COTSWOLD
DISTRICT COUNCIL

Sustainable construction policies

Operational energy and carbon evidence base

December 2023 | Rev D

Levitt Bernstein
People.Design

Etude

This document

Operational energy and carbon

Technical evidence base / New buildings only

Recommends specific policies to reduce new buildings' operational energy use, require low carbon heating systems, increase renewable energy generation and ensure that targeted performance is delivered. Demonstrates that they are technically feasible and comments on their viability.

Embodied carbon

Topic paper / New buildings and retrofit

Explains the concepts of upfront embodied carbon and life cycle carbon. Recommends and assesses specific policies.

District heating

Information paper for officers / New buildings and retrofit

Explains the different types of district heating systems, how they compare with an individual heating system and which systems would help to deliver Net Zero.

Retrofit

Topic paper / Retrofit

Articulates the crucial role of retrofit to achieve Cotswold's carbon targets and how the Local Plan (and wider planning system) can better support and incentivise decarbonisation.

This work was led by

COTSWOLD DISTRICT COUNCIL

James Brain
Sophia Price

The consultant team includes two organisations who have previously collaborated on a range of new construction and retrofit projects, net zero guidance and policy work. It includes architects, engineers, conservation and energy specialists. It brings together a diverse set of skills with a shared ethos of collaboration, practicality, and commitment to accelerate the reduction of carbon emissions from buildings.

Levitt Bernstein People.Design

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This evidence base

The main purpose if this document is to constitute a technical evidence base to inform the policy making process for planning officers at Cotswold District Council.

Seven new policies are proposed to reduce operational energy and carbon emissions from new buildings and enable Cotswold District Council to meet its climate change commitments through their inclusion in the Local Plan.

Policy 1: Net Zero Carbon new buildings

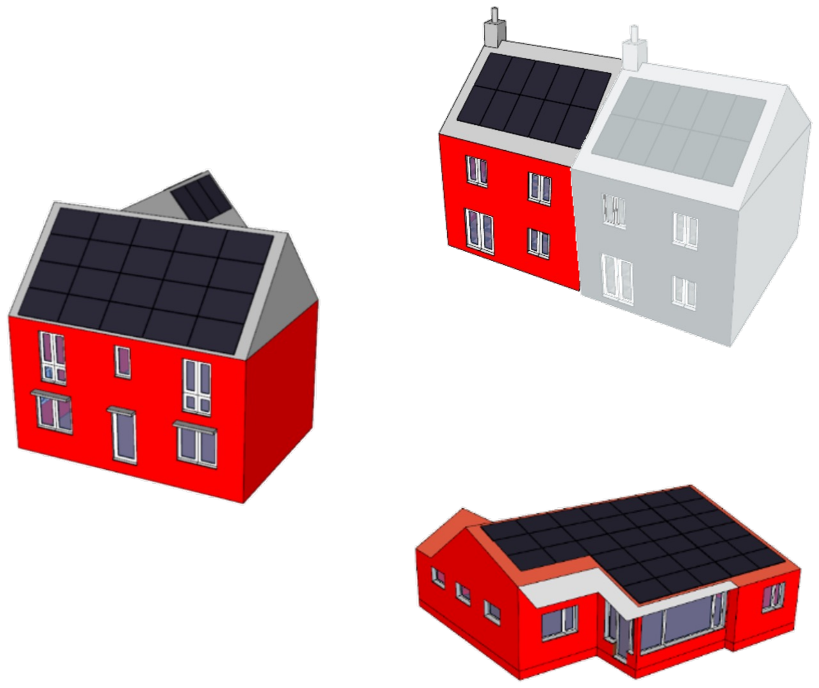
This is the overarching policy. It recommends that all new buildings should be designed and built to be Net Zero Carbon in operation. They should be ultra-low energy buildings, use low carbon heat, contribute to the generation of renewable energy on-site and be constructed with low levels of embodied carbon.

It relies on compliance with six other proposed policies.

- Policy 2: Space heating and cooling demand
- Policy 3: Energy Use Intensity (EUI)
- Policy 4: Fossil fuel free
- Policy 5: On-site renewable energy generation
- Policy 6: Assured energy performance
- Policy 7: Offsetting of energy (as last resort)

Potential policies on embodied carbon, district heating and retrofit are dealt with in other documents.

After evidencing the need for the policies listed above, this document demonstrates why current policies are not fit for purpose anymore and why these proposed policies are technically feasible. These policies have been formulated drawing on the evidence bases created for other local authorities including Cornwall Council, Bath & North East Somerset Council, the London Borough of Newham Essex County Council, Greater Cambridge and Central Lincolnshire. Energy models and typologies have been adapted to reflect Cotswold District Council.



A semi-detached house, a detached house, and a bungalow were modelled to demonstrate that the proposed policies are technically feasible.

1.0

Evidence of need

Cotswold District Council's Local Plan must comply with global carbon commitments

There is a climate emergency

There is overwhelming scientific consensus that significant climate change is happening. This is evidenced in the latest assessment of the Intergovernmental Panel on Climate Change (IPCC AR6). The IPCC special report published in 2022 on the impacts of global warming of 1.5°C above pre-industrial levels highlights the **urgency for action** and has generated a high level of interest and concern in society.

The Glasgow Agreement (2021)

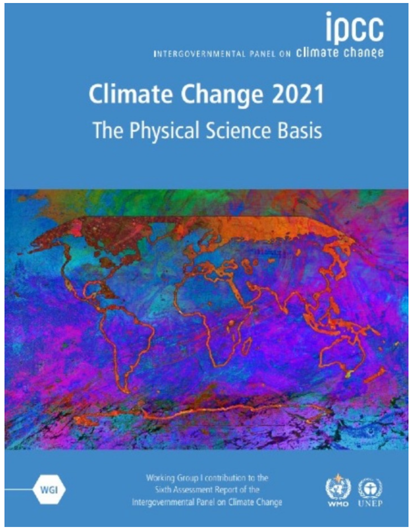
International negotiations on climate change are governed through the United Nations Framework Convention on Climate Change (UNFCCC). The most recent negotiations concluded with the Glasgow Agreement in 2021. Nations collectively agreed to work to reduce the gap between existing emission reduction plans and what is required to reduce emissions, so that the rise in the global average temperature can be limited to 1.5 degrees.

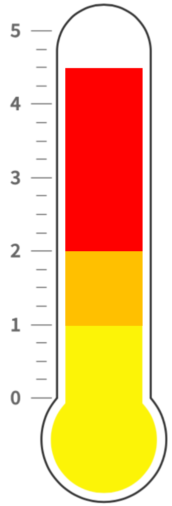
Global carbon budgets

The concept of carbon budgets is absolutely critical to understand; Net Zero is not only about a destination; a very significant and fast required decarbonisation pathway is needed from now on.

The IPCC Special Report on 1.5°C has estimated the quantity of CO_2 that can be emitted globally and still be consistent with keeping global temperatures well below 2°C, with a chance of stabilising at 1.5°C. The report gives different budgets for different temperature rises and probabilities. At the start of 2020, the global carbon budget for a 66% probability of keeping global warming to below 1.5°C was 400Gt CO_2.

Recent work by Lamboll et al has indicated that at the start of 2023 the global carbon budget for a 50% probability of keeping global warming to below 1.5°C was 250Gt CO_2. This budget will be consumed within under 6 years at current emission rates.



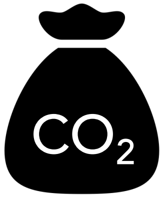


3°C the temperature rise we are likely to see with currently agreed policies and actions

Well below 2°C (and aim for 1.5°C) the global warming limits agreed through the Paris Agreement

1.2°C The temperature rise already created

Source: Copernicus Climate Change Service, ECMWF



250,000 $MtCO_2$

Remaining global carbon budget (from January 2023) for a 50% chance of limiting temperature rises to below 1.5°C (Lamboll et al, 2023). Includes updates to climate models and incorporation of new knowledge on contribution from non-CO_2 emissions

<6 years

The number of years it would take to **consume our entire global carbon budget** at current global emissions rates for a 50% chance of limiting temperature rises to below 1.5°C

Cotswold District Council's Local Plan must comply with national carbon commitments

National commitment

The UK's national commitment is set through the Climate Change Act 2008, which was updated in 2019. It legislates that the UK must be net zero carbon by 2050 and sets a system of carbon budgets to ensure that the UK does not emit more than its allowance in the next 27 years. This legal requirement is underpinned by the Climate Change Committee's report '*Net Zero: The UK's Contribution to Stopping Global Warming*'.

The carbon budget for the UK

The Climate Change Committee have produced a series of five year carbon budgets for the UK. While these are useful and have enabled the Committee to map out a 1.5˚C compliant policy pathway, the budgets are not directly comparable to the IPCC's carbon budgets due to variations in their scope over time.

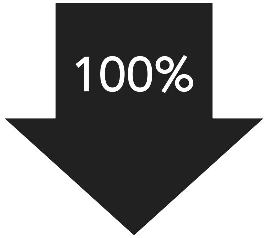
Scaling the global carbon budget to the UK based on population indicates a remaining national carbon budget of 2,080 $MtCO_2$ as of the start of 2023.

Achieving Net Zero Carbon by 2050

Key measures identified by the Climate Change Committee (CCC) include:

- 100% low carbon electricity by 2050.
- Ultra-efficient new homes and non-domestic buildings.
- Low carbon heat to all but the most difficult to treat buildings.
- Ambitious programme of retrofit of existing buildings.
- Complete electrification of small vehicles.
- Large reduction in waste and zero biodegradable waste to landfill.
- Significant afforestation and restoration of land, including peatland.

The UK Government has committed in June 2019 to Net Zero emissions by 2050



Reduction in CO_2 emissions the UK government is **legally required** to achieve by 2050 over 1990 levels.

250,000 $MtCO_2$ Global CO_2 budget

2,080 $MtCO_2$
UK budget (start of 2023)

The UK's remaining carbon budget for limiting warming to under 1.5°C was 2,080 Mt CO2 at the start of 2023, based on scaling the remaining global carbon budget by population. The UK also has a series of five year carbon budgets set by the CCC, however these are not directly comparable to the figure above as their scope has changed over time.

Regional carbon reduction commitments

Cotswold will exceed our carbon budget by 2027 unless action is taken

In 2020 the Tyndall Centre for Climate Change Research developed carbon budget reports for each UK local authorities, based on the IPCC's global carbon budget*. They are powerful in their simplicity, since they are directly related to actual CO_2 emissions from energy, which represents 80% of the UK's greenhouse gas emissions. A local authority can monitor their own local CO_2 emissions from energy (using BEIS datasets) and plan to reduce them in line with the recommended trajectory.

The methodology used to calculate the Tyndall centre's budgets contains some differences to the approaches used by the IPCC to calculate the global carbon budget, and the Climate Change Committee to calculate the UK's 5-year carbon budgets. For example, The Tyndall centre's budgets are calculated based on 1.7˚C of warming, rather than 1.5˚C.

In summary, the report recommends:

- Cotswold District Council should stay within a maximum cumulative CO_2 emissions budget of 3.9 million tonnes of CO_2 ($MtCO_2$) for the period 2020-2100.
- If emissions continue at 2017 levels, the entire carbon budget for the area would be used by 2027.
- Emissions cuts must average -13.8% per year to deliver a Paris aligned carbon budget.
- Meeting the budget must not rely on carbon offsets.

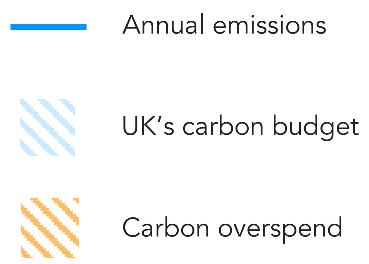
A zero carbon target date is not enough

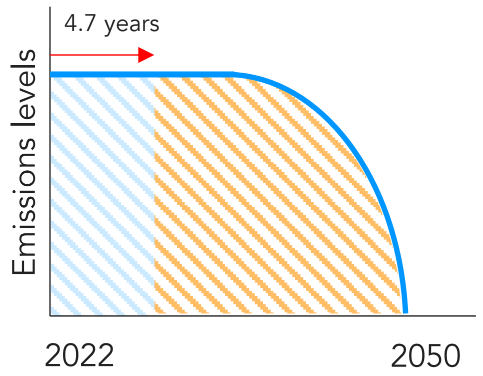
The UK government's zero carbon by 2050 target is not enough without also taking a science-based carbon budgets approach. The graphs on the right illustrate different emissions trajectories, both of which get to zero carbon by 2050. However, trajectory A emits three times as much carbon as trajectory B, and would put us on a path to much higher global temperature rises than the target 1.5-2 C.

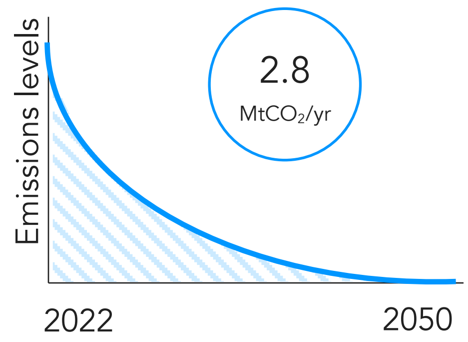
Cotswold District Council's carbon budget = 2.8 $MtCO_2$ (from 2022)*

Current emissions rate = 0.59 $MtCO_2$/yr

Years left of budget at current emissions rate: **4.7 years**







Trajectory type A

This trajectory continues at current emissions rates until the 2030s at which point it drops off steeply.

It is zero carbon by 2050 but the carbon budget is far exceeded.

Trajectory type B

This trajectory sees a 13.8% reduction in emissions year on year. Cumulative emissions stays within the carbon budget.

Other trajectories are possible – but it's imperative that we do not overspend on carbon, otherwise we will not be on a Paris compliant trajectory.

**Since 2020, advances in climate science and carbon budget calculations indicate that remaining carbon budgets are now even smaller.*

New buildings should now stop adding to the problem: they need to be part of the solution

New buildings are currently adding to the problem

Operational carbon emissions associated with new buildings (that meet current planning policy) are still very significant. They are not energy efficient enough, they continue to use of fossil fuels for heating and hot water, and they generate very small amounts of renewable energy. In summary, they keep adding to the problem of climate change and are not compliant with international, national and local carbon reduction and Net Zero commitments. They keep on using far too much of the Cotswold District Council's carbon budgets and that is not sustainable.

They create a future retrofit burden

If new buildings continue to be designed and built to the current standards, they will need to be retrofitted in the next 10-30 years in order to reduce their carbon emissions. For example, their new gas boiler will have to be replaced with a low carbon heating system. This would be much more expensive than designing and constructing them to the right standard now, and this cost would fall mostly on residents, local authorities and housing associations.

New buildings compliant with our climate change commitments

New buildings designed and built, today, with available and affordable skills, techniques and technologies can be compliant with these climate change commitments. In their *UK housing: Fit for the future?* Report the CCC provides clear guidance on what should be expected from new buildings from now on and in particular:

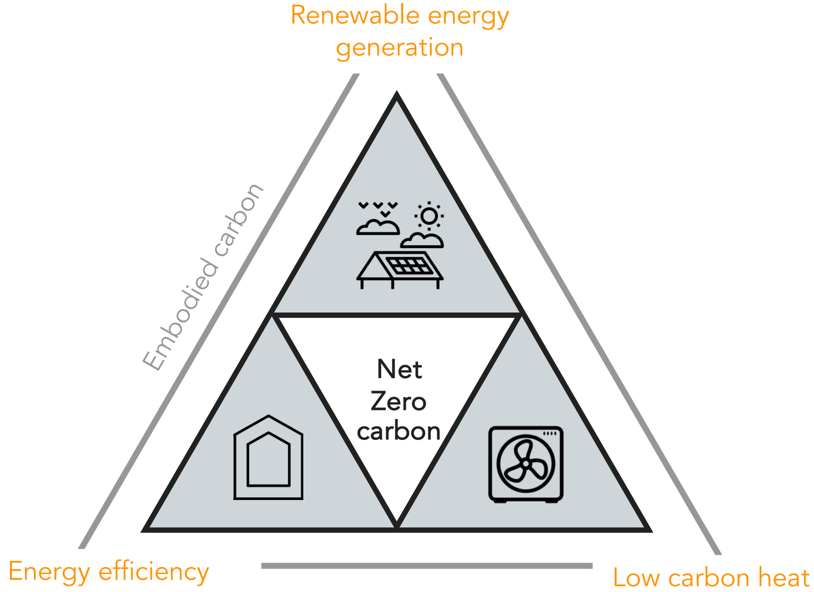
- an ultra-low level of energy use (i.e. 15-20 kWh/m^2.yr space heating)
- a low carbon heating system.

Beyond the issue of operational carbon: embodied carbon

In addition to operational carbon emissions, embodied carbon associated with new buildings must be reduced. Potential policies associated with embodied carbon are discussed in the 'Embodied carbon topic paper' prepared separately.

"New homes should deliver ultra-high levels of energy efficiency as soon as possible and by 2025 at the latest, consistent with a space heat demand of 15-20 kWh/m^2/yr. Designing in these features from the start is around one-fifth of the cost of retrofitting to the same quality and standard."

Extract from UK Housing: Fit for the Future? Committee on Climate Change, 2019.



For the Climate Change Committee, energy efficiency and low carbon heat represent two key pillars of future buildings compliant with our climate change commitments

2.0

The Local Plan can introduce specific energy and carbon requirements

Cotswold District Council can set their own energy and carbon requirements

In 2023 Cornwall Council and Bath & North East Somerset Council were the first local authorities to adopt Net Zero policy based on energy metrics. The policies were justified by an evidence base and were found sound by the Planning Inspectorate. The importance of the 2015 written ministerial statement was clarified and reduced, bringing an end to years of uncertainty.

2008-2014: the realisation that the planning system has a key role to play to mitigate climate change

- The **Planning and Compulsory Purchase Act 2004** requires the local plan to ensure that development and use of land contribute to mitigation of climate change.
- The **Climate Change Act 2008** obliges the government to set policy that will enable the UK to meet its carbon budgets.
- The **Planning and Energy Act 2008** empowers local plans to set "*reasonable requirements*" for new builds to comply with "*energy efficiency standards that exceed … building regulations*" and "*supply a proportion of their energy from nearby renewable or low carbon sources*".

2015-2019: deregulation and the misguided reliance on ambitious national standards (incl. the 2016 Zero Carbon homes policy)

The **Deregulation Act 2015** was intended to dis-apply s.1(c) of the Planning and Energy Act to dwellings removing the ability of LPAs to impose local requirements above building regulations on energy efficiency standards. However, this has not been brought into force.

On 25th March 2015, a **Ministerial Statement** stated that, for the specific issue of energy performance, LPAs will be able to set and apply polices in their local plans which exceed building regulations until change to optional requirements under Deregulation Act 2015 takes place. This was expected to happen alongside the introduction of zero carbon homes policy late in 2016 (which was not introduced). Until then LPAs were expected not to set conditions with requirements above CfSH level 4 (i.e. 19% improvement over Part L).

Since 2019: the turning point of Net Zero

Further to a special report completed by the Climate Change Committee, the **Climate Change Act** was updated in 2019: the overall greenhouse gas reduction was changed from an 80% reduction to a 100% reduction by 2050, i.e. Net Zero.

An updated **NPPF** (National Planning Policy Framework) (2021) now expects the planning system to contribute to a "radical reduction in greenhouse gas emissions" (Para 148) and plans to take a proactive approach (Para 149).

In 2021, the Government also published their **response to the Future Homes Standard consultation** stating the following:

"We recognise that there is a need to provide local authorities with a renewed understanding of the role that Government expects local plans to play in creating a greener built environment; … the Government will not amend the Planning and Energy Act 2008, which means that local planning authorities will retain powers to set local energy efficiency standards for new homes."

Essex County Council: Open Legal Advice

In April 2023, Essex Climate Action Commission and Essex County Council commissions legal advice on the matter concerning the ability of local planning authorities to set local plan policies that require developments to achieve energy efficiency standards above Building Regulations. The document is available at: https://www.essexdesignguide.co.uk/climate-change/net-zero-evidence/essex-open-legal-advice-energy-policy-and-building-regulations/

The advice mentions that with one exception, Local Planning Authorities (LPAs) which have sought to include ambitious net zero carbon policies have been successful, and inspectors have been satisfied that such policies will not have an unreasonable impact on the viability and deliverability of new developments. Energy efficiency polices which have passed examination and are considered include Policy SI 2 of the London Plan 2021, Policy H5 of the Reading Borough Local Plan, Policy PSP6 of the South Gloucestershire Policies, Sites and Places Plan, Cornwall's Climate Emergency Development Plan and Bath and North East Somerset's Local Plan Partial Update and the Central Lincolnshire Local Plan.

Based on the evidence reviewed, the legal advice concluded that Government ministers and planning inspectors alike have recognised the power of Local Planning Authorities to set ambitious energy efficiency targets through their local plans.

Bath and North East Somerset adopted their new policy in January 2023, becoming the first council in England to successfully adopt an energy-based net zero housing policy as part of its commitment to tackling the climate emergency.

"The new housing development policy will ensure the energy use of any proposed development is measured and meets a specified target — setting a limit on the total energy use and demand for space heating. It will also require sufficient on-site renewable energy generation to match the total energy consumption of the buildings — ensuring the development is 100% self-sufficient.

The council will also impose net zero operational carbon standards for new major non-residential development.

The policy is the first new housing policy to be net-zero aligned based on 2030 trajectories of industry-leading organisations such as the London Energy Transformation Initiative (LETI), the Royal Institute of British Architects (RIBA) and the Chartered Institute of Building Services Engineers (CIBSE)."

Source: B&NES Council's website

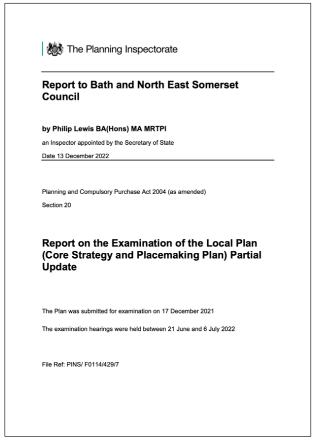
Policy SCR6 - New Build Residential

New build residential development will be required to meet the standards set out below.

New build residential development will aim to achieve zero operational emissions by reducing heat and power demand then supplying all energy demand through onsite renewables. Through the submission of an appropriate energy assessment, having regard to the Sustainable Construction Checklist SPD, proposed new residential development will demonstrate the following:

- Space heating demand less than 30kWh/m^2/annum;
- Total energy use less than 40kWh/m^2/annum; and
- On site renewable energy generation to match the total energy use, with a preference for roof mounted solar PV
- Connection to a low- or zero-carbon district heating network where available

Net Zero policy adopted by Bath & North East Somerset Council based on energy metrics


The Planning Inspectorate

Report to Bath and North East Somerset Council

by Philip Lewis BA(Hons) MA MRTPI

an Inspector appointed by the Secretary of State

Date 13 December 2022

Planning and Compulsory Purchase Act 2004 (as amended)

Section 20

Report on the Examination of the Local Plan (Core Strategy and Placemaking Plan) Partial Update

The Plan was submitted for examination on 17 December 2021

The examination hearings were held between 21 June and 6 July 2022

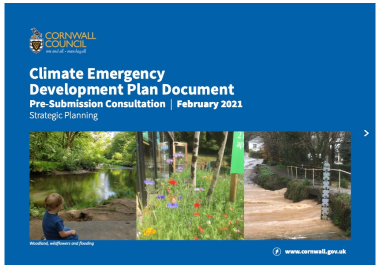
File Ref: PINS/ F0114/429/7

Selected extracts of the Planning Inspector's report on the examination of B&NES's Local Plan partial update (December 2022)

*79. Policy SCR6 is concerned with sustainable construction for new residential buildings, aiming to achieve zero operational emissions by reducing heat and power demand and supplying all energy demand through onsite renewables. The Policy includes **limits on space heating and total energy use**, taking an **energy based approach**, rather than being based upon carbon reduction as per the Building Regulations. The approach taken in the Plan to energy usage applies to **both regulated and non-regulated energy use**, which is a further difference to that taken in the Building Regulations which are concerned only with regulated energy use.*

85. I therefore consider that the relevance of the WMS 2015 to assessing the soundness of the Policy has been reduced significantly. […] For the reasons set out, that whilst I give the WMS 2015 some weight, any inconsistency with it, given that it has been overtaken by events, does not lead me to conclude that Policy SCR6 is unsound, nor inconsistent with relevant national policies.

*86. **I am satisfied that the energy efficiency standards set out in Policy SCR6 are justified and that they would not threaten deliverability or viability of housing development***



Net Zero policy adopted by Cornwall Council based on energy metrics

Policy SEC1 – Sustainable Energy and Construction

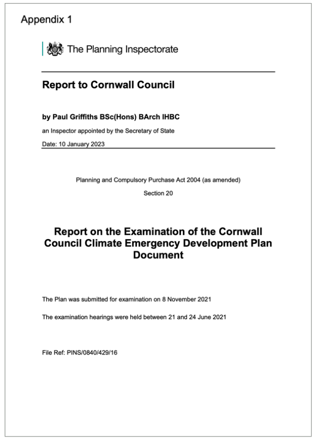
Development proposals will be required to demonstrate how they have implemented the principles and requirements set out in the policy below.

2b. New Development – Residential

Residential development proposals will be required to achieve Net Zero Carbon and submit an 'Energy and Carbon Statement' that demonstrates how the proposal will achieve:

- Space heating demand less than 30kWh/m2/annum;
- Total energy use less than 40kWh/m2/annum; and
- On-site renewable generation to match the total energy use, with a preference for roof mounted solar PV.

Where the use of onsite renewables to match total energy consumption is demonstrated to be not technically feasible (for example with apartments) or economically viable, renewable energy generation should be maximised as much as possible; and/or connection to an existing or proposed district energy network; or where this is not possible the residual carbon offset by a contribution to Cornwall Council's offset fund.


Appendix 1

The Planning Inspectorate

Report to Cornwall Council

by Paul Griffiths BSc(Hons) BArch IHBC

an Inspector appointed by the Secretary of State

Date: 10 January 2023

Planning and Compulsory Purchase Act 2004 (as amended)

Section 20

Report on the Examination of the Cornwall Council Climate Emergency Development Plan Document

The Plan was submitted for examination on 8 November 2021

The examination hearings were held between 21 and 24 June 2021

File Ref: PINS/0840/429/16

Selected extracts of the Planning Inspector's report on the examination of Cornwall Council's Climate Emergency Development Plan Document (January 2023)

Cornwall Council's Climate Emergency DPD has successfully completed the examination process in January 2023.

Relevant extracts of the Planning Inspector's report include the following:

172. […] the Plan requires residential development proposals to achieve net zero carbon with applications to be accompanied by an Energy and Carbon Statement demonstrating how the proposal will achieve: space heating demand of less that 30kWh per square metre per annum; total energy consumption of less than 40kWh per square metre per annum; and on-site renewable energy generation to match the total energy consumption with roof mounted solar PV as a preference. It goes on to say that where meeting onsite energy demands through renewables is not possible on-site technically, or not viable, renewable energy generation on-site should be maximised and/or a connection to an existing or proposed District Heating Network facilitated. If this is not possible, then the residual carbon should be offset through a contribution to Cornwall Council's offset fund.

*174. Broadly, as set out above, **this approach is soundly based and justified**. There is however a need to make some parts of these requirements more transparent given that the policy is aimed at energy use, not carbon emissions. First, given the approach taken the initial part of this policy element needs to say that what is required is an Energy Statement rather than an Energy and Carbon Statement. Second, and linked to that point, it needs to set out that it is the residual energy that must be offset by a contribution rather than the residual carbon. These changes are needed to make the policy effective.*

Conclusion

*182. With these MMs, my view is that **the requirements of Policy SEC1 are acceptable in the light of what the Plan aims to achieve**.*

3.0

Definition of Net Zero Carbon buildings

There is an industry definition of Net Zero carbon buildings in operation

Net Zero carbon budlings use energy much more efficiently, do not use fossil fuels and are powered by renewable energy sources. Emphasis must also be placed on reducing their embodied carbon during construction and their long-term environmental impact, including demolition and re-use.

A growing evidence base has led to an industry definition

A significant amount of work has been undertaken over the last five years to define and articulate the detailed requirements of a Net Zero Carbon building. This includes the work undertaken and published by the Climate Change Committee, the Royal Institute of British Architects (RIBA), the Chartered Institute of Building Services (CIBSE), the UK Green Building Council (UKGBC), the Better Buildings Partnership (BBP), the Passivhaus Trust, the Good Homes Alliance (GHA) and the London Energy Transformation Initiative (LETI).

This work has led to various standards and guidance that are very similar in their approach, setting similar metrics and Key Performance Indicators (KPIs) that include:

- Energy Use Intensity (EUI) targets (kWh/m^2/yr)
- Embodied carbon targets (kgCO_2/m$_2$ either upfront embodied carbon (A1-A5) , lifecycle embodied carbon (A1-C4) or both.

Several criteria form the definition

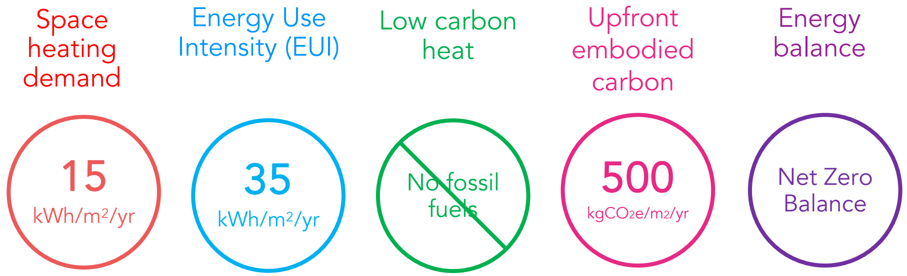
We have learnt over the last 15 years that delivering high-quality energy efficient and low carbon buildings requires addressing several aspects. It is not one-dimensional, hence why the delivery of Net Zero carbon buildings relies on meeting requirements in different areas, including quality assurance to deliver performance in practice.

Future evolution of this definition

It is possible that the definition of Net Zero Carbon buildings will evolve over time, for example as a result of the work currently undertaken by the building industry on the Net Zero Carbon building standard. This evidence base has sought to be consistent with this work.

Industry publications on Net Zero

Key Performance Indicators: Net Zero Carbon homes



The five target key performance indicators (KPIs) that define a net zero carbon (NZC) home according to the current industry definition (Source: LETI-UKGBC)

The principles of Net Zero Carbon in operation

Net Zero carbon buildings in operation are supported by five core principles.

1 - Energy efficiency

Buildings use energy for heating, hot water, ventilation, lighting, cooking and appliances. All energy use within the building must be considered, i.e. not only "regulated" energy use. The efficient use of energy reduces both carbon emissions and running costs.

2 - Low carbon heat

Low carbon heat is an essential feature of Net Zero carbon buildings. All new buildings should be built with a low carbon heating system and must not connect to the gas network or, more generally, use fossil fuels on-site.

3 - Renewable energy generation

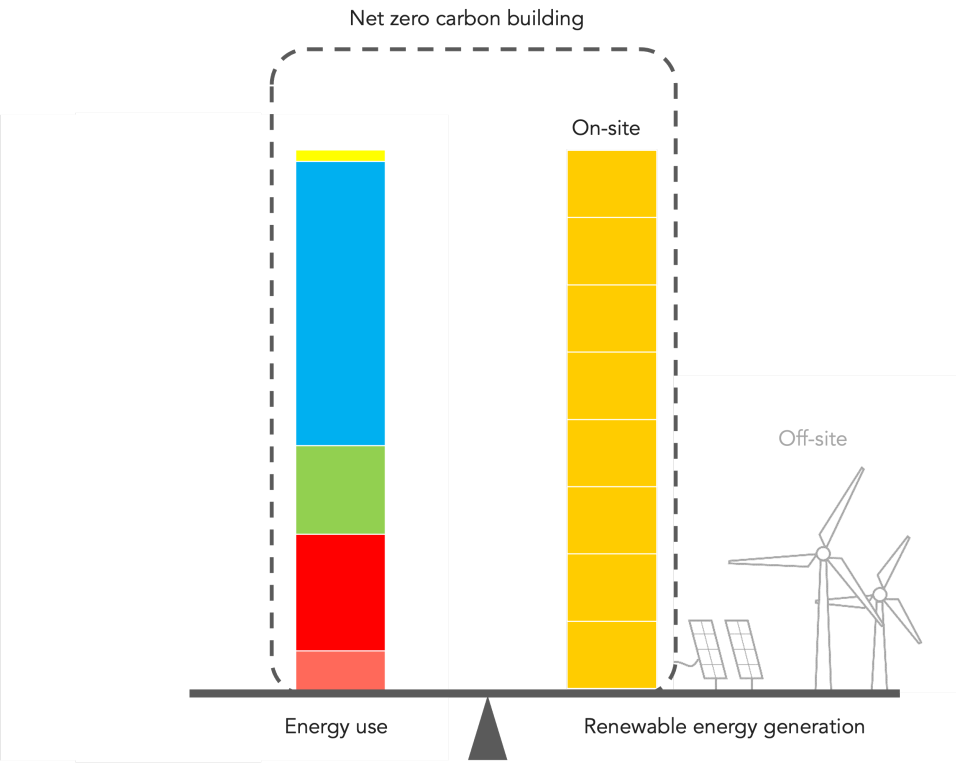
New buildings should seek to add at least as much renewable energy generation to the energy system as the energy they will use in an annual basis. In Cotswold, solar photovoltaic (PV) panels will be the renewable energy system to deliver this objective.

4 - Embodied carbon

Operational carbon is only part of the story. Net Zero carbon buildings should also minimise embodied carbon in materials and their impact throughout their lifecycle, including demolition.

5 - No carbon offsetting and a very limited role for energy offsetting

The Climate Change Committee is clear: offsetting must have a very limited and defined role if we are to achieve Net Zero by 2050, and it should not be relied on as a key mechanism to decarbonise new buildings. Its role should therefore be clearly defined and restricted.



To achieve net zero carbon in a new building, the energy consumption of a building should be matched by renewable energy generation. The example shown is for an energy efficient house that is heated by a heat pump. Each yellow block represents the energy produced by a single solar photovoltaic panel. In this case, off-site generation is not required to achieve net zero.

How design plays a role in achieving Net Zero Carbon

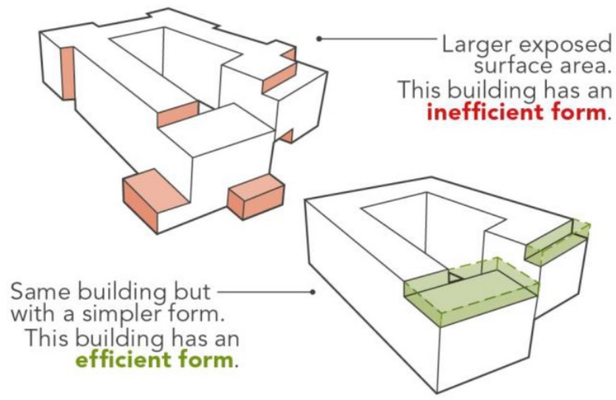
The importance of the design process

In order to achieve Net Zero Carbon, some simple design steps and processes can help to deliver an ultra-low energy building. This goes beyond best practice U-values, efficient systems and adding renewables onto to roofs. More emphasis needs to be placed on the early building design decisions and on the way, buildings are modelled at design stage (using predictive modelling tools such as PHPP or CIBSE TM54). A building's form, orientation and window proportions are all aspects that do not add extra construction cost, but if optimised within the design can significantly improve the building's efficiency.

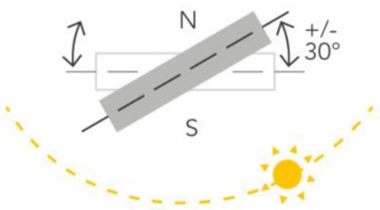
Ultra-low energy building fabric can be defined as meeting a set space heating demand. This requires careful consideration to be given to the building form to reduce heat loss areas and to the architectural features and associated junctions for reduced thermal bridging. Orientation of homes and facade design need to carefully balance heat loss and heat gain, with shading considered to reduce overheating. This early rationalisation also means that the buildings are simpler and more cost effective to build.

These design measures go hand in hand with low U-values, high levels of airtightness and an efficient mechanical ventilation system with heat recovery (MVHR).

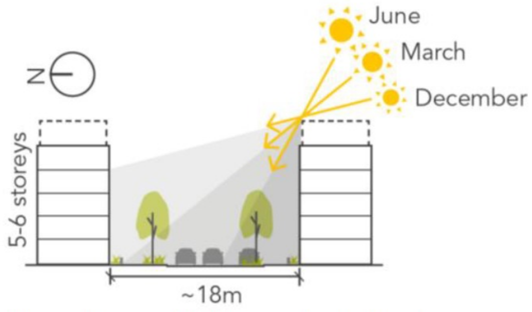
For more details refer to the Net Zero Carbon Toolkit prepared by Cotswold Council.



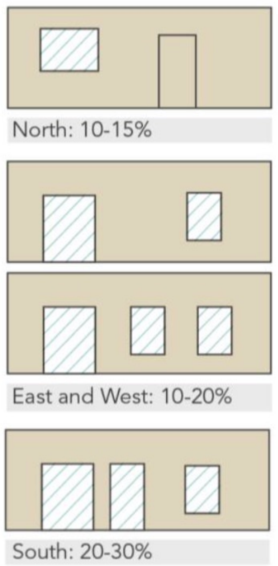
Designing the building to have an efficient form



Elevations facing +/- 30° south will benefit from useful solar gains in the winter



Allow a distance of 1-1.5 times the building's height between buildings



Recommended glazing percentages of each external facade

Extract from the Net Zero Carbon Toolkit.

4.0

Current policy is not fit for purpose to deliver Net Zero Carbon buildings

The anticipated ambition from current building regulations is not enough

Building regulations set a minimum standard, not Net Zero Carbon

Building regulations are not delivering the rapid carbon reductions needed in buildings. Part L, the aspect of building regulations associated with energy and carbon, was updated in June 2022 with a subsequential likely change like with the Future Homes and Buildings Standard in 2025. Part L 2021 is not delivering Net Zero carbon dwellings for a number of reasons:

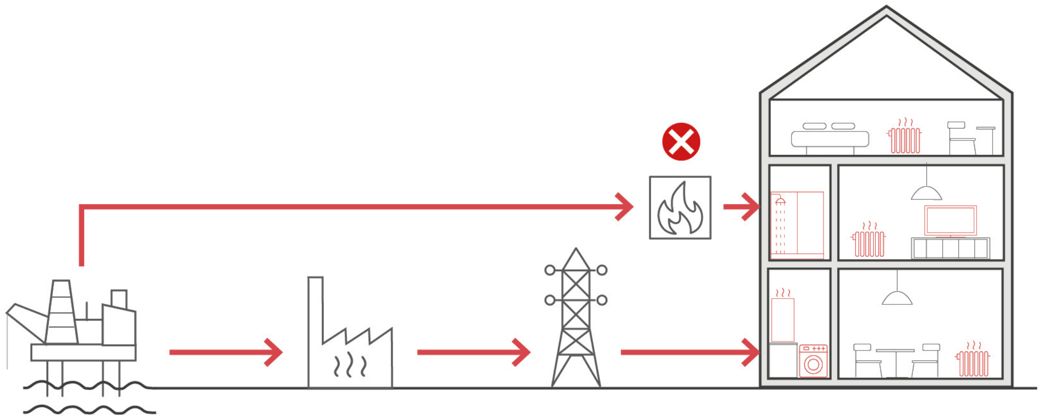
- The use of gas boilers is still permitted.
- The level of energy efficiency required is not consistent with what the Committee on Climate Change recommends.
- Solar PVs may not be necessary to comply with Part L 2021 of the Building Regulations, and when they are a small amount may be sufficient. It is a missed opportunity to generate much needed renewable energy and displace gas consumption from power stations.

Building regulations do not account for all energy consumption

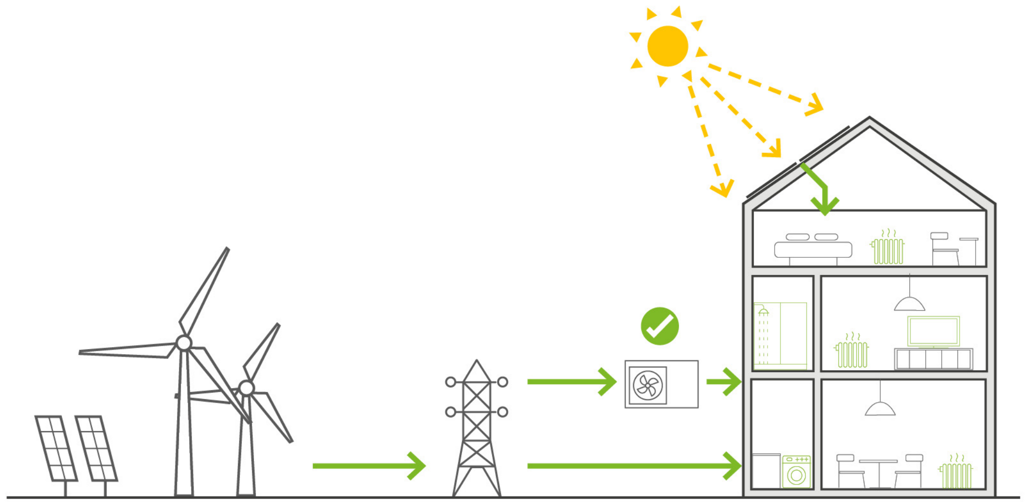
Building regulations calculations for Part L include only some of the energy consumption of a building: heating, cooling, hot water, lighting, pumps and fans. They does not cover energy used for cooking and appliances. This can represent a large proportion of energy use – particularly for low energy buildings.

The performance gap leads to increased emissions

There is a significant amount of evidence that actual building energy use, and therefore carbon emissions, are much higher than the pre-planning estimates. This is mainly due to inadequate energy modelling (tools and software used are actually not meant to predict energy use), poor quality of construction, commissioning and handover. The planning system put in place by Cotswold District Council should seek to reduce the performance gap to ensure that the targeted energy performance will be delivered during detailed design and construction.



Current building regulations enable choices which are not compatible with Net Zero.
For example, gas boilers are a heating system which is still being allowed.



Current building regulations do not require sufficient efforts in key areas.
For example, roofs of housing developments are generally ideal for solar PV panels. However, this is not mandated and very often not necessary to comply with building regulations.

The % improvement over Part L: A non-satisfactory metric for Net Zero Carbon buildings

A metric which cannot be measured post-completion

Current policy is often based on a required improvement over a baseline: the ‘notional building’. The notional building has the same shape, orientation and, up to a point, window proportions as the actual building. For clarity, the notional building is fictional and is used only for building regulations purposes.

The % improvement over a notional building is an intangible, relative performance requirement that cannot be measured once a building is occupied. This causes confusion and inability to compare the actual performance of different buildings. It makes post-construction verification and learning from a feedback loop more complicated.

A more efficient building form is not incentivised

Improving the design of a building by reducing the extent of heat loss areas, the number of complex junctions, and by optimising elevation design for winter solar gains are widely considered as essential components of an energy efficient design. However, comparing a development to its own notional building does not reward efficient design as it essentially neutralises the impact of these measures. Moreover, the use of a notional building does not penalise inefficient building designs and enables these to achieve similar levels of performance as good design practice, due to the use of the wrong metric.

Moving to absolute metrics: a recommended focus on outcomes

Absolute targets that are directly comparable across all designs are recommended to deliver Net Zero on a Council-wide scale.

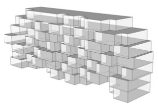
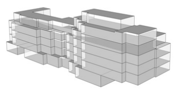
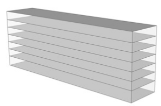
% improvement over notional building

- ✗ Is not a ‘physical’ metric
- ✗ Is a concept only experts can understand
- ✗ Cannot be checked during operation
- ✗ Cannot be used to ‘close the loop’ and improve the system over time
- ✗ Does not reward good design e.g. form

$kWh/m^2/yr$ at the meter (EUI)

- ✓ Is a ‘physical’ metric which can be measured
- ✓ Can be understood by all professionals, and most consumers
- ✓ Can be checked against in-use data
- ✓ Can be checked to improve SAP prediction of energy use over time

The relative metric used by current building regulations and planning policy (i.e. % improvement over Part L) has a number of unintended consequences which hinder the continuous improvement of building design, consumer trust and performance outcomes.

		Improvement over Part L (%) SAP	Space heating demand ($kWh/m^2/yr$) PHPP
High form factor		35%	26
Medium form factor		35%	20
Low form factor		37%	13

A more efficient form factor can significantly reduce space heating demand. Unfortunately, Part L does not reward designs with more efficient form. The % improvement over Part L of the three buildings above is broadly similar despite the space heating demand being up to 50% smaller for the lowest form factor.

Predictive energy modelling is required

Part L compliance modelling

SAP (domestic) and the National Calculation Methodology (NCM) (non-domestic) are the calculation methodologies used to demonstrate compliance with Part L of the Building Regulations.

SAP (Standard Assessment Procedure) is used through the associated SAP software and the NCM (National Calculation Methodology) through SBEM and Dynamic Simulation Modelling (DSM) tools.

However, until now, these Part L assessment methodologies were developed only to check compliance with Building Regulations. They were never meant to perform key functions that are required to deliver Net Zero carbon buildings, and most importantly they were not meant to predict future energy use accurately. There is a large consensus on this in the building industry.

Why predicting energy use is necessary

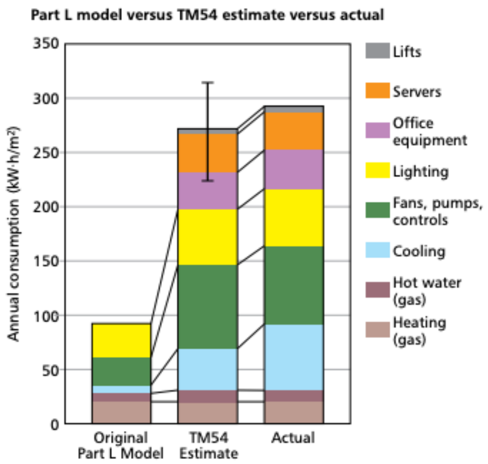
The accuracy of energy modelling prediction is important to ensure it provides a reasonable indication of future energy use. While behaviour of the users may vary once a building is occupied, predictive energy modelling can be used to reliably estimate energy use and to drive suitable design and construction decisions.

For domestic buildings, the PHPP methodology, an excel based tool, have been shown to predict energy use more accurately than the current version of SAP.

For non-domestic buildings, predictive energy modelling using the methodology set out in CIBSE Technical Memorandum 54 (TM54) allows estimation of the operational energy for all end uses of a building. IESVE, TAS and PHPP are three energy modelling packages that can be used to carry out TM54 assessments.

	Part L compliance modelling	Predictive energy modelling
Domestic	SAP 10.2 (Part L1A)	PHPP
Non-domestic	NCM (Part L2A)	PHPP or DSM (TM54)

There is a significant difference between Part L modelling currently used to demonstrate compliance with planning policy and predicted energy use modelling.



In the UK, energy models are used at the design stage to compare design options and to check compliance with Building Regulations. ***These energy models are not intended as predictions of energy use but are sometimes mistakenly used as such.***

In some other countries, total energy use at the design stage is estimated through voluntary standards. For example, the Australian NABERS (a building rating system) encourages the estimation of energy use at the design stage and provides guidance for designers/modellers.

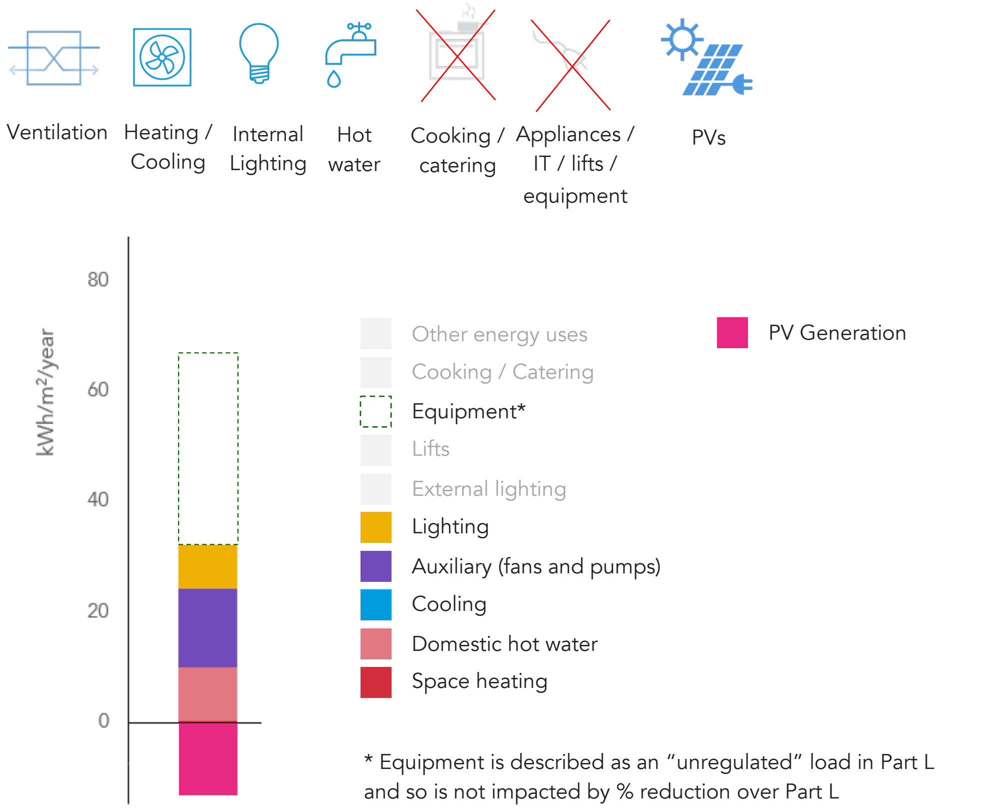
Extracts of CIBSE Technical Memorandum 54 (TM54): Evaluating operational energy performance of buildings at the design stage

The difference between Part L compliance modelling and Predictive energy modelling

Part L compliance energy modelling

Energy use

Renewable generation

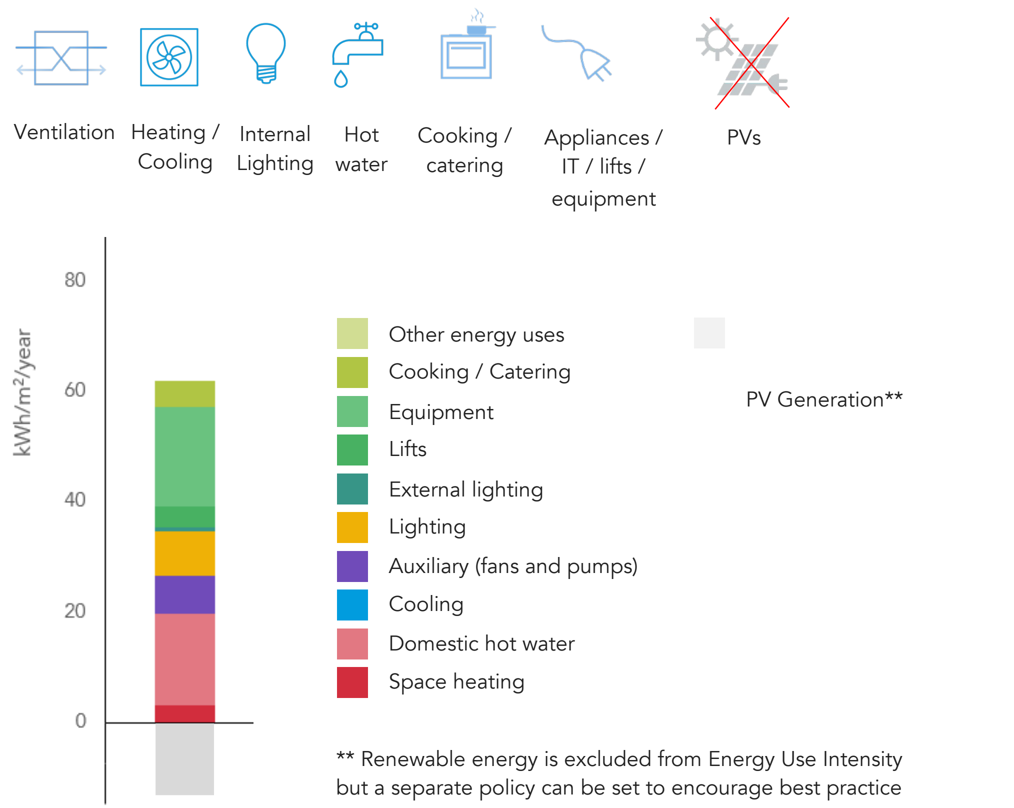


Energy uses assessed by a typical Part L compliance energy model

Predictive energy modelling

Energy use

Renewable generation



Energy uses assessed by a typical predictive energy model

Note: *the Part L software can assess unregulated energy use and this assessment can be used for 'be seen'. However, this is a standard assessment which does not reflect the actual building. And as it is not considered in any Part L / policy / Be seen target there is no incentive to reduce it.*

5.0

Proposed Net Zero Carbon new building policies for the Cotswold District Council's new Local Plan

Policy 1 | Overarching policy

Introduction

This section details policy recommendations for Cotswold District Council's new Local Plan in terms of operational energy and carbon requirements for new buildings. For each policy, a summary justification is provided along with the proposed policy wording.

Recommended policy 1 (overarching policy)

Net Zero Carbon new buildings

New buildings should be designed and constructed to be Net Zero carbon in operation to enable Cotswold District Council to stay within challenging remaining carbon budgets. This is in line with the recommendations of the Climate Change Committee, the London Energy Transformation Initiative (LETI), the UK Green Building Council (UKGBC) and the Royal Institute of British Architects (RIBA).

Proposed policy wording

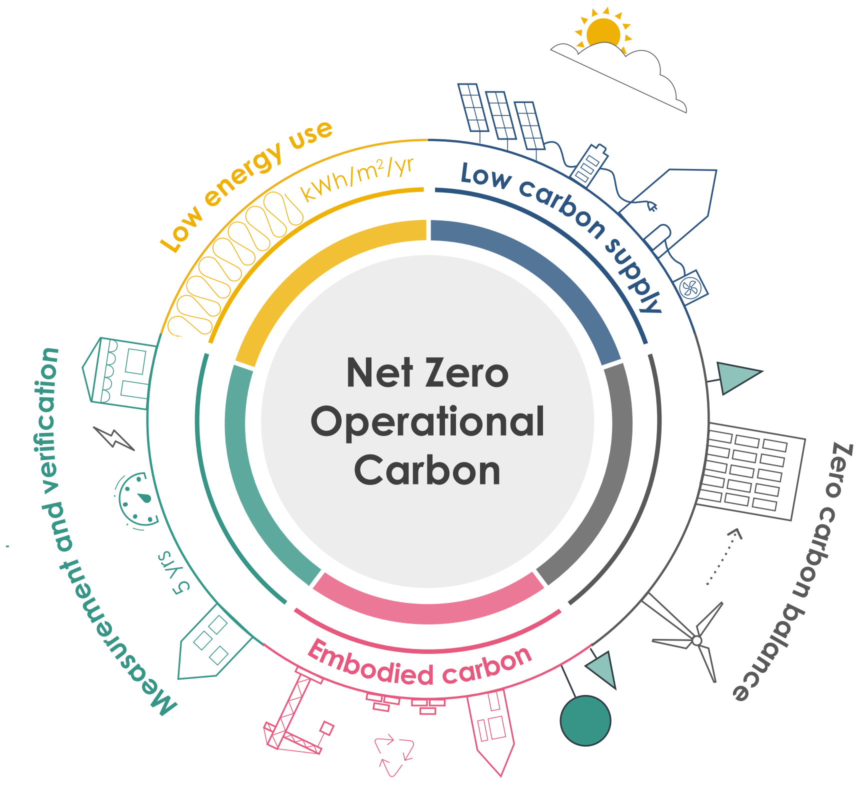
All new buildings should be designed and built to be Net Zero Carbon in operation. They should be ultra-low energy buildings, use low carbon heat, contribute to the generation of renewable energy on-site and be constructed with low levels of embodied carbon.

This is an overarching policy. Compliance with it relies on compliance with the following policies:

- Policy 2: Space heating demand.
- Policy 3: Energy Use Intensity (EUI).
- Policy 4: Fossil fuel free.
- Policy 5: On-site renewable energy generation
- Policy 6: Assured energy performance
- Policy 7: Energy offsetting (as last resort)

Embodied carbon policies are included in a separate document.

Buildings must also comply with all requirements of the Building Regulations Part L (2021).



Extract from the current definition of Net Zero Carbon new buildings.

Net zero operational carbon must cover all energy use within a building (both "regulated" and "unregulated").

Policy 2 I Space heating demand

Recommended policy 2

Net zero carbon new buildings: space heating demand

The space heating demand is the amount of heat energy needed to heat a home over a year and is expressed in $kWh/m^2/yr$. It is a measure of the thermal efficiency of the building elements.

Various design and specification decisions affect space heating demand including building form and orientation, insulation, air-tightness, windows and doors and the type of ventilation system.

The Climate Change Committee recommends a space heating demand of less than 15-20 $kWh/m^2/yr$ for new homes. This recommendation is also in line with the recommendations of the Royal Institute of British Architects (RIBA), the Low Energy Transformation Initiative (LETI) and the UK Green Building Council (UKGBC).

As a dwelling with a low space heating demand would lose heat very slowly, it will make it easier for the wider energy system to deliver energy in a flexible way, helping to maximise the contribution from renewable energy and reduce energy cost benefits for the residents.

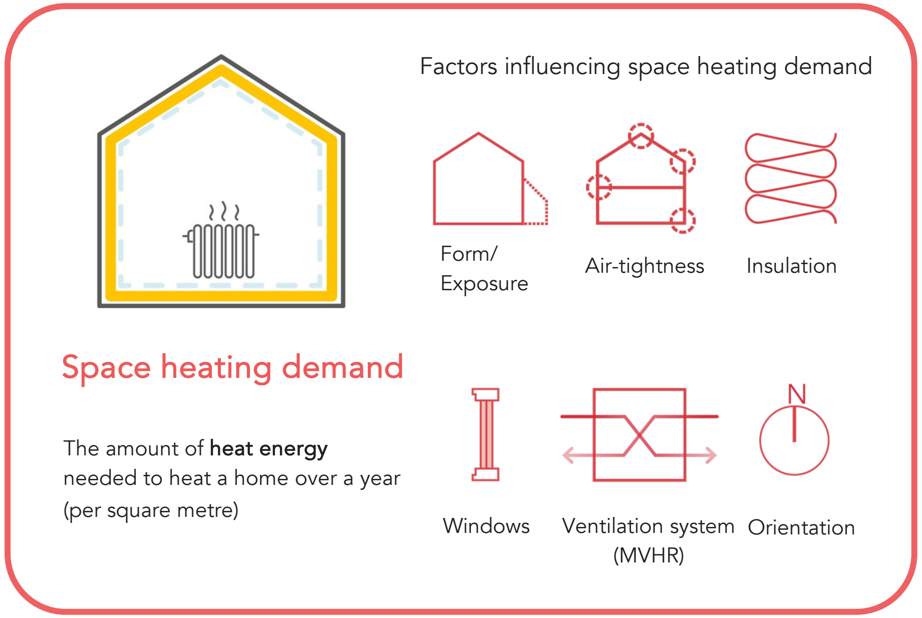
Proposed policy wording

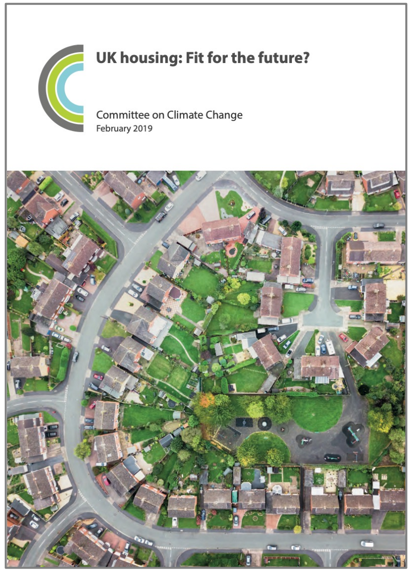
- All domestic buildings, apart form bungalows, should achieve a space heating demand of less than 15-20 $kWh/m^2_{GIA}/yr$.
- Bungalows, should aim to achieve a space heating demand of less than 30 $kWh/m^2_{GIA}/yr$.

Applicants must undertake predictive energy modelling to demonstrate compliance.

Policies for extension and building alterations are included in a separate document.

** A description of bungalows is included in Section 6.*





The Climate Change Committee has published a report in 2019 named 'UK housing – fit for the future?'. The report highlights the need to build new buildings with 'ultra-low' levels of energy use.

It makes a specific reference to space heating demand and recommends a maximum of 15-20 kWh/m2/yr for new dwellings.

For reference, Passivhaus requires 15 $kWh/m^2/yr$, and most new domestic buildings have a heating demand of 40-120 $kWh/m^2/yr$.

Policy 3 | Energy use intensity

Recommended policy 3

Net zero carbon new buildings: Energy Use Intensity (EUI)

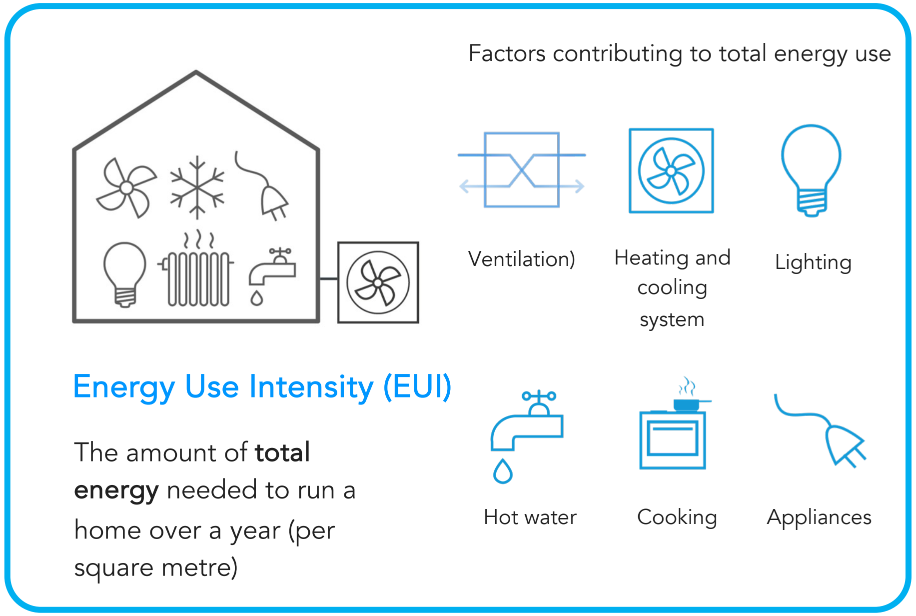
For new buildings to be compliant with our climate change targets, they need to use a total amount of energy which is small enough so that it can be generated entirely, on an annual basis, with renewable energy and low carbon energy sources. Reducing total energy use is also beneficial as it would directly reduce energy costs for residents and building users.

The EUI metric is also very beneficial as it can be measured post-construction, therefore helping to drive down the performance gap which is a significant issue in the construction industry.

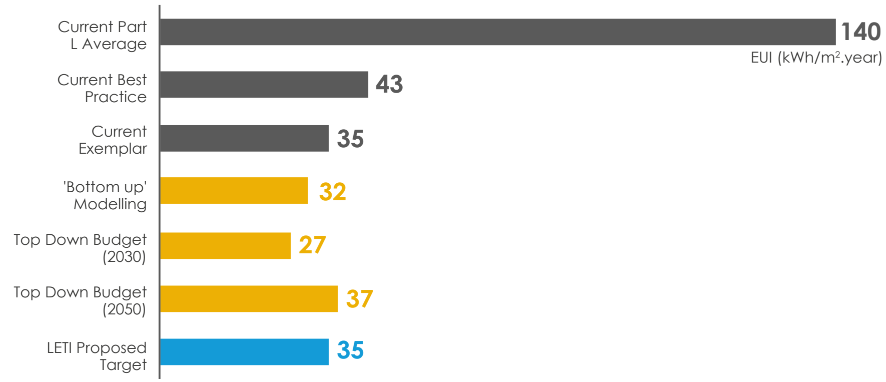
Proposed policy wording

- **Residential:** All dwellings should achieve an Energy Use Intensity (EUI) of no more than 35 kWh/m$^2_{GIA}$/yr.
- **Non-residential:** Non-domestic buildings should achieve an Energy Use Intensity (EUI) of no more than the following (where technically feasible) by building type or nearest equivalent:
    - o Warehouses and light industrial units (heated): 35 kWh/m$^2_{GIA}$/yr
    - o Student/keyworker accommodation, care homes: 35 kWh/m$^2_{GIA}$/yr
    - o Offices, retail, HE teaching facilities, GP surgery: 70 kWh/m$^2_{GIA}$/yr
    - o Schools: 65 kWh/m$^2_{GIA}$/yr

Applicants must undertake predictive energy modelling to demonstrate compliance, using an approved software and approach.



For more information about the EU metric, please refer to Appendix 1.



LETI residential top-down analysis taken from LETI Climate Emergency Design Guide

LETI has undertaken some top-down and bottom-up analysis establishing which levels of total energy use (or Energy Use Intensity – EUI) would be both achievable and compatible with the level of renewable energy generation likely to be available in the UK by 2050.

Policy 4 | No fossil fuel use

Recommended policy 4

Net zero carbon new buildings: no fossil fuel use

New buildings cannot continue to burn fossil fuels for heating if Cotswold District Council is to stay within carbon budgets. Low carbon heat is therefore an essential component of a Net Zero Carbon building and fossil fuels shall not be used on-site to provide heating or cooling.

Low carbon alternatives to fossil fuels that are currently available generally use electricity. Electricity can be provided through on-site renewables and through grid electricity, which is becoming increasingly decarbonised. The use of electricity for heating and cooling would also benefit air quality as there would be no local emissions. However, it is important that energy use is limited to reduce the burden on the national grid in the wider context of electrification of transport and buildings.

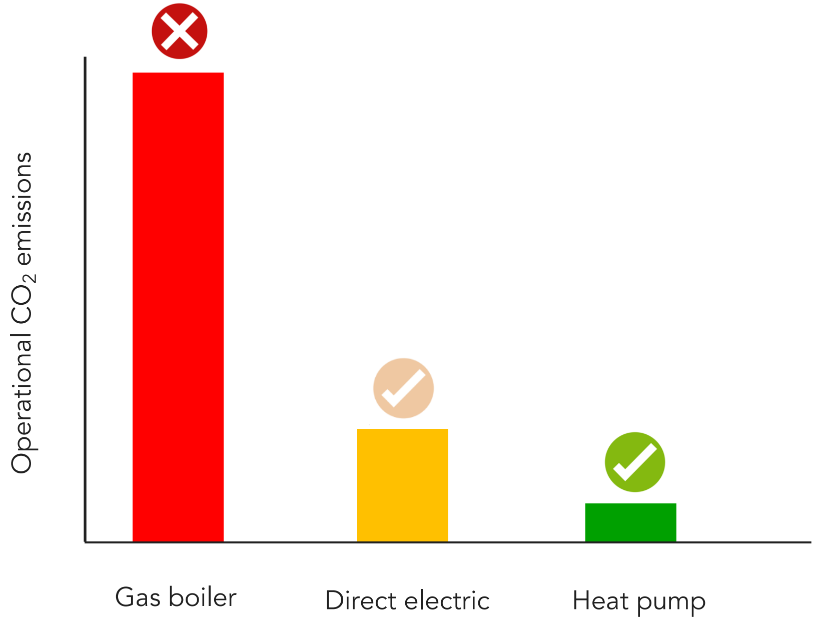
Heat pumps can provide both space heating and domestic hot water and can serve individual homes or communal heating systems. The key benefit of heat pumps is their efficiency. Efficiencies vary but are typically around 250-300% for an Air Source Heat Pump. Heat sources can include outside air, the ground or a local water source.

Direct electric heating systems convert electricity directly into heat through resistive heating. It is typically 100% efficient. When direct electric is used it is crucial to use an independently certified assured performance standard that limits space heating demand (e.g. Passivhaus), which reduces the risk of high energy bills.

Sustainable green hydrogen is not currently a viable option.

Proposed policy wording

- No new developments shall be connected to the gas grid.
- Fossil fuels shall not be used on-site to provide space heating, cooling, domestic hot water or catering.
- Larger scale combustion of biomass for heat or electricity generation is discouraged unless paired with carbon capture and storage.



The choice of heating system will affect operational CO_2 emissions over a long time. Electric forms of heating (direct electric and heat pumps) will emit a fraction of a gas boiler carbon emissions.

The graph above shows a comparison of the average emissions of different types of heating applied to the same building (no changes on the building fabric) over a period between 2022 and 2050.

Policy 5 | On-site renewable energy

Recommended policy 5

Net zero carbon new buildings: On-site renewable energy generation

New buildings should contribute to the significant increase in renewable energy generation required between now and 2050.

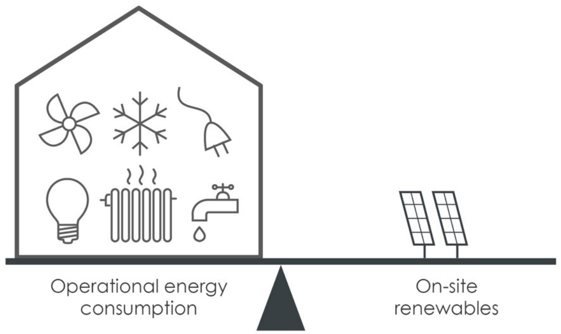
The simplest way to work towards the overall objective of a balance between total energy use and renewable energy generation for new buildings at a system level is to seek to achieve this balance at the site level. An additional advantage will be the generation of 'free' electricity close to its point of use, helping to deliver significant energy cost savings for residents and building users.

Proposed policy wording

- Renewable energy should be generated on-site for all new developments.
- As a minimum, the amount of energy generated in a year must be:
  - at least 80 $kWh/m^2_{building\ footprint}$ per year* for all building types
  - at least 120 $kWh/m^2_{building\ footprint}$ per year for industrial buildings

  (measured in per square meter of building footprint)
- The amount of energy generated in a year should match or exceed the predicted annual energy demand of the building, i.e. Renewable energy generation ($kWh/m^2/yr$) = or > EUI ($kWh/m^2/yr$).
- When this is not technically possible and suitably justified, the applicant should fund renewable energy generation (equivalent to the shortfall) elsewhere in the District (see Policy 7).

* This evidence base shows that this level of generation is deliverable for typical new development whilst enabling some roof space to be used for other purposes.

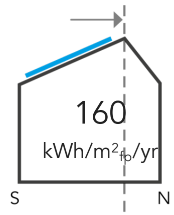


Energy balance

The amount of renewable energy generated in a year matches should match or exceed the EUI

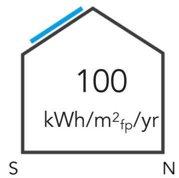
A key component of a net zero carbon building is achieving an energy balance – the amount of renewable energy generated in a year matches the energy used by the building in a year.

Pitched Roof



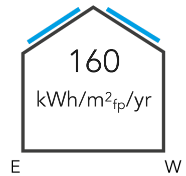
North South

Asymmetric pitch roof with a majority south facing roof



North South

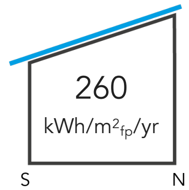
Pitch roof with a south facing roof



East West

Pitch roof with a majority east/west facing roof

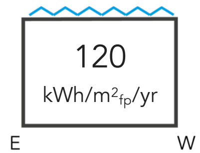
Monopitch Roof



North South

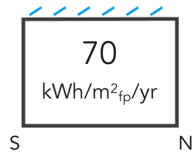
Monopitch roof with a majority south facing roof

Flat Roof



East West

Flat roof with a east/west concertina PV array



North South

Flat roof with an angled south PV array

Roof design can be optimised to maximise energy output from photovoltaics. A useful indicator of this is expressed in kWh generated per m² of building footprint per year ($kWh/m^2_{fp}/yr$)

Policy 6 | Assured energy performance

Recommended policy 6

Net zero carbon new buildings: Assured energy performance

For the Net Zero Carbon buildings policy to deliver its benefits in practice, it is important that new buildings deliver their intended performance. Unfortunately, the actual energy performance of buildings is very often much worse than anticipated at the planning stage. This difference is commonly referred to as ‘the Performance Gap’. The Zero Carbon Hub concluded in their Evidence Review Report in 2014 that a compliance process focused on design rather than as built performance is a key contributor to the performance gap.

Excellent design and detailing need to be matched by high quality construction and commissioning in order for the ‘performance gap’ between the design and actual in-use energy to be reduced. This can be achieved by energy performance construction quality assurance schemes such as the Passivhaus standard or the AECB Building standards.

Good examples of insulation installed on site, showing methods to eliminate gaps (wedging and overfilling). Left: Goldsmith street © Etude, Right: © Green building store.

Proposed policy wording

- All developments (domestic and non-domestic) must demonstrate and commit to the use of an assured performance method to ensure that the buildings' operational energy performance will meet the design intentions.
- All developments should monitor their total energy use and renewable energy generation and submit the annual figures to Cotswold District Council for the first 5 years of operation.

Recommended policy 6

Net zero carbon new buildings: Energy offsetting (as last resort)

The Climate Change Committee is clear: offsetting must have a very limited and defined role if we are to achieve Net Zero by 2050. Its role in the Local Plan as part of the Net zero carbon new buildings suite of policies should therefore be limited to a mechanism which enables buildings which **cannot technically achieve net zero energy balance on site** to be 'deemed compliant' with planning policy.

Our recommendation is to limit the role and scope of the offset mechanism to a 'renewable energy offset' with the offset price could be expressed in £/kWh instead of £/tCO_2. This would make it independent from carbon factor changes.

Proposed policy wording

Offsetting will only be accepted as a means to achieving planning policy compliance a last resort if the building is compliant with all other Net Zero carbon buildings policies and in particular if the following conditions have been met:

- The proposed building must not use fossil fuels on-site.
- It must have a level of space heating demand and Energy Use Intensity (EUI) compliant with the Local Plan.
- On-site renewable energy generation (e.g. through PVs) has been maximised and achieves at least 80 kWh/$m^2_{\text{building footprint}}$ for all building types (and 120 kWh/$m^2_{\text{building footprint}}$ for industrial buildings).

In these circumstances, the applicant should establish the shortfall in renewable energy generation to enable the annual renewable energy generation to match the Energy Use Intensity in kWh. The applicant should pay into the Council's offset fund a sum of money equivalent to this shortfall.

Reduced operational energy consumption	**Achieve a Space Heating Demand and an Energy Use Intensity (EUI) lower than the levels required in the Local Plan** (e.g. 15 kWh/m^2_{GIA}/yr and 35 kWh/m^2_{GIA}/yr respectively for domestic buildings)	✓
Low carbon energy supply	**No gas connection or fossil fuel use on site** (or connection to heat networks using fossil fuels)	✓
On-site renewable energy generation	**Achieve a minimum electricity generation intensity compliant with the requirement in the local plan** (e.g. > 80-120kWh/$m^2_{\text{building footprint}}$/yr)	✓
Net Zero energy balance	**Annual balance of zero** for the whole development showing predicted energy use and renewable energy generation on-site.	✗ (offset role)

List of requirements an application would have to meet before being allowed to use offsetting as a planning compliance mechanism. It is proposed to restrict the offset mechanism to fund 'missing' PVs

6.0

Evidence base for Net Zero Carbon housing policies

Existing evidence base in support of proposed policies

The proposed policy approach has already been adopted

Other local authorities around England are integrating similar policies into their local plans or are already using them.

Cornwall Council, Bath and North East Somerset Council and Central Lincolnshire policies have passed inspections and are already adopted within their local plans. The technical and cost viability evidence base passed scrutiny at inspection. Other local councils, including Greater Cambridge, are in the process of updating their local plans to include similar policies.

All local authorities listed on this page have adopted, or are in the process of adopting, energy policies for buildings that embrace energy-based targets as opposed to CO_2 based targets.

Updating evidence for Cotswold District Council

The energy modelling and technical feasibility analysis for this evidence base for Cotswold District Council is built upon the modelling and results obtained for Cornwall Council. The specifications proposed have been adapted to reflect Cotswold District Council.

Additionally, the Technical Appendices developed for the Cornwall Council evidence base contain much detailed analysis on topics such as:

- Demonstration on Passivhaus Planning Package is currently the best method of assessing performance against policy KPIs.
- Correction factors for SAP outputs to make them more appropriate for assessing performance against policies.
- Calculating and modelling appliance electricity use.

The main report for the Cornwall Council Climate Emergency DPD update has been adapted and updated (including the energy models) for Cotswold District Council. The Technical Appendices are a useful source of evidence for justifying the approach to the proposed policies.

Local Authority	Policy title	Year	Comments
18 London Boroughs	Delivering net zero	2023	Non-domestic buildings and energy models used as the basis for Cotswold District Council evidence base.
Bath and North East Somerset	Bath and North East Somerset Local Plan Partial Update	2022	Re-used Cornwall energy modelling with updated cost data
Cornwall	Cornwall's Climate Emergency Development Plan	2021	Used as the basis for Cotswold District Council evidence base (residential), with updated energy models.
Central Lincolnshire	Central Lincolnshire Local Plan	2020	
Greater Cambridge	Greater Cambridge Local Plan: Net zero carbon evidence base	2020	

There are existing publicly available evidence bases produced for Local Authorities which use the same approach to energy in buildings policies.

Energy modelling I Building type selection

Building types

Three types of building that are typical for new developments in Cotswold were selected: a semi-detached house, a detached house, and a bungalow. Testing a selection of building types was important to ensure that the new housing policies function correctly across buildings with different attributes.

Heat loss form factor

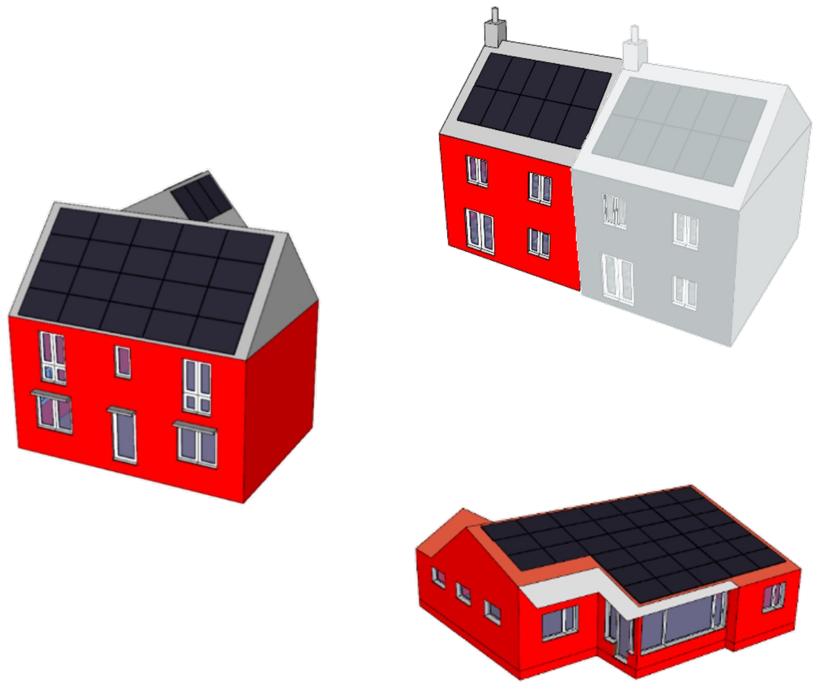
The heat loss form factor, often abbreviated to 'form factor', is the ratio of a building's heat loss area to its internal floor area. Buildings with a high form factor generally require higher levels of insulation and airtightness to reduce heat loss. They may also have greater thermal bridging if their form is more complex. The dwellings modelled covered a wide range of form factors, from 2.2 to 4.4.

Potential for solar PVs

The amount of roof area that is suitable for solar PV panels varies across different types of buildings. Single storey buildings such as bungalows typically have a large amount of roof area relative to their energy needs, whereas taller buildings with more complex roof shapes may have less area. The buildings modelled represented a range of roof designs.

Orientation

Limited sensitivity testing was carried out for building orientation. Due to the relatively modest window proportions, it was not found to have a significant impact on the space heating demand or total energy use. While renewable energy generation did vary with orientation, all policy compliant dwellings had more than enough roof area to achieve a net zero energy balance regardless of orientation.



A semi-detached house, a detached house, and a bungalow were modelled. With the exception of the bungalow, these were based on recent designs from large developers.

Energy modelling | Modelling scenarios

Four scenarios were modelled to represent the range of performance specifications that could be considered for the new planning policies. More detailed tables of assumptions used in the modelling are provided later in Appendix 3.

In developing our assumptions, we have tried to adopt the mindset of a developer, i.e. finding the simplest and most economic ways of complying with the policy requirement.

Scenario 1: Part L 2021

This scenario is based on the Part L 2021 notional building. We assume airtightness of $5m^3/m^2hr$ @50Pa and that ventilation is achieved mechanically without heat recovery. Part L compliance is achieved by use of waste water heat recovery and solar PV. A gas boiler is assumed to provide all heating. While buildings with gas boilers are not compliant with a net zero planning policy, it is important to understand and test the performance of such buildings that represent a baseline level of performance that can be expected to be delivered under Part L 2021.

Scenario 2: Part L 2025/FHS

This scenario is based on the Part L 2025 notional building specification provided by the government in their response to the Future Homes Standard Consultation. Insulation levels and window performance are increased close to that required for Passivhaus, however airtightness remains poor at $5m^3/m^2hr$ @50Pa, and no heat recovery ventilation is fitted. Shower drain wastewater heat recovery is dropped from the notional building, but a heat pump is added.

Scenario 3: Low energy

This scenario uses a Part L 2021 compliant fabric specification, with an improved airtightness of $1m^3/m^2hr$ @50Pa, and use of heat recovery ventilation to achieve a space heating demand of <30kWh/m^2/yr. Space heating and water heating is provided by a heat pump, which is required to achieve a total energy use intensity target of <40kWh/m^2/yr. Sufficient solar PV has been installed to achieve a net zero energy balance on site.

Scenario 4: Ultra-low energy

This scenario's bring fabric efficiency is in line with the Climate Change Committee's recommended 15-20kWh/m^2/yr range, and the total energy use in line with LETI and RIBA's recommended 35kWh/m^2/yr. Sufficient solar PV has been installed to achieve a net zero energy balance on site.

Semi-detached house | Introduction

Description

A single-family house build on two stories and sharing one common wall with the next house.

Building fabric

The property has a gross internal floor area of 93m². The main entrance faces the street to the North East, while the rear of the house faces to the South West and features a small garden. The property has typical glazing proportions and layout for this type of home. The form heat loss factor of 2.8 is within the expected range for a semi-detached home. Although the property has chimneys fitted, these are not assumed to be functional as this would prevent adequate airtightness being achieved.

Heating system

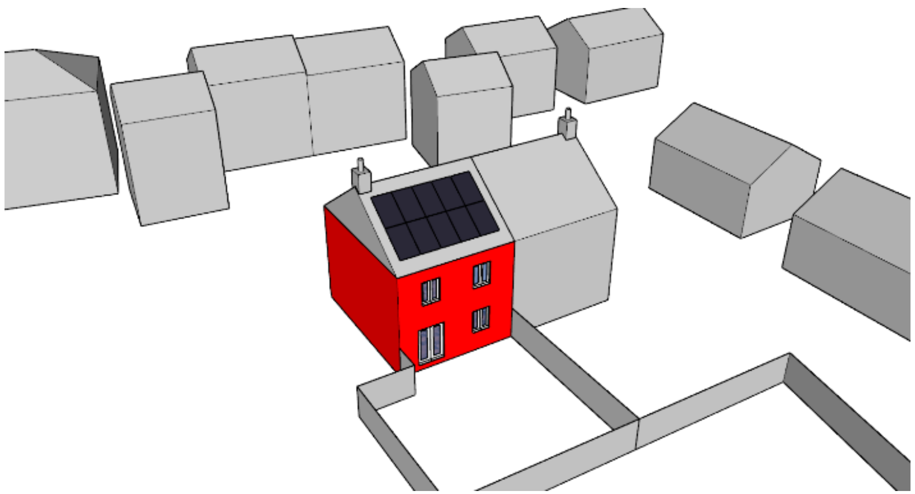
The baseline Part L 2021 scenario assumes use of a combi boiler, while the remaining scenarios assume use of an air-water heat pump. A cheaper air-air heat pump, or a ground source heat pump could also be used. Suitable heat emitters include radiators, or underfloor heating for scenarios with poorer fabric efficiency.

Solar PV

The property has more than enough space to achieve a net zero energy balance on-site in any orientation. As presented on plans, the South West roof has space for up to 15 solar panels, and if the property faced East-West, this could be doubled.

The number of panels required to achieve net zero under the proposed policy requirement is 7, which reduces to 6 for the future policy option with improved fabric efficiency.

A typical 3 bedroom semi-detached house was selected from a Wainhomes development.



A 3D model of the house and surrounding features was created in DesignPH 2.1.15 and used to calculate solar gains and shading for PHPP.

Semi-detached house I Energy modelling results

Space heating demand

Policy 2 requires all dwellings to achieve a space heating demand of less than 15-20 kWh/m$^2_{GIA}$/yr.

Scenario 4, demonstrates that with an ultra-low energy specification the semi-detached house could achieve a space heating demand of around 20 kWh/m²/yr. Best performance in all areas is required, including a fully insulated building fabric, the use of mechanical ventilation with heat recovery (MVHR), an air permeability of <0.6 m³/m².hr and triple glazing. A further 15-20% reduction could be achieved by improving junction design to reduce thermal bridging. Full specification is provided in Appendix 3.

Based on the above, it can be concluded that policy 2 is technically feasible for the semi-detached house using an ultra-low specification.

To factor potential challenges in policy implementation, a low energy scenario has been considered with a transitional net zero policy requirement of 30 kWh/m²/yr, if required. This target could be achieved in several ways, but all would require improved airtightness and use of MVHR and an air permeability of <1 m³/m².hr, which reduces heat loss so much that double glazing can be used, together with relaxed wall U-values.

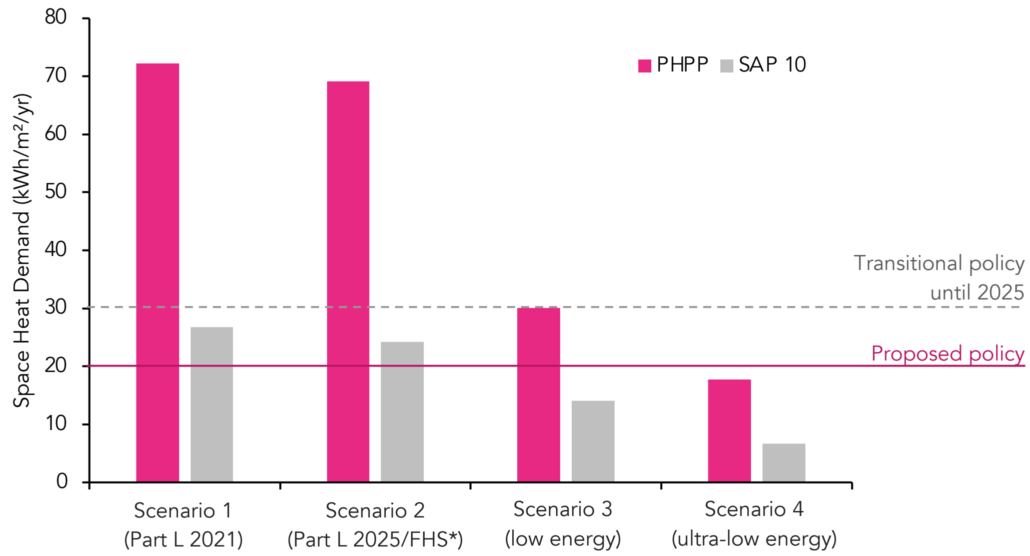
Energy Use Intensity (EUI)

Policy 3 requires all dwellings to achieve an Energy Use Intensity (EUI) of no more than 35 kWh/m$^2_{GIA}$/yr.

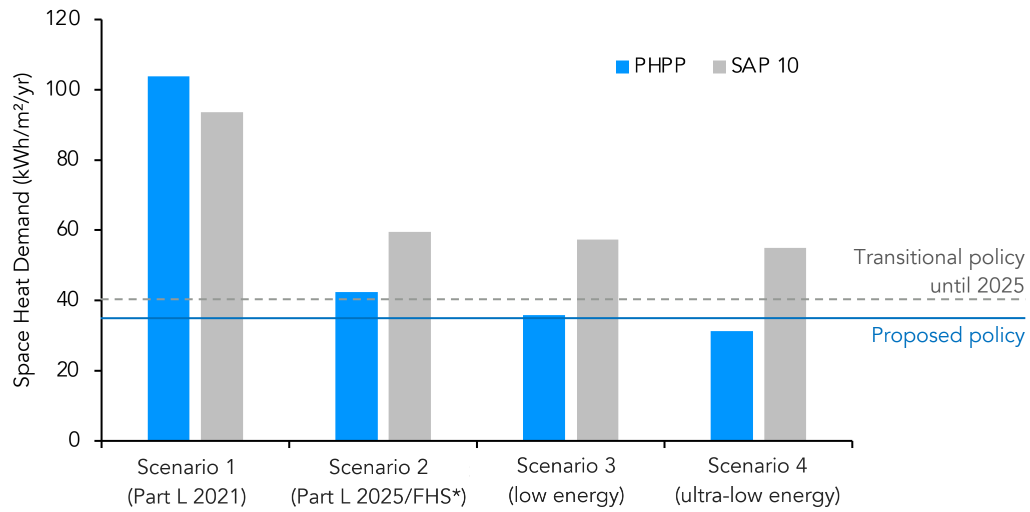
Energy modelling using PHPP software show that for this typology, both, low energy and ultra-low energy scenarios are compliant with the proposed policy requirement of 35 kWh/m²/yr, demonstrating the policy is feasible. If required, a transitional target of 40 kWh/m²/yr has been considered to factor implementation challenges.

Solar PV generation

Solar generation is not shown; however, the dwelling could easily be net energy positive for both, the proposed and transitional policies.



Space heating demand for the semi-detached house modelled in PHPP 10.4a and SAP 10.2



Total energy use for the semi-detached house modelled in PHPP 10.4a and SAP 10.2

Note: SAP 10 results are shown in both graphs for context, but discussion is based on PHPP results, as these provide more realistic results. See report page on correcting SAP 10 outputs for discussion of how SAP can be used to provide more reliable results.

Description

A stand-alone dwelling that does not share any outside walls with other houses or buildings.

Building fabric

The property has a gross internal floor area of 142m². The main entrance faces the street to the South, while the rear of the house faces to the North and features a small garden. The property is a typical developer spec detached house, with reasonable glazing proportions and layout. The form heat loss factor of 3.0 is fairly poor but is as expected for a small detached home. As a result, good levels of insulation are required to achieve the required space heating demand.

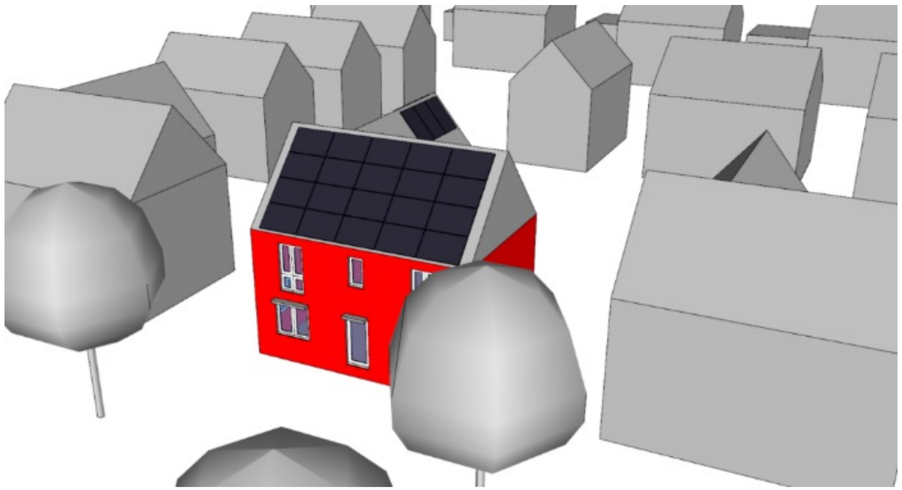
Heating system

The baseline Part L 2021 scenario assumes use of a combi boiler, while the remaining scenarios assume use of an air-water heat pump. A cheaper air-air heat pump, or a ground source heat pump could also be used. Suitable heat emitters include radiators, or underfloor heating for scenarios with poorer fabric efficiency.

Solar PV

The property has more than enough space to achieve a net zero energy balance on-site in any orientation. As presented on plans, the property has sufficient space for 22 solar panels. This includes allowance for 2 panels on the smaller rear roof section. If the property faced East or West, it would be possible to install more panels on the rear plane of the main roof. The number of panels required to achieve net zero under the proposed policy requirement is 10, which reduces to 8 for the future policy option with improved fabric efficiency.

A typical 4 bedroom detached house was selected from a Barrett Homes planning application.



A 3D model of the house and surrounding features was created in DesignPH 2.1.15 and used to calculate solar gains and shading for PHPP.

Detached house | Energy modelling results

Space heating demand

Policy 2 requires all dwellings to achieve a space heating demand of less than 15-20 15-20 kWh/m$^2_{GIA}$/yr.

Scenario 4, demonstrates that with an ultra-low energy specification the semi-detached house could achieve a space heating demand of around 20 kWh/m²/yr. Best performance in all areas is required, including a fully insulated building fabric, the use of mechanical ventilation with heat recovery (MVHR), an air permeability of <0.6 m³/m².hr and triple glazing. A further 10% reduction could be achieved by improving junction design to reduce thermal bridging. Full specification is provided in Appendix 3.

Based on the above, it can be concluded that policy 2 is technically feasible for the detached house using an ultra-low specification.

To factor potential challenges in policy implementation, a low energy scenario has been considered with a transitional net zero policy requirement of 30 kWh/m²/yr, if required. This target could be achieved in several ways, but all would require improved airtightness and use of MVHR and an air permeability of <1 m³/m².hr, which reduces heat loss so much that double glazing can be used.

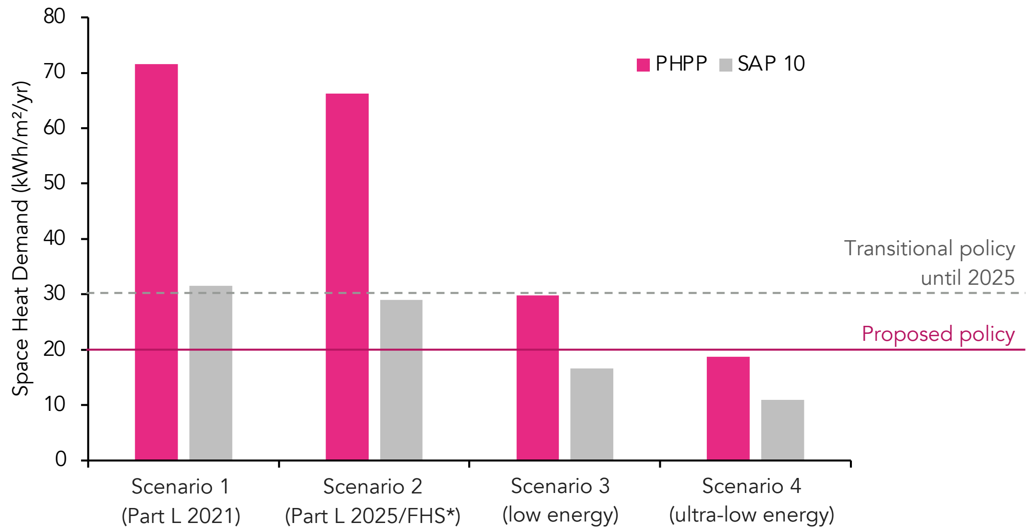
Energy Use Intensity (EUI)

Policy 3 requires all dwellings to achieve an Energy Use Intensity (EUI) of no more than 35 kWh/m$^2_{GIA}$/yr.

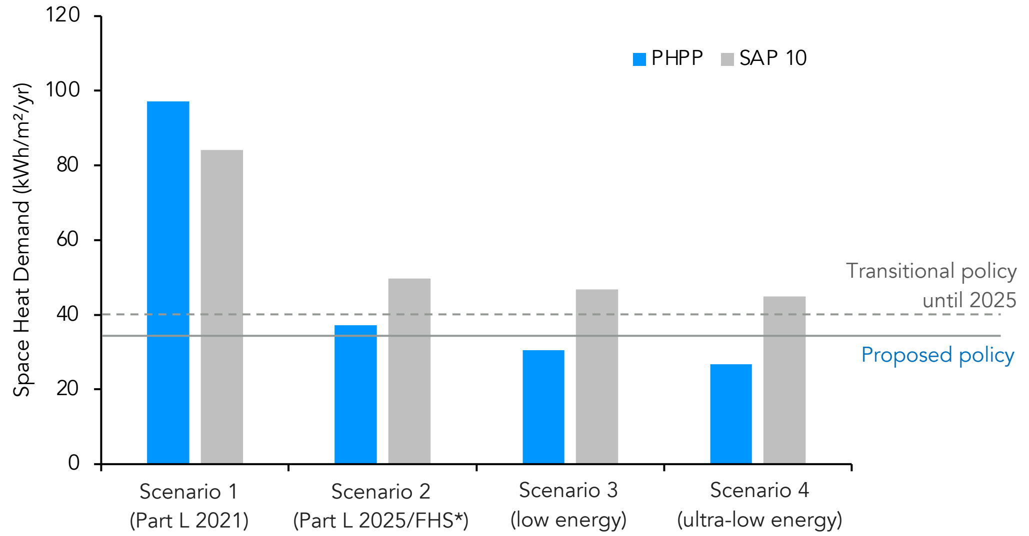
Energy modelling using PHPP software show that for this typology, both, low energy and ultra-low energy scenarios are compliant with the proposed policy requirement of 35 kWh/m²/yr, demonstrating the policy is feasible. If required, a proposed transitional target of 40 kWh/m²/yr has been considered to factor implementation challenges.

Solar PV generation

Solar generation is not shown; however, the dwelling could easily be net energy positive for both, the proposed and transitional policies.



Space heating demand for the detached house modelled in PHPP 10.4a and SAP 10.2



Total energy use for the detached house modelled in PHPP 10.4a and SAP 10.2

Note: SAP 10 results are shown in both graphs for context, but discussion is based on PHPP results, as these provide more realistic results. See report page on correcting SAP 10 outputs for discussion of how SAP can be used to provide more reliable results.

Bungalow | Introduction

Description

A house built on a single story without a staircase. This typology does not include basements or habitable attics.

Building fabric

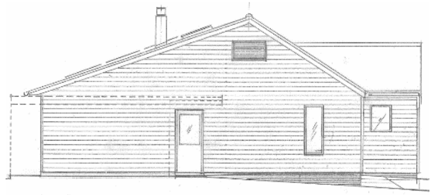
The property has a gross internal floor area of 108m². The main entrance faces the street to the South, while the rear of the house faces to the North and features a small garden. The property has typical glazing proportions and layout. The form heat loss factor of 4.4 is poor but is expected for a detached bungalow. As a result, even with high levels of insulation, the space heating demand is higher than the other house types. In practice, we would expect developers to reduce heat loss by optimising the design of the building, as this would be cheaper than using high levels of insulation. For example, glazing ratios could be reduced.

Heating system

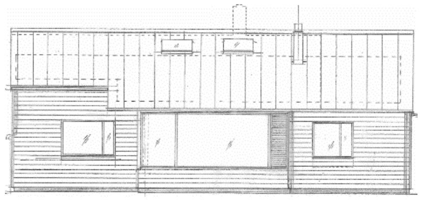
The baseline Part L 2021 scenario assumes use of a combi boiler, while the remaining scenarios assume use of an air-water heat pump. A cheaper air-air heat pump, or a ground source heat pump could also be used. Suitable heat emitters include radiators, or underfloor heating for scenarios with poorer fabric efficiency.

Solar PV

The property has more than enough space to achieve a net zero energy balance on-site in any orientation. As presented on plans, the property has sufficient space for 36 solar panels. There is additional space for 2 panels on the smaller roof section to the rear of the property. If the property faced East or West, it would be possible to install more panels on the rear plane of the main roof. The number of panels required to achieve net zero under the proposed and future policy requirements is 8.

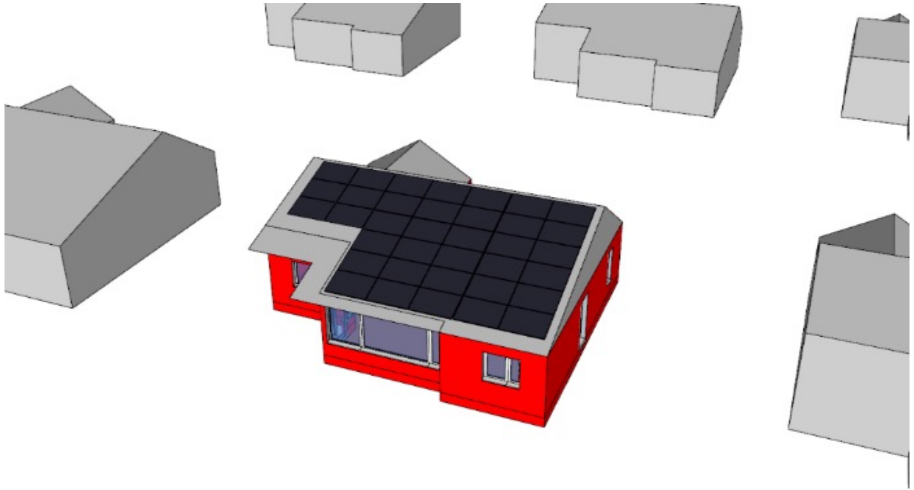


East Elevation



South Elevation

A typical 3 bedroom bungalow was selected



A 3D model of the house and surrounding features was created in DesignPH 2.1.15 and used to calculate solar gains and shading for PHPP.

Bungalow | Energy modelling results

Space heating demand

Policy 2 requires all bungalows to achieve a space heating demand of less than 30 kWh/m$^2_{GIA}$/yr.

Modelling results demonstrate that with a low energy specification scenario the bungalow could achieve a space heating demand of around 30 kWh/m²/yr. This target could be achieved in several ways, but all would require improved U-values, the use of MVHR and an air permeability of <1 m³/m².hr, which reduces heat loss so much that double glazing can be used.

Scenario 4, shows that with an ultra-low energy specification the semi-detached house could achieve a space heating demand of around 24 kWh/m²/yr. A further 5% reduction could be achieved by improving junction design to reduce thermal bridging. Best performance in all areas is required, including a fully insulated building fabric, the use of mechanical ventilation with heat recovery (MVHR), an air permeability of <0.6 m³/m².hr and triple glazing. Full specification is provided in Appendix 3.

Based on the above, it can be concluded that policy 2 is technically feasible for the bungalow using an ultra-low specification and improved junction design.

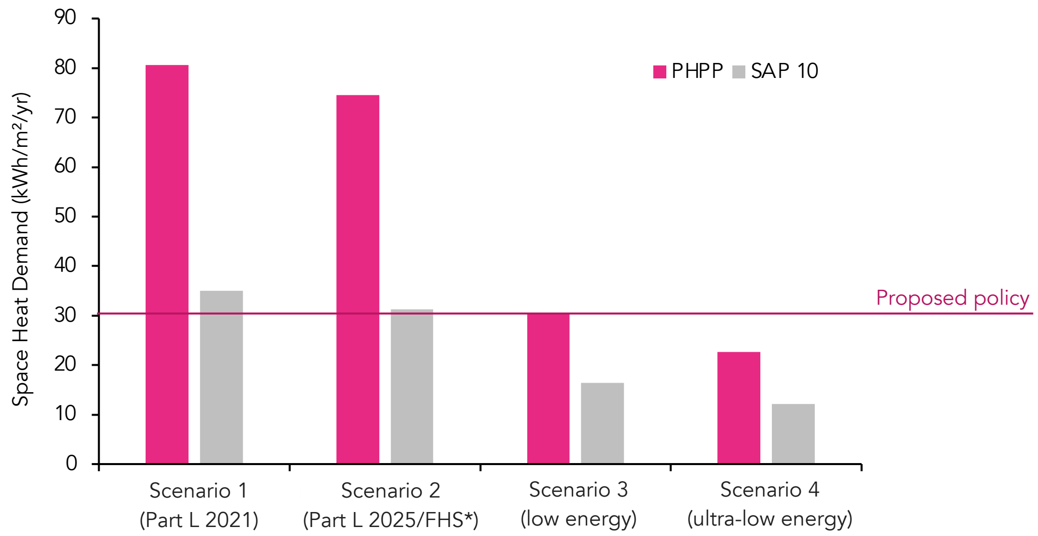
Energy Use Intensity (EUI)

Policy 3 requires all dwellings to achieve an Energy Use Intensity (EUI) of no more than 35 kWh/m$^2_{GIA}$/yr.

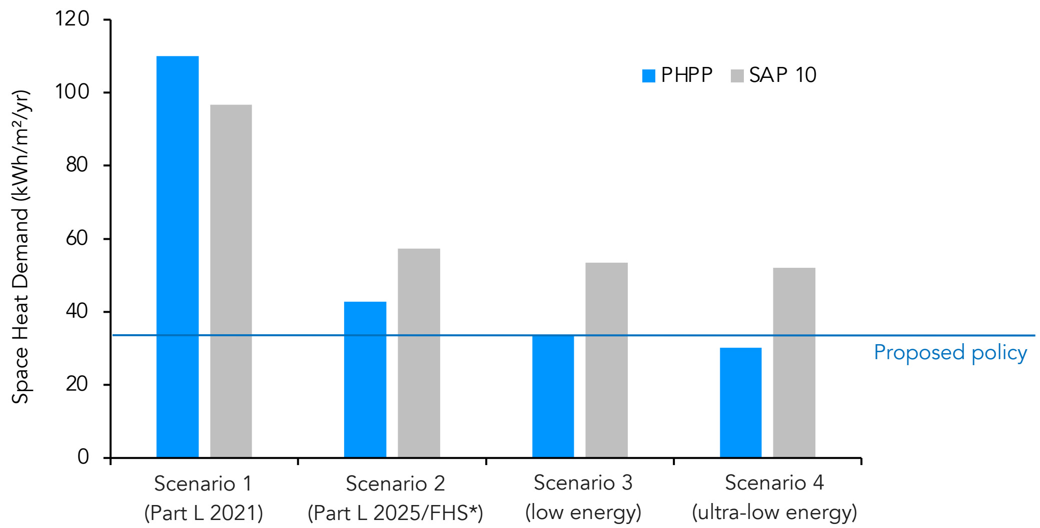
Energy modelling using PHPP software show that for this typology, both, low energy and ultra-low energy scenarios are compliant with the proposed policy requirement of 35 kWh/m²/yr, demonstrating the policy is feasible.

Solar PV generation

Solar generation is not shown; however, the dwelling could easily be net energy positive for both, the proposed and transitional policies.



Space heating demand for the bungalow modelled in PHPP 10.4a and SAP 10.2



Total energy use for the bungalow modelled in PHPP 10.4a and SAP 10.2

Note: SAP 10 results are shown in both graphs for context, but discussion is based on PHPP results, as these provide more realistic results. See report page on correcting SAP 10 outputs for discussion of how SAP can be used to provide more reliable results.

Non-domestic typologies

There are several other common building types in Cotswold, which can vary widely, making it difficult to reliably determine generic forms, energy use or occupancy models .

Our analysis of the building stock showed a larger presence of agricultural buildings, as well as holiday homes where space heating patterns will vary drastically.

Below, we have suggested indicative provisional energy performance targets based on published guidance, such as RIBA, LETI and UKGBC. In each case, the same structure of targets has been followed.

Warehouses and light industrial (heated)

- Space heating demand of less than 15 $kWh/m^2_{GIA}/yr$.
- Energy use intensity of 35 $kWh/m^2_{GIA}/yr$ or less.
- Solar electricity generation of at least 120 $kWh/m^2_{GIA}/yr$.

Warehouses and light industrial (unheated)

- Solar electricity generation of at least 120 $kWh/m^2_{GIA}/yr$.

Student/keyworker accommodation, care homes

- Space heating demand of less than 15 $kWh/m^2_{GIA}/yr$.
- Energy use intensity of 35 $kWh/m^2_{GIA}/yr$ or less.
- Solar electricity generation of at least 80 $kWh/m^2_{GIA}/yr$.

Offices, retail, HE teaching facilities, GP surgery

- Space heating demand of less than 15 $kWh/m^2_{GIA}/yr$.
- Energy use intensity of 70 $kWh/m^2_{GIA}/yr$ or less.
- Solar electricity generation of at least 80 $kWh/m^2_{GIA}/yr$.

Schools

- Space heating demand of less than 15 $kWh/m^2_{GIA}/yr$.
- Energy use intensity of 65 $kWh/m^2_{GIA}/yr$ or less.
- Solar electricity generation of at least 80 $kWh/m^2_{GIA}/yr$.

Existing buildings

Existing buildings present a much greater challenge than new, and the rules cannot be as prescriptive. Proposed policies are detailed in a separate document.

Agricultural and light industrial buildings offer a great opportunity for energy generation through PVs.

The first Passivhaus supermarket in the world was created in 2008 in Tramore, Ireland. It has solar photovoltaic panels and a ground source heat pump that provides water heating from waste heat taken from the cooling cabinets. © Joseph Doyle Architects

Cost and viability | Considerations

Both, Cornwall Council and Bath and North East Somerset Council's net zero carbon buildings policies successfully passed inspection and cost viability tests. Cost uplifts from these projects are illustrated on the right. Please note however that the cost analysis for these evidence bases were done in early 2021 and were based on a targeted space heating demand of 30 kWh/m^2/yr and a targeted EUI of 40 kWh/m^2/yr. **We would recommend, as a next step, that a bespoke cost analysis is undertaken for the Cotswold Local Plan to reflect inflation and current prices.**

Costs and inflation

In recent years we have seen an overall inflation in construction costs. Inflation is driven by a wide range of factors: materials pricing, wage increases, supply shortages, exchange rates, and wider inflation across the UK and global economy.

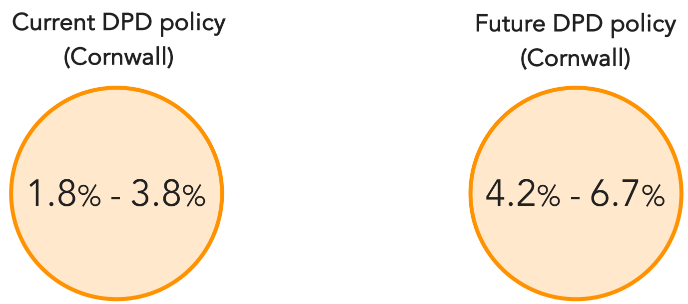
Materials pricing indices show more significant inflation for some products particularly aggregates (over 60%) and insulation (30%).

Some products, notably photovoltaics, are experiencing more significant short-term cost 'spikes' due to fleeting stock availability. However, we do not believe these elevated rates will be sustained beyond the short term as the cost of material is lower than ever.

Establishing a realistic baseline

A building regulations compliant specification is usually used as the baseline when assessing the cost uplifts of increasing the specification to achieve net zero carbon.

Part L 2021 is the current version of the building regulations but will be replaced in 2025 by the Future Homes Standard (Part L 2025), which will be in place for the majority of the Local Plan's lifetime. It could therefore be argued the the Future Homes Standard (FHS) would be a more appropriate baseline to use, although full details of this regulation are not yet confirmed. **Using a Future Homes Standard baseline would reduce cost uplifts to zero carbon.**

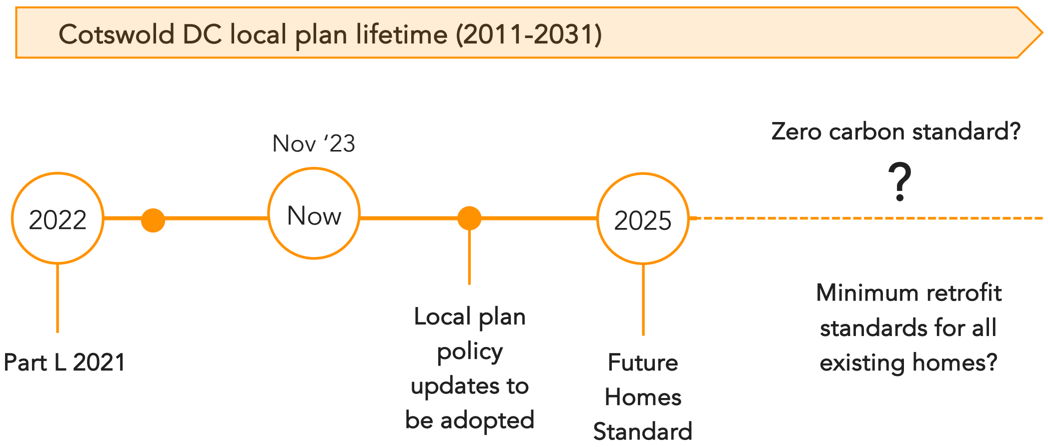


The range of cost uplifts for different residential typologies from the Cornwall Council Climate Emergency Technical Evidence base (2021). A bespoke cost analysis should be undertaken for Cotswold to reflect inflation and current prices.

More detailed cost breakdowns can be found on the next page.

Current DPD policy: net zero carbon with space heating demand limit of 30kWh/m^2/yr.

Future DPD policy: net zero carbon with space heating demand limit of 15-20 kWh/m^2/yr.



Policy changes are moving towards zero carbon. The current version of the building regulations (Part L 2021) is due to be replaced in 2025, with more stringent requirements for building fabric and heating systems. Therefore, the cost baseline will shift, and cost uplifts to zero carbon will be relatively smaller. These changes are likely to come into effect soon after the adoption of these new policies.

Cost and viability | Uplifts associated to an improved specification

Any increases in construction costs associated with implementing the policies recommended in this evidence base will be associated with meeting the key requirements below:

Space heating demand

This requirement affects the building fabric and ventilation costs. The costs could increase due to an increase on insulation levels, need for more efficient windows and a demand for increased quality control on site to ensure air tightness targets are met. Some of these additional costs can be compensated for by simplification to the building form and avoidance of excessive extents of glazing.

Fossil fuel free developments and low carbon heat

Current building regulations allow the continued use of gas boilers in new homes until 2025. Indicative uplifts in costs are therefore reflective of a gas boiler baseline.

Policy compliant buildings will not use fossil fuel-based heating systems (e.g. gas boilers) and will instead use low carbon heating systems (e.g. air source heat pumps). Cost uplifts to achieve this element of the policy are therefore associated with the heating system and associated distribution work (e.g. potentially larger radiators).

During the lifetime of this local plan, air source heat pumps are likely to be the new baseline, and therefore, these cost uplifts will be negated.

Renewable energy

Photovoltaic panels will be required to achieve a net zero energy balance. Part L 2021 does assume that PVs will be installed but does not mandate that the output must balance the demand. The NZC homes therefore may have a slightly increased PV array size in order to achieve that energy balance. In other cases, an energy balance can be achieved with a slightly smaller array (leading to a cost saving).

Cornwall Current DPD policy Space heating demand 30kwh/m²/yr	Bungalow	Detached	Semi-detached	Terrace
Fabric efficiency	3%	1.7%	1.7%	2.5%
Low carbon heat	0.3%	0.3%	0.5%	0.5%
Renewable energy	-1.2%	-0.2%	0.12%	0.4%
Total*	2.0%	1.8%	2.3%	3.8%

Cornwall Future DPD policy Space heating demand 15-20kwh/m²/yr	Bungalow	Detached	Semi-detached	Terrace
Fabric efficiency	6.2%	4.8%	3.9%	5.9%
Low carbon heat	0.2%	0.2%	0.4%	0.4%
Renewable energy	-1.4%	-0.4%	-0.10%	0.4%
Total*	4.9%	4.6%	4.2%	6.7%

Costings above taken from Cornwall Council Climate Emergency DPD evidence base (2021). %s are in relation to a Part L 2021 compliant baseline. A more demanding space heating demand target has the impact of increasing costs for the fabric, but slightly decreasing costs for the heating system. Savings can be realised for renewable energy due to the Part L 2021 baseline requiring a large amount of PV to offset the emissions from the gas boiler heating system.

These costings should be updated to reflect local and current prices for Cotswold District Council.

**Totals account for rounded figures*

7.0

Other considerations

Minor applications

Should minor applications be exempt from the requirements of the proposed policies?

The definition of a minor application

This is generally set by each Council, but as a guide, under the Town and Country Planning Act, a major development is defined as:

- 10 or more dwellings, (or a site with an area of 0.5 hectares or more where the number of dwellings is unknown), or
- the floor space to be created by the development is 1,000 square metres or more; or
- a site having an area of 1 hectare or more.

A minor application would therefore be one under these thresholds.

There is no technical reason to create an exemption

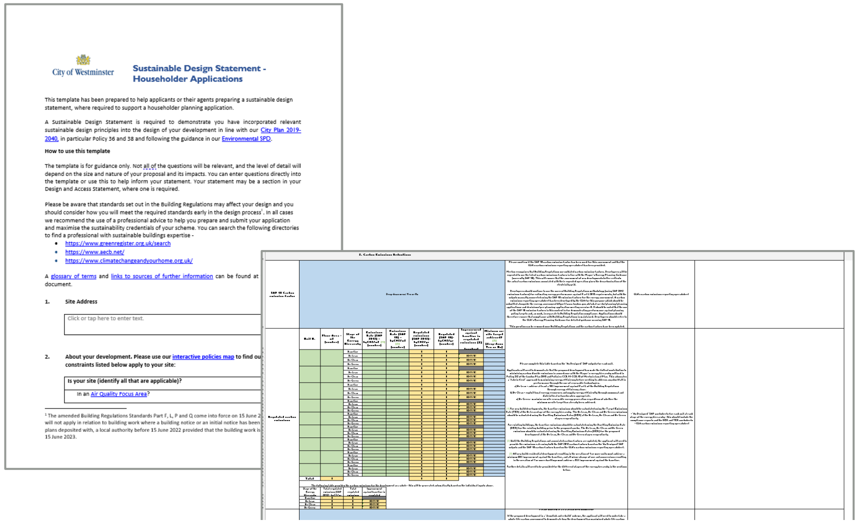
The implications of the polices in terms of design and construction (e.g. wall U-values, low carbon heat, PV renewable energy generation) are not different for minor applications, and it is not easier or more challenging to comply with the policies for them.

It is also important that the performance requirements of all new developments are consistent with the Net Zero ambition and with each other. Allowing a derogation for schemes below an arbitrary threshold would create a 'loophole' that would be exploited.

Simplifying reporting requirements

Simplifying the reporting requirements for minor applications through the use of pro forma reports for developments that fall under a set threshold would reduce the pre-planning costs to developers.

Developers of individual houses or commercial units or shops may also not have access to the resources needed to carry out predictive energy modelling. An exemption may be envisaged for these very small developments, but this exemption should be handled with care and restricted only to specific applications.



Many boroughs in London have standard templates for minor applications for specific aspects of the application. A similar approach could be adopted for energy reporting for specific schemes less than a threshold number of homes or m² of commercial development.

(Examples shown are Westminster City Council and London Borough of Merton)

- Development of less than 100 square metres, unless this consists of one or more dwelling
- Buildings into which people do not normally go
- Buildings into which people go only intermittently for the purpose of inspecting or maintaining fixed plant or machinery
- Structures which are not buildings, such as pylons and wind turbines;

The following can be subject to an exemption or relief where the relevant criteria are met, and the exemptions are applied for prior to work commencing:

- residential annexes and extensions ;
- 'self-build' houses and flats,
- social housing that meets specific criteria
- charitable development that meets specific criteria

Examples of exemptions: the Community Infrastructure Levy (CIL)

What about biomass?

Overview

In their 2019 report on housing, the Climate Change Committee did not consider combustion of biomass in open fires a low carbon heat source nor did consider the use of biomass for heat to be the best long-term use of the UK's limited biomass resource.

This view was based on a 2018 paper published by the Committee, which considered the role for biomass in a low carbon economy. The report specifically recommended that support for use of biomass in buildings is limited to niche uses, while also minimising air quality impacts, for example by favouring use of biogas produced from anaerobic digestion over direct combustion of biomass. More generally, the report discourages larger scale combustion of biomass for heat or electricity generation unless paired with carbon capture and storage.

Anaerobic Digestion

This is a process where biomass is digested by bacteria in the absence of air to produce methane gas, which can then be burned to generate electricity or heat. Suitable feedstocks can include plants, manure, crop residues, food waste, paper, and wastewater.

The contribution this could make to the Cotswold's electricity requirements is likely to be very small.

Domestic Combustion

Direct combustion of woody biomass in homes to provide heat produces significant quantities of carbon dioxide and air pollution and should not be encouraged by policy.

The use of biogas produced by anaerobic digestion facilities for heating in homes can be expected to produce smaller amounts of pollution but is not a scalable solution.

Direct combustion of biomass in buildings to provide heat should not be encouraged due to carbon emissions and adverse impacts on air quality.

Typical anaerobic digestion facility. Biogas can be produced from waste and used to generate electricity. © The association for renewable energy and clean technology.

Implications for infrastructure

The electrical infrastructure is highly likely to become of crucial importance to the Net-Zero objective and will need to adapt and be reinforced to be able to support a different energy demand and supply pattern than has historically been the case.

The key implications of net zero carbon for infrastructure include:

- Increasing demand for electricity for heating and other uses.
- A significant increase in the amount of renewable energy generated.
- A growth in small, distributed photovoltaic systems in urban areas.
- The growth of electrified transport (e.g. electric vehicles).

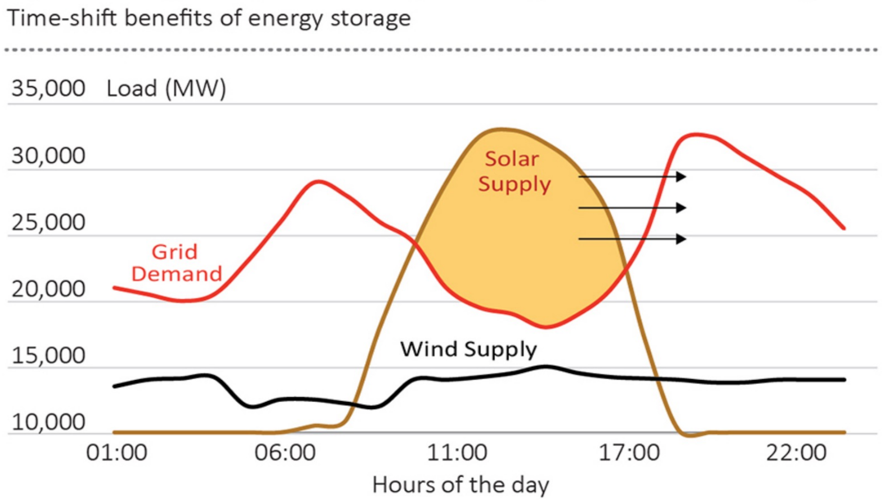
Forward planning

The District Network Operators (DNOs) are required by the regulator, Ofgem, to submit business plans for 5-year periods.

Ofgem demands that business and investment plans are based on the established needs in each area and will punish' investments made without evidence of that need. The Local Plan will form part of the primary evidence base which the DNOs can use to formulate their plans for future investment in the area, so policies for net zero carbon need to be clearly set out within it, and we recommend that Cotswold District Council ensures the DNO is made aware of these in sufficient time to adapt their business plan.

Energy storage

The intermittent and seasonal nature of most renewable energy sources (e.g. due to weather dependency) needs to be managed to maximise the use of the renewable power. The Local Plan should encourage the incorporation of demand management and storage systems (at the building and the network level) which will enable the system to be more flexible.



Notional graph of renewable energy supply vs energy demand showing how energy storage can help to match the supply to the demand.

The electrical infrastructure will have to be reinforced to support increased demand and a more distributed supply with more renewable energy.

6.0

Appendices

Appendix 1 | Energy Use Intensity (EUI): a simple, measurable metric

What is the EUI?

The Energy Use Intensity (EUI) represents the total amount of energy used by a building divided by its floor area (GIA). It is reported in kWh/m^2.year. It is based on delivered energy and does not need to be converted in primary energy using any factors.

The EUI is a good indicator of the energy efficiency of a home/building and can be calculated or checked at both design stage and post completion. For homes/buildings heated by an individual heating system, it is will be very easy to check for the occupant/resident as it will be the annual 'energy at the meter' divided by the floor area.

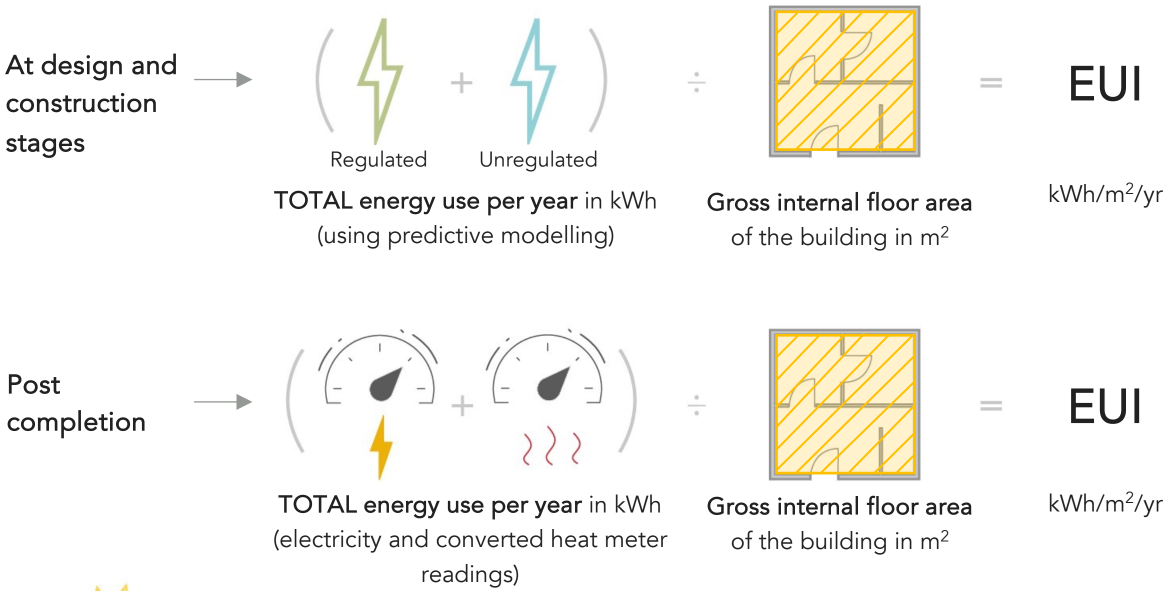
For communally heated dwellings/buildings heat 'at the meter' will need to be converted to heat energy.

What is included in the EUI?

EUI includes both the regulated energy use and unregulated energy use. This covers both heating and cooling.

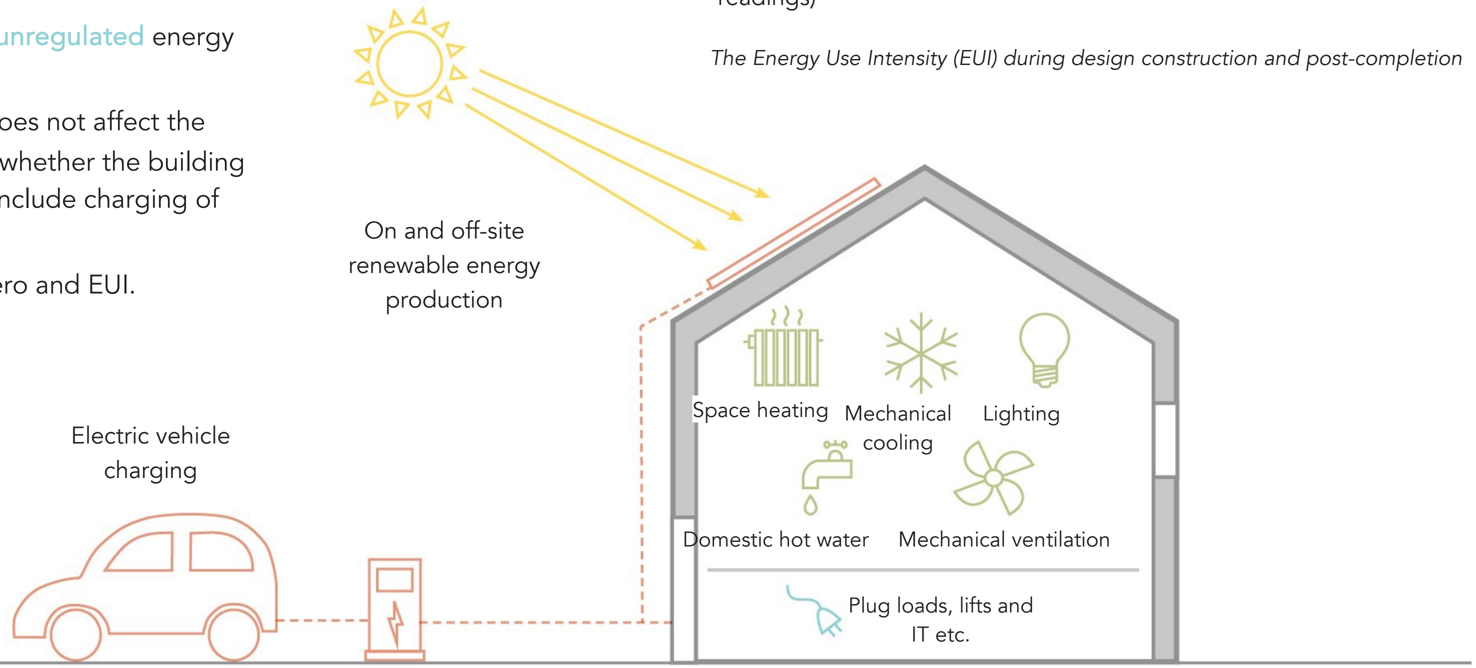
Energy generated by on or off-site **renewables** does not affect the EUI value. For example, the EUI will be the same whether the building has PV or not. The EUI calculation does also not include charging of electric vehicles, as long as this is sub-metered.

For further detail refer to [LETI guidance] on net zero and EUI.



The Energy Use Intensity (EUI) during design construction and post-completion

KEY
- Regulated energy
- Unregulated energy
- Not included in the EUI calculation



What is included in the EUI?

Note: *EUI should not be confused with Primary Energy which rely on the multiplication of energy use by primary energy factors specific to each fuel (similarly to carbon emissions which rely on the multiplication of energy use by carbon factors.*

Software

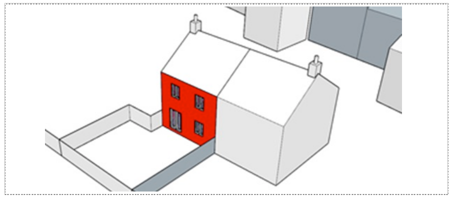
We modelled the performance of several dwellings in **Elmhurst DesignSAP**, to provide a baseline set of Part L SAP 10 calculations. Due to the importance of these calculations for this evidence base, more attention to detail was applied than would be typical for a normal SAP calculation. For example, the frame factors were calculated for each individual window.

The same dwellings were then modelled in **PHPP 10.4** and **DesignPH 2.1.15** to provide a set of indicative 'real-world' energy performance figures. PHPP was used for this on the basis that post occupancy studies* have consistently shown it can provide more reliable predictions of a building's space heating demand and total energy use.

DesignPH was used in combination with PHPP to provide more accurate shading analysis, based on a 3D model of the building, its openings, and some allowance for typical surrounding objects.

We carried out thermal bridge modelling using **PSI-Therm 6** to provide two sets of thermal bridge performance values using LABC details for a beam and block floor with masonry cavity wall construction and insulation at ceiling level. One of these sets is based on internal dimensions and was used in DesignSAP. The other set was based on external dimensions and was used in PHPP. Each individual PSI-value was selected by interpolating between a best and worst case U-value for the adjacent floor/wall/roof elements, with the best and worst case U-values based on the range permitted under Part L 2021. Appendix A provides further information.

PHPP-Energy balance calculation 10.4a EN



Building:	Semi Detached House
Street:	
Postcode/City:	
Province/Country:	Cornwall, GB-United Kingdom/ Britain
Building type:	3-Double house
Climate data set:	GB0005a-Exeter, Altitude corrected
Climate zone:	4: Warm-temperate; Altitude of location: 85 m
Home owner / Client:	
Street:	
Postcode/City:	
Province/Country:	
Architecture:	
Street:	
Postcode/City:	
Province/Country:	
Mechanical engineer:	
Street:	
Postcode/City:	
Province/Country:	
Energy consultancy:	Etude
Street:	5 Baldwin Terrace
Postcode/City:	N1 7RU London
Province/Country:	Greater London, GB-United Kingdom/ Britain
Certification:	
Street:	
Postcode/City:	
Province/Country:	

Year of construction:		Interior temperature winter [°C]:	20.0	Interior temp. summer [°C]:	25.0
No. of dwelling units:	1	Internal heat gains (IHG) winter [W/m²]:	2.7	IHG summer [W/m²]:	2.7
No. of occupants:	2.1	Specific heat capacity [Wh/K per m² TFA]:	84	Mechanical cooling:	

Specific building characteristics with reference to the treated floor area — 1 error message(s) in 'Check' worksheet'

		Value		Criteria	Alternative criteria	Fullfilled?[2]
	Treated floor area m²	84.9				
Space heating	Heating demand kWh/(m²a)	30	≤	-	-	-
	Heating load W/m²	16	≤	-	-	
Space cooling	Cooling & dehum. demand kWh/(m²a)	-	≤	-		-
	Frequency of overheating (> 25 °C) %	0	≤	-		-
	Frequency of excessively high humidity (> 12 g/kg) %	0	≤	-		-
Airtightness	Pressurisation test result n_{50} 1/h	1.0	≤	-		-
Non-renewable Primary Energy (PE)	PE demand kWh/(m²a)	38	≤	-		-
Primary Energy Renewable (PER)	PER demand kWh/(m²a)	45	≤	-	-	-
	Renew. energy generation (in rel. to projected building footprint area) kWh/(m²a)	61	≥	-	-	

I confirm that the values given here have been determined following the PHPP methodology and based on the characteristic values of the building. The PHPP calculations are attached to this verification. -

Task: First name: Surname: Signature:

Certificate-ID Issued on: City:

PHPP 10.4 was used to model expected real-world energy performance of the three dwelling types.

*Examples include the CEPHEUS project and Mitchell, R and Natarajan, S (2020) *UK Passivhaus and the energy performance gap*. Energy and Buildings. Vol 224

Climate

One reason SAP results can be less suitable for assessing local policy compliance is that some outputs are based on UK average, rather than local, weather conditions. Table 1 summarises the weather data used for different outputs in SAP 10.2.

Output	Weather Data
Dwelling Emission Rate	UK Average
Fabric Energy Efficiency	UK Average
Energy Rating	UK Average
Energy Performance Certificate Costs	Local

Weather data used for different SAP 10.2 outputs

The modelling for this evidence base uses calculation results from SAP 10's Energy Performance Certificate outputs to ensure local weather data is used.

PHPP modelling also used local weather data, and the building altitudes were set to match the representative heights indicated in the SAP 10.2 manual, shown in the adjacent table.

Table U4: Representative latitude and height above mean sea level

Region		Representative Latitude (°N)	Representative height above sea level (m)
0	**UK average**	**53.5**	**79**
1	Thames	51.6	53
2	South East England	51.1	55
3	Southern England	50.9	50
4	South West England	50.5	85
5	Severn Wales / Severn England	51.5	99
6	Midlands	52.6	116
7	West Pennines Wales / West Pennines England	53.5	71
8	North West England / South West Scotland	54.6	119
9	Borders Scotland / Borders England	55.2	101
10	North East England	54.4	78
11	East Pennines	53.5	79
12	East Anglia	52.1	29
13	Wales	52.6	138
14	West Scotland	55.9	113
15	East Scotland	56.2	117
16	North East Scotland	57.3	123
17	Highland	57.5	218
18	Western Isles	57.7	59
19	Orkney	59.0	53
20	Shetland	60.1	50
21	Northern Ireland	54.6	72

Table U4 from the SAP 10.2 manual indicates that different heights above sea level are assumed for different climate regions. These assumptions have been replicated in PHPP modelling.

Appendix 3 | Specifications | Semi-detached house

	Scenario 1: Part L 2021	Scenario 2: Part L 2025	Scenario 3: Low energy	Scenario 4: Ultra-low energy
Building fabric strategy	Part L 2021 compliant fabric, developer spec	Part L 2025 notional building specification	To achieve space heat demand of 30 kWh/m²/yr	To achieve space heat demand of 15-20 kWh/m²/yr
Floor (W/m^{2}K, SAP adjusted)	0.110	0.110	0.110	0.090
Walls (W/m^{2}K)	0.160	0.150	0.200	0.130
Roof (W/m^{2}K)	0.100	0.110	0.100	0.100
Windows (W/m^{2}K)	1.2 (double-glazed)	0.8 (triple-glazed)	1.2 (double-glazed)	0.8 (triple-glazed)
Doors (W/m^{2}K)	1.0	1.0	1.0	1.0
Thermal bridging* (W/K)	10.35 (SAP) 6.1 (PHPP)	10.25 (SAP) 6.3 (PHPP)	10.38 (SAP) 5.1 (PHPP)	10.10 (SAP) 6.9 (PHPP)
Air Permeability (m^3/m^2/hr)	5	5	1	0.60
Ventilation	0% heat recovery 0.08 Wh/m^3 0.18 W/l/s	0% heat recovery 0.08 Wh/m^3 0.18 W/l/s	88% HR. 2m duct 25mm insulation 0.24 Wh/m^3 0.60 W/l/s	88% HR. 2m duct 25mm insulation 0.24 Wh/m^3 0.60 W/l/s
Space Heating	Gas combi boiler Radiators at <60˚C Weather comp	5kW ASHP Radiators at <45˚C Weather comp	5kW ASHP Radiators at <35˚C Weather comp	5kW ASHP Radiators at <35˚C Weather comp
Domestic Hot Water	Gas combi boiler WWHR 36%	200l heat pump tank at 55˚C 1.4kWh/day loss	200l heat pump tank at 55˚C 1.4kWh/day loss	200l heat pump tank at 55˚C 1.4kWh/day loss
Solar PV	2.52 kW	0 kW	3.36kW	2.94kW

**Thermal bridging values include window and door installation thermal bridges*

Appendix 3 I Specifications I Detached house

	Scenario 1: Part L 2021	Scenario 1: Part L 2025	Scenario 3: Low energy	Scenario 4: Ultra-low energy
Building fabric strategy	Part L 2021 compliant fabric, developer spec	Part L 2025 notional building specification	To achieve space heat demand of 30 kWh/m²/yr	To achieve space heat demand of 15-20 kWh/m²/yr
Floor (W/m^2K, SAP adjusted)	0.120	0.110	0.110	0.090
Walls (W/m^2K)	0.150	0.150	0.150	0.130
Roof (W/m^2K)	0.110	0.110	0.100	0.100
Windows (W/m^2K)	1.2 (double-glazed)	0.8 (triple-glazed)	1.2 (double-glazed)	0.8 (triple-glazed)
Doors (W/m^2K)	1.0	1.0	1.0	1.0
Thermal bridging* (W/K)	14.94 (SAP) 6.3 (PHPP)	14.94 (SAP) 6.5 (PHPP)	14.94 (SAP) 6.6 (PHPP)	14.99 (SAP) 7.6 (PHPP)
Air Permeability ($m^3/m^2/hr$)	5	5	1	0.60
Ventilation	0% heat recovery 0.08 Wh/m^3 0.18 W/l/s	0% heat recovery 0.08 Wh/m^3 0.18 W/l/s	88% HR. 2m duct 25mm insulation 0.24 Wh/m^3 0.60 W/l/s	88% HR. 2m duct 25mm insulation 0.24 Wh/m^3 0.60 W/l/s
Space Heating	Gas combi boiler Radiators at <60˚C Weather comp	5kW ASHP Radiators at <45˚C Weather comp	5kW ASHP Radiators at <35˚C Weather comp	5kW ASHP Radiators at <35˚C Weather comp
Domestic Hot Water	Gas combi boiler WWHR 36%	200l heat pump tank at 55˚C 1.4kWh/day loss	200l heat pump tank at 55˚C 1.4kWh/day loss	200l heat pump tank at 55˚C 1.4kWh/day loss
Solar PV	4.62 kW	0 kW	4.20 kW	3.36 kW

**Thermal bridging values include window and door installation thermal bridges*

Appendix 3 | Specifications | Bungalow

	Scenario 1: Part L 2021	Scenario 1: Part L 2025	Scenario 3: Low energy	Scenario 4: Ultra-low energy
Building fabric strategy	Part L 2021 compliant fabric, developer spec	Part L 2025 notional building specification	To achieve space heat demand of 30 kWh/m²/yr	To achieve space heat demand of 15-20 kWh/m²/yr
Floor (W/m^{2}K, SAP adjusted)	0.130	0.110	0.090	0.090
Walls (W/m^{2}K)	0.160	0.150	0.130	0.130
Roof (W/m^{2}K)	0.100	0.110	0.090	0.090
Windows (W/m^{2}K)	1.2 (double-glazed)	0.8 (triple-glazed)	1.2 (double-glazed)	0.8 (triple-glazed)
Doors (W/m^{2}K)	1.0	1.0	1.0	1.0
Thermal bridging* (W/K)	16.64 (SAP) 5.6 (PHPP)	16.46 (SAP) 6.3 (PHPP)	16.54 (SAP) 7.6 (PHPP)	16.54 (SAP) 7.6 (PHPP)
Air Permeability (m^3/m^2/hr) (as built)	5	5	1	0.60
Ventilation	0% heat recovery 0.08 Wh/m^3 0.18 W/l/s	0% heat recovery 0.08 Wh/m^3 0.18 W/l/s	88% HR. 2m duct 25mm insulation 0.24 Wh/m^3 0.60 W/l/s	88% HR. 2m duct 25mm insulation 0.24 Wh/m^3 0.60 W/l/s
Space Heating	Gas combi boiler Radiators at <60˚C Weather comp	5kW ASHP Radiators at <45˚C Weather comp	5kW ASHP Radiators at <35˚C Weather comp	5kW ASHP Radiators at <35˚C Weather comp
Domestic Hot Water	Gas combi boiler WWHR 36%	200l heat pump tank at 55˚C 1.4kWh/day loss	200l heat pump tank at 55˚C 1.4kWh/day loss	200l heat pump tank at 55˚C 1.4kWh/day loss
Solar PV	5.88 kW	0 kW	3.36 kW	3.36 kW

**Thermal bridging values include window and door installation thermal bridges*

Appendix 4 | Approach to thermal bridging

Causes of thermal bridging

Thermal bridging often occurs at junctions in the building envelope due to:

1. Structural thermal bridging, which result from additional structural materials required in these locations.
2. Geometrical thermal bridging, which results from the under or over counting of heat loss areas. In SAP, heat loss areas are typically under counted, while in PHPP they are usually over counted.

In the development of this evidence base, it was necessary to calculate the expected thermal bridging in SAP and PHPP to ensure accurate reporting of the expected performance.

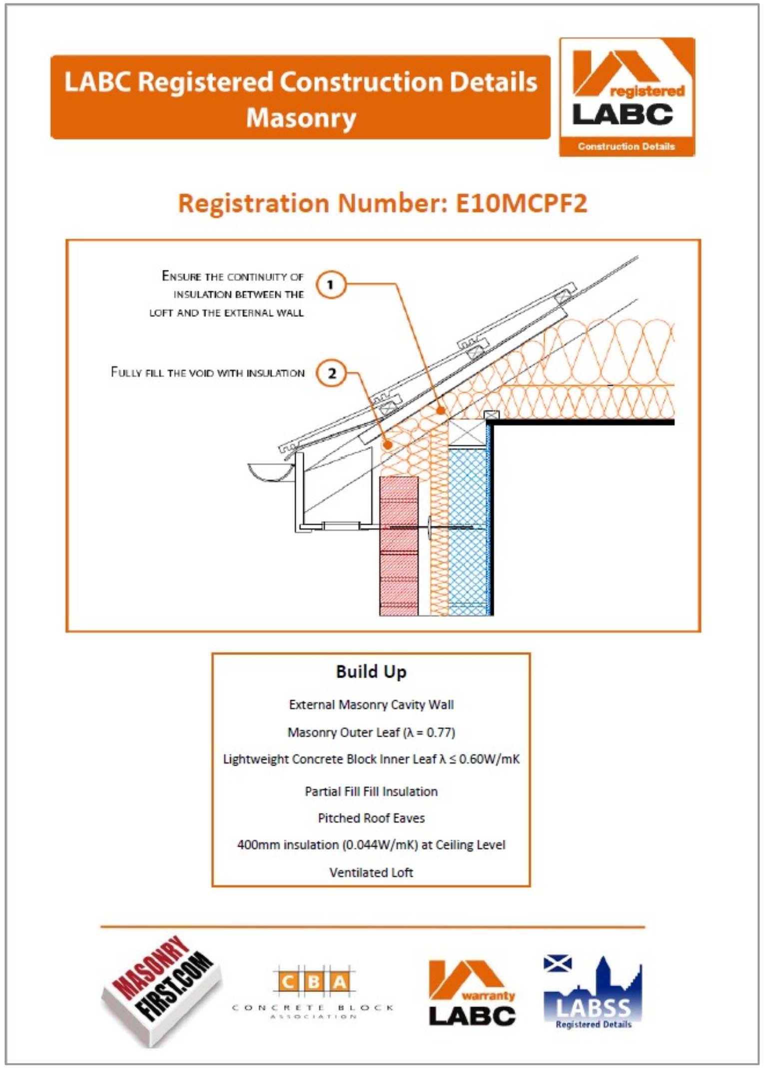
Thermal bridging locations

Thermal bridging may be expected at the following junctions for the buildings modelled:

- Window/door sills/thresholds, jambs and lintels
- External wall to ground floor
- Eaves
- Gable
- Vertical wall corners (both normal and inverted)
- Vertical party wall junctions
- Party wall to ground floor
- Party wall to ceiling

Junction Designs

LABC details for most of these junctions were used as the basis for thermal bridge modelling to create a full set of values that could be used for all the dwellings. The details assumed beam and block floors with masonry cavity wall construction and insulation at ceiling level.



Example of an LABC detail that was used for thermal bridge modelling of the eaves junction. Insulation depths were varied according to scenario. © LABC

Appendix 4 | Approach to thermal bridging

Internal vs External

Thermal bridging for most junctions is measured as the amount of Watts of heat loss per linear meter of junction. This is called a PSI-value. When PSI-values are calculated, the way the heat loss areas are measured in the thermal bridge model must be the same as the way they are modelled in the energy model (SAP or PHPP).

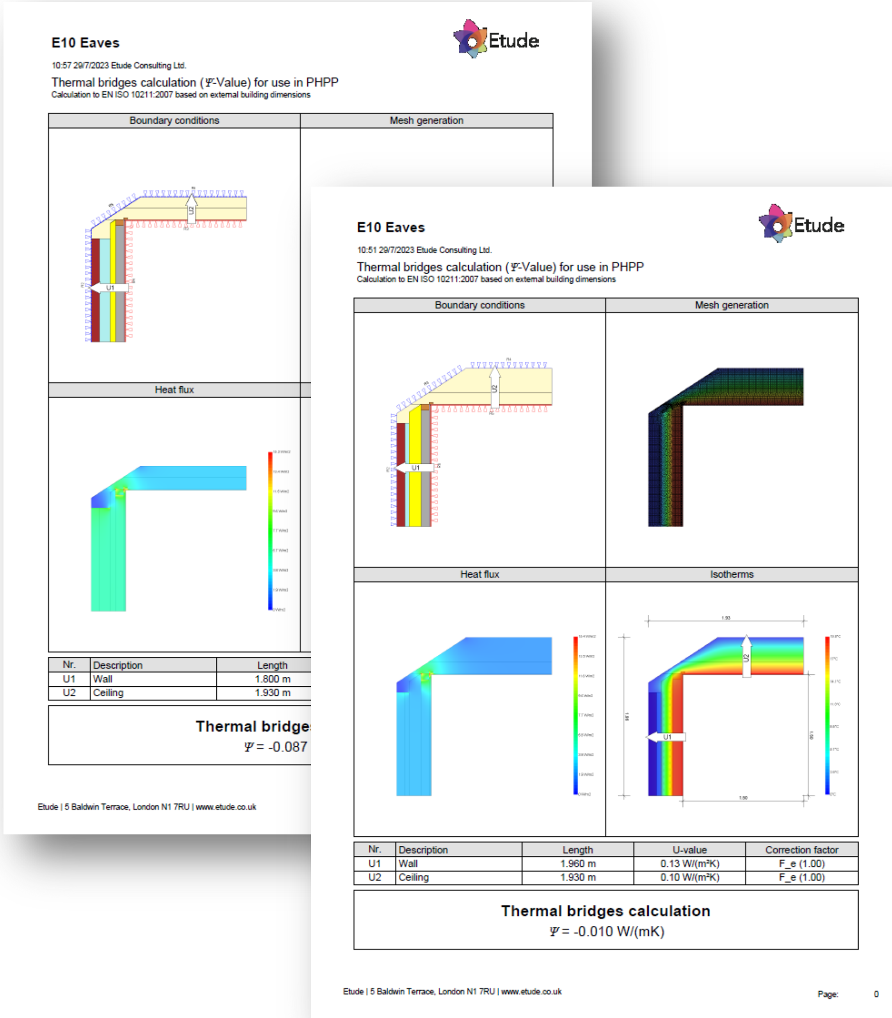
In SAP, the heat loss areas are measured based on the internal dimensions of the building, this means the thermal bridge calculations must also use the internal dimensions. In PHPP, the heat loss areas are measured based on the external dimensions of the building's thermal envelope, this means the thermal bridge calculations must also use the external dimensions.

For each junction, two sets of thermal bridge calculations were carried out, one based on the internal dimensions of the junction, and one based on the external dimensions.

Insulation Depth

The amount of thermal bridging present in a junction, and therefore the PSI-value, vary depending on the amount of insulation present in the adjacent building elements. As different amounts of insulation were assumed for each dwelling and performance scenario, this meant it would not be accurate to use a single set of PSI-values.

To address this, for each junction two thermal bridge calculations were done, with different U-values for the adjacent floors/walls/roofs. One calculation assumed the best U-values that were expected, and one assumed the worst U-values permitted under Part L 2021. This provided an upper and lower PSI-value for each junction. For any specific combination of U-values that were assumed in the main energy model, a bespoke PSI-value could then be determined by interpolating between the best and worst cases. This assumes a linear relationship between the U-values of adjacent elements and the junction's PSI-value, which is unlikely to be the case in practice, however the approach is expected to be accurate enough for the purposes of this evidence base.



Example of separate thermal bridge calculations for the best (foreground) and worst (background) case U-values expected for the wall and ceiling adjacent to the eaves junction. These calculations provided a range of PSI-values, from which a bespoke value could be interpolated, depending on the U-values of the adjacent wall and ceiling in each scenario.