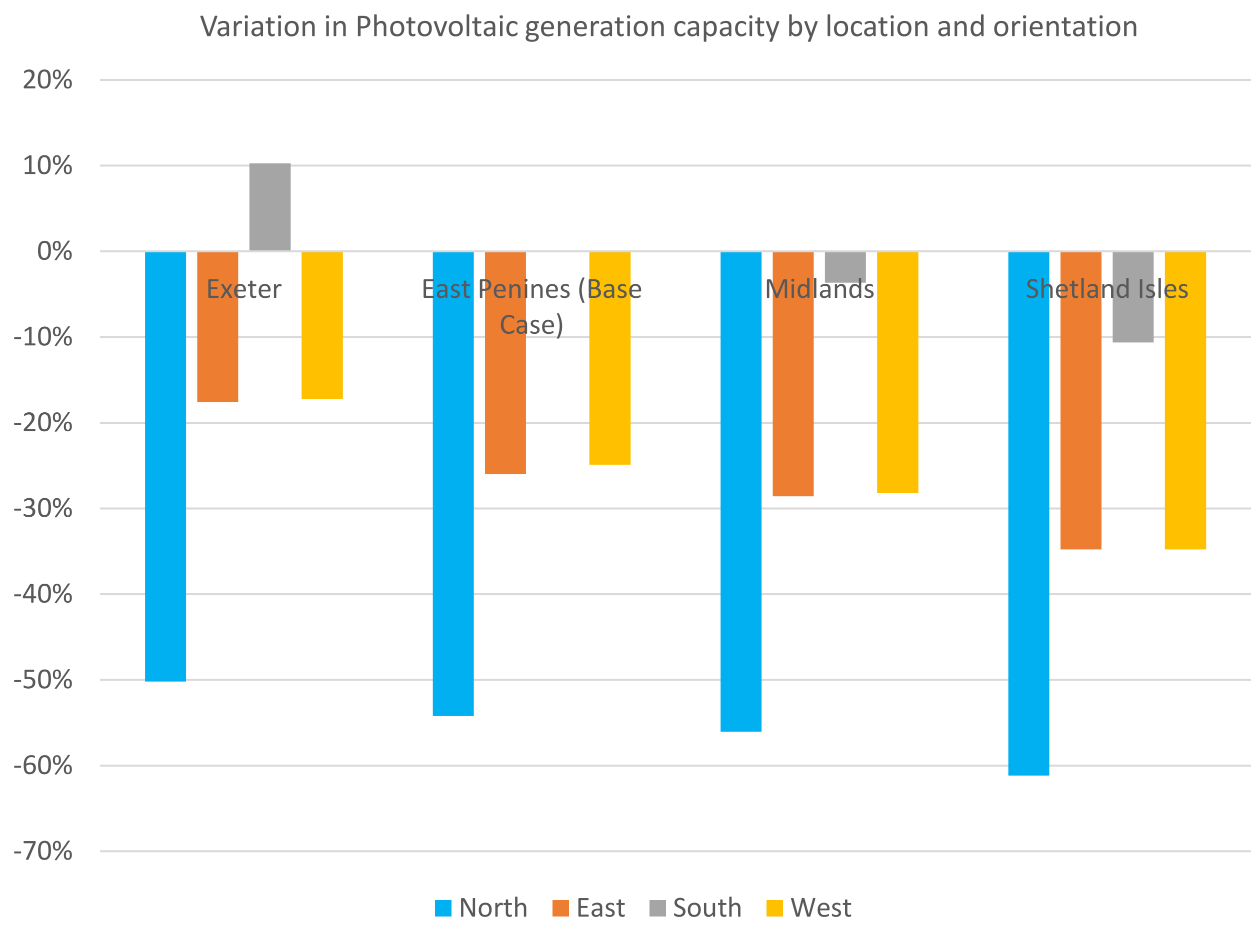


Thus, getting to net zero on site needs to be put into context. It is not necessarily possible to generate enough from the available space to get to a net zero position. In particular, buildings such as archetype 1 (12 dwellings in a building over 3 storeys) will have limited roof space per dwelling and thus generation is limited. Therefore, once again, minimising demand becomes the key point in creating the best opportunity for net zero. The chart below sets out what percentage of available roof space would be required to generate sufficient energy to get to a net zero position on site. Clearly, anything above 100% means that it is not feasible to achieve net zero.



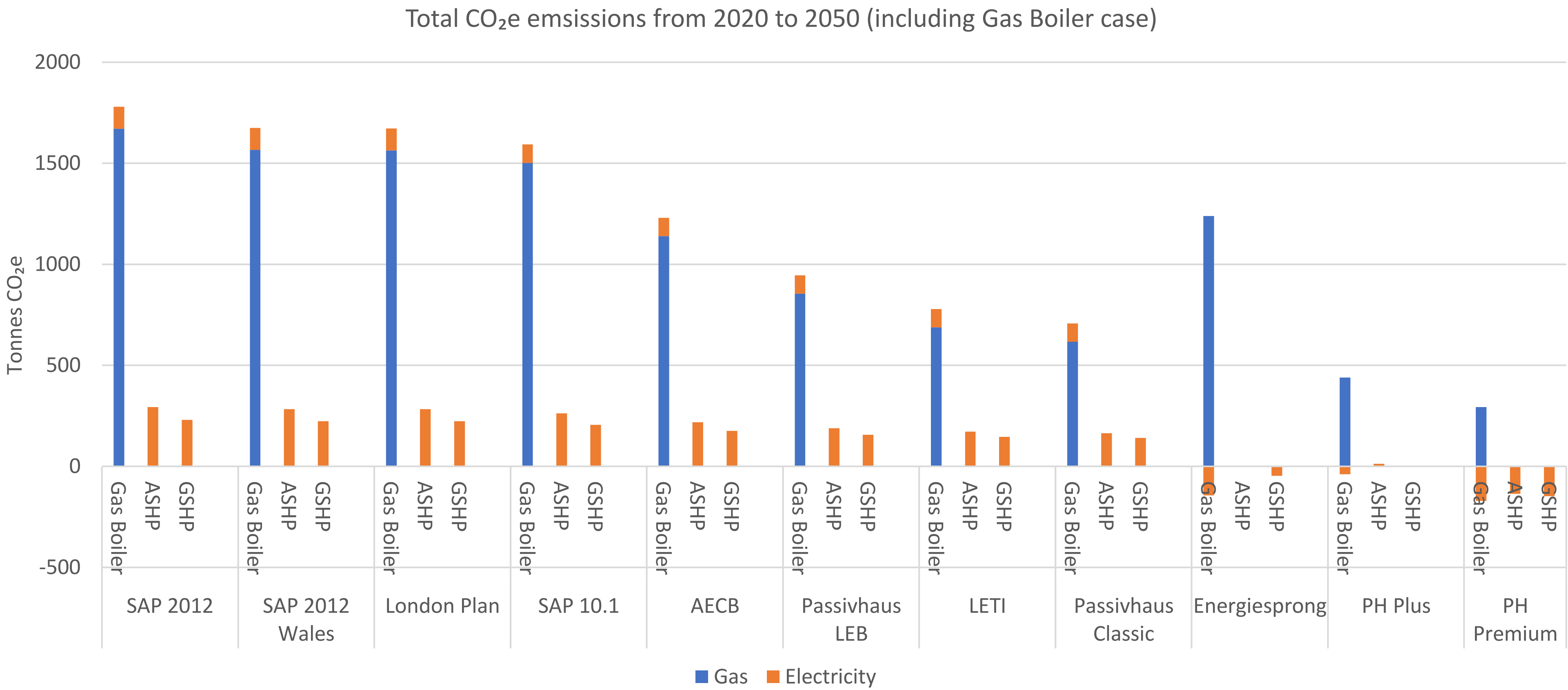
These calculations have been derived assuming a south facing pitched roof at an angle of 45 degrees, with the property located in the East Pennines[6]. The chart below shows how the potential for solar generation will change if the building is moved around the country and also as it is rotated away from due south. It shows that location has an impact of up to 10% whilst orientation can reduce yield by more than 50%. As a south facing pitched roof cannot always be achieved, this means that our net zero position will be even more difficult to achieve in sub optimal situations. This further bolsters the argument that net zero must also consider off-site generation as part of the development or, in extremis, an offsetting scheme.

[6] Chosen as this is the location that SAP 2012 uses as an approximate average for the UK to produce consistent EPC results

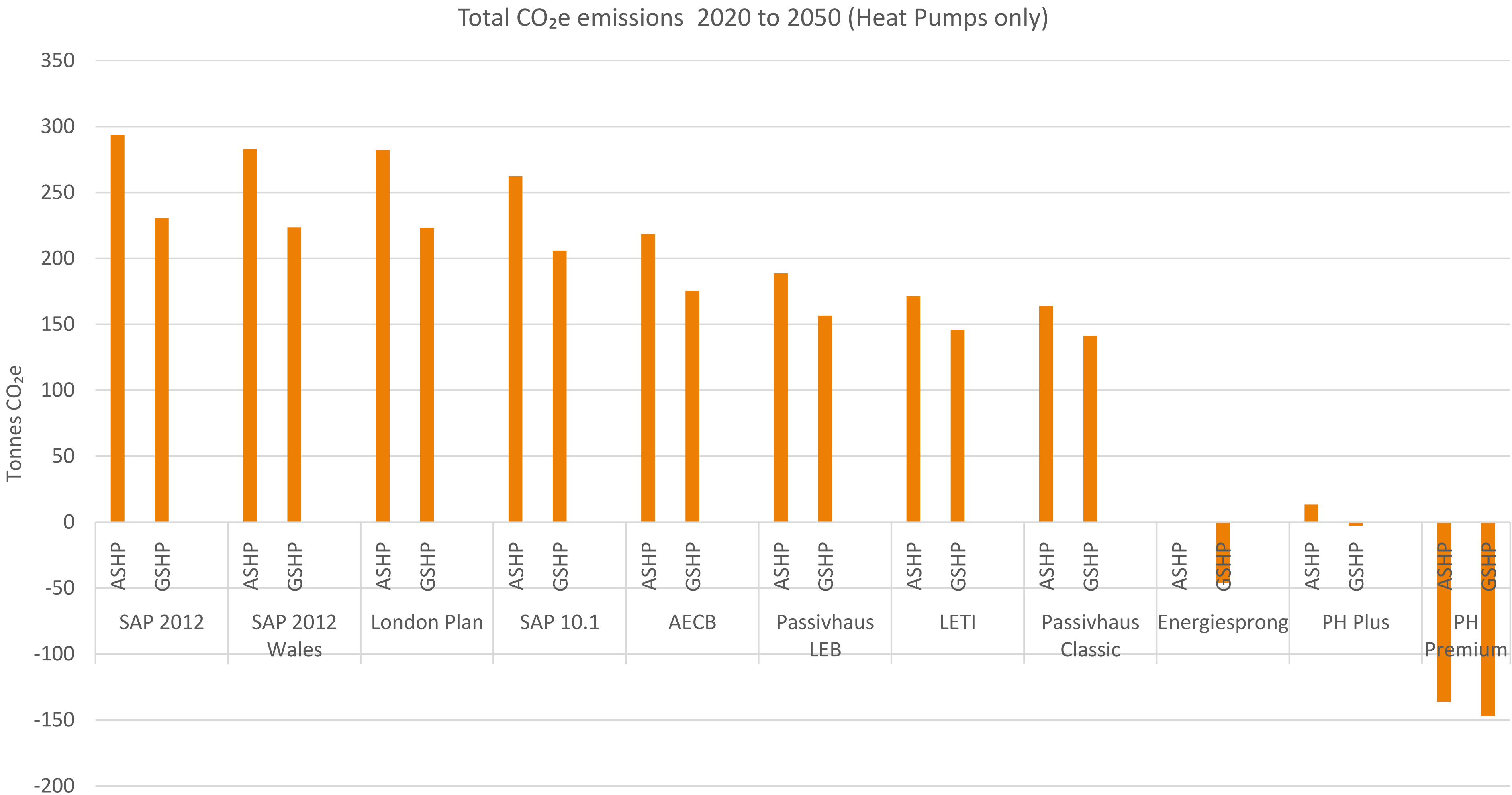

Variation in Photovoltaic generation capacity by location and orientation
20%
10%
0%
-10%
-20%
-30%
-40%
-50%
-60%
-70%
Exeter
East Penines (Base Case)
Midlands
Shetland Isles
North
East
South
West

Carbon Emissions

Finally, the forecast carbon factors for electricity and gas through to 2050 have been used to derive the total emissions for archetype 3 between 2020 and 2050. In each case, the totals for three different cases have been included – a gas boiler, an Air Source Heat Pump and a Ground Source Heat Pump. As mentioned earlier, the emissions from a gas boiler cannot be offset by generation and, with the grid rapidly decarbonising, it can be seen that gas is now a much worse polluter than electricity.



Finally, as the effect of gas emissions in the previous chart are so significant, that chart below sets out the emissions just for the Air Source and Ground Source heat pump cases. Note that this assumes no significant improvements in heat pump performance over the period.



Annex A – Analysis of each standard

Note that the results shown for each standard are for archetype 3.

SAP 2012 / Part L

The current English energy efficiency requirements are enshrined in Part L of the Building Regulations and use the Standard Assessment Procedure (SAP) version from 2012 to produce the targets and assess performance of new buildings against those targets.

This mechanism does not use definitive targets, but rather uses a notional building with a defined set of fabric performance values to determine a Target Emissions Rate (TER) for new dwellings. This TER will be different for every dwelling and will be affected by the building, size, shape, orientation and amount of glazing. To determine what this actually means in practice, we have taken data from the national EPC database for newly constructed dwellings during 2019. By analysing these submissions, we are able to determine the modelled final energy performance of new build dwellings in the UK. Further detail is in annex B.

The Part L standard does not calculate or set targets for unregulated energy. Thus, to ensure an equitable comparisons with other standards, and also to ensure that all energy which is used by the dwelling is taken into account, the Passivhaus PHPP model has been used to calculate unregulated energy demand for each archetype. Further detail is in annex C.

The performance gap for this standard has been taken to be 60% of space heating demand[7].

In summary, the energy demand of this standard for an averaged sized dwelling[8] is as follows:

Category	Final Demand (Modelled)	Final Demand (Actual)	Delivered Energy (Gas boiler)	Delivered Energy (Air Source Heat Pump)	Delivered Energy (Ground Source Heat Pump)
	kWh/m².year				
Heating	46.6	74.5	87.6	33.9	21.3
Hot Water	31.1	31.1	36.6	17.3	12.4
Lighting etc	7.8	7.8	7.8	7.8	7.8
Unregulated	21.9	21.9	21.9	21.9	21.9
Total	**107.4**	**135.3**	**154.0**	**80.9**	**63.5**

Total annual consumption	80.9	kWh/m2.year
Generation provided	0.0	kWh/m2.year
Generation balance to nz	80.9	kWh/m2.year
Total Solar Panels required	18	no.
%age of roofspace required	134%	%

Illustration of net zero position for an Air Source Heat Pump

[7] Passivhaus: The Route to Zero Carbon? Passivhaus Trust, March 2019, Appendix 2
[8] Assumed to be around 83m² – see https://www.labc.co.uk/news/what-average-house-size-uk

Welsh Part L Regulations

The Welsh Part L regulations use the same principle of Target Emissions Rate as the English version, but there is some divergence in the values used for the notional building and therefore the energy efficiency of Welsh new dwellings could be different from English.

Thus, a similar process used for English dwellings was used to determine the average modelled energy demand for Welsh new build dwellings. Details are included at annex B.

As for England, The Part L standard does not calculate or set targets for unregulated energy. Thus, to ensure an equitable comparison with other standards, and also to ensure that all energy which is used by the dwelling is taken into account, the Passivhaus PHPP model has been used to calculate unregulated energy demand for each archetype. Further detail is in annex C.

The performance gap for this standard has been taken to be 60% of space heating demand[9].

In summary, the energy demand of this standard for an averaged sized dwelling[10] is as follows:

Category	**Final Demand (Modelled)**	**Final Demand (Actual)**	**Delivered Energy (Gas boiler)**	**Delivered Energy (Air Source Heat Pump)**	Delivered Energy (Ground Source Heat Pump)
	kWh/m².year				
Heating	42.4	67.9	79.9	30.9	19.4
Hot Water	31.1	31.1	36.6	17.3	12.4
Lighting etc	7.8	7.8	7.8	7.8	7.8
Unregulated	21.9	21.9	21.9	21.9	21.9
Total	**103.3**	**128.7**	**146.2**	**77.9**	**61.6**

Total annual consumption	77.9	kWh/m2.year
Generation provided	0.0	kWh/m2.year
Generation balance to nz	77.9	kWh/m2.year
Total Solar Panels required	17	no.
%age of roofspace required	129%	%

Illustration of net zero position for an Air Source Heat Pump

[9] Passivhaus: The Route to Zero Carbon? Passivhaus Trust, March 2019, Appendix 2
[10] Assumed to be around 83m² – see https://www.labc.co.uk/news/what-average-house-size-uk

SAP 10.1 / Part L 2020

The details of changes to Part L to be adopted in 2020 are yet to be announced, however, the proposed next version of SAP has been published (10.1) and the government has consulted on options for tightening Part L. Thus, some indicative calculations can be compared for this standard.

The primary changes to SAP 10.1 from SAP 2012 affecting this calculation are:

- Different method of calculating lighting energy
- Accounting for baths and showers in hot water use rather than an occupancy based calculation
- Other changes affecting the accuracy of the heating demand calculation

The Part L consultation proposed two main options for the next iteration of Building Regulations:

- A further 20% reduction in Target Emissions Rate based on fabric improvements;
- Or a 31% reduction in Target Emissions Rate based on more modest fabric improvements combined with increased photovoltaics

Using the same derivation of unregulated energy as for SAP 2012 and assuming that a 20% fabric-led improvement in emissions rate will correlate with a 20% reduction in space heating demand, the results for a potential new 2020 Part L (England) are:

Category	**Final Demand (Modelled)**	**Final Demand (Actual)**	**Delivered Energy (Gas boiler)**	**Delivered Energy (Air Source Heat Pump)**	Delivered Energy (Ground Source Heat Pump)
	kWh/m².year				
Heating	37.2	59.6	70.1	27.1	17.0
Hot Water	35.3	35.3	41.5	19.6	14.1
Lighting etc	3.7	3.7	3.7	3.7	3.7
Unregulated	21.9	21.9	21.9	21.9	21.9
Total	**98.1**	**120.4**	**137.2**	**72.3**	**56.7**

Total annual consumption	72.3	kWh/m2.year
Generation provided	0.0	kWh/m2.year
Generation balance to nz	72.3	kWh/m2.year
Total Solar Panels required	16	no.
%age of roofspace required	120%	%

Illustration of net zero position for an Air Source Heat Pump

Passivhaus Classic

The Passivhaus Classic standard has a specific target for space heating demand and then an overall primary energy target for all energy uses. Whilst this can be achieved in several ways, a typical average sized dwelling has been modelled.

There is considerable evidence[11] that the space heating demand of a Passivhaus in use correlates almost exactly (on average) with the modelled demand. The performance gap for this standard is therefore set to zero.

Category	Final Demand (Modelled)	Final Demand (Actual)	Delivered Energy (Gas boiler)	Delivered Energy (Air Source Heat Pump)	Delivered Energy (Ground Source Heat Pump)
	kWh/m².year				
Heating	15.0	15.0	17.6	6.8	4.3
Hot Water	24.0	24.0	28.2	13.3	9.6
Lighting etc	3.1	3.1	3.1	3.1	3.1
Unregulated	21.9	21.9	21.9	21.9	21.9
Total	**64.0**	**64.0**	**70.9**	**45.2**	**38.9**

Total annual consumption	45.2	kWh/m2.year
Generation provided	0.0	kWh/m2.year
Generation balance to nz	45.2	kWh/m2.year
Total Solar Panels required	10	no.
%age of roofspace required	75%	%

Illustration of net zero position for an Air Source Heat Pump

[11] Passivhaus: The Route to Zero Carbon? Passivhaus Trust, March 2019, Appendix 2

Passivhaus Low Energy Building

This standard is identical to the Passivhaus Classic standard other than the space heating demand is relaxed to 30 kWh/m2.year.

Category	Final Demand (Modelled)	Final Demand (Actual)	Delivered Energy (Gas boiler)	Delivered Energy (Air Source Heat Pump)	Delivered Energy (Ground Source Heat Pump)
	kWh/m².year				
Heating	30.0	30.0	35.3	13.6	8.6
Hot Water	24.0	24.0	28.2	13.3	9.6
Lighting etc	3.1	3.1	3.1	3.1	3.1
Unregulated	21.9	21.9	21.9	21.9	21.9
Total	**79.0**	**79.0**	**88.5**	**52.0**	**43.2**

Total annual consumption	52.0	kWh/m2.year
Generation provided	0.0	kWh/m2.year
Generation balance to nz	52.0	kWh/m2.year
Total Solar Panels required	12	no.
%age of roofspace required	86%	%

Illustration of net zero position for an Air Source Heat Pump

AECB Building Standard

The AECB building standard follows Passivhaus principles and criteria, with a target space heating demand of 40 kWh/m2.year.

Whilst evidence is required to support a certification claim, this is a self-certified scheme which is reliant on the project's energy consultant to provide a formal declaration. Whilst this is likely to provide much better quality assurance than a typical project, it is not likely to achieve full compliance in all cases as would be expected from an independently assessed scheme. The performance gap for this standard has therefore been assumed at 20%.

Category	**Final Demand (Modelled)**	**Final Demand (Actual)**	**Delivered Energy (Gas boiler)**	**Delivered Energy (Air Source Heat Pump)**	**Delivered Energy (Ground Source Heat Pump)**
	kWh/m².year				
Heating	40.0	48.0	56.5	21.8	13.7
Hot Water	24.0	24.0	28.2	13.3	9.6
Lighting etc	3.1	3.1	3.1	3.1	3.1
Unregulated	21.9	21.9	21.9	21.9	21.9
Total	**89.0**	**97.0**	**109.7**	**60.2**	**48.3**

Total annual consumption	60.2	kWh/m2.year
Generation provided	0.0	kWh/m2.year
Generation balance to nz	60.2	kWh/m2.year
Total Solar Panels required	13	no.
%age of roofspace required	100%	%

Illustration of net zero position for an Air Source Heat Pump

London Plan

The London Plan requires a 35% reduction of on-site carbon emissions beyond the Building Regulations baseline. However, this can typically be achieved by a combination of energy efficiency together with low carbon energy sources. Renewable generation will also contribute towards this, but is not required as part of the standard. A minimum of 10% reduction in emissions must be achieved from energy efficiency measures.

This standard has therefore been modelled using the SAP 2012 baseline with a 10% reduction in space heating demand. A performance gap of 60% for space heating, as for a typical building regulation s dwelling, has been assumed.

Category	**Final Demand (Modelled)**	**Final Demand (Actual)**	**Delivered Energy (Gas boiler)**	**Delivered Energy (Air Source Heat Pump)**	**Delivered Energy (Ground Source Heat Pump)**
	kWh/m2.year				
Heating	42.3	67.7	79.7	30.8	19.3
Hot Water	31.1	31.1	36.6	17.3	12.4
Lighting etc	7.8	7.8	7.8	7.8	7.8
Unregulated	21.9	21.9	21.9	21.9	21.9
Total	**103.2**	**128.6**	**146.0**	**77.8**	**61.5**

Total annual consumption	77.8	kWh/m2.year
Generation provided	0.0	kWh/m2.year
Generation balance to nz	77.8	kWh/m2.year
Total Solar Panels required	17	no.
%age of roofspace required	129%	%

Illustration of net zero position for an Air Source Heat Pump

LETI Net Zero Operational Carbon Standard

The LETI Net Zero standard for residential dwellings sets an overall delivered energy target of 35 kWh/m2.year with a space heating demand limit of 15 kWh/m2.year. This means that the standard is taking into account the efficiency of delivered energy.

Whilst this can be achieved in several ways, it would appear that the final energy performance is very similar to the Passivhaus Classic standard. This standard has therefore been modelled as being very similar to the Passivhaus standard. In addition, a 30% space heating performance gap has been included as, whilst there is no formal quality assurance process, it is a voluntary standard and adoptees are encouraged to monitor performance and make this information public.

Category	**Final Demand (Modelled)**	**Final Demand (Actual)**	**Delivered Energy (Gas boiler)**	**Delivered Energy (Air Source Heat Pump)**	**Delivered Energy (Ground Source Heat Pump)**
	kWh/m².year				
Heating	15.0	19.5	22.9	8.9	5.6
Hot Water	24.0	24.0	28.2	13.3	9.6
Lighting etc	3.1	3.1	3.1	3.1	3.1
Unregulated	21.9	21.9	21.9	21.9	21.9
Total	**64.0**	**68.5**	**76.2**	**47.2**	**40.2**

Total annual consumption	47.2	kWh/m2.year
Generation provided	0.0	kWh/m2.year
Generation balance to nz	47.2	kWh/m2.year
Total Solar Panels required	11	no.
%age of roofspace required	78%	%

Illustration of net zero position for an Air Source Heat Pump

EnergieSprong New Build

The EnergieSprong space heating demand target is 40 kWh/m2.year. Hot water demand is set at 64+26N where N is the number of residents. This is slightly different from the SAP 2012 equation of 36+26N and so has been modelled accordingly. Lighting and Unregulated energy target is 2300 kWh/year, however it is not clear for what size property this applies, so the average UK figure of 90m² has been used to derive a figure for all archetypes. The equivalent percentage split seen in SAP 10.1 has been used to divide this figure between lighting and unregulated.

The EnergieSprong model includes a contractual requirement to deliver the energy consumption that has been targeted. The performance gap for this standard has therefore been assumed to be zero.

There is no specific generation target for Energiesprong, however, the standard does commit to achieve net zero (consumption – export) in some dwellings and to achieve <1500 kWh/yr net consumption in others. For the purposes of this paper, it is assumed that net zero is achieved when using an Air Source Heat Pump

Category	**Final Demand (Modelled)**	**Final Demand (Actual)**	**Delivered Energy (Gas boiler)**	**Delivered Energy (Air Source Heat Pump)**	**Delivered Energy (Ground Source Heat Pump)**
	kWh/m².year				
Heating	40.0	40.0	47.1	18.2	11.4
Hot Water	38.3	38.3	45.1	21.3	15.3
Lighting etc	3.7	3.7	3.7	3.7	3.7
Unregulated	21.9	21.9	21.9	21.9	21.9
Total Consumption	**103.9**	**103.9**	**117.7**	**65.0**	**52.3**

Total annual consumption	65.0	kWh/m2.year
Generation provided	65.0	kWh/m2.year
Generation balance to nz	0.0	kWh/m2.year
Total Solar Panels required	15	no.
%age of roofspace required	108%	%

Illustration of net zero position for an Air Source Heat Pump

Passivhaus Plus

The Passivhaus Plus standard is similar to the Passivhaus Classic standard other than the delivered energy demand reduces from 60 kWh/m².year to 45 kWh/m².year inclusive of an allowance for storage losses of around 30%. The space heating demand limit remains at 15 kWh/m².year. This standard is very difficult to achieve with a gas boiler but, is achievable using an Air Source Heat Pump.

Passivhaus Plus also introduces a renewable energy generation requirement of 60 kWh/m².year based on the building footprint area.

As for Passivhaus Classic, zero performance gap has been assumed.

Category	Final Demand (Modelled)	Final Demand (Actual)	Delivered Energy (Gas boiler)	Delivered Energy (Air Source Heat Pump)	Delivered Energy (Ground Source Heat Pump)
	kWh/m².year				
Heating	9.4	9.4	11.1	4.3	2.7
Hot Water	18.4	18.4	21.6	10.2	7.4
Lighting etc	2.4	2.4	2.4	2.4	2.4
Unregulated	16.8	16.8	16.8	16.8	16.8
Total	**47.0**	**47.0**	**51.9**	**33.7**	**29.2**

Total annual consumption	33.7	kWh/m2.year
Generation provided	30.0	kWh/m2.year
Generation balance to nz	3.7	kWh/m2.year
Total Solar Panels required	8	no.
%age of roofspace required	56%	%

Illustration of net zero position for an Air Source Heat Pump

Passivhaus Premium

Passivhaus Premium is similar to Passivhaus Plus other than the delivered energy demand reduces further to 30 kWh/m².year including storage losses and the generation requirement increases to 120 kWh/m².year. This standard is only achievable by reducing space heating demand further as well as reducing hot water demand and unregulated energy.

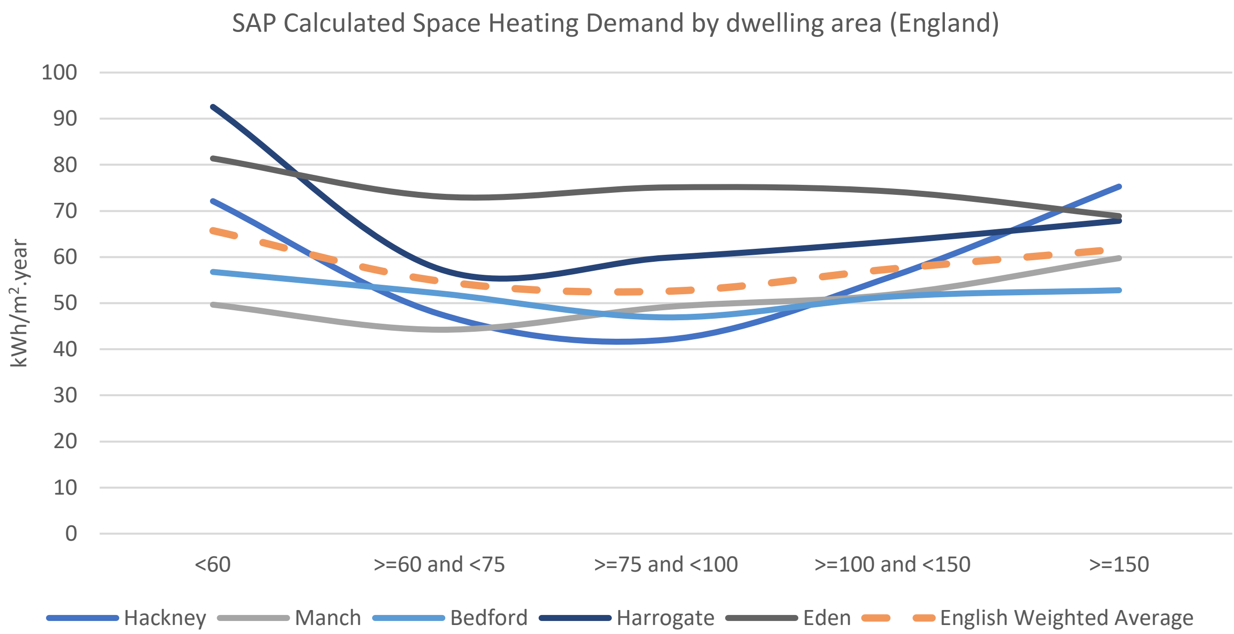
Category	Final Demand (Modelled)	Final Demand (Actual)	Delivered Energy (Gas boiler)	Delivered Energy (Air Source Heat Pump)	Delivered Energy (Ground Source Heat Pump)
	kWh/m².year				
Heating	6.3	6.3	7.4	2.9	1.8
Hot Water	12.3	12.3	14.4	6.8	4.9
Lighting etc	1.6	1.6	1.6	1.6	1.6
Unregulated	11.2	11.2	11.2	11.2	11.2
Total	**31.3**	**31.3**	**34.6**	**22.4**	**19.5**

Total annual consumption	22.4	kWh/m2.year
Generation provided	60.0	kWh/m2.year
Generation balance to nz	-37.6	kWh/m2.year
Total Solar Panels required	5	no.
%age of roofspace required	37%	%

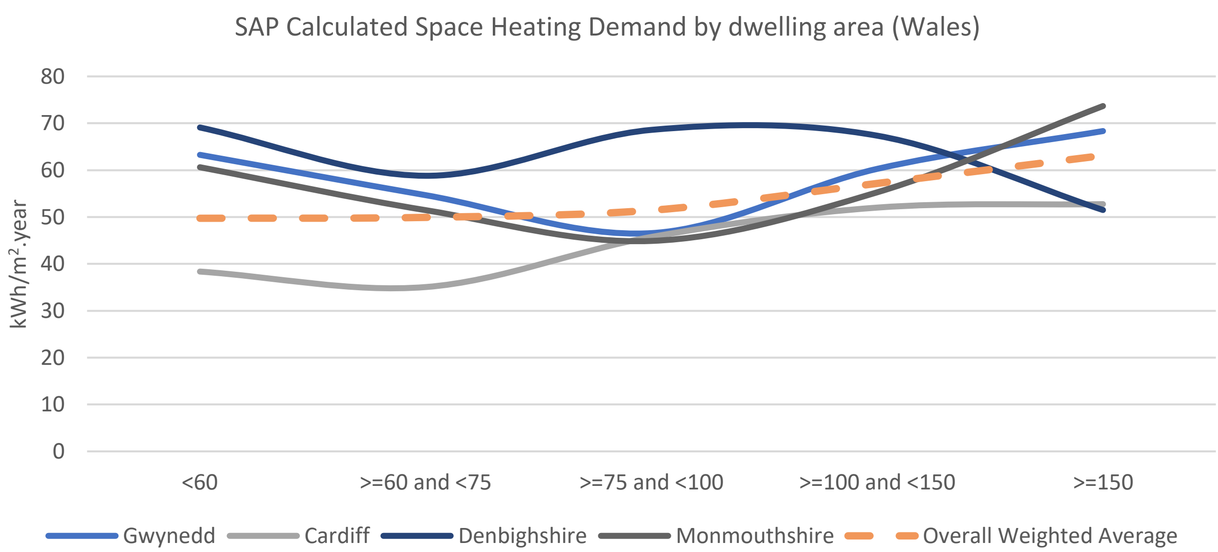
Illustration of net zero position for an Air Source Heat Pump

Annex B – Deriving Space Heating Demand and Hot Water Demand for SAP 2012 (England and Wales)

Total energy use for dwellings, as derived by the EPC, has been obtained for a sample of dwellings across England. Dwellings have been filtered to select only properties using mains gas for heating and hot water and with no photovoltaic generation. A SAP Domestic Hot Water calculation has then been undertaken for each property to calculate the proportion of the energy use required for hot water. Similarly, energy for lighting, pumps and fans has been calculated. This then means the remaining energy must be allocated for space heating demand. The results of this analysis are shown below and indicate a good correlation across locations with smaller dwellings having a higher space heating demand per m².



An identical process has been followed to determine the equivalent for Wales:

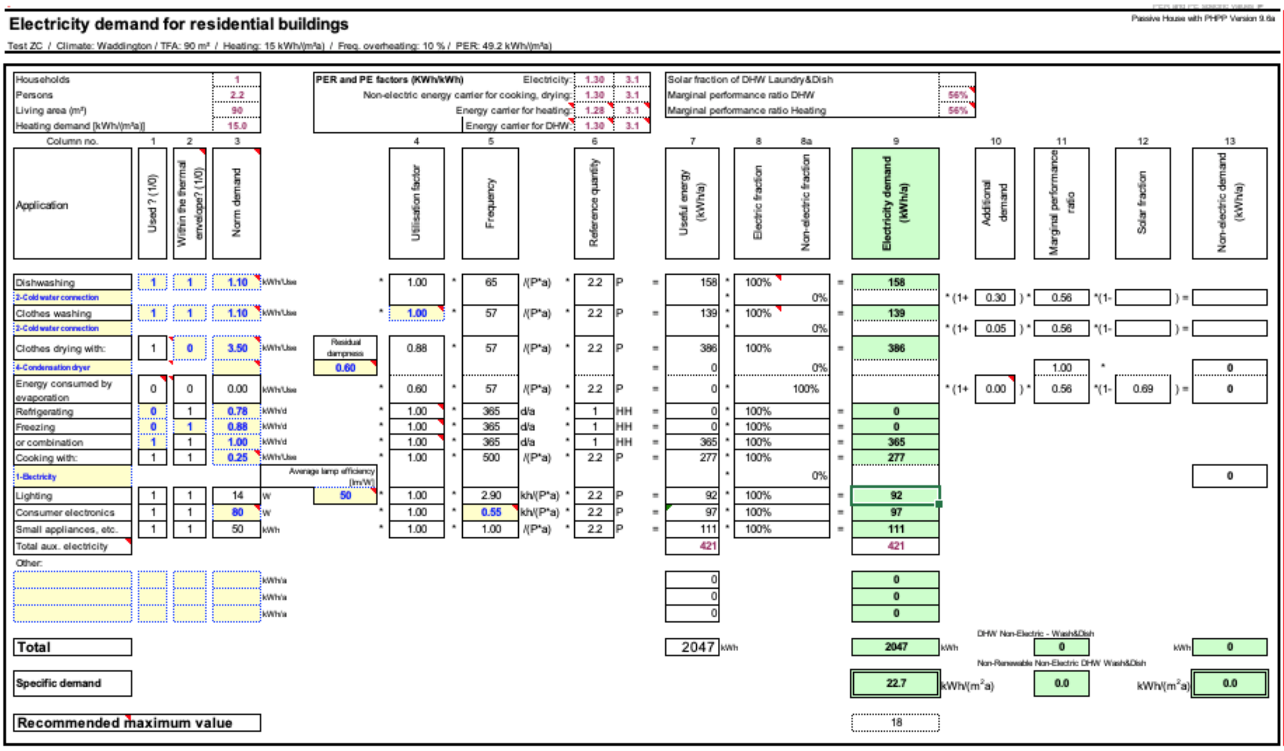


The following method was used to calculate the Domestic Hot Water demand in SAP 2012:

Gross internal Area (A)	m^2	As measured
Occupancy		1+1.76*(1-EXP(-0.000349*(A-13.9)^2))+0.0013*(A-13.9)
HW Demand	litres/ day	(25 * Occupancy) + 36
HW Usage	kWh/ year	4.18 * Litres/day * DeltaT * no days/3600
Average annual Delta t	degK	37
Dist Losses	%	15% of Usage
Storage Loss Factor		0.005+0.55/(Cyliiner Insulation Thickenss+4)
Volume Factor		(120/Volume)^(1/3)
Temp Factor for indirect cylinder		0.54
Storage Losses	kWh/ day	Volume * Storage Loss Factor * Volume Factor * Temp Factor
Primary Circuit Losses	kWh/ year	No. days * 14 * ((0.009 * Fraction Insulated + 0.0245 * (1 - Fraction Insulated)) * Circulation Hours per Day + 0.0263
Circulation hours per day	Hours /day	3
Total DHW Demand	kWh/ year	(HW Usage * 0.85) + All losses

Annex C - Deriving an estimate of Unregulated energy use

Using the PHPP sheet, unregulated energy can be calculated based on occupancy:



For the archetypes being considered, this gives the following results:

Archetype	Gross Internal Floor Area (m²)	Calculated Occupancy (SAP)	Given Occupancy	Unregulated Energy (Calculated Occupancy) kWh/m².year	Unregulated Energy (Given Occupancy) kWh/m².year
1	50	1.69	2	24.4	30.1
2	61	2.01	3	21.9	34
3	84	2.53	4	19.3	31.5
4	84	2.53	4	19.3	31.5
5	110	2.81	6	16.3	34.4

Annex D – Modelling Parameters

Gas Boiler Efficiency	%	0.85
ASHP Efficiency (Hot Water)	%	1.80
GSHP Efficiency (Hot Water)	%	2.50
ASHP Efficiency (Heating)	%	2.20
GSHP Efficiency (Heating)	%	3.50
Solar yield per panel	kWh/year	273.0
Solar Panel area	m2	1.6
Building location		East Pennines
Roof orientation		South
Roof pitch	Degrees	45