

West of England TER Study

Technical Evidence Base



Executive Summary | Why is this evidence base considering an alternative Part L-based policy?

A complex policy development context

Bath and North-East Somerset Council, Bristol City Council, North Somerset Council and South Gloucestershire Council Council have proposed Net Zero Carbon development policies based on energy-based metrics and predictive energy use modelling.

However, a Written Ministerial Statement (WMS) was made on 13th December 2023 by the Parliamentary Under Secretary of State for Levelling Up, Housing and Communities. Legal opinion is divided on whether the 2023 WMS mandates the use of Building Regulations Part L metrics in local planning policy or whether energy-based metrics can be used as long as it is justified by a robust evidence base. This evidence base has been prepared in case the Planning Inspector adopts a 'narrow' interpretation of the 2023 WMS and mandates the use of Part L metrics.

A 'Low carbon', not a 'Net zero carbon' development policy

Although the proposed policy is the best possible policy the Councils could have put forward using the Building Regulations Part L framework, it cannot be called a 'Net zero carbon development' policy as it does not cover unregulated energy use, is not consistent with the industry definition of Net Zero Carbon development, is not based on predictive energy modelling and does not enable actual energy use to be compared with the planning stage prediction.

Methodology

[Four policy scenarios](#) were assessed for [seven residential typologies](#) through detailed [Part L \(SAP\) modelling](#).

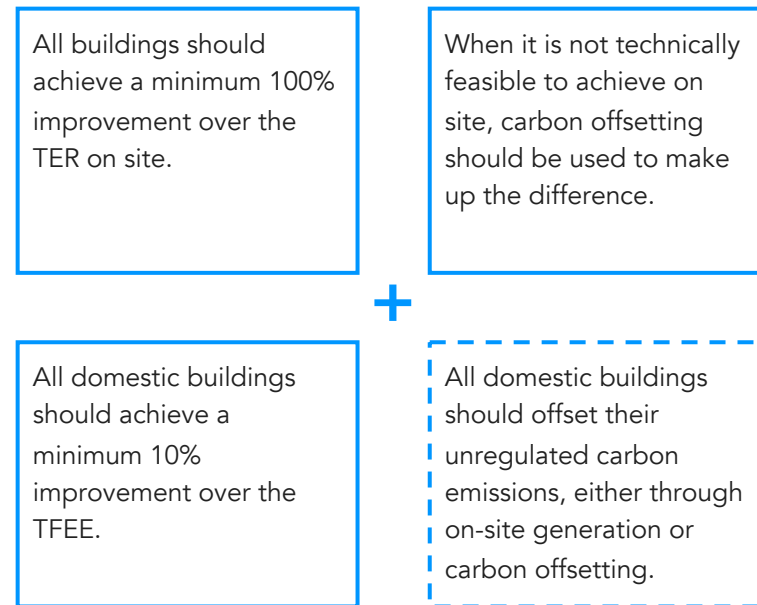
The results were analysed and a summary of key conclusions and findings can be found on the following page.

What is the recommendation from this evidence base?

Our recommendation is that policy 1D is the most able to deliver low carbon buildings and that it is technically possible to meet the policy requirements for the range of buildings modelled.

Although this could be the costliest of the four policy options examined in this evidence base, it will ensure buildings delivered will have high levels of efficiency, while incentivising applicants to minimise carbon emissions.

Policy 1D



Policy 1C is the next best alternative for Councils to consider and would reduce the risk of offsetting unregulated energy not being WMS compliant.

Executive Summary | What is demonstrated by this evidence base?

Technical feasibility

Summary of key conclusions and findings:

1. It is technically feasible for all assessed policies to be met by each typology, with one exception (see 2).
2. For the case where high-rise blocks of flats are connected to a District Heat Network in 2026 and must reduce their emissions on-site by 70% (Policy 1A), the maximum possible reduction in CO₂ emissions is 63%, and offsetting is not permitted so this case would not be able to technically comply with Policy 1A.
3. An additional requirements based on a 10% improvement over the Target Fabric Energy Efficiency (TFEE) can help ensure the delivery of more efficient buildings.
4. Additional requirements based on the Target Primary Energy Rate (TPER) do not appear useful.
5. Allowing carbon offsetting can be a useful tool to allow buildings to comply with policy that would otherwise be unable to. However, the carbon offset price should be high enough for carbon offsetting not to become a cheaper alternative than further improvements on-site.
6. Currently, Part L1A calculations do not include unregulated energy. This is a significant proportion (up to 50%) of the energy consumed by new buildings.
7. Policy 1D is likely to be the most effective at helping to deliver low carbon developments: it sets a high standard for carbon emission reduction over the TER, requires energy efficiency improvements, and accounts for residual carbon emissions that cannot be dealt with on-site as well as unregulated emissions.

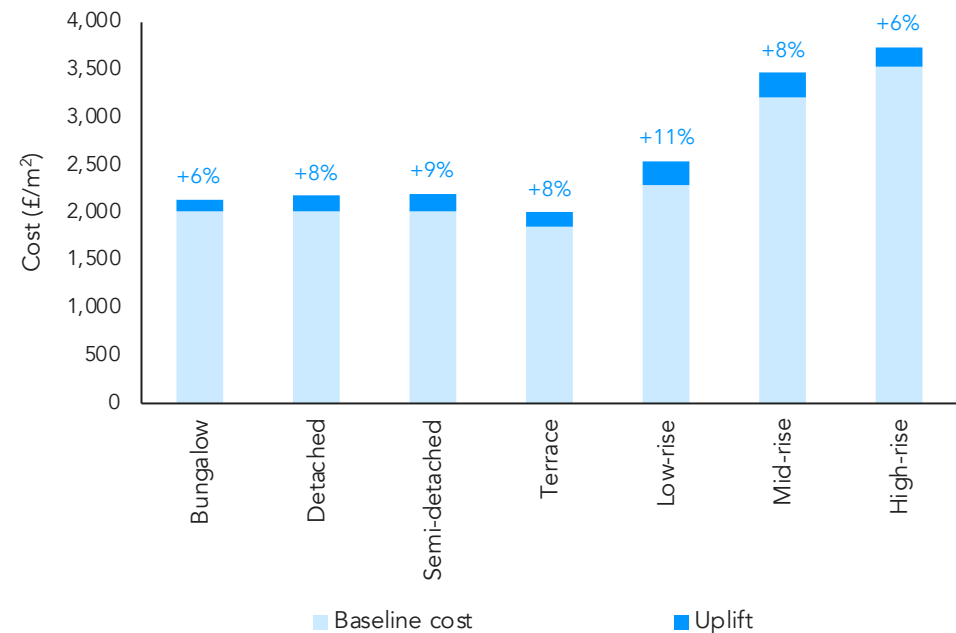
Cost assessment

The proposed technical specifications for each typology were [costed against each policy option](#). These costs were then compared against a Part L 2021 compliant baseline specification to determine the uplift in cost for each typology under each policy option.

The additional cost ranges from 0-11% across all typologies and scenarios, with the highest uplifts being for the low-rise block of flats.

Policy 1D requires the largest cost uplift but it will be the most effective at delivering low carbon developments.

Policy 1D cost uplift (analysis by Currie & Brown)



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Why has this TER study been undertaken and what is its purpose?



Local Authorities have primary duties and powers to mitigate climate change

Primary duties to mitigate climate change

- The **Climate Change Act 2008** sets a clear direction for the UK. It obliges the government to set policy that will enable the UK to achieve Net Zero by 2050 at the latest and to meet its carbon budgets between now and 2050.
- The **National Planning Policy Framework 2023** recognises that the Climate Change Act 2008 duties are relevant to planning for climate change. Paragraph 158 requires that local plans should “take a proactive approach to mitigating and adapting to climate change”.
- Section 19 of the **Planning and Compulsory Purchase Act 2004** requires that development plan documents must include policies designed to secure that development and use of land “contribute to mitigation of, and adaptation to, climate change”.

The CCC 2024 progress report: National policy is not enough

In its 2024 Progress Report to Parliament, the Climate Change Committee’s assessment was that credible plans cover only a third of the emissions reductions required to achieve the 2030 target and only a quarter of those needed to meet the Sixth Carbon Budget. In particular, the CCC found that missing or incomplete policies included those on energy efficiency in buildings.

Primary powers to mitigate climate change

The **Planning and Energy Act 2008** empowers local plans to set “reasonable requirements” for new buildings to comply with “energy efficiency standards that exceed ... building regulations” and “supply a proportion of their energy from nearby renewable or low carbon sources”.

In their **response to the Future Homes Standard consultation** in 2021, the Government stated that “Local authorities have a unique combination of powers, assets, access to funding, local knowledge, relationships with key stakeholders and democratic accountability.”



Climate Change Act 2008

2008 CHAPTER 27



Department for Levelling Up,
Housing & Communities

National Planning Policy Framework



Planning and Compulsory Purchase Act 2004

2004 CHAPTER 5

An Act to make provision relating to spatial development and town and country planning; and the compulsory acquisition of land.
[13th May 2004]



Planning and Energy Act 2008

The 2023 WMS

A Written Ministerial Statement (WMS) was made on 13th December 2023 by the Parliamentary Under Secretary of State for Levelling Up, Housing and Communities. A key extract of the statement is:

*Any planning policies that propose local energy efficiency standards for buildings that go beyond current or planned buildings regulation should be rejected at examination **if they do not have a well-reasoned and robustly costed rationale** that ensures:*

- *That development remains viable, and the impact on housing supply and affordability is considered in accordance with the National Planning Policy Framework.*
- *The additional requirement is expressed as a percentage uplift of a dwelling's Target Emissions Rate (TER) calculated using a specified version of the Standard Assessment Procedure (SAP).*

Interpreting the 2023 WMS

A judicial review of the 2023 WMS has been undertaken. The judgment by Mrs Justice Lieven (published on 2 July 2024) rejected the three grounds which formed the basis of the judicial review.

It highlighted that Government *"has chosen to put considerable weight on the impact that might have on the supply of new housing, over the potential benefits of imposing higher standards. This is a policy choice for the Minister and is explained in the assessment and does not disclose any error of law. Experts might disagree on the issue, but that is a matter for policy makers and not the Court"*.

Legal opinion is divided on whether the 2023 WMS recommends the use of Building Regulations Part L metrics in local planning policy or whether energy-based metrics can be used as long as it is justified by a robust evidence base. This evidence base has been prepared in case the Planning Inspector adopts a 'narrow' interpretation of the 2023 WMS and recommends the use of Part L metrics.

The screenshot shows a webpage with a dark red header. The main title is 'Planning - Local Energy Efficiency Standards Update' in white. Below it, in smaller white text, is 'Statement made on 13 December 2023'. Underneath that is 'Statement UIN HLWS120'. The main content area has a light grey background. On the left, under 'Statement made by', there is a profile for Baroness Penn, Parliamentary Under Secretary of State for Levelling Up, Housing and Communities, Conservative, Life peer. On the right, under 'Statement from', it says 'Department for Levelling Up, Housing and Communities'. Below this, under 'Statement', it begins with 'As a Government, we continue to make progress towards the net zero goal set out in legislation in 2019, including by improving the energy efficiency of homes and moving to cleaner technologies and sources of power within the homes and building sector.' There is a 'Notes' button at the bottom right of the statement text.

The 2023 Written Ministerial Statement on Planning – Local Energy Efficiency Standards Update can be found at <https://questions-statements.parliament.uk/written-statements/detail/2023-12-13/hlws120>

The screenshot shows a document with a white background and black text. At the top, in bold, is 'IN THE MATTERS OF THE PLANNING AND ENERGY ACT 2008 AND THE PLANNING AND COMPULSORY PURCHASE ACT 2004'. Below that, in bold, is 'Re: Legal basis for planning policies delivering Net Zero Carbon developments'. There is a horizontal line, followed by the text 'OPEN ADVICE' in bold, followed by another horizontal line. Below that, in bold, is 'INTRODUCTION AND SUMMARY'. Underneath, there is a numbered list starting with '1. In May 2023, an evidence study to support planning policies which deliver Net Zero Carbon developments, entitled *Delivering Net Zero* ("the Evidence Study"), was published. It provides a technical evidence base to inform the policy making process for 18 participating London boroughs. It proposes two policy options, with indicative wording.'

Written legal advice provided to Etude in September 2024 concludes that the 2023 WMS does not prevent local plan policies based on energy-based metrics from being brought forward by local planning authorities or being found sound in examination.

Purpose of this study

Four local authorities in the West of England

This technical study was commissioned by four local authorities in the West of England:

- Bath & North East Somerset Council
- Bristol City Council
- North Somerset Council
- South Gloucestershire Council

Proposed approach to policy for new buildings

The four local authorities are currently proposing policies based on energy-based metrics and predicted energy use modelling. This is the result of their policy development process informed by published evidence as well as viability testing.

However, the 2023 Written Ministerial Statement (WMS) introduces a risk that the proposed policies will not be deemed acceptable if the Planning Inspector considers that the WMS has more weight than the justification, evidence and viability testing put forward by these local authorities.

Given the difficulty in assessing this risk, the four local authorities have commissioned this study to help their design of the best possible 'alternative' policy for new buildings.

Alternative 'back up' approach

The alternative policies are based on a strict and narrow interpretation of the 2023 WMS. They are using a percentage improvement over the TER metric and will require the use of Part L modelling.

A suboptimal alternative

Although it is not the purpose of this study, we have summarised why the alternative approach would not be as satisfactory in terms of outcomes; both in building performance and impact on residents, as compared to the currently proposed policy approach.

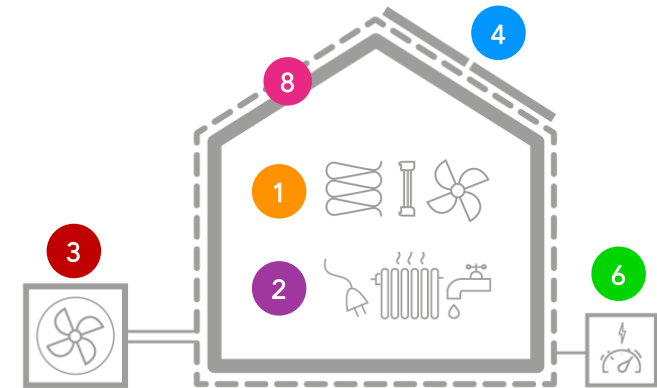


The four local authorities in the West of England who have commissioned this study

Key principles of Net Zero Carbon buildings

There is currently no Government definition of what a Net Zero Carbon building is. However, local authorities and the industry have developed several definitions over the last five years, gradually moving towards a consensus.

“A Net Zero Carbon building is constructed with a low level of embodied carbon. It is fossil fuel free, energy efficient, and its net operational CO₂ emissions are zero as renewable energy generated on site (or off-site when it is not feasible) balances, on an annual basis, the energy it is using.”



1 Energy efficient fabric and ventilation

Space heating demand (kWh/m²_{GIA}/yr)

The building should achieve an ultra-low level of space heating demand, in line with the recommendations of the Climate Change Committee. This target is related to the efficiency of the fabric and ventilation, independent of the efficiency of the heating system.

2 Low total energy use

Energy Use Intensity (EUI) (kWh/m²_{GIA}/yr)

The predicted level of total energy use of the building (regulated and unregulated) should be less than a limit. This metric is closely related to the building's utility bills. Lower EUI values translate into lower energy consumption, and lower energy bills.

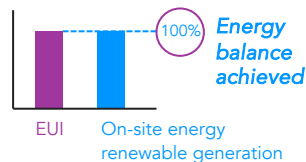
3 Fossil fuel free

Yes/ No

The building must not connect to the gas network or, more generally, use fossil fuels on-site. It must use a low carbon heating system (e.g. heat pump).

4 On-site renewable energy generation

kWh/m²_{f_p} and % of total energy use



The building should seek to generate as much renewable energy as possible. Ideally there should be a balance between predicted annual energy use and annual renewable energy generation. 'Specific energy generation' where the total amount of electricity generation divided by the footprint of the buildings are good indicators of efficiency.

5 Energy flexibility

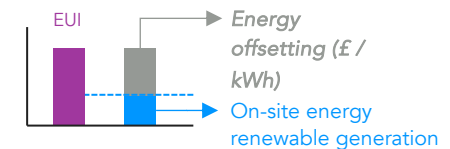
The building should be able to shift its electricity demand in order to reduce peak demand on the national grid.

6 Assured energy performance

In order for energy performance to be delivered during operation, a quality assurance scheme should be adopted during design and construction.

Energy performance should also be monitored and reported during the first 5 years of occupation.

7 Energy offsetting as last resort



If the building cannot generate enough renewable energy to match energy use on an annual basis, an energy offset contribution will be required.

8 Embodied carbon

Upfront embodied carbon limit (kgCO_{2e}/m²_{GIA})

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

Proposed energy-based metrics and alternative (suboptimal) TER-based metric

Clear metrics for each policy objective

The current policy proposal is based on a set of metrics to separately measure each of the key attributes needed to achieve Net Zero:

- **Space heating demand (kWh/m².yr)** for energy efficiency
- **EUI (kWh/m².yr)** for energy efficiency (including system efficiencies)
- Total **renewable energy generated ((kWh/m²_{fp}.yr)** and **energy balance (%)** for renewable energy generation.

Having a dedicated metric per key policy objective helps to deliver a minimum or threshold performance for each objective. This avoids 'trading' between the different objectives and recognises each as being essential components of a Net Zero Carbon building.

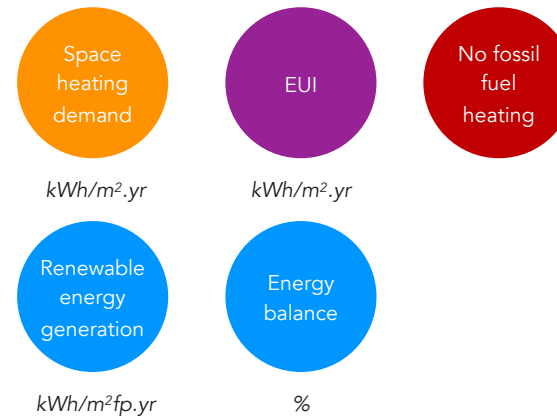
Alternative metrics for an alternative 'back up' policy

Should the planning inspection process conclude that it is not possible for the Local Plan to use energy-based metrics, an alternative metric would have to be used: the reduction in regulated carbon emissions over the building regulations Part L limit expressed as a percentage, i.e. **% better than the Part L 2021 TER**. Unfortunately, this single metric has a number of limitations:

1. It aggregates the influence of fabric and ventilation specifications as well as the heating system and PVs.
2. It does not consider the impact of the design of the building (form), a key factor in energy efficiency.
3. It is carbon-based: therefore, the decarbonisation of the grid will dilute differences in energy efficiency performance.
4. It only covers regulated energy use and therefore ignores energy use from appliances, cooking and equipment, which can account for 50% of energy in low-energy dwellings.
5. It is not a proxy for energy costs and cannot be translated into energy costs.

In light of this metric's weaknesses, another regulatory metric, the % improvement over the Part L 2021 TFEE (Target Fabric Energy Efficiency) should be considered.

Current policy metrics



Key metrics used to produce this evidence base

Back-up policy



The TER (or Target Emission Rating) represents the regulated carbon emission limit set by Building Regulations)

It is the metric mentioned in the 2023 WMS



The TFEE (or Target Fabric Energy Efficiency) represents the 'fabric performance' limit set by Building Regulations)

Although not mentioned in the 2023 WMS, it is used in the Building Regulations and therefore likely to be deemed compliant with the WMS.

Proposed predictive energy use modelling and alternative (suboptimal) Part L modelling

The benefits of predictive energy modelling

For policy requirements to have a measurable impact on the actual energy performance of new buildings, predictive energy modelling is necessary. The accuracy of energy modelling is important to ensure it provides a reasonable indication of buildings' 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.


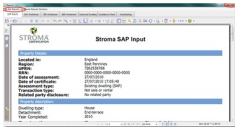

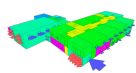
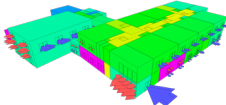
- For domestic buildings, the PHPP methodology and excel based tool have been shown to predict energy use much more accurately than the current version of SAP.
- For non-domestic buildings, predictive energy modelling using the methodology set out in CIBSE Technical Memorandum 54 (TM54) allows estimation 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 modelling

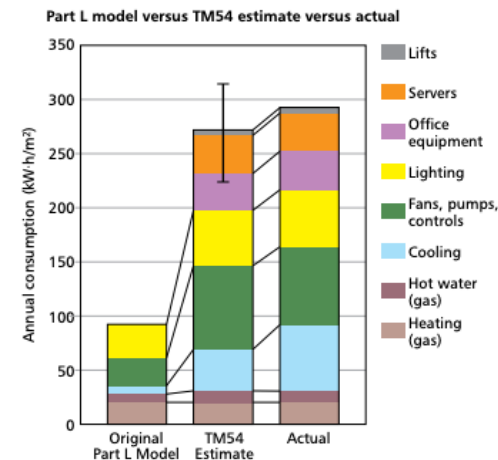
Should the planning inspection process conclude that a % better than TER metric should be used, predictive energy modelling would have to be replaced by Part L modelling.

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.

However, it is very important to note that these Part L energy assessment methodologies were developed only to check compliance with Building Regulations and were never meant to perform key functions that are required to deliver Net Zero carbon buildings. Most importantly, these methodologies were not meant to predict future energy use accurately. The 'performance gap' between the energy that buildings are calculated to consume using these methodologies, compared to the energy they actually consume is well known and documented. Evidence of this can be found in [research from the Zero Carbon Hub](#).

	Predicted energy use modelling	Part L modelling
Domestic	 PHPP	 SAP (Part L1A)
Non-domestic	  PHPP or DSM (TM54)	 NCM (Part L2A)

There is a significant difference between predictive energy use modelling and Part L modelling. The table above shows the methodologies used for each for domestic and non-domestic buildings.



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

Policy routes | Comparison

	Policy based on energy metrics	Policy based on TER reduction
Metrics used	<p>Absolute energy metrics:</p> <ul style="list-style-type: none"> • Space Heating Demand (kWh/m²/yr) • Energy Use Intensity (kWh/m²/yr) • Renewable Energy generation (kWh/m²/yr) 	<p>Target Emissions Rate (TER) (CO₂)</p> <p>The TER is a relative metric, it will change from building to building. And for the same building, will change from one revision of Part L to the next. It does not predict actual CO₂ emissions (or energy use).</p>
Definition of “net zero”	<p>Energy balance (annual energy consumption = annual renewable energy generation).</p>	<p>100% reduction on the Target Emissions Rate (TER)</p>
Regulated energy included?	<ul style="list-style-type: none"> • space heating ✓ • Hot water ✓ • Pumps and fans ✓ • Lighting ✓ 	<ul style="list-style-type: none"> • Space heating ✓ • Hot water ✓ • Pumps and fans ✓ • Lighting ✓
Unregulated energy included?	<ul style="list-style-type: none"> • Cooking ✓ • Appliances ✓ 	<ul style="list-style-type: none"> • Cooking ✗ • Appliances ✗ <p>Unregulated energy can account for 50% of energy in low-energy dwellings.</p>
Renewable energy included?	<p>Yes. Renewable energy generation has its own metric, so it is clear to see what contribution is being made.</p>	<p>Yes. Renewable energy is accounted for in the calculations. Carbon savings are rolled into one metric, so it is not possible to isolate the contribution renewable energy is making.</p>
Embodied carbon included?	<p>Additional policy mechanism required.</p>	<p>Additional policy mechanism required.</p>
Calculation methodologies	<p>Calculation through design tools:</p> <ul style="list-style-type: none"> • PassivHaus Planning Package (PHPP) for dwellings. • TM54 or Dynamic Simulation for non-dwellings. 	<p>Calculation through compliance tools:</p> <ul style="list-style-type: none"> • Building regulations Standard Assessment Procedure (SAP) for dwellings. • Building regulations National Calculation Methodology (NCM) for non-dwellings.
Aligned with national Building Regulations?	<p>Not yet.</p>	<p>Yes. Also in line with the Climate Change Act commitments.</p>
Does it promote NZC building design?	<p>Yes. The significant impacts that building design and orientation have on energy use are captured through the space heating demand metric and the use of accurate calculation methodologies.</p>	<p>No. The benefits of building design and orientation is not captured in building regulations assessment methodologies.</p>
Can it be verified or measured in operation?	<p>Yes. The EUI can be calculated by reading the energy used at the main electricity meter and dividing it by the floor area of the building.</p>	<p>No. Abstract metrics and only accounting for regulated energy means that this does not be checked in operation.</p>

2.0

Part L 2021 and its key metrics, and Part L 2025



The building regulations landscape

The current Building Regulations

The current section of the building regulations that governs energy and carbon emissions is Part L 2021. It came into force in June 2022 and is due to be replaced by the Future Homes Standard (residential) and the Future Buildings Standard (non-residential) in 2025.

Future Homes Standard Consultation

At the time of compiling this evidence base (July-August 2024), the Government held a consultation on the content, standards and methodologies of the Future Homes Standard, the Future Buildings Standard and the Home Energy Model (Dec 2023-March 2024).

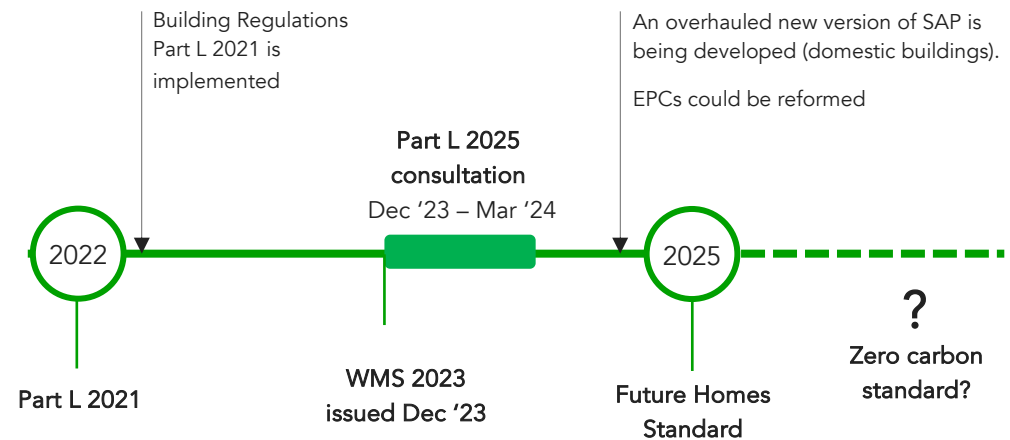
Whilst the specifics are yet to be determined, it is understood that a home with fossil fuel heating (such as gas boilers) will find it very challenging to comply. Additionally, it is expected that buildings will need to be 'zero carbon ready', with no retrofit work required to benefit from the decarbonisation of the electricity grid and the electrification of heating.

Although a date has not been confirmed, it is expected that the new regulations will be released in 2025, along with the Home Energy Model, its associated calculation methodology. The latter, will replace the Standard Assessment Procedure (SAP), currently used to determine compliance with Part L of the building regulations for dwellings.

The impact on Future Homes and Future Buildings Standards on this study

Although the Future Homes and Future Buildings Standards are welcome signs of the ambition to reduce carbon emissions from new buildings at Government level, there is not enough evidence or certainty on the proposed changes to influence this study significantly. As evidenced in the [Government's 2023 consultation](#), it is possible that the new standards will not demand any further improvements to fabric.

However, it is important to note that any policy based on Part L 2021 will need to be revised when Part L 2025 will come into force.



Policy changes are moving towards zero carbon, however there is much uncertainty surrounding the details.

Part L1A 2021 for domestic buildings

The Building Regulations set out the statutory standards developments are to meet. These standards include Part L Volume 1 (2021), which came into force in June 2022 and sets the minimum energy performance that a new dwelling must achieve, including:

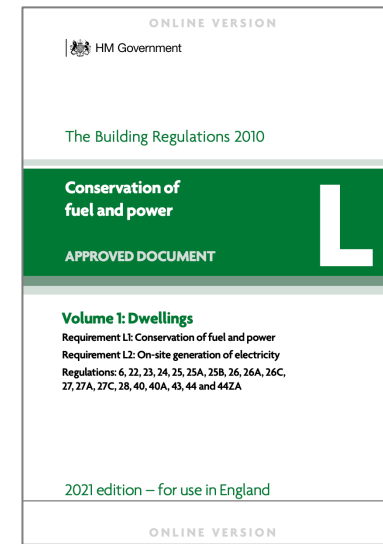
- The primary energy rate ($\text{kWh}_{\text{PE}}/\text{m}^2$).
- The carbon emission rate (kgCO_2/m^2).
- The fabric energy efficiency standard, FEES (kWh/m^2).

SAP 10.2 is the approved methodology to be used for Part L 2021 compliance modelling.

Key requirements and changes from previous versions

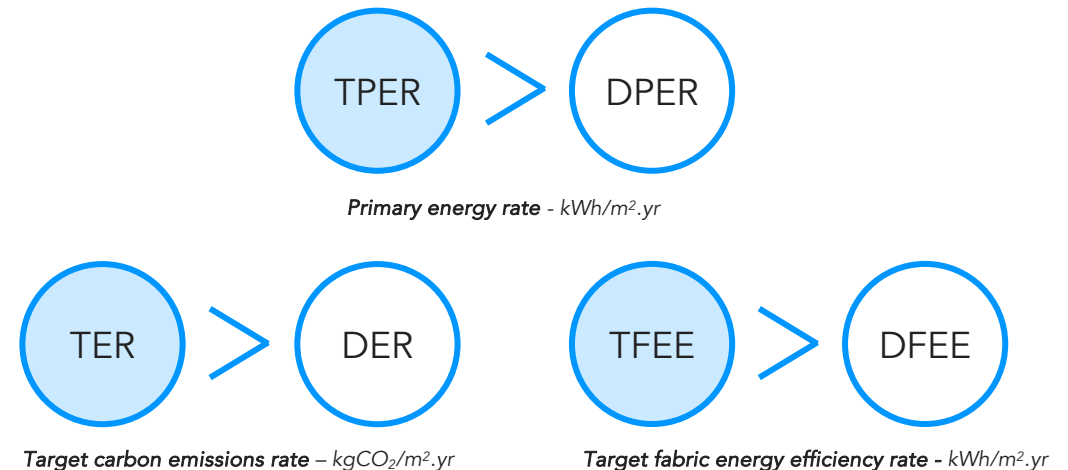
The list below summarises key requirements included into the latest version of Part L1:

- **Primary energy use** – This is set using the notional building approach. Primary energy use relates to how much delivered energy is required by the new home; it is then converted (using primary energy factors) into primary energy, reported as $\text{kWh}/\text{m}^2\text{yr}$.
- **Carbon factors** – The carbon factors have been updated, and electricity has dropped to $0.136 \text{ kgCO}_2/\text{kWh}$ which is 74% lower than the electricity carbon factor in Part L 2013 (i.e. $0.519 \text{ kgCO}_2/\text{kWh}$), and lower than gas (i.e. $0.210 \text{ kgCO}_2/\text{kWh}$). The implication is that electric modes of heating (e.g. heat pumps, direct electric) are now lower carbon than fossil fuel heating (e.g. gas boilers).
- **Revised “notional” building specification** – The assumptions used for the notional dwelling to derive the Target Emission Rate (TER) have been revised. The most significant change is that PVs and Waste Water Heat Recovery (WWHR) are assumed.
- **Continuity of insulation** – There is now a requirement to clearly identify the insulation layer on drawings to ensure the insulation layer is continuous, buildable and robust.
- **Evidence for as-built SAP calculations** – There is now an onus on providing photographic evidence to demonstrate construction quality in order to reduce the performance gap.



Part L 2021 – Conservation of fuel and power – Volume 1: Dwellings

Summary of key criteria (T = Target – D = Dwelling)



New dwellings must comply with the energy and carbon requirements highlighted above.

Unregulated energy (as assessed by SAP 10.2)

Unregulated energy and SAP 10.2

Part L 2021 calculations report the estimated carbon emissions of a dwelling over the course of a typical year. However, these carbon emissions are calculated from regulated energy use only. This includes energy consumed for space heating, hot water, lighting, and pumps and fans, less any energy generated by renewable sources.

It is possible to calculate an estimated unregulated energy consumption through the Part L 2021 methodology, although this is not directly reported. Unregulated energy is consumed through electrical appliances and cooking.

In the SAP10.2 methodology, unregulated energy use is heavily tied to the floor area of the dwelling.

As buildings become more efficient and use less energy, unregulated energy consumption becomes more important, as it becomes a larger proportion of a dwelling's total energy consumption. For new dwellings, unregulated energy can account for 50% of a dwelling's total energy consumption.

Known issues and future calculations

There are some known issues with the calculation of unregulated energy in the Part L 2021 methodology. These include the basis of energy use data for appliances which comes from an outdated source (1998) and the fact that all unregulated energy use has been aggregated into one energy use instead of being based on the individual contribution from individual appliances.

Therefore, a change in the calculation is expected in the Home Energy Model for the Future Homes Standard which will come into effect in 2025.



High-rated (A+++) washing machine model from Bosch



High-rated (A+++) free standing fridge-freezer model from Bosch

What about the Future Homes Standard?

Future Homes Standard (FHS)

The UK Government's proposed Future Homes Standard (FHS) aims to make all new homes 'zero carbon ready' by 2025 as an interim step towards net zero emissions by 2050. Key requirements cover:

- Energy efficiency (e.g. insulation, window performance and airtightness) broadly similar to the level required by the current Part L 2021 requirements (i.e. no notable improvement).
- Low-carbon heating systems in all new homes (no gas boilers)
- The potential requirement for PV systems, although one option does not include any.

Future Buildings Standard (FBS)

The Future Buildings Standard (FBS) proposes changes to Part L (conservation of fuel and power) and Part F (ventilation) of the Building Regulations for new and existing non-domestic buildings.

Comments on the 'usability' of the FHS/FBS for Local Plan making

There are a number of considerations limiting the ability for a Local Planning Authority to base their new policies on the FHS/FBS:

1. Two options are proposed for the 'notional building' in the consultation and the Government have not yet responded to the consultation and/or indicated which option (or a potential hybrid) will form the basis of the FHS. Until a consultation response is published, these two options do not represent a firm basis.
2. Concerns remain that the proposed standards do not go far enough to be in line with the recommendations of the Climate Change Committee. Limitations include continued use of a relative performance approach instead of absolute targets, the use of metrics which cannot be easily measured during operation and the exclusion of unregulated energy use.
3. Calculation methodologies required to demonstrate compliance are not yet available and cannot therefore reliably be used.

The screenshot shows the cover page of a consultation document. At the top, it says 'Closed consultation' in white text on a blue background. Below that, the title 'The Future Homes and Buildings Standards: 2023 consultation' is written in large white font. Underneath the title, it says 'Updated 4 March 2024'. A grey bar below the title contains the text 'Applies to England'. To the left, there is a 'Contents' section with a list of eight items, each with a blue number and text. To the right of the contents, there is a grey box containing a summary of the consultation: 'The Future Homes and Buildings Standards: 2023 consultation on changes to Part 6, Part L (conservation of fuel and power) and Part F (ventilation) of the Building Regulations for dwellings and non-domestic buildings and seeking evidence on previous changes to Part O (overheating)'. Below the contents and summary, the heading '1. Scope of consultation' is displayed in bold black text.

Closed consultation

The Future Homes and Buildings Standards: 2023 consultation

Updated 4 March 2024

Applies to England

Contents

1. [Scope of consultation](#)
2. [Acronyms](#)
3. [Introduction](#)
4. [Performance requirements for new buildings](#)
5. [Metrics](#)
6. [Updated guidance and minimum standards](#)
7. [Material Change of Use](#)
8. [Real-world performance of homes](#)

The Future Homes and Buildings Standards: 2023 consultation on changes to Part 6, Part L (conservation of fuel and power) and Part F (ventilation) of the Building Regulations for dwellings and non-domestic buildings and seeking evidence on previous changes to Part O (overheating)

1. Scope of consultation

The Future Homes and Building Standards consultation ran between December 2023 and March 2024.

3.0

Potential Part L 2021 based policies



Overview

Creating policies

This study has considered 4 different potential policy options. These are described opposite.

Etude have modelled each of the typologies to show how they may be able to meet each of the policy options.

Policy 1A

All domestic buildings should achieve a minimum 70% improvement over the TER on site.

Policy 1B

All domestic buildings should achieve a minimum 100% improvement over the TER on site.

+

When it is not technically feasible to achieve on site, carbon offsetting should be used to make up the difference.

Policy 1C

All domestic buildings should achieve a minimum 100% improvement over the TER on site.

+

When it is not technically feasible to achieve on site, carbon offsetting should be used to make up the difference.

+

All domestic buildings should achieve a minimum 10% improvement over the TFEE.

Policy 1D

All domestic buildings should achieve a minimum 100% improvement over the TER on site.

+

When it is not technically feasible to achieve on site, carbon offsetting should be used to make up the difference.

+

All domestic buildings should achieve a minimum 10% improvement over the TFEE.

+

All domestic buildings should offset their unregulated carbon emissions, either through on-site generation or carbon offsetting.

Policy 1A

Policy 1A requires all domestic buildings to achieve a minimum of a 70% improvement over the TER on site.

As the modelling results show later, this is achievable for all typologies, except for the high-rise block of flats connected to a District Heat Network in 2026.

Policy 1A

All domestic buildings should achieve a minimum 70% improvement over the TER on site.

Policy 1B

All domestic buildings should achieve a minimum 100% improvement over the TER on site.



When it is not technically feasible to achieve on site, carbon offsetting should be used to make up the difference.

Policy 1C

All domestic buildings should achieve a minimum 100% improvement over the TER on site.



When it is not technically feasible to achieve on site, carbon offsetting should be used to make up the difference.



All domestic buildings should achieve a minimum 10% improvement over the TFEE.

Policy 1D

All domestic buildings should achieve a minimum 100% improvement over the TER on site.



When it is not technically feasible to achieve on site, carbon offsetting should be used to make up the difference.



All domestic buildings should achieve a minimum 10% improvement over the TFEE.



All domestic buildings should offset their unregulated carbon emissions, either through on-site generation or carbon offsetting.

Policy 1B

Policy 1B requires all domestic buildings to achieve a minimum of a 100% improvement over the TER. For any building where this is not technically feasible, the remaining carbon emissions should be offset.

As the modelling results show later, it is possible for bungalows, detached houses and semi-detached houses to meet the 100% improvement over the TER on site. For terraced townhouses, low-rise flats, mid-rise flats and high-rise flats, some offsetting will be required.

Policy 1A

All domestic buildings should achieve a minimum 70% improvement over the TER on site.

Policy 1B

All domestic buildings should achieve a minimum 100% improvement over the TER on site.



When it is not technically feasible to achieve on site, carbon offsetting should be used to make up the difference.

Policy 1C

All domestic buildings should achieve a minimum 100% improvement over the TER on site.



When it is not technically feasible to achieve on site, carbon offsetting should be used to make up the difference.



All domestic buildings should achieve a minimum 10% improvement over the TFEE.

Policy 1D

All domestic buildings should achieve a minimum 100% improvement over the TER on site.



When it is not technically feasible to achieve on site, carbon offsetting should be used to make up the difference.



All domestic buildings should achieve a minimum 10% improvement over the TFEE.



All domestic buildings should offset their unregulated carbon emissions, either through on-site generation or carbon offsetting.

Policy 1C

Policy 1C builds on policy 1B with an additional requirement for all domestic buildings to achieve a 10% improvement over the TFEE. This additional policy requirement is shown to be possible for all typologies through the modelling results.

Policy 1A

All domestic buildings should achieve a minimum 70% improvement over the TER on site.

Policy 1B

All domestic buildings should achieve a minimum 100% improvement over the TER on site.

+

When it is not technically feasible to achieve on site, carbon offsetting should be used to make up the difference.

Policy 1C

All domestic buildings should achieve a minimum 100% improvement over the TER on site.

+

When it is not technically feasible to achieve on site, carbon offsetting should be used to make up the difference.

+

All domestic buildings should achieve a minimum 10% improvement over the TFEE.

Policy 1D

All domestic buildings should achieve a minimum 100% improvement over the TER on site.

+

When it is not technically feasible to achieve on site, carbon offsetting should be used to make up the difference.

+

All domestic buildings should achieve a minimum 10% improvement over the TFEE.

+

All domestic buildings should offset their unregulated carbon emissions, either through on-site generation or carbon offsetting.

Policy 1D

Finally, Policy 1D adds a requirement that unregulated energy should be offset, either through on-site generation, or through offsetting.

This additional policy requirement is shown to be possible for all typologies through the modelling results.

Policy 1A

All domestic buildings should achieve a minimum 70% improvement over the TER on site.

Policy 1B

All domestic buildings should achieve a minimum 100% improvement over the TER on site.

+

When it is not technically feasible to achieve on site, carbon offsetting should be used to make up the difference.

Policy 1C

All domestic buildings should achieve a minimum 100% improvement over the TER on site.

+

When it is not technically feasible to achieve on site, carbon offsetting should be used to make up the difference.

+

All domestic buildings should achieve a minimum 10% improvement over the TFEE.

Policy 1D

All domestic buildings should achieve a minimum 100% improvement over the TER on site.

+

When it is not technically feasible to achieve on site, carbon offsetting should be used to make up the difference.

+

All domestic buildings should achieve a minimum 10% improvement over the TFEE.

+

All domestic buildings should offset their unregulated carbon emissions, either through on-site generation or carbon offsetting.

Proposed approach to carbon offsetting

The role of offsetting in policies 1A-1D

All policy options (1A-1D) include a requirement to achieve an improvement over Part L 2021 on-site.

This level is 70% better than the TER for Policy option 1A and therefore, technically possible and viable by most domestic applications to achieve this policy requirement on-site without any need for carbon offsetting.

This level is 100% better than the TER for Policy options 1B, 1C and 1D and some domestic applications, particularly those with high density buildings will find it impossible to comply. For these applications to be deemed 'policy compliant' it will be necessary for applicants to determine the residual regulated carbon emissions and offset them.

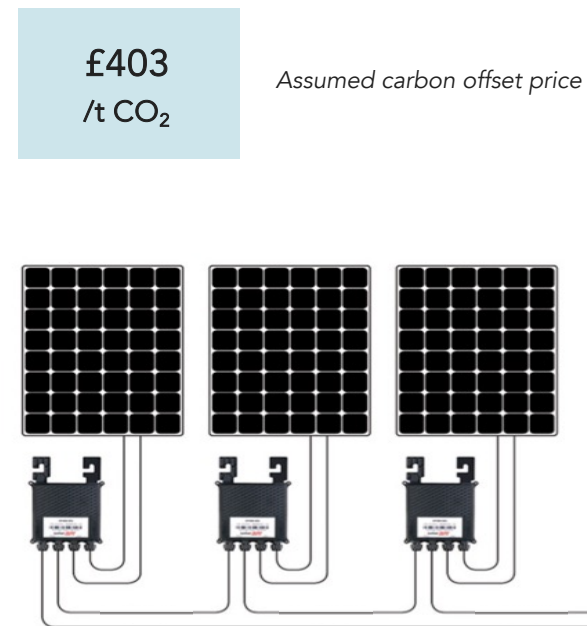
In addition to this, Policy option 1D requires unregulated carbon emissions to be offset. This requirement may not be deemed compliant with the 2023 WMS.

The question of carbon pricing

Carbon offsetting should not be cheaper than installing additional PVs on site otherwise applicants will be incentivised to offset instead of saving more carbon on-site. In this study, we used a carbon offset price of £403/tCO₂ as suggested by the [Green Book supplementary guidance](#) values.

Other issues and risks associated with carbon offsetting

- **Delivering carbon savings with offset funds on other sites is not straightforward.** Applicants pay into the Local Authority's offset fund, effectively shifting the responsibility of carbon savings away from the applicant/the building to the Council/off-site. Saving carbon elsewhere has its own challenges.
- **Unregulated missions are not even offset with policies 1A-1C.** They focus on regulated carbon emissions only and therefore can only require the residual regulated emissions to be offset. This means that unregulated emissions are not offset.



If the carbon offset price is £403/tCO₂ it is likely to favour installation of PVs on site over offsetting which is beneficial. If it is not possible to install PVs on site, this price is likely to be sufficient for installing additional PVs off-site.

4.0

Energy and cost modelling undertaken



Energy and cost modelling analysis | Purpose and archetype selection

Purpose of energy and cost modelling

Energy and cost modelling constitutes an important part of this technical evidence base. Its purpose is to investigate whether different building typologies can comply with the requirements of the proposed policies and, if they can, to assess the cost of compliance.

Typology selection

There are a wide range of building types in the West of England and within each building type an almost infinite variety of buildings.

In order to undertake the energy and cost modelling for this technical evidence base, a number of options were identified and assessed:

- Three single homes (i.e. bungalow, terrace house, semi-detached house and detached house).
- Three multi residential types (i.e. low-rise, medium-rise and high-rise apartment buildings).

One building for each of the typologies was selected as 'representative' and each one is a typical developer-built example of that particular typology. The buildings selected are illustrated on this page.

Although there will be variations in designs and specifications that could impact energy, carbon and cost, it is very common for technical evidence bases to use representative samples and it is reasonable to assume that the findings for each building can be extrapolated to other types building designs within the same typology.

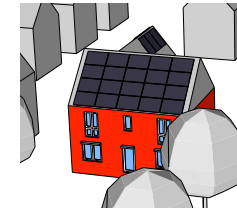
11 different scenarios/combinations of specifications

For each of these buildings, 11 different scenarios were modelled, combining different specifications in terms of fabric and ventilation, heating system and solar PVs (see following page). Additional specifications were developed to assess the connection to heat networks for the mid-rise and high-rise typologies.

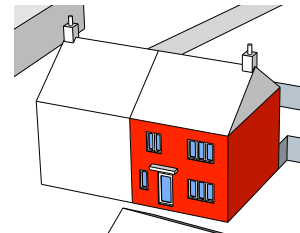
Typologies selected

Image redacted

Bungalow
1 storey
1 unit
115 sqm



Detached house
2 storeys
1 unit
114 sqm



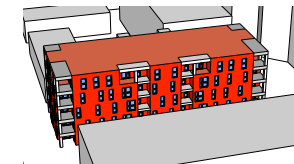
Semi-detached house
2 storeys
1 unit
93 sqm



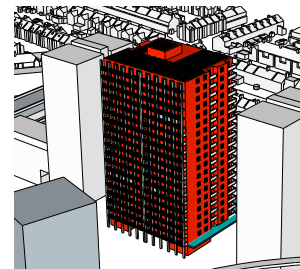
Terraced town house
3 storeys
1 unit
112 sqm

Image redacted

Low-rise
4 storeys
16 units
980 sqm



Mid-rise
6 storeys
34 units
3,200 sqm



High-rise
20 storeys
180 units
15,540 sqm

Graphical representation of the 7 buildings chosen as typologies

Energy and cost modelling analysis | Initial modelling phase

Specification scenarios modelled

A fair and balanced set of specifications which considered various levels of performance for fabric, infiltration and ventilation, heating systems, and renewable energy provision were modelled.

Starting from a Part L 2021 compliant specification for each of the typologies, Etude tested the impact of improving building fabric, infiltration and ventilation, heating, and renewable energy specifications individually to a best practice scenario for each typology. Finally, a scenario was tested for each typology which encompassed all changes to show the maximum possible impact on the Part L 2021 metrics for each typology.

For the mid-rise and high-rise blocks of flats typologies, additional scenarios were modelled to show how the buildings would perform when connected to a district heating system. The system modelled was proposed by Bristol City Council, who provided the relevant mix of heat sources along with their proportions and efficiencies, both for a 2026 scenario and a 2030 scenario.

Etude also modelled the Future Homes Standard specification (Option 1) for each of the typologies to show how the Part L 2021 metrics are impacted, but this has not been considered further in this study due to uncertainty around the specification and calculation method.

An example for the detached house is provided in this section and the specific assumptions for all seven building archetypes are all available in the appendices.

			Part L 2021 (Baseline)	Future Homes Standard (Option 1)	Fabric upgrade	Ventilation upgrade	Heating system upgrade	Maximise PV	All improvements
Building fabric and ventilation strategy	Floor Walls Roof (W/m ² K)		Part L 2021 compliant fabric 0.12 0.15 0.11	FHS compliant fabric 0.12 0.15 0.11	Low energy fabric 0.09 0.12 0.10	Part L 2021 compliant fabric 0.12 0.15 0.11	Part L 2021 compliant fabric 0.12 0.15 0.11	Part L 2021 compliant fabric 0.12 0.15 0.11	Low Energy Fabric 0.09 0.12 0.10
	Windows (W) Doors (D) (W/m ² K)		Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Triple glazing W - 0.8 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Triple glazing W - 0.8 D - 1.0
	Airtightness (m ³ /m ² h)		5	4	5	1	5	5	1
	Ventilation strategy		Natural ventilation with intermittent extract fans	Decentralised mechanical ventilation (dMEV) system	Natural ventilation with intermittent extract fans	MVHR < 84% SFP < 0.7 W/l/s < 2m external ducts	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	MVHR < 84% SFP < 0.7 W/l/s < 2m external ducts
Heating, hot water	Heating system		Gas combi boiler (55°C)	5kW ASHP (<45°C)	Gas combi boiler (55°C)	Gas combi boiler (55°C)	5kW ASHP (<45°C)	Gas combi boiler (55°C)	5kW ASHP (<45°C)
	Hot water heating system		No additional cylinder	200l cylinder 120mm jacket insulation	No additional cylinder	No additional cylinder	200l cylinder 120mm jacket insulation	No additional cylinder	200l cylinder 120mm jacket insulation
	Waste water heat recovery (WWHR)		Yes 36%	Yes 50%	Yes 36%	Yes 36%	Yes 36%	Yes 36%	Yes 36%
Renewables	PV panels		4.8 kW	7.5 kW	4.8 kW	4.8 kW	0 kW	6.5 kW	6.5 kW

Example of the modelled scenarios for the detached house, showing incremental best practice upgrades to building fabric, infiltration and ventilation, heating, and renewable energy provision. Finally, a scenario encompassing best practice specifications for all areas of the building is included.

The full list of assumptions for each typology can be found in the appendices.

Energy and cost modelling analysis | Policy compliance modelling phase

Specification scenarios modelled

Four potential policy options have been tested by modelling possible specifications an applicant may detail to comply with the policy requirements.

For each typology, scenarios have been modelled where the specification does not necessarily meet the best practice specifications but is enough of an improvement to comply with the policy requirements.

An example for the detached house is provided in this section and the specific assumptions for all seven building archetypes are all available in the appendices.

		Part L 2021 (Baseline)	All improvements	70% TER reduction	100% TER reduction	100% TER reduction 10% TFEe reduction	100% TER reduction 10% TFEe reduction Offset unregulated
Building fabric and ventilation strategy	Floor Walls Roof (W/m ² K)	Part L 2021 compliant fabric 0.12 0.15 0.11	Low Energy Fabric 0.09 0.12 0.10	Part L 2021 compliant fabric 0.12 0.15 0.11	Part L 2021 compliant fabric 0.12 0.15 0.11	Improved fabric 0.09 0.12 0.10	Improved fabric 0.09 0.12 0.10
	Windows (W) Doors (D) (W/m ² K)	Double glazing W - 1.2 D - 1.0	Triple glazing W - 0.8 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0
	Airtightness (m ³ /m ² h)	5	1	5	5	3	3
	Ventilation strategy	Natural ventilation with intermittent extract fans	MVHR < 84% SFP < 0.7 W/l/s < 2m external ducts	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans
Heating, hot water	Heating system	Gas combi boiler (55°C)	5kW ASHP (<45°C)	5kW ASHP (<45°C)	5kW ASHP (<45°C)	5kW ASHP (<45°C)	5kW ASHP (<45°C)
	Hot water heating system	No additional cylinder	200l cylinder 120mm jacket insulation	200l cylinder 120mm jacket insulation	200l cylinder 120mm jacket insulation	200l cylinder 120mm jacket insulation	200l cylinder 120mm jacket insulation
	Waste water heat recovery (WWHR)	Yes 36%	Yes 36%	No	No	No	No
Renewables	PV panels	4.8 kW	6.5 kW	1.5 kW	5.1 kW	4.8 kW	6.5 kW
	Offsetting required? (tCO ₂)	-	-	No	No	No	Yes (for unreg)

Example of the modelled scenarios for the detached house, showing potential routes to compliance for each of the tested policies.

The full list of assumptions for each typology can be found in the appendices.

Energy and cost modelling analysis | Heat Networks

For this study, Bristol City Council have asked for some District Heat Network (DHN) analysis to be included.

Heat Networks are most effective and efficient in densely populated areas. To be Net Zero Carbon compatible, they should not use any fossil fuel sources, and should not be prohibitively costly to residents.

For mid-rise and high-rise blocks of flats, scenarios have been modelled with a connection to Bristol's District Heat Network in both 2026 and 2030. Details of the heat sources, their proportions and efficiencies are shown opposite.

Bristol City Leap have a commitment to provide connections to new developments at an equivalent or lower cost than a communal ASHP system. After modelling the DHN scenarios, the difference in price uplift compared to the build cost of the same scenario with communal ASHPs is marginal (<1%) for all policy scenarios.

Bristol Heat Network 2026

Heat Source	Proportion	Efficiency
ASHP	41%	320%
WSHP	29%	350%
Electric boiler	18%	99%
Gas boiler	5%	88%
Biomass boiler	4%	82%
CHP	3%	44% heat 35% power

Bristol Heat Network 2030

Heat Source	Proportion	Efficiency
ASHP	59.6%	281%
WSHP	33%	298%
Electric boiler	4.2%	99%
Biomass boiler	2.6%	90%
High grade heat recovered from process	0.6%	100%

Costing methodology and inflation

Approach to the assessment of construction costs

Costing identifies the variance between the baseline and the enhanced specifications for elements affected by the proposed operational energy/carbon policies. Elements not materially affected by these policies, e.g. substructure, roof coverings, kitchen and bathrooms, were not costed in detail. These other costs were incorporated within a 'balance of construction' cost estimated using a typical whole building construction cost rate per m² for each building type. The whole building cost was adjusted based on the changes in the elements linked to energy/carbon performance to determine the overall percentage impact on construction costs. Costs included in this study reflect the design of each archetype. Actual costs incurred on specific projects will vary depending on detail of design, specification and procurement processes, nonetheless these cost allowances are deemed representative for policy development purposes.

Cost data

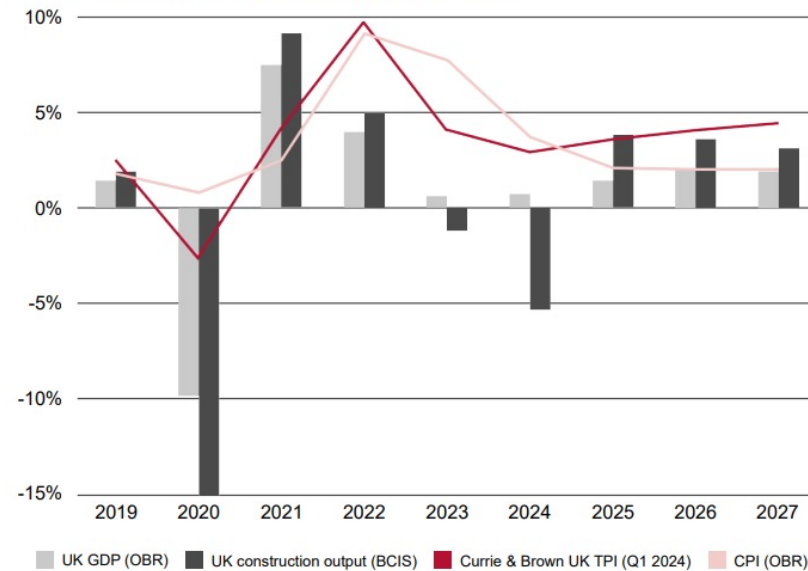
The uplift costs were estimated using Currie & Brown's cost datasets for energy efficiency and low carbon technologies. These incorporate information from market prices, specific market testing and first principles cost planning by their specialist quantity surveyors. They reflect a West and Central England cost base inclusive of overheads, profit and preliminaries, but excluding fees, land, planning, s106 and other non-construction related development costs. **The costs are based on Q3 2024 prices.**

Inflation

After a period of high cost inflation in 2021-22, inflation is falling to a range of 4-5% and is projected to continue at around this level to 2027. Over the period to 2027 the Office for Budget Responsibility (OBR) forecast that the Consumer Prices Index (CPI) will decline to around 2%. This means that construction will suffer proportionately higher inflation than the average for the economy.

The chart below illustrates recent inflation and market data and short term projections for the CPI and Currie & Browns projected Tender Price Index (TPI) based on OBR projections for UK Gross Domestic Product and the Build Cost Information Service's projection for construction output.

Indicative economic data forecast (%) (2019-2027)



Inflation projection to 2027

Currently construction inflation is driven primarily by labour costs with material costs remaining static or falling slightly. This suggests that design changes requiring a switch to more expensive materials may become less expensive as a proportion of overall construction costs and also in relation to changes that increase labour requirements.

Summary | Capital costs by policy option

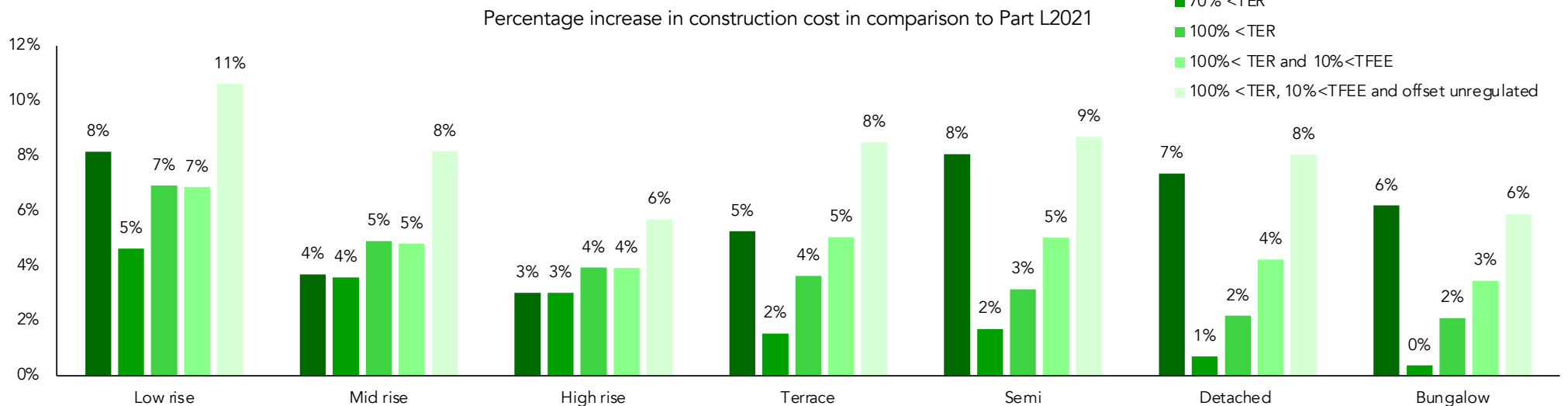
The table on the right and chart below summarise the cost analysis for each archetype showing the net additional costs of the different policy options in comparison to a Part L2021 baseline. The most expensive policy option is that requiring 100% reduction in TER, 10% reduction in TFEE and offsetting of unregulated emissions, this is heavily influenced by the relatively significant cost of offset payments (priced at £403 per tCO₂e for 30 years).

The reasons for increased costs vary considerably between archetypes and policy options as shown on the following pages. In general, the cost of improving fabric standards are higher for houses than flats whereas the costs of offsetting (where required) are higher for flats due to the more limited availability of roof space for onsite generation.

Uplift costs are highest in both absolute and relative terms for low-rise blocks of flats. This is due to the relatively high fixed costs of MEP upgrades, and the lower baseline cost per m² for these homes in comparison to mid-rise and high-rise flats.

Since the difference in price between the mid-rise and high-rise blocks while connected to a DHN compared to communal ASHPs is marginal (<1%), the DHN scenarios have not been shown separately.

Archetype	Part L 2021 (Baseline)	All improvements	70% <TER	100% <TER	100% < TER and 10% <TFEE	100% <TER, 10%< TFEE and offset unregulated
Low rise	£0 (0%)	£189 (8%)	£107 (5%)	£160 (7%)	£159 (7%)	£246 (11%)
Mid rise	£0 (0%)	£120 (4%)	£116 (4%)	£159 (5%)	£156 (5%)	£264 (8%)
High rise	£0 (0%)	£107 (3%)	£107 (3%)	£140 (4%)	£139 (4%)	£203 (6%)
Terrace	£0 (0%)	£98 (5%)	£29 (2%)	£68 (4%)	£94 (5%)	£159 (8%)
Semi	£0 (0%)	£164 (8%)	£35 (2%)	£64 (3%)	£102 (5%)	£177 (9%)
Detached	£0 (0%)	£149 (7%)	£15 (1%)	£44 (2%)	£86 (4%)	£163 (8%)
Bungalow	£0 (0%)	£126 (6%)	£7 (0%)	£42 (2%)	£70 (3%)	£119 (6%)



Cost assessment | Flats

Summary of cost information

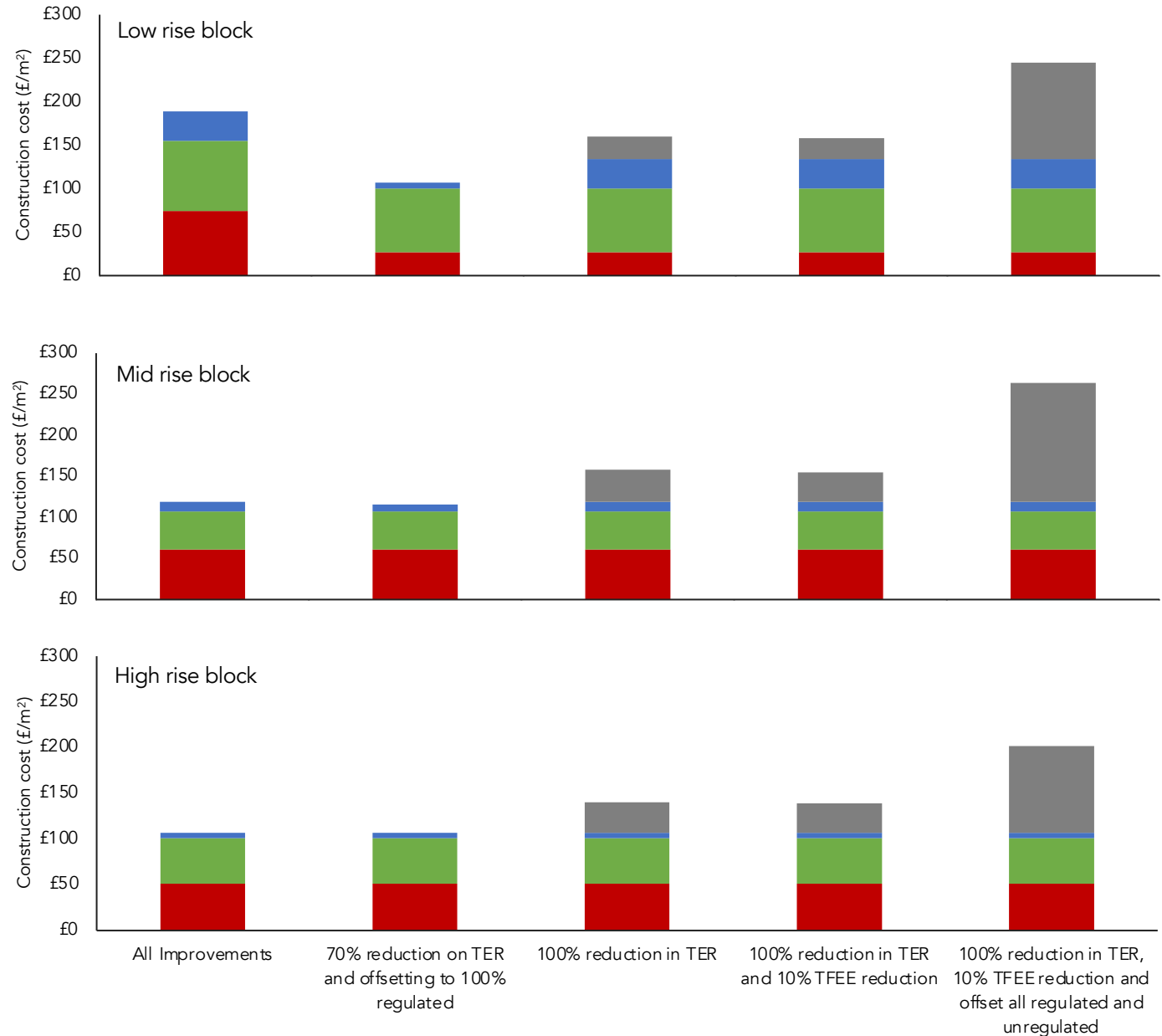
The most significant variation in cost between options is typically associated with the introduction of a low carbon heating system, followed by carbon offsetting payments where required and then PV and fabric measures.

For medium and high rise flats there is no difference in fabric specification or cost between all of the policy options that go beyond Part L 2021. For the low rise flat the TER based policy options utilise a slightly lower fabric specification which results in a small cost saving for these elements in comparison to the All Improvements option.

The cost of offsetting where included is more expensive than achieving carbon reductions through the use of PV and in the most ambitious TER based policy results the costs associated with offsetting are the range of £95 to £111 per m², this forms nearly half of the total associated uplifts associated with each meeting the policy requirement. Offsetting costs are particularly high for flats (especially medium and high rise) because of the more limited relative potential to include photovoltaics in these buildings.

Key

- Fabric & Ventilation
- Heating system
- PV Panels
- Offsetting at £403/tCO₂



Cost assessment | Houses

Summary of cost information

The profile of costs across each policy option is relatively similar for each house type. In general, the greater the roof area to floor area ratio the lower the reliance on offsetting to meet policy targets.

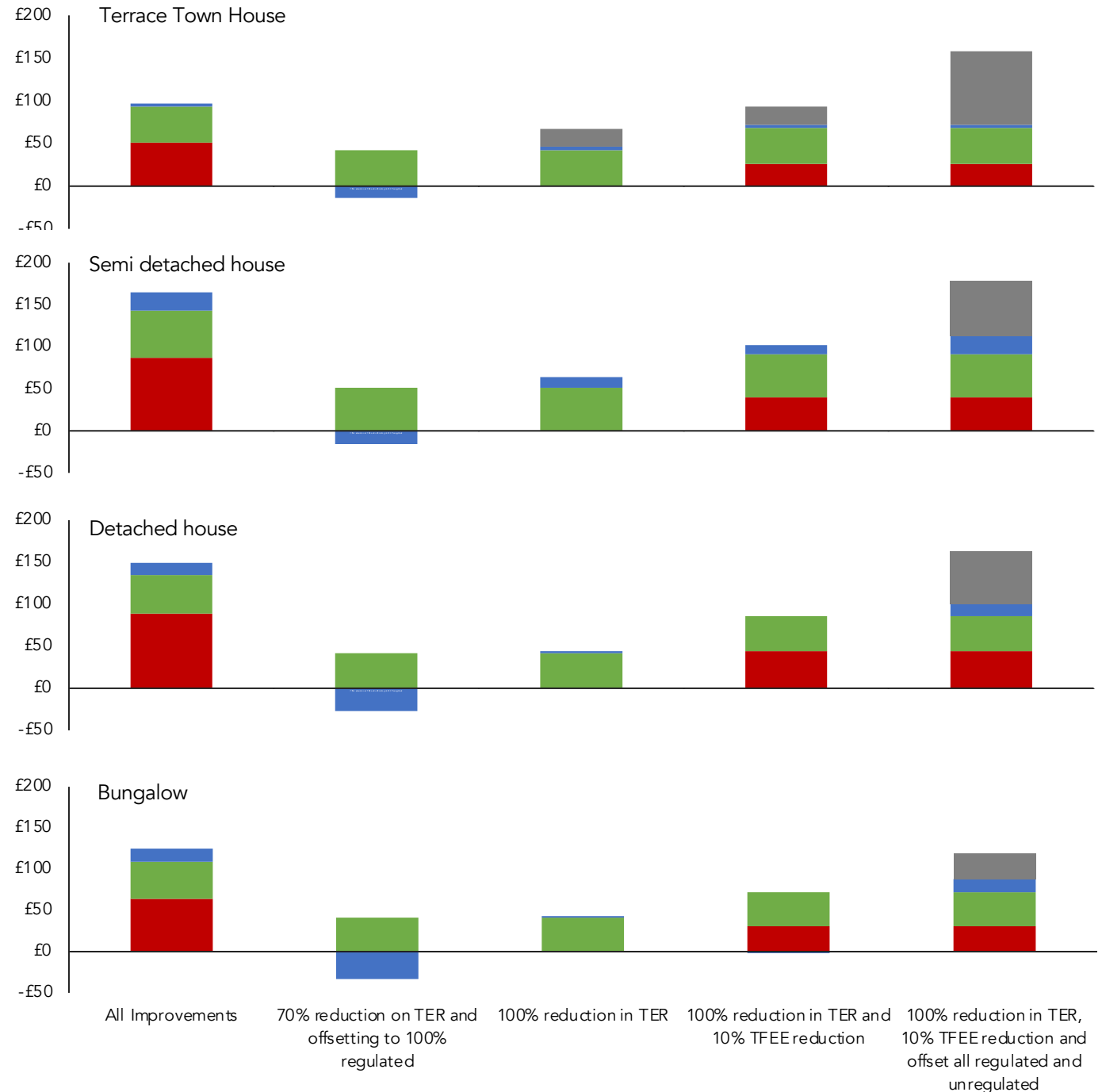
The 70% reduction in TER policy option typically requires less PV to be installed than would be required to meet Part L2021, however the need to offset to 100% of TER results in a higher overall cost than that associated with achieving a 100% reduction entirely onsite.

It is possible to achieve a 100% reduction in TER without improving the fabric standard beyond the Part L 2021 compliant specification. Where there is a requirement for an improvement in fabric energy efficiency this results in an increase in construction costs of £26 to £41m² depending on house type.

A specification that requires offsetting of all regulated emissions is the most expensive option for all house types except the bungalow.

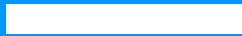
Key

- Fabric & Ventilation
- Heating system
- PV Panels
- Offsetting at £403/tCO₂



5.0

Technical feasibility and cost of policy options



TER-based policy option 1A | Technical feasibility and cost assessment

Etude have modelled each of the typologies against Policy 1A, showing a potential route to policy compliance.

As shown, each of the typologies can meet the policy and achieve a 70% reduction over the TER on site.

In all cases, except for the high-rise block of flats, the performance of the building itself does not have to be improved over a Part L 2021 compliant specification for the building to achieve the policy requirement. Small improvements must be made to the building performance for the high-rise block of flats to achieve the policy requirement.

For the four house typologies, the cost uplift over the baseline cost ranges from 0-2% to meet this policy requirement. For the three flat typologies, cost uplifts range between 3-5%.

Policy 1A

All domestic buildings should achieve a minimum 70% improvement over the TER on site.

		Bungalow	Detached house	Semi-detached house	Terraced house	Low-rise block of flats	Mid-rise block of flats	High-rise block of flats
Summary of specifications	Building fabric	External wall U-value 0.15W/m ² K Double glazed windows U-value 1.2W/m ² K	External wall U-value 0.15W/m ² K Double glazed windows U-value 1.2W/m ² K	External wall U-value 0.16W/m ² K Double glazed windows U-value 1.2W/m ² K	External wall U-value 0.16W/m ² K Double glazing U-value 1.2W/m ² K	External wall U-value 0.15W/m ² K Double glazing U-value 1.2W/m ² K	External wall U-value 0.15W/m ² K Double glazing U-value 1.2W/m ² K	External wall U-value 0.15W/m ² K Double glazing U-value 1.2W/m ² K
	Infiltration and ventilation	5 m ³ /m ² h Intermittent extract ventilation	5 m ³ /m ² h Intermittent extract ventilation	5 m ³ /m ² h Intermittent extract ventilation	5 m ³ /m ² h Intermittent extract ventilation	5 m ³ /m ² h Intermittent extract ventilation	5 m ³ /m ² h Intermittent extract ventilation	5 m ³ /m ² h Intermittent extract ventilation
	Heating system	5 kW ASHP 200l cylinder	5 kW ASHP 200l cylinder	5 kW ASHP 200l cylinder	5 kW ASHP 200l cylinder	5 kW ASHP 200l cylinder	Communal ASHP HIU	Communal ASHP HIU WWHR
	PVs	3 kWp	1.5 kWp	1.2 kWp	1.5 kWp	15 kWp <i>*0.92 kWp/dwelling</i>	45 kWp <i>*0.97 kWp/dwelling</i>	111.6 kWp <i>*0.56 kWp/dwelling</i>
Summary of results	% improvement over TER (on-site)	71%	71%	71%	71%	71%	71%	71%
	Residual regulated carbon emissions (tCO₂/yr)	0.3	0.4	0.3	0.3	3.8	11.4	42.3
	% improvement over TFEE	0%	0%	0%	0%	0%	0%	6%
Costs	Construction cost	£2,026/m ²	£2,034/m ²	£2,054/m ²	£1,882/m ²	£2,401/m ²	£3,327/m ²	£3,642/m ²
	Offsetting cost	-	-	-	-	-	-	-
	% uplift over Part L 2021 baseline cost	0%	1%	2%	2%	5%	4%	3%

**based on a typical dwelling size of 60 m²*

TER-based policy option 1B | Technical feasibility and cost assessment

Etude have modelled each of the typologies against Policy 1B, showing a potential route to policy compliance. Changes to the specification from Policy 1A have been highlighted in bold.

As shown in the table opposite, the bungalow, detached house, and semi-detached house are all able to meet the policy and achieve a 100% reduction over the TER on site.

However, the terraced house, low rise flats, mid-rise flats and high-rise flats are unable to achieve a 100% improvement over the TER on site and will need to offset the residual carbon emissions.

While these typologies could improve their specifications to reduce residual carbon emissions further, it may be cheaper for a developer to pay into an offsetting fund.

In all cases, except for the high-rise block of flats, the performance of the building itself has not been improved over a Part L 2021 compliant specification to achieve these results. Small improvements have been made to the building performance for the high-rise block of flats.

For the four house typologies, the cost uplift over the baseline cost ranges from 2-3% to meet this policy requirement. For the three flat typologies, cost uplifts range between 4-7%.

Policy 1B

All domestic buildings should achieve a minimum 100% improvement over the TER on site.



When it is not technically feasible to achieve on site, carbon offsetting should be used to make up the difference.

		Bungalow	Detached house	Semi-detached house	Terraced house	Low-rise block of flats	Mid-rise block of flats	High-rise block of flats
Summary of specifications	Building fabric	External wall U-value 0.15W/m ² K Double glazing U-value 1.2W/m ² K	External wall U-value 0.15W/m ² K Double glazing U-value 1.2W/m ² K	External wall U-value 0.16W/m ² K Double glazing U-value 1.2W/m ² K	External wall U-value 0.16W/m ² K Double glazing U-value 1.2W/m ² K	External wall U-value 0.15W/m ² K Double glazing U-value 1.2W/m ² K	External wall U-value 0.15W/m ² K Double glazing U-value 1.2W/m ² K	External wall U-value 0.15W/m ² K Double glazing U-value 1.2W/m ² K
	Infiltration and ventilation	5 m ³ /m ² h Intermittent extract ventilation	5 m ³ /m ² h Intermittent extract ventilation	5 m ³ /m ² h Intermittent extract ventilation	5 m ³ /m ² h Intermittent extract ventilation	5 m ³ /m ² h Intermittent extract ventilation	5 m ³ /m ² h Intermittent extract ventilation	5 m ³ /m ² h Intermittent extract ventilation
	Heating system	5 kW ASHP 200l cylinder	5 kW ASHP 200l cylinder	5 kW ASHP 200l cylinder	5 kW ASHP 200l cylinder	5 kW ASHP 200l cylinder	Communal ASHP HIU	Communal ASHP HIU WWHR
	PVs	7.3 kWp	5.1 kWp	4.1 kWp	3.6 kWp	43.2 kWp *2.64 kWp/dwelling	57.6 kWp *1.24 kWp/dwelling	111.6 kWp <i>*0.56 kWp/dwelling</i>
	Summary of results	% improvement over TER (on-site)	100%	101%	101%	83%	83%	74%
	Residual regulated carbon emissions (tCO₂/yr)	0.0	0.0	0.0	0.2	2.1	10.5	42.3
	% improvement over TFEE	0%	0%	0%	0%	0%	0%	6%
Costs	Construction cost	£2,061/m ²	£2,063/m ²	£2,083/m ²	£1,900/m ²	£2,430/m ²	£3,334/m ²	£3,643/m ²
	Offsetting cost	£0/m ²	£0/m ²	£0/m ²	£21/m ²	£24/m ²	£36/m ²	£32/m ²
	% uplift over Part L 2021 baseline cost	2%	2%	3%	2%	7%	5%	4%

*based on a typical dwelling size of 60 m²

TER-based policy option 1C | Technical feasibility and cost assessment

Etude have modelled each of the typologies against Policy 1C, showing a potential route to policy compliance. Changes to the specification from Policy 1B have been highlighted in bold.

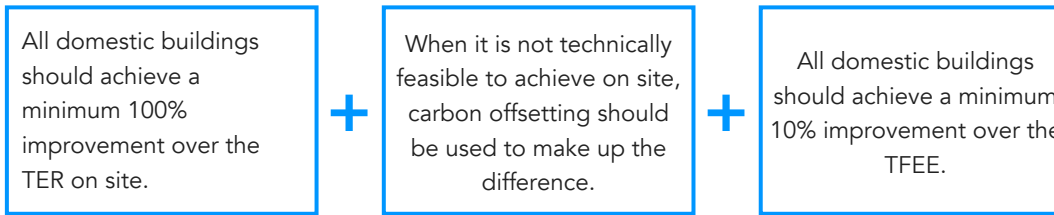
As with policy 1B, all typologies are able to meet the policy requirement to achieve a 100% improvement over the TER through on site measures and offsetting any residual carbon.

The specification of each typology has also been able to achieve a 10% improvement over the TFEE, showing an improvement to the performance of the buildings themselves.

While these typologies could improve their specifications to reduce residual carbon emissions further, it may be cheaper for a developer to pay into an offsetting fund.

For the four house typologies, the cost uplift over the baseline cost ranges from 3-5% to meet this policy requirement. For the three flat typologies, cost uplifts range between 4-7%.

Policy 1C



		Bungalow	Detached house	Semi-detached house	Terraced house	Low-rise block of flats	Mid-rise block of flats	High-rise block of flats
Summary of specifications	Building fabric	External wall U-value 0.15W/m ² K Double glazing U-value 1.2W/m ² K	External wall U-value 0.12W/m²K Double glazing U-value 1.2W/m ² K	External wall U-value 0.13W/m²K Double glazing U-value 1.2W/m ² K	External wall U-value 0.13W/m²K Triple glazing U-value 0.8W/m²K	External wall U-value 0.13W/m²K Double glazing U-value 1.2W/m ² K	External wall U-value 0.15W/m ² K Triple glazing U-value 0.8W/m²K	External wall U-value 0.15W/m ² K Triple glazing U-value 0.8W/m²K
	Infiltration and ventilation	3 m³/m²h Intermittent extract ventilation	3 m³/m²h Intermittent extract ventilation	3 m³/m²h Intermittent extract ventilation	4.5 m³/m²h Intermittent extract ventilation	2.5 m³/m²h Intermittent extract ventilation	5 m ³ /m ² h Intermittent extract ventilation	3 m³/m²h Intermittent extract ventilation
	Heating system	5 kW ASHP 200l cylinder	5 kW ASHP 200l cylinder	5 kW ASHP 200l cylinder	5 kW ASHP 200l cylinder	5 kW ASHP 200l cylinder	Communal ASHP HIU	Communal ASHP HIU WWHR
	PVs	6.8 kWp	4.8 kWp	3.9 kWp	3.6 kWp	43.2 kWp <i>*2.64 kWp/dwelling</i>	57.6 kWp <i>*1.24 kWp/dwelling</i>	111.6 kWp <i>*0.56 kWp/dwelling</i>
Summary of results	% improvement over TER (on-site)	100%	101%	101%	85%	84%	76%	72%
	Residual regulated carbon emissions (tCO ₂ /yr)	0.0	0.0	0.0	0.2	2.0	9.6	41.4
	% improvement over TFEE	11%	11%	10%	11%	11%	12%	10%
Costs	Construction cost	£2,089/m ²	£2,105/m ²	£2,121/m ²	£1,926/m ²	£2,429/m ²	£3,331/m ²	£3,642/m ²
	Offsetting cost	£0/m ²	£0/m ²	£0/m ²	£21/m ²	£24/m ²	£36/m ²	£32/m ²
	% uplift over Part L 2021 baseline cost	3%	4%	5%	4%	7%	5%	4%

**based on a typical dwelling size of 60 m²*

TER-based policy option 1D | Technical feasibility and cost assessment

Etude have modelled each of the typologies against Policy 1D, showing a potential route to policy compliance. Changes to the specification from Policy 1C have been highlighted in bold.

As shown in the table opposite, the specifications have changed very little for each of the typologies compared to their specifications to meet policy 1C.

For the bungalow, detached house and semi-detached house, PV has been maximised to reduce the amount of carbon to be offset through maximising generation.

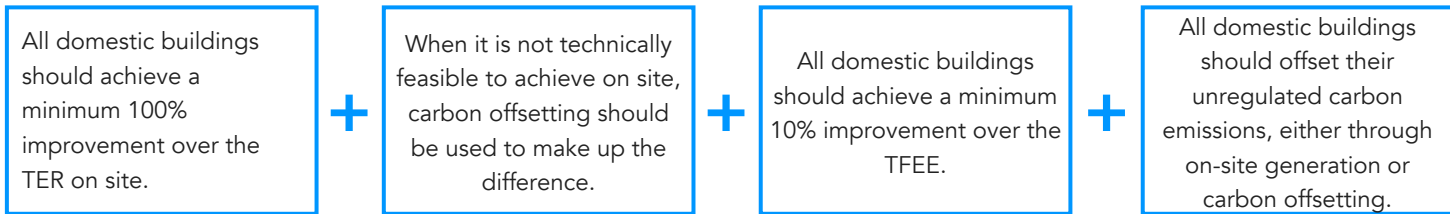
For the terraced house, the airtightness of the building has been improved to reduce the amount of carbon to be offset.

For the blocks of flats, no changes have been made to the specifications, as it may be cheaper for a developer to pay into an offsetting fund.

For the four house typologies, the cost uplift over the baseline cost ranges from 6-9% to meet this policy requirement.

For the three flat typologies, cost uplifts range between 6-11%.

Policy 1D

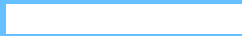


		Bungalow	Detached house	Semi-detached house	Terraced house	Low-rise block of flats	Mid-rise block of flats	High-rise block of flats
Summary of specifications	Building fabric	External wall U-value 0.15W/m ² K Double glazing U-value 1.2W/m ² K	External wall U-value 0.12W/m ² K Double glazing U-value 1.2W/m ² K	External wall U-value 0.13W/m ² K Double glazing U-value 1.2W/m ² K	External wall U-value 0.13W/m ² K Triple glazing U-value 0.8W/m ² K	External wall U-value 0.13W/m ² K Double glazing U-value 1.2W/m ² K	External wall U-value 0.15W/m ² K Triple glazing U-value 0.8W/m ² K	External wall U-value 0.15W/m ² K Triple glazing U-value 0.8W/m ² K
	Infiltration and ventilation	3 m ³ /m ² h Intermittent extract ventilation	3 m ³ /m ² h Intermittent extract ventilation	3 m ³ /m ² h Intermittent extract ventilation	3 m³/m²h Intermittent extract ventilation	2.5 m ³ /m ² h Intermittent extract ventilation	5 m ³ /m ² h Intermittent extract ventilation	3 m ³ /m ² h Intermittent extract ventilation
	Heating system	5 kW ASHP 200l cylinder	5 kW ASHP 200l cylinder	5 kW ASHP 200l cylinder	5 kW ASHP 200l cylinder	5 kW ASHP 200l cylinder	Communal ASHP HIU	Communal ASHP HIU WWHR
	PVs	9 kWp	6.5 kWp	4.9 kWp	3.6 kWp	43.2 kWp <i>*2.64 kWp/dwelling</i>	57.6 kWp <i>*1.24 kWp/dwelling</i>	111.6 kWp <i>*0.56 kWp/dwelling</i>
Summary of results	% improvement over TER (on-site)	111%	104%	111%	85%	84%	76%	72%
	Residual regulated carbon emissions (tCO₂/yr)	-0.1	-0.1	-0.1	0.2	2.0	9.6	41.4
	% improvement over TFEE	11%	11%	10%	11%	11%	12%	10%
Costs	Construction cost	£2,107/m ²	£2,119/m ²	£2,131/m ²	£1,926/m ²	£2,465/m ²	£3,330/m ²	£3,627/m ²
	Offsetting cost	£31/m ²	£63/m ²	£65/m ²	£86/m ²	£95/m ²	£145/m ²	£111/m ²
	% uplift over Part L 2021 baseline cost	6%	8%	9%	6%	11%	8%	6%

**based on a typical dwelling size of 60 m²*

6.0

Conclusions and recommendations



Conclusions and recommendations

While policies 1A and 1B provide ambitious goals for each typology in terms of carbon emissions reductions, applicants are likely to focus on including PVs and paying offsetting charges over implementing measures that reduce the energy demand of the building. This is likely to lead to buildings which are not as energy efficient and low carbon as they could be, increasing the need for retrofitting in the future.

These policies require a relatively small construction cost uplift, which is attractive to applicants, but still allow excess carbon emissions to be offset through monetary contributions.

Policies 1C and 1D push applicants towards best practice solutions in building fabric, infiltration and ventilation, heating, and renewable energy provision for all typologies, while allowing applicants some freedom to choose what is and is not feasible for their development.

Policy 1D also considers unregulated energy, which becomes a higher proportion of a building's energy consumption as building performance improves.

Policies 1C and 1D require the largest construction cost uplift, however they encourage the applicant to reduce carbon emissions as much as possible on site.

Recommendation

While a TER based policy is not as robust as an energy based policy, this study aims to create a WMS compliant TER based policy that replicates the intentions of an energy based policy as closely as possible.

Etude recommend that **policy 1D** is adopted for all local authorities in the absence of an energy-based policy. However, there is a risk that offsetting unregulated carbon emissions is not WMS compliant. Therefore, the local authorities may prefer to propose policy 1C as the next best alternative.

Policy 1D

All domestic buildings should achieve a minimum 100% improvement over the TER on site.



When it is not technically feasible to achieve on site, carbon offsetting should be used to make up the difference.



All domestic buildings should achieve a minimum 10% improvement over the TFEE.



All domestic buildings should offset their unregulated carbon emissions, either through on-site generation or carbon offsetting.

Policy 1C

All domestic buildings should achieve a minimum 100% improvement over the TER on site.



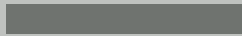
When it is not technically feasible to achieve on site, carbon offsetting should be used to make up the difference.



All domestic buildings should achieve a minimum 10% improvement over the TFEE.

7.0

Appendix



7.1

Bungalow




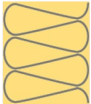







Bungalow

The following 2-bed single story bungalow has been selected for modelling as a representative example. Based on a bungalow in North Somerset.

GIA: 115 m²

Images redacted

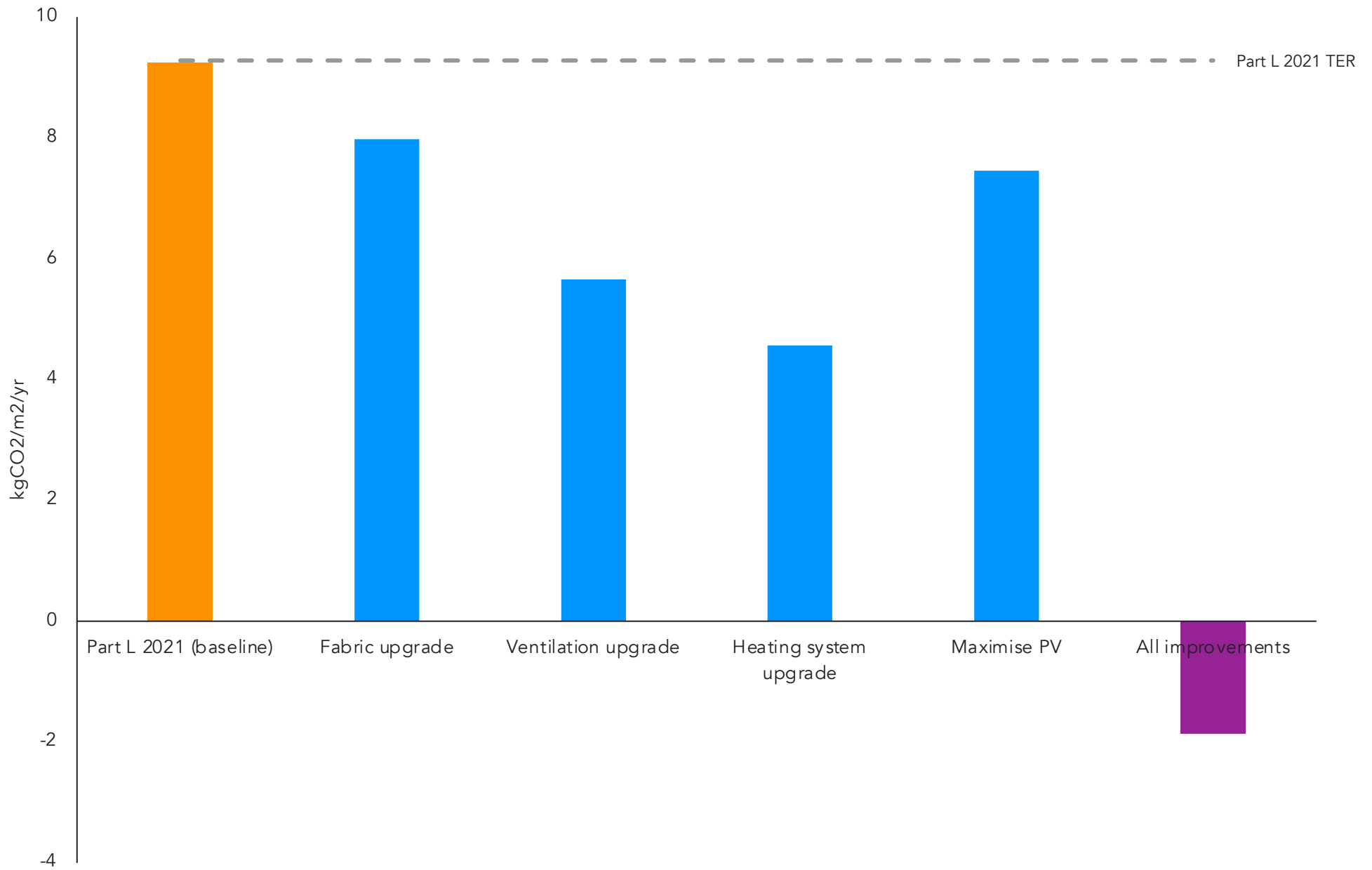
Modelling specifications | Bungalow

		Part L 2021 (Baseline)	Future Homes Standard (Option 1)	Fabric upgrade	Ventilation Upgrade	Heating system upgrade	Maximise PV	All improvements	
Building fabric and ventilation strategy 	Floor Walls Roof (W/m ² K) 	Part L 2021 compliant fabric 0.12 0.15 0.13	FHS compliant fabric 0.13 0.16 0.10	Low energy fabric 0.10 0.13 0.10	Part L 2021 compliant fabric 0.12 0.15 0.13	Part L 2021 compliant fabric 0.12 0.15 0.13	Part L 2021 compliant fabric 0.12 0.15 0.13	Low energy fabric 0.10 0.13 0.10	
	Windows (W) Doors (D) (W/m ² K) 	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Triple glazing W - 1.0 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Triple glazing W - 1.0 D - 1.0
	Airtightness (m ³ /m ² h) 	5	4	5	1	5	5	5	1
	Ventilation strategy	Natural ventilation with intermittent extract fans	Decentralised mechanical ventilation (dMEV) system	Natural ventilation with intermittent extract fans	MVHR 84% SFP <0.7	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	MVHR 84% SFP <0.7
Heating, hot water 	Heating system 	Gas combi boiler (55°C)	5kW ASHP (<45°C)	Gas combi boiler (55°C)	Gas combi boiler (55°C)	5kW ASHP (<45°C)	Gas combi boiler (55°C)	5kW ASHP (<45°C)	
	Hot water heating system 	No additional cylinder	200l cylinder 120mm jacket insulation	No additional cylinder	No additional cylinder	200l cylinder 120mm jacket insulation	No additional cylinder	200l cylinder 120mm jacket insulation	
	Waste water heat recovery (WWHR)	Yes 36%	Yes 50%	Yes 36%	Yes 36%	Yes 36%	Yes 36%	Yes 36%	Yes 36%
Renewables 	PV panels 	7 kW	4.9 kW	7 kW	7 kW	0 kW	9 kW	9 kW	


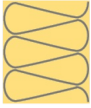





Results | Bungalow

	Part L 2021 (Baseline)	Future Homes Standard (Option 1)	Fabric upgrade	Ventilation upgrade	Heating system upgrade	Maximise PV	All improvements
Description	Part L 2021 notional assumptions	FHS notional assumptions	Improved U-values	MVHR Improved airtightness	ASHP No PV	Maximum PV	Improved U-values MVHR Improved airtightness ASHP Maximum PV
DER kgCO ₂ /m ² /yr	9.2	0.8	8.0	5.7	4.6	7.5	-1.9
% DER < TER (Carbon emissions)	-	91%	14%	39%	51%	20%	120%
% DPER < TPER (Primary energy)	-	72%	14%	36%	5%	16%	112%
% DFEE < TFEE (Fabric energy efficiency)	-	6%	13%	9%	2%	2%	20%

Results | Bungalow



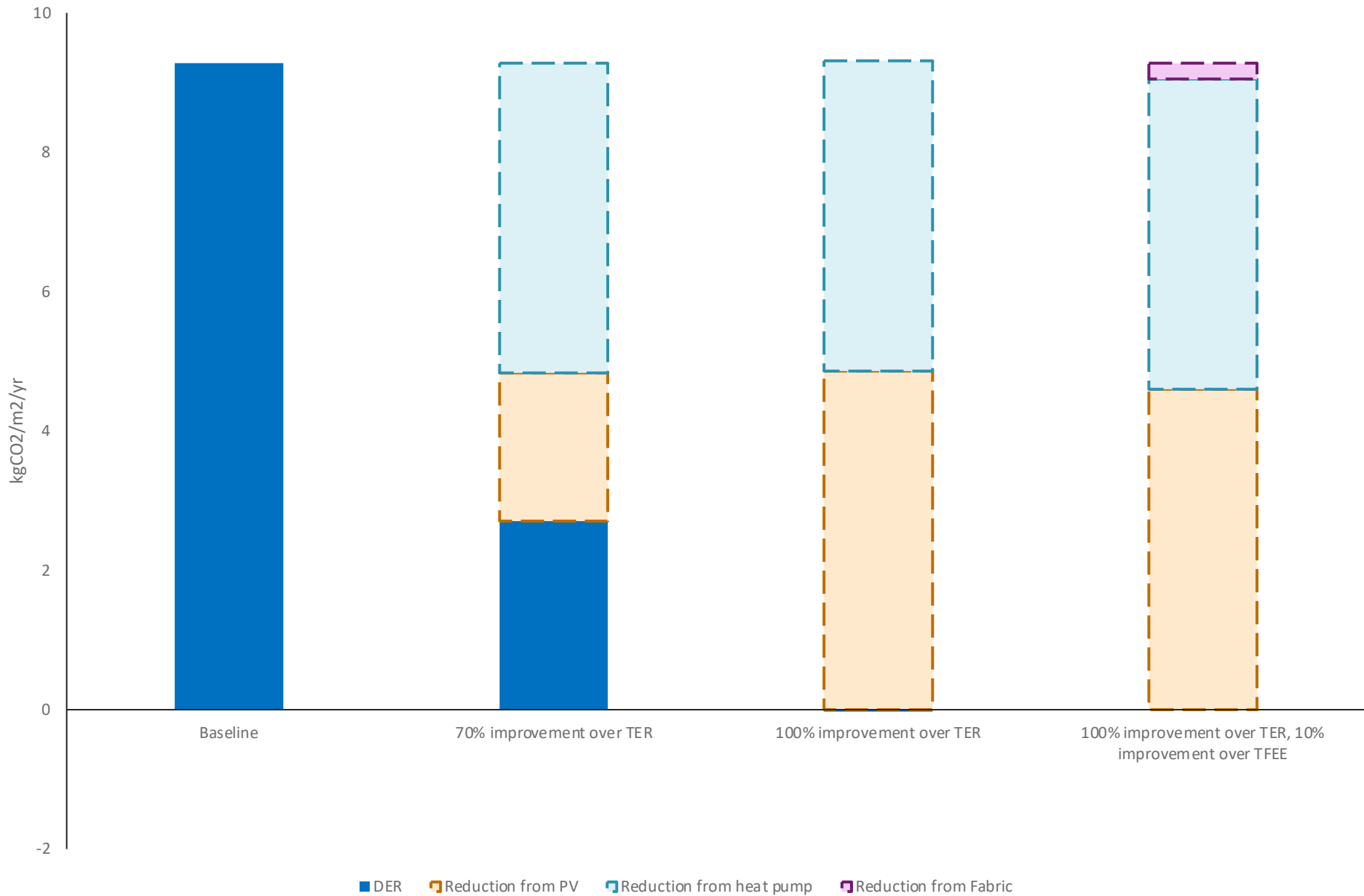
Policy compliant specifications | Bungalow

		Part L 2021 (Baseline)	All improvements	70% TER reduction	100% TER reduction	100% TER reduction 10% TFEF reduction	100% TER reduction 10% TFEF reduction Offset unregulated	
Building fabric and ventilation strategy 	Floor Walls Roof (W/m ² K) 	Part L 2021 compliant fabric 0.12 0.15 0.13	Low energy fabric 0.10 0.13 0.10	Part L 2021 compliant fabric 0.12 0.15 0.13	Part L 2021 compliant fabric 0.12 0.15 0.13	Improved fabric 0.11 0.15 0.10	Improved fabric 0.11 0.15 0.10	
	Windows (W) Doors (D) (W/m ² K) 	Double glazing W - 1.2 D - 1.0	Triple glazing W - 1.0 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0
	Airtightness (m ³ /m ² h) 	5	1	5	5	3	3	
	Ventilation strategy	Natural ventilation with intermittent extract fans	MVHR 84% SFP <0.7	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	
	Heating system	Gas combi boiler (55°C)	5kW ASHP (<45°C)	5kW ASHP (<45°C)	5kW ASHP (<45°C)	5kW ASHP (<45°C)	5kW ASHP (<45°C)	
Heating, hot water 	Hot water heating system	No additional cylinder	200l cylinder 120mm jacket insulation	200l cylinder 120mm jacket insulation	200l cylinder 120mm jacket insulation	200l cylinder 120mm jacket insulation	200l cylinder 120mm jacket insulation	
	Waste water heat recovery (WWHR) 	Yes 36%	Yes 36%	No	No	No	No	
Renewables 	PV panels	7 kW	9 kW	3 kW	7.3 kW	6.8 kW	9 kW	
	Offsetting required? (tCO2)	-	-	-	No	No	Yes	

Policy compliant results | Bungalow

	Part L 2021 (Baseline)	All improvements	70% TER reduction	100% TER reduction	100% TER reduction 10% TFEE reduction	100% TER reduction 10% TFEE reduction Offset unregulated
Description	Part L 2021 notional assumptions	Improved U-values MVHR Improved airtightness ASHP Maximum PV	ASHP No WWHR PV	ASHP No WWHR Additional PV	Improved U-values Improved airtightness ASHP No WWHR Additional PV	Improved U-values Improved airtightness ASHP No WWHR Maximum PV
DER kgCO ₂ /m ² /yr	9.2	-1.5	2.7	0	0	-1.0
% DER < TER (Carbon emissions)	-	116%	71%	100%	100%	111%
Residual regulated tCO ₂ /yr	0.88	-0.1	0.3	0	0	-0.1
% DPER < TPER (Primary energy)	-	104%	43%	83%	84%	97%
% DFEE < TFEE (Fabric energy efficiency)	-	20%	0%	0%	11%	11%
Unreg tCO ₂ /yr	0.4	0.4	0.4	0.4	0.4	0.4
Total CO ₂ to offset (at £403/tCO ₂ /yr)	n/a	n/a	n/a	0	0	0.3

Policy compliant results | Bengalow



7.2

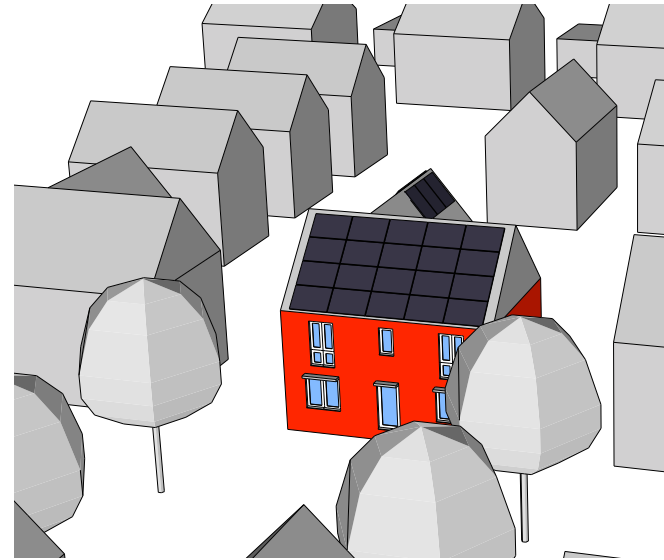
Detached house



Detached house

A 4-bed 2-storey detached house has been selected for modelling as a representative example

GIA: 114 m²



GROUND FLOOR PLAN



FIRST FLOOR PLAN


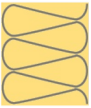









FRONT ELEVATION



FRONT ELEVATION

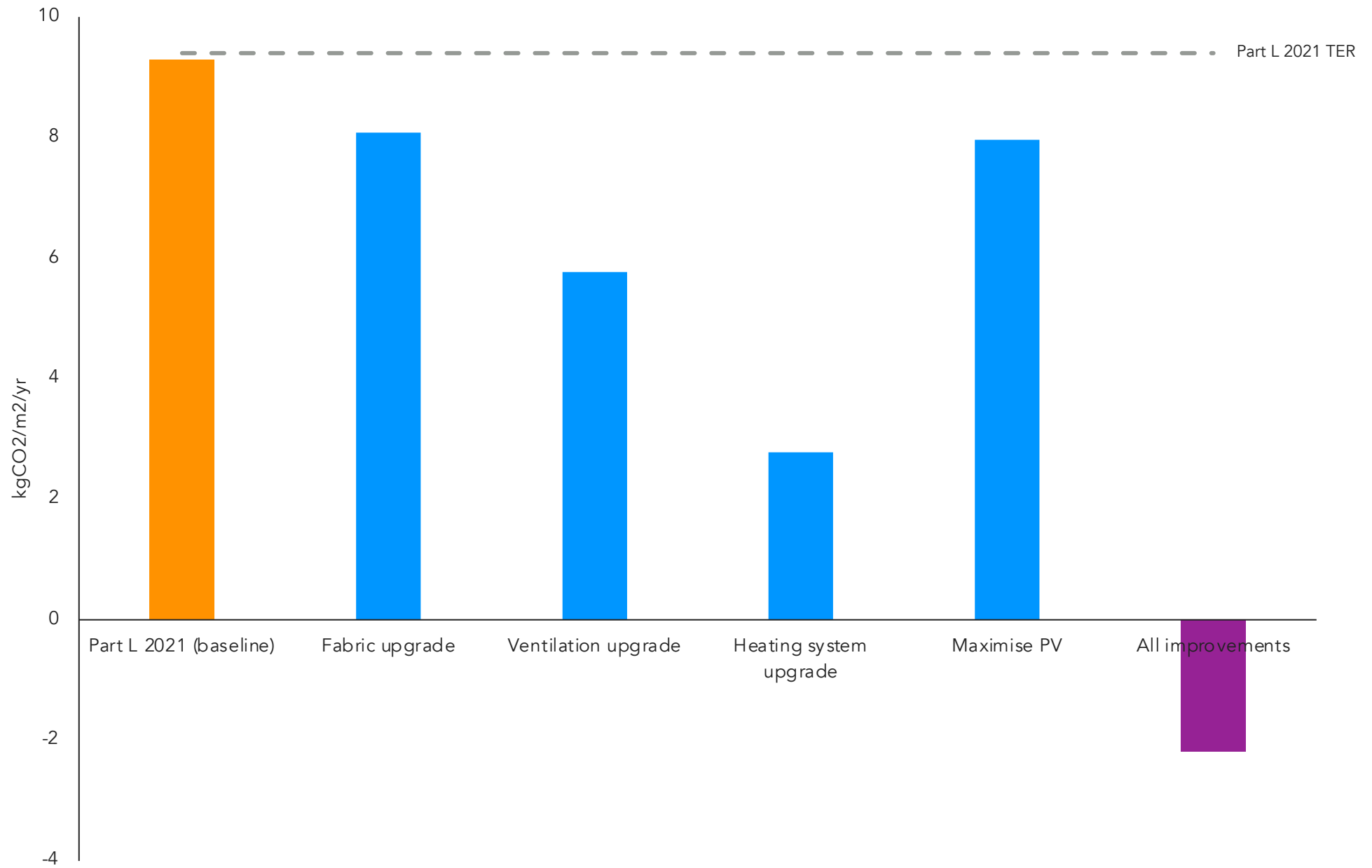
Modelling specifications | Detached house

			Part L 2021 (Baseline)	Future Homes Standard (Option 1)	Fabric upgrade	Ventilation upgrade	Heating system upgrade	Maximise PV	All improvements	
Building fabric and ventilation strategy 	Floor Walls Roof (W/m ² K)		Part L 2021 compliant fabric 0.12 0.15 0.11	FHS compliant fabric 0.12 0.15 0.11	Low energy fabric 0.09 0.12 0.10	Part L 2021 compliant fabric 0.12 0.15 0.11	Part L 2021 compliant fabric 0.12 0.15 0.11	Part L 2021 compliant fabric 0.12 0.15 0.11	Low Energy Fabric 0.09 0.12 0.10	
	Windows (W) Doors (D) (W/m ² K)		Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Triple glazing W - 0.8 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Triple glazing W - 0.8 D - 1.0
	Airtightness (m ³ /m ² h)		5	4	5	1	5	5	5	1
	Ventilation strategy		Natural ventilation with intermittent extract fans	Decentralised mechanical ventilation (dMEV) system	Natural ventilation with intermittent extract fans	MVHR < 84% SFP < 0.7 W/l/s < 2m external ducts	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	MVHR < 84% SFP < 0.7 W/l/s < 2m external ducts
	<hr/>									
Heating, hot water 	Heating system		Gas combi boiler (55°C)	5kW ASHP (<45°C)	Gas combi boiler (55°C)	Gas combi boiler (55°C)	5kW ASHP (<45°C)	Gas combi boiler (55°C)	5kW ASHP (<45°C)	
	Hot water heating system		No additional cylinder	200l cylinder 120mm jacket insulation	No additional cylinder	No additional cylinder	200l cylinder 120mm jacket insulation	No additional cylinder	200l cylinder 120mm jacket insulation	
	Waste water heat recovery (WWHR)		Yes 36%	Yes 50%	Yes 36%	Yes 36%	Yes 36%	Yes 36%	Yes 36%	Yes 36%
Renewables 	PV panels		4.8 kW	7.5 kW	4.8 kW	4.8 kW	0 kW	6.5 kW	6.5 kW	


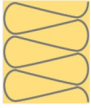








Results | Detached

	Part L 2021 (Baseline)	Future Homes Standard (Option 1)	Fabric upgrade	Ventilation upgrade	Heating system upgrade	Maximise PV	All improvements
Description	Part L 2021 notional assumptions	FHS notional assumptions	Improved U-values	MVHR Improved airtightness	ASHP No PV	Maximum PV	Improved U-values MVHR Improved airtightness ASHP Maximum PV
DER kgCO ₂ /m ² /yr	9.3	-2.3	8.1	5.8	2.8	8.0	-2.2
% DER < TER (Carbon emissions)	-	124%	14%	39%	70%	15%	123%
% DPER < TPER (Primary energy)	-	95%	13%	35%	42%	13%	102%
% DFEE < TFEE (Fabric energy efficiency)	-	3%	13%	8%	0%	0%	21%

Results | Detached house



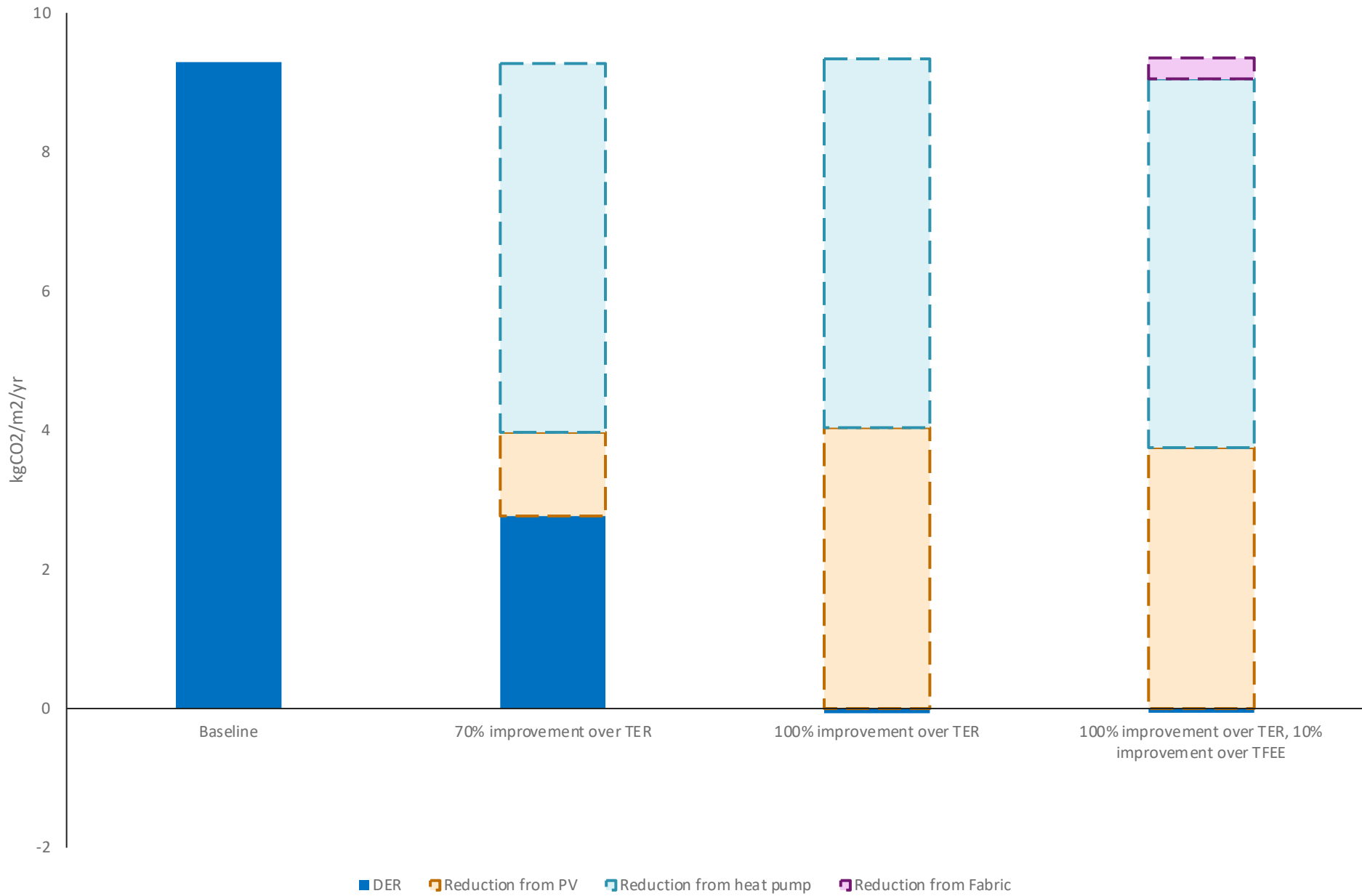
Policy compliant specifications | Detached house

		Part L 2021 (Baseline)	All improvements	70% TER reduction	100% TER reduction	100% TER reduction 10% TFEF reduction	100% TER reduction 10% TFEF reduction Offset unregulated	
Building fabric and ventilation strategy 	Floor Walls Roof (W/m ² K) 	Part L 2021 compliant fabric 0.12 0.15 0.11	Low Energy Fabric 0.09 0.12 0.10	Part L 2021 compliant fabric 0.12 0.15 0.11	Part L 2021 compliant fabric 0.12 0.15 0.11	Improved fabric 0.09 0.12 0.10	Improved fabric 0.09 0.12 0.10	
	Windows (W) Doors (D) (W/m ² K) 	Double glazing W - 1.2 D - 1.0	Triple glazing W - 0.8 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0
	Airtightness (m ³ /m ² h) 	5	1	5	5	3	3	
	Ventilation strategy 	Natural ventilation with intermittent extract fans	MVHR < 84% SFP < 0.7 W/l/s < 2m external ducts	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	
	Heating system Hot water heating system 	Gas combi boiler (55°C)	5kW ASHP (<45°C)	5kW ASHP (<45°C)	5kW ASHP (<45°C)	5kW ASHP (<45°C)	5kW ASHP (<45°C)	
Hot water heating system 	No additional cylinder	200l cylinder 120mm jacket insulation	200l cylinder 120mm jacket insulation	200l cylinder 120mm jacket insulation	200l cylinder 120mm jacket insulation	200l cylinder 120mm jacket insulation		
Waste water heat recovery (WWHR) 	Yes 36%	Yes 36%	No	No	No	No		
Renewables 	PV panels	4.8 kW	6.5 kW	1.5 kW	5.1 kW	4.8 kW	6.5 kW	
	Offsetting requirement (tCO₂) 	-	-	-	No	No	Yes	

Policy compliant results | Detached

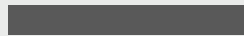
	Part L 2021 (Baseline)	All improvements	70% TER reduction	100% TER reduction	100% TER reduction 10% TFEE reduction	100% TER reduction 10% TFEE reduction Offset unregulated
Description	Part L 2021 notional assumptions	Improved U- values MVHR Improved airtightness ASHP Maximum PV	ASHP No WWHR Additional PV	ASHP No WWHR Additional PV	Improved U- values Improved airtightness ASHP No WWHR Additional PV	Improved U- values Improved airtightness ASHP No WWHR Maximum PV
DER kgCO ₂ /m ² /yr	9.3	-2.2	2.8	-0.1	-0.1	-0.4
% DER < TER (Carbon emissions)	-	118%	71%	101%	101%	104%
Residual regulated tCO ₂ /yr	1.3	-0.3	0.39	-0.01	-0.01	-0.05
% DPER < TPER (Primary energy)	-	102%	36%	70%	72%	76%
% DFEE < TFEE (Fabric energy efficiency)	-	21%	0%	0%	11%	11%
Unreg tCO ₂ /yr	0.7	0.7	0.7	0.7	0.7	0.7
Total CO₂ to offset (at £403/tCO ₂ /yr)	n/a	n/a	n/a	0	0	0.6

Policy compliant results | Detached house



7.3

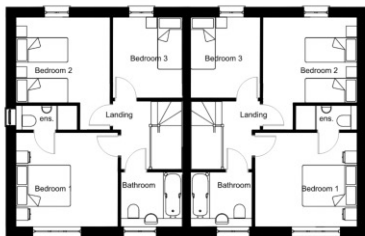
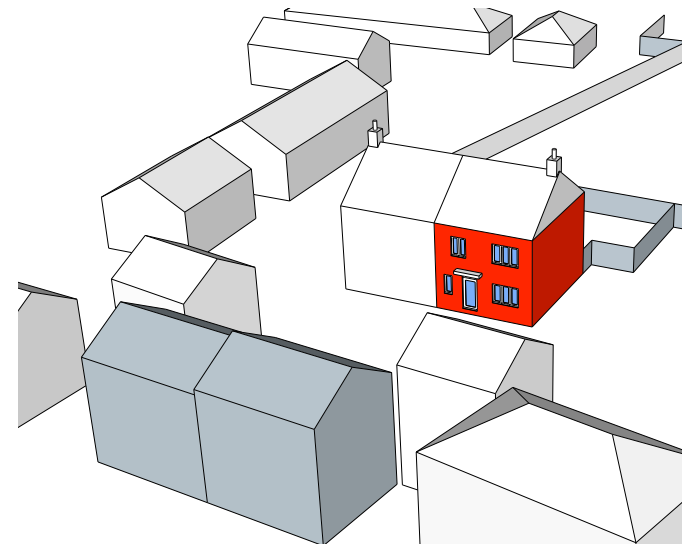
Semi-detached house



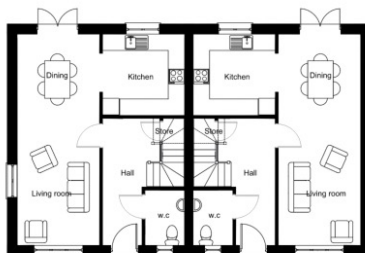
Semi-detached house

A 3-bed 2-storey semi-detached house has been selected for modelling.

GIA: 93 m²



Plot 55
Plot 54
First Floor Plan



Plot 55
Plot 54
Total Floor Area= 93.06 m² / 1001.68 ft²
Ground Floor Plan

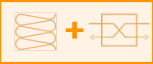











Plot 55
Plot 54
East Elevation



Plot 54
Plot 55
West Elevation

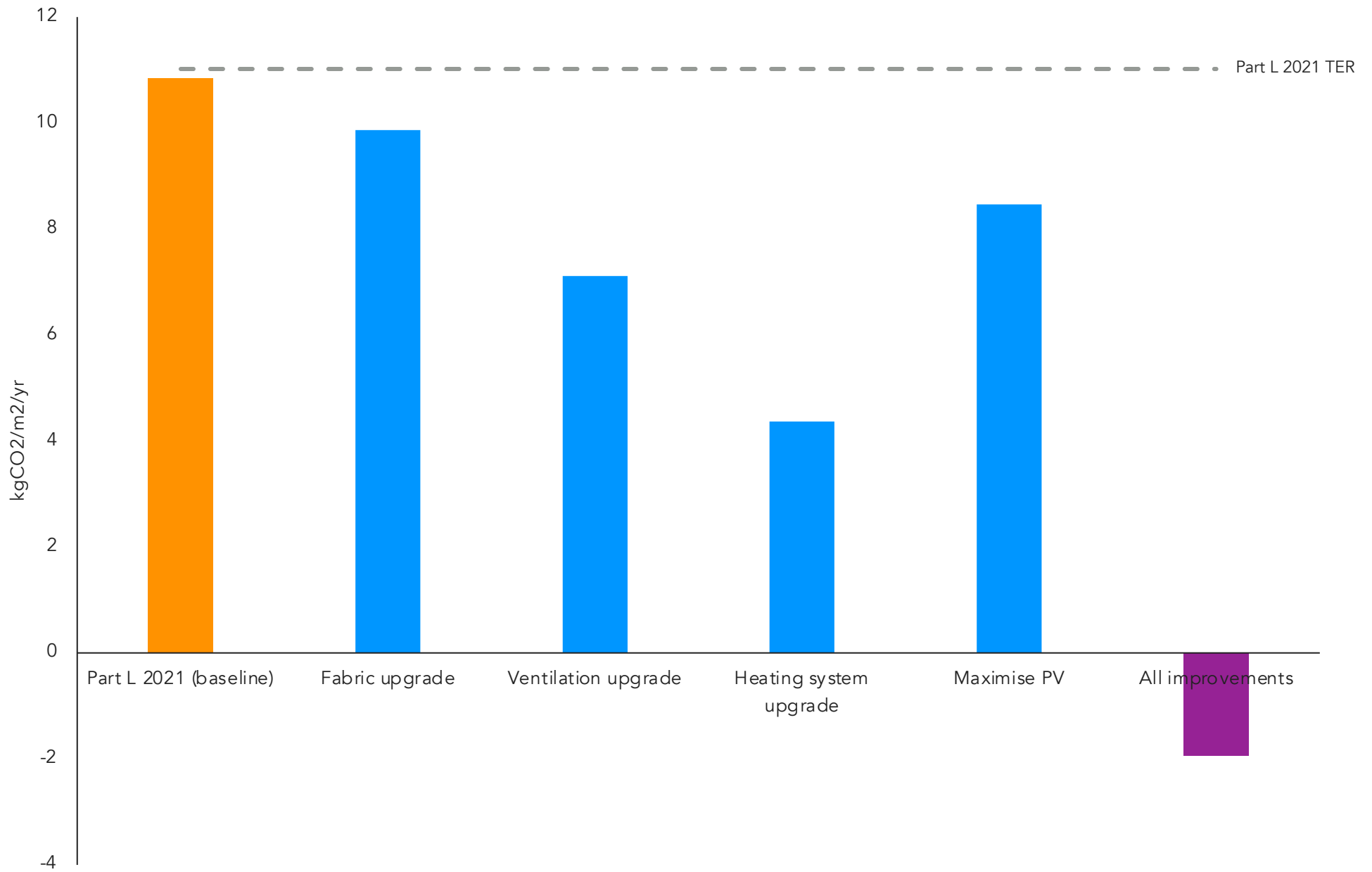
Modelling specifications | Semi-detached house

		Part L 2021 (Baseline)	Future Homes Standard (Option 1)	Fabric upgrade	Ventilation upgrade	Heating system upgrade	Maximise PV	All improvements	
Building fabric and ventilation strategy 	Floor Walls Roof (W/m ² K) 	Part L 2021 compliant fabric 0.11 0.16 0.10	FHS compliant fabric 0.13 0.16 0.10	Low energy fabric 0.09 0.13 0.10	Part L 2021 compliant fabric 0.11 0.16 0.10	Part L 2021 compliant fabric 0.11 0.16 0.10	Part L 2021 compliant fabric 0.11 0.16 0.10	Low energy fabric 0.09 0.13 0.10	
	Windows (W) Doors (D) (W/m ² K) 	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Triple glazing W - 0.8 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Triple glazing W - 0.8 D - 1.0
	Airtightness (m ³ /m ² h) 	5	4	5	1	5	5	5	1
	Ventilation strategy	Natural ventilation with intermittent extract fans	Decentralised mechanical ventilation (dMEV) system	Natural ventilation with intermittent extract fans	MVHR 84% SFP <0.7W/l/s <2m external ducts	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	MVHR 84% SFP <0.7W/l/s <2m external ducts
Heating, hot water 	Heating system 	Gas combi boiler (55°C) 89%	5kW ASHP (<45°C) 300/190%	Gas combi boiler (55°C) 89%	Gas combi boiler (55°C) 89%	5kW ASHP (<45°C) 300/190%	Gas combi boiler (55°C) 89%	5kW ASHP (<45°C) 300/190%	
	Hot water heating system 	No additional cylinder	200l cylinder 120mm jacket insulation 1.6 kWh/day	No additional cylinder	No additional cylinder	200l cylinder 120mm jacket insulation 1.6 kWh/day	No additional cylinder	200l cylinder 120mm jacket insulation 1.6 kWh/day	
	Waste water heat recovery (WWHR) 	Yes 36% System A	Yes 50% System A	Yes 36% System A	Yes 36% System A	Yes 36% System A	Yes 36% System A	Yes 36% System A	Yes 36% System A
Renewables 	PV panels 	2.8 kW	4.05 kW	2.8 kW	2.8 kW	0 kW	4.9 kW	4.9 kW	


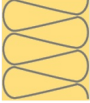







All results | Semi-detached

	Part L 2021 (Baseline)	Future Homes Standard (Option 1)	Fabric upgrade	Ventilation upgrade	Heating system upgrade	Maximise PV	All improvements
Description	Part L 2021 notional assumptions	FHS notional assumptions	Improved U-values	MVHR Improved airtightness	ASHP No PV	Maximum PV	Improved U-values MVHR Improved airtightness ASHP Maximum PV
DER kgCO ₂ /m ² /yr	10.9	-0.4	9.9	7.1	4.4	8.5	-1.9
% DER < TER (Carbon emissions)	-	104%	10%	35%	60%	23%	118%
% DPER < TPER (Primary energy)	-	76%	10%	32%	10%	21%	94%
% DFEE < TFEE (Fabric energy efficiency)	-	2%	12%	8%	0%	0%	20%

Results | Semi-detached house



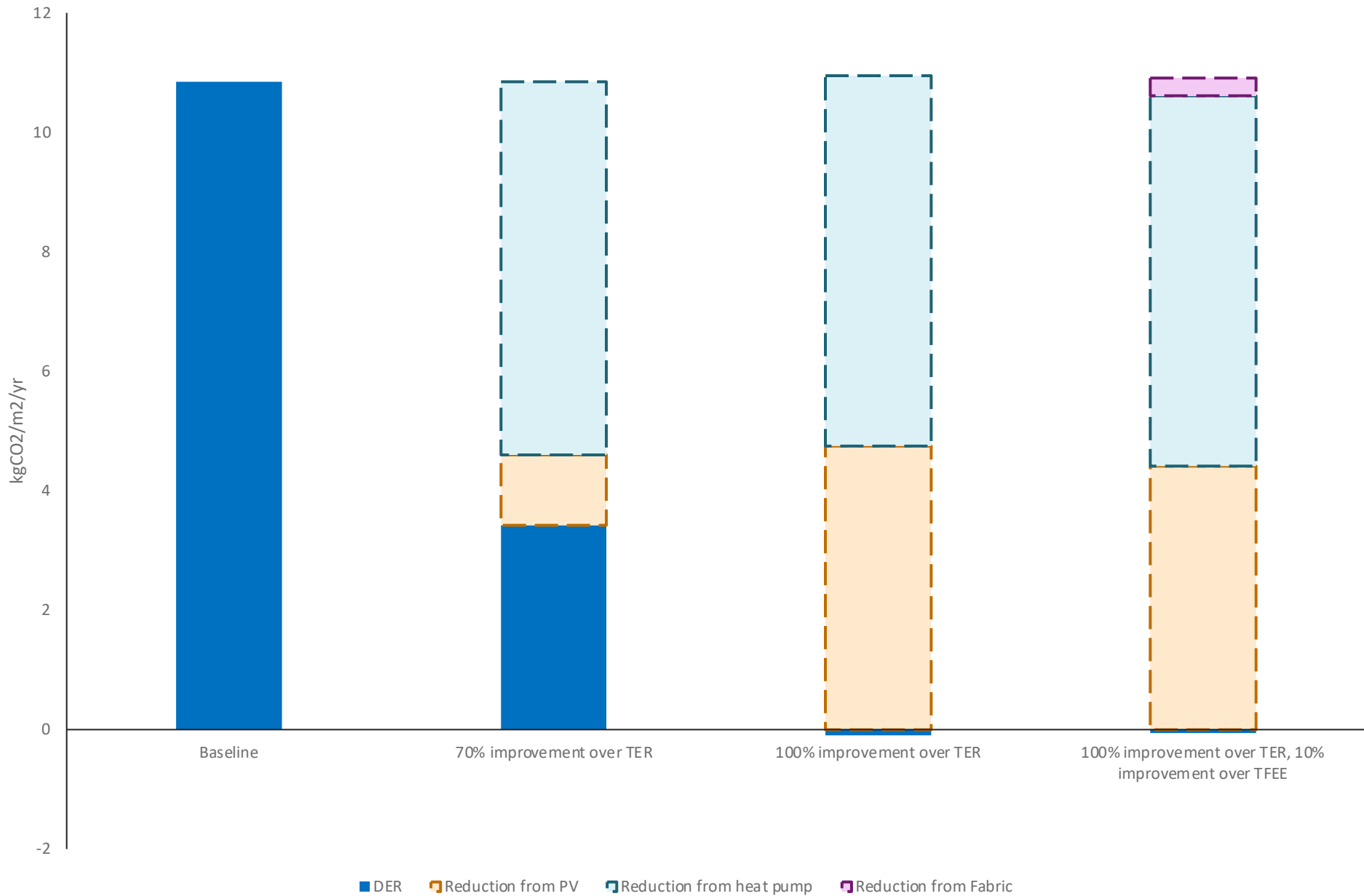
Modelling specifications | Semi Detached house

		Part L 2021 (Baseline)	All improvements	70% TER reduction	100% TER reduction	100% TER reduction 10% TFEF reduction	100% TER reduction 10% TFEF reduction Offset unregulated	
Building fabric and ventilation strategy 	Floor Walls Roof (W/m ² K) 	Part L 2021 compliant fabric 0.11 0.16 0.10	Low energy fabric 0.09 0.13 0.10	Part L 2021 compliant fabric 0.11 0.16 0.10	Part L 2021 compliant fabric 0.11 0.16 0.10	Improved fabric 0.09 0.13 0.10	Improved fabric 0.09 0.13 0.10	
	Windows (W) Doors (D) (W/m ² K) 	Double glazing W - 1.2 D - 1.0	Triple glazing W - 0.8 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0
	Airtightness (m ³ /m ² h) 	5	1	5	5	3	3	
	Ventilation strategy	Natural ventilation with intermittent extract fans	MVHR 84% SFP <0.7W/l/s <2m external ducts	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	
	Heating system 	Gas combi boiler (55°C) 89%	5kW ASHP (<45°C) 300/190%	5kW ASHP (<45°C)	5kW ASHP (<45°C)	5kW ASHP (<45°C)	5kW ASHP (<45°C)	
Heating, hot water 	Hot water heating system	No additional cylinder	200l cylinder 120mm jacket insulation 1.6 kWh/day	200l cylinder 120mm jacket insulation	200l cylinder 120mm jacket insulation	200l cylinder 120mm jacket insulation	200l cylinder 120mm jacket insulation	
	Waste water heat recovery (WWHR) 	Yes 36% System A	Yes 36% System A	No	No	No	No	
Renewables 	PV panels	2.8 kW	4.9 kW	1.2 kW	4.1 kW	3.9 kW	4.9 kW	
	Offsetting required? (tCO₂) 	-	-	-	No	No	Yes	

All results | Semi-detached house

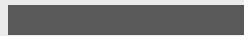
	Part L 2021 (Baseline)	All improvements	70% TER reduction	100% TER reduction	100% TER reduction 10% TFEE reduction	100% TER reduction 10% TFEE reduction Offset unregulated
Description	Part L 2021 notional assumptions	Improved U- values MVHR Improved airtightness ASHP Maximum PV	ASHP No WWHR Additional PV	ASHP No WWHR Additional PV	Improved U- values Improved airtightness ASHP No WWHR Additional PV	Improved U- values Improved airtightness ASHP No WWHR Maximum PV
DER kgCO ₂ /m ² /yr	10.9	-1.9	3.2	-0.1	-0.1	-1.2
% DER < TER (Carbon emissions)	-	118%	71%	101%	101%	111%
Residual regulated tCO ₂ /yr	1.0	-0.2	0.3	0	0	-0.1
% DPER < TPER (Primary energy)	-	94%	36%	71%	72%	82%
% DFEE < TFEE (Fabric energy efficiency)	-	20%	0%	0%	10%	10%
Unreg tCO ₂ /yr	0.6	0.6	0.6	0.6	0.6	0.6
Total CO₂ to offset (at £403/tCO ₂ /yr)	n/a	n/a	n/a	0	0	0.5

Policy compliant results | Semi-detached house



7.4

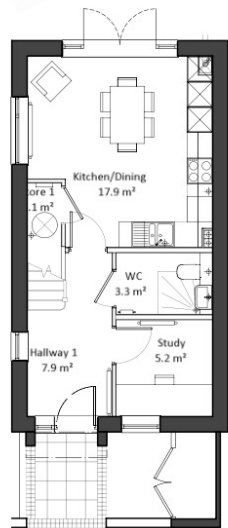
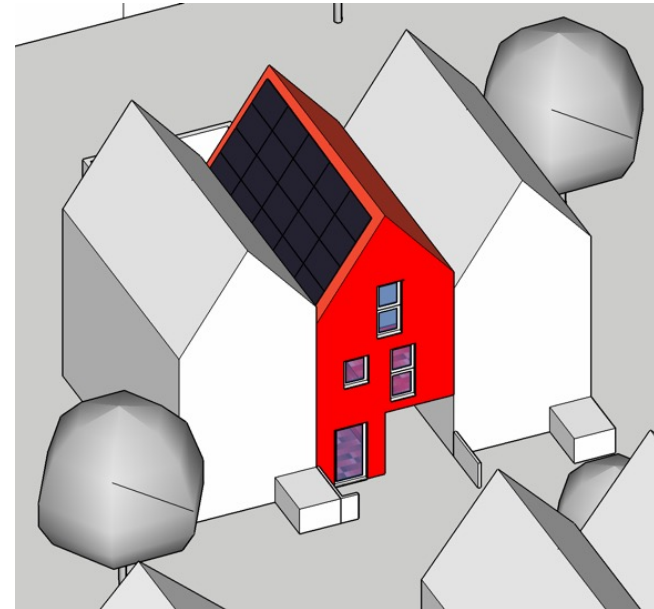
Terraced townhouse



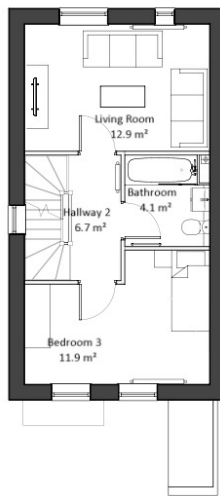
Terraced town house

A 4-bed 3-storey terraced town house has been modelled as a representative example based on a house in Bristol.

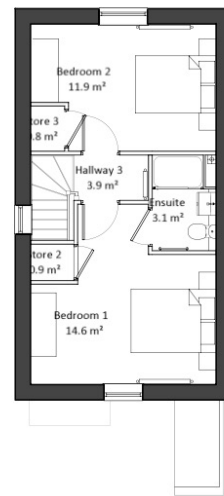
GIA: 111.5 m²



Ground floor



First floor




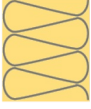







Second floor



Side elevation

Street elevation

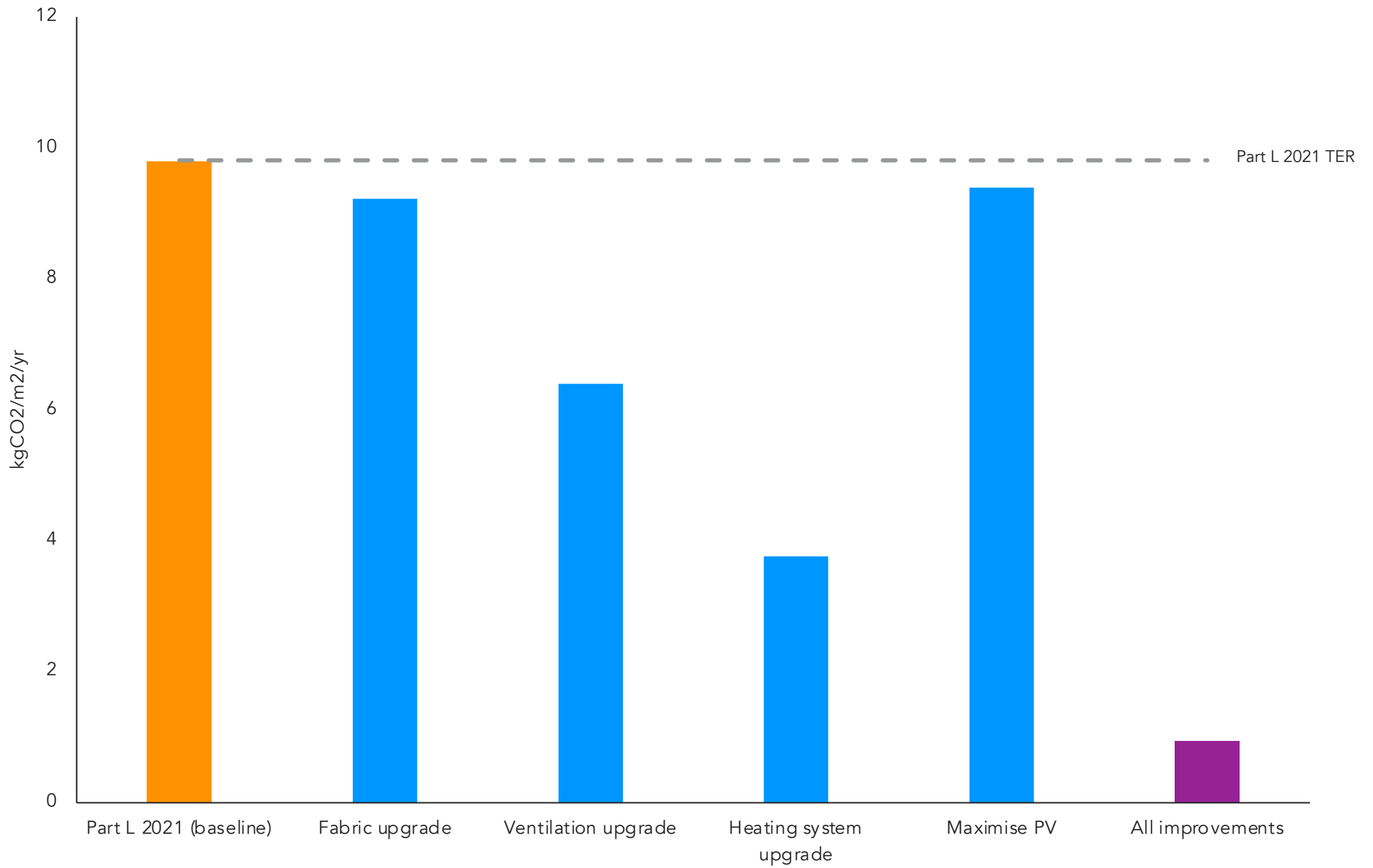
Modelling specifications | Terraced Town House

			Part L 2021 (Baseline)	Future Homes Standard (Option 1)	Fabric upgrade	Ventilation Upgrade	Heating system upgrade	Maximise PV	All improvements
Building fabric and ventilation strategy 	Floor Walls Roof (W/m ² K) 	Part L 2021 compliant fabric 0.10 0.16 0.10	FHS compliant fabric 0.10 0.16 0.10	Low energy fabric 0.10 0.13 0.10	Part L 2021 compliant fabric 0.10 0.16 0.10	Part L 2021 compliant fabric 0.10 0.16 0.10	Part L 2021 compliant fabric 0.10 0.16 0.10	Low energy fabric 0.10 0.13 0.10	
	Windows (W) Doors (D) (W/m ² K) 	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Triple glazing W - 1.0 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Triple glazing W - 1.0 D - 1.0
	Airtightness (m ³ /m ² h) 	5	4	5	1	5	5	1	
	Ventilation strategy	Natural ventilation with intermittent extract fans	Decentralised mechanical ventilation (dMEV) system	Natural ventilation with intermittent extract fans	MVHR 84% SFP < 0.7 W/l/s < 2 m external ducts	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	MVHR 84% SFP < 0.7 W/l/s < 2 m external ducts	
Heating, hot water 	Heating system 	Gas combi boiler (55°C)	5kW ASHP (<45°C)	Gas combi boiler (55°C)	Gas combi boiler (55°C)	5kW ASHP (<45°C)	Gas combi boiler (55°C)	5kW ASHP (<45°C)	
	Hot water heating system 	No additional cylinder	200l cylinder 120mm jacket insulation	No additional cylinder	No additional cylinder	200l cylinder 120mm jacket insulation	No additional cylinder	200l cylinder 120mm jacket insulation	
	Waste water heat recovery (WWHR)	Yes 36%	No	Yes 36%	Yes 36%	Yes 36%	Yes 36%	Yes 36%	
Renewables 	PV panels 	3.1 kW	4.9 kW	3.1 kW	3.1kW	0 kW	3.6 kW	3.6 kW	




All results | Terraced townhouse

	Part L 2021 (Baseline)	Future Homes Standard (Option 1)	Fabric upgrade	Ventilation upgrade	Heating system upgrade	Maximise PV	All improvements
Notes	Part L 2021 notional assumptions	FHS notional assumptions	Improved U-values	MVHR Improved airtightness	ASHP No PV	Maximum PV	Improved U-values MVHR Improved airtightness ASHP Maximum PV
Carbon emissions DER (kgCO ₂ /yr)	9.8	0.8	9.2	6.4	3.8	9.4	0.9
Carbon emissions reductions % DER < TER	-	92%	6%	35%	62%	4%	90%
Primary energy reduction % DPER < TPER	-	79%	6%	32%	23%	5%	78%
Fabric efficiency improvement % DFEE < TFEE	-	3%	9%	8%	0%	0%	17%

Results | Terraced house



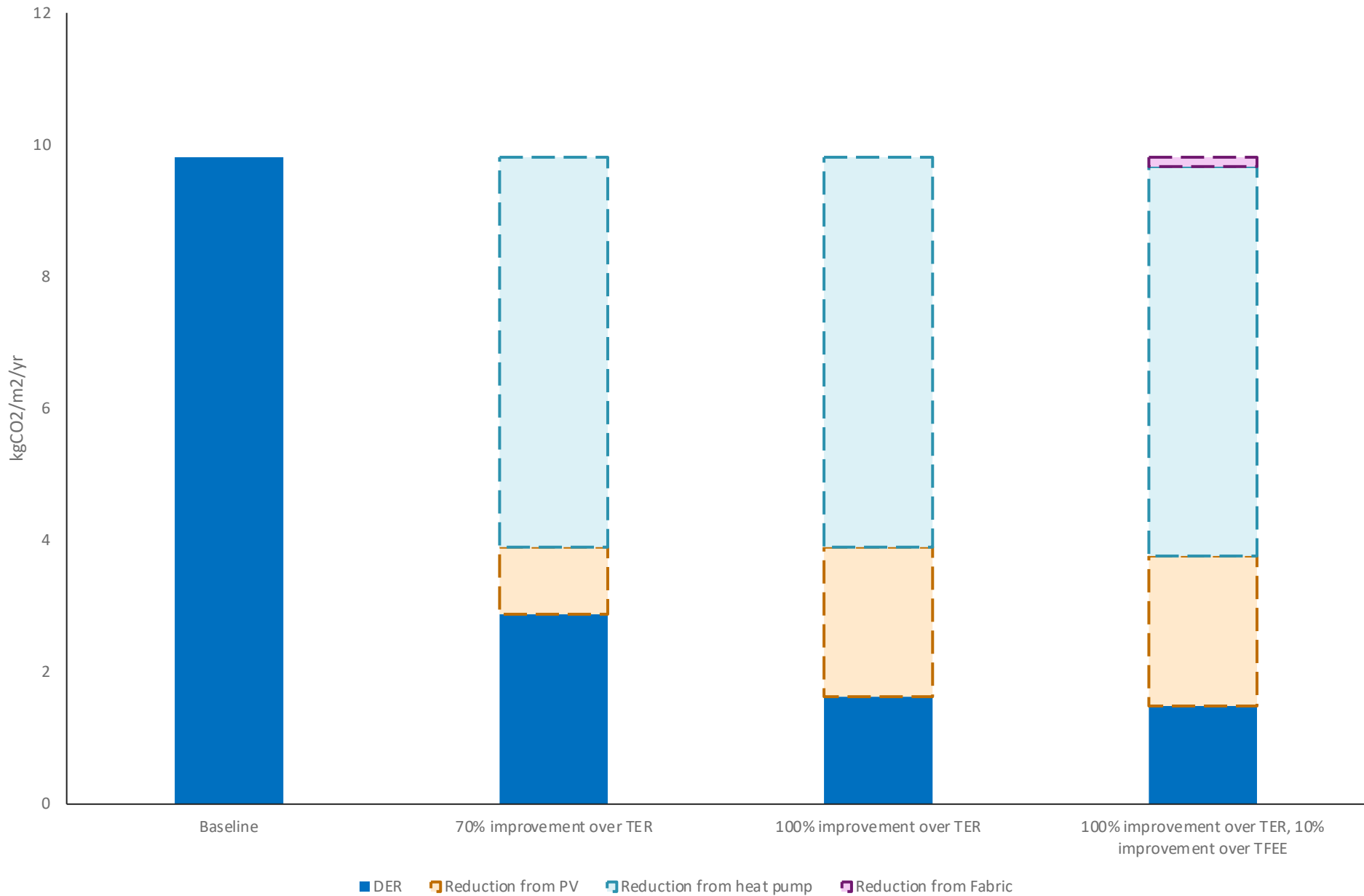
Modelling specifications | Terraced Town House

		Part L 2021 (Baseline)	All improvements	70% TER reduction	100% TER reduction	100% TER reduction 10% TFEF reduction	100% TER reduction 10% TFEF reduction Offset unregulated
Building fabric and ventilation strategy 	Floor Walls Roof (W/m ² K) 	Part L 2021 compliant fabric 0.10 0.16 0.10	Low energy fabric 0.10 0.13 0.10	Part L 2021 compliant fabric 0.10 0.16 0.10	Part L 2021 compliant fabric 0.10 0.16 0.10	Improved fabric 0.10 0.13 0.10	Improved fabric 0.10 0.13 0.10
	Windows (W) Doors (D) (W/m ² K) 	Double glazing W - 1.2 D - 1.0	Triple glazing W - 0.8 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Triple Glazing W - 0.8 D - 1.0	Triple Glazing W - 0.8 D - 1.0
	Airtightness (m ³ /m ² h) 	5	1	5	5	4.5	3
	Ventilation strategy	Natural ventilation with intermittent extract fans	MVHR 84% SFP < 0.7 W/l/s < 2 m external ducts	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans
Heating, hot water 	Heating system 	Gas combi boiler (55°C)	5kW ASHP (<45°C)	5kW ASHP (<45°C)	5kW ASHP (<45°C)	5kW ASHP (<45°C)	5kW ASHP (<45°C)
	Hot water heating system	No additional cylinder	200l cylinder 120mm jacket insulation	200l cylinder 120mm jacket insulation	200l cylinder 120mm jacket insulation	200l cylinder 120mm jacket insulation	200l cylinder 120mm jacket insulation
	Waste water heat recovery (WWHR) 	Yes 36%	Yes 36%	No	No	No	No
Renewables 	PV panels	3.1 kW	3.6 kW	1.5 kW	3.6 kW	3.6 kW	3.6 kW
	Offsetting required? (tCO₂) 	-	-	-	Yes	Yes	Yes

All results | Terraced townhouse

	Part L 2021 (Baseline)	All improvements	70% TER reduction	100% TER reduction	100% TER reduction 10% TFEE reduction	100% TER reduction 10% TFEE reduction Offset unregulated
Description	Part L 2021 notional assumptions	Improved U-values MVHR Improved airtightness ASHP Maximum PV	ASHP No WWHR Additional PV	ASHP No WWHR Additional PV	Improved U-values Improved airtightness ASHP No WWHR Additional PV	Improved U-values Improved airtightness ASHP No WWHR Maximum PV
DER kgCO ₂ /m ² /yr	9.8	0.9	2.9	1.6	1.5	1.4
% DER < TER (Carbon emissions)	-	90%	71%	83%	85%	85%
Residual regulated tCO ₂ /yr	1.1	0.1	0.3	0.2	0.2	0.2
% DPER < TPER (Primary energy)	-	78%	41%	65%	68%	69%
% DFEE < TFEE (Fabric energy efficiency)	-	17%	0%	0%	11%	11%
Unreg tCO ₂ /yr	0.6	0.6	0.6	0.6	0.6	0.6
Total CO ₂ to offset (at £403/tCO ₂ /yr)	n/a	n/a	n/a	0.2	0.2	0.8

Policy compliant results | Terraced house



7.5

Low-rise block of flats




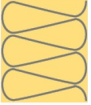







Low-rise block of flats

A 4-storeys block of 16 flats has been selected for modelling, Based on a block in South Gloucestershire

GIA: 980 m² (whole building)

Images redacted

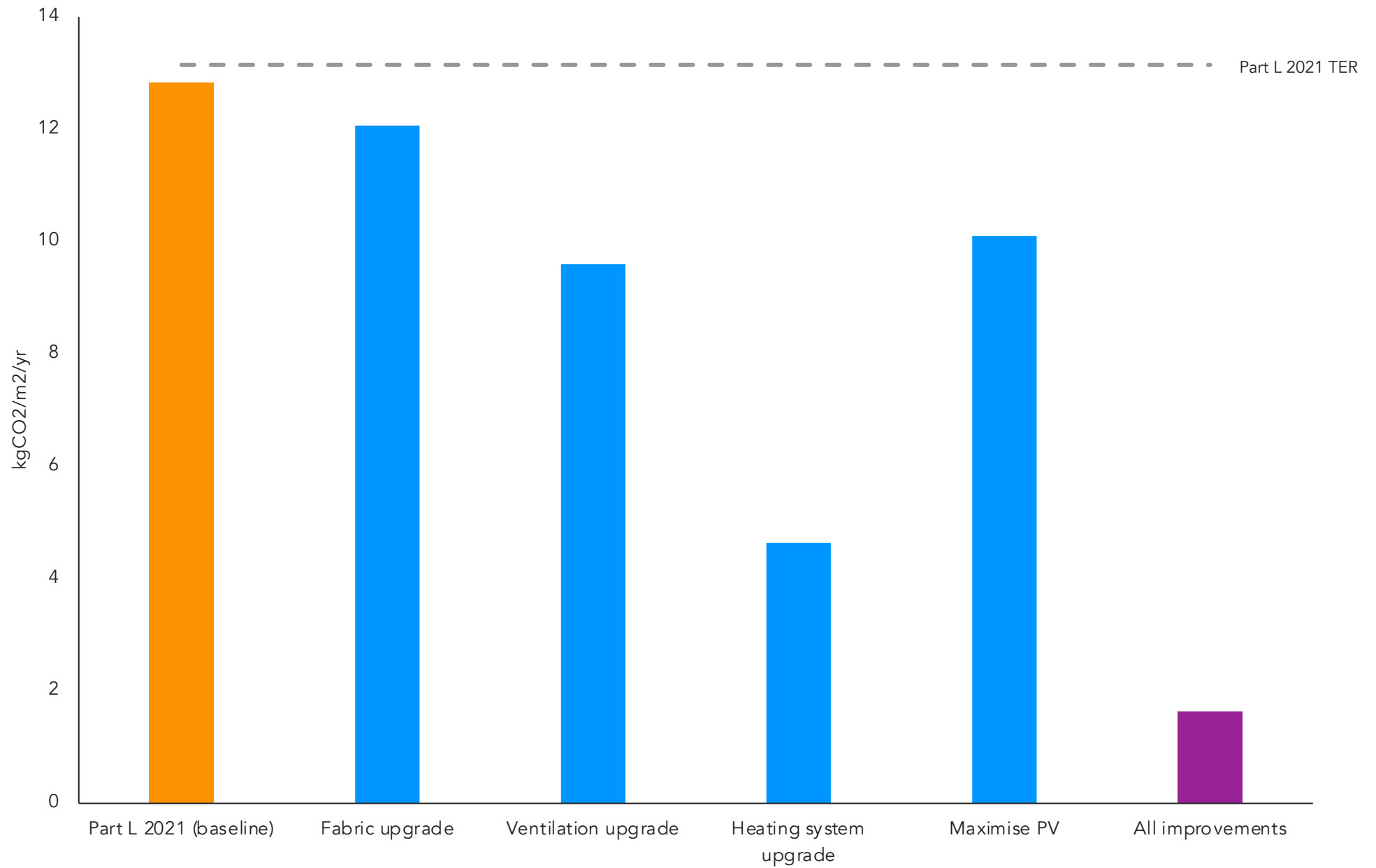
Modelling specifications | Low rise flats

			Part L 2021 (Baseline)	Future Homes Standard (Option 1)	Fabric upgrade	Ventilation Upgrade	Heating system upgrade	Add PV	All improvements (100%)
Building fabric and ventilation strategy 	Floor Walls Roof (W/m ² K) 	Part L 2021 compliant fabric 0.12 0.15 0.13	FHS compliant fabric 13 0.16 0.10	Low energy fabric 0.10 0.13 0.10	Part L 2021 compliant fabric 0.12 0.15 0.13	Part L 2021 compliant fabric 0.11 0.15 0.10	Part L 2021 compliant fabric 0.11 0.15 0.10	Low energy fabric 0.10 0.13 0.10	
	Windows (W) Doors (D) (W/m ² K) 	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Triple glazing W - 1.0 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Triple glazing W - 1.0 D - 1.0	
	Airtightness (m ³ /m ² h) 	5	4	5	1	5	5	1	
	Ventilation strategy	Natural ventilation with intermittent extract fans	Decentralised mechanical ventilation (dMEV) system	Natural ventilation with intermittent extract fans	MVHR 84% SFP <0.7 W/l/s	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	MVHR 84% SFP <0.7W/l/s	
	<hr/>								
Heating, hot water 	Heating system 	Gas combi boiler (55°C)	5kW ASHP (<45°C)	Gas combi boiler (55°C)	Gas combi boiler (55°C)	5kW ASHP (<45°C)	Gas combi boiler (55°C)	5kW ASHP (<45°C)	
	Hot water heating system 	No additional cylinder	200l cylinder 120mm jacket insulation	No additional cylinder	No additional cylinder	200l cylinder 120mm jacket insulation	No additional cylinder	200l cylinder 120mm jacket insulation	
	Waste water heat recovery (WWHR)	Yes 36%	Yes 50%	Yes 36%	Yes 36%	Yes 36%	Yes 36%	Yes 36%	
Renewables 	PV panels 	8.2 kW	4.9 kW	8.2 kW	8.2 kW	0 kW	43.2 kW	43.2 kW	


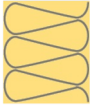





All results | Low rise flats

	Part L 2021 (Baseline)	Future Homes Standard (Option 1)	Fabric upgrade	Ventilation upgrade	Heating system upgrade	Maximise PV	All improvements
Notes	Part L 2021 notional assumptions	FHS notional assumptions	Improved U-values	MVHR Improved airtightness	ASHP	Maximum PV	Improved U-values MVHR Improved airtightness ASHP Maximum PV
Carbon emissions DER (kgCO ₂ /yr)	12.8	5.0	12.1	9.6	4.6	10.1	1.6
Carbon emissions reductions % DER < TER	-	62%	8%	27%	65%	23%	88%
Primary energy reduction % DPER < TPER	-	24%	6%	22%	30%	24%	73%
Fabric efficiency improvement % DFEE < TFEE	-	3%	11%	10%	0%	0%	20%

Results | Low rise flats



Modelling specifications | Low rise flats

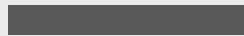
		Part L 2021 (Baseline)	All improvements	70% TER reduction	100% TER reduction	100% TER reduction 10% TFEF reduction	100% TER reduction 10% TFEF reduction Offset unregulated	
Building fabric and ventilation strategy 	Floor Walls Roof (W/m ² K) 	Part L 2021 compliant fabric 0.12 0.15 0.13	Low energy fabric 0.10 0.13 0.10	Part L 2021 compliant fabric 0.12 0.15 0.13	Part L 2021 compliant fabric 0.12 0.15 0.13	Low energy fabric 0.10 0.13 0.10	Low energy fabric 0.10 0.13 0.10	
	Windows (W) Doors (D) (W/m ² K) 	Double glazing W - 1.2 D - 1.0	Triple glazing W - 1.0 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0
	Airtightness (m ³ /m ² h) 	5	1	5	5	2.5	2.5	
	Ventilation strategy	Natural ventilation with intermittent extract fans	MVHR 84% SFP <0.7 W/l/s	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	
	Heating system 	Gas combi boiler (55°C)	5kW ASHP (<45°C)	5kW ASHP (<45°C)	5kW ASHP (<45°C)	5kW ASHP (<45°C)	5kW ASHP (<45°C)	
Heating, hot water 	Hot water heating system	No additional cylinder	200l cylinder 120mm jacket insulation	200l cylinder 120mm jacket insulation	200l cylinder 120mm jacket insulation	200l cylinder 120mm jacket insulation		
	Waste water heat recovery (WWHR) 	Yes 36%	Yes 36%	No	No	No	No	
Renewables 	PV panels 	8.2 kWp	43.2 kWp	15 kWp	43.2 kWp	43.2 kWp	43.2 kWp	
	Offsetting required? (tCO₂)	-	-	-	Yes	Yes	Yes	

All results | Low rise flats

	Part L 2021 (Baseline)	All improvements	70% TER reduction	100% TER reduction	100% TER reduction 10% TFEE reduction	100% TER reduction 10% TFEE reduction Offset unregulated
Description	Part L 2021 notional assumptions	Improved U- values MVHR Improved airtightness ASHP Maximum PV	ASHP No WWHR Additional PV	ASHP No WWHR Additional PV	Improved U- values Improved airtightness ASHP No WWHR Additional PV	Improved U- values Improved airtightness ASHP No WWHR Maximum PV
DER kgCO ₂ /m ² /yr	12.8	1.6	3.8	2.2	2.0	2.0
% DER < TER (Carbon emissions)	-	88%	71%	83%	84%	84%
Residual regulated tCO ₂ /yr	12.6	1.6	3.8	2.1	2.0	2.0
% DPER < TPER (Primary energy)	-	73%	42%	65%	67%	67%
% DFEE < TFEE (Fabric energy efficiency)	-	20%	0%	0%	11%	11%
Unreg tCO ₂ /yr	7.1	7.1	7.1	7.1	7.1	7.1
Total CO ₂ to offset (at £403/tCO ₂ /yr)	n/a	n/a	n/a	2.1	2.0	9.1

7.6

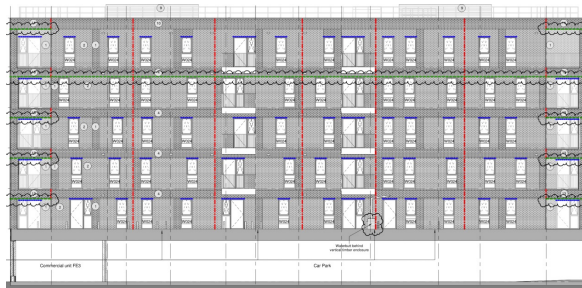
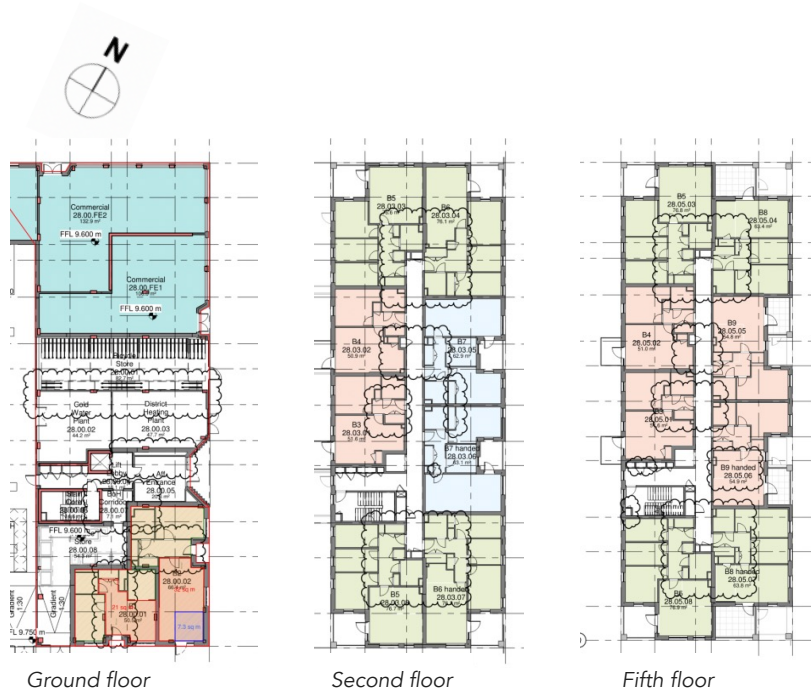
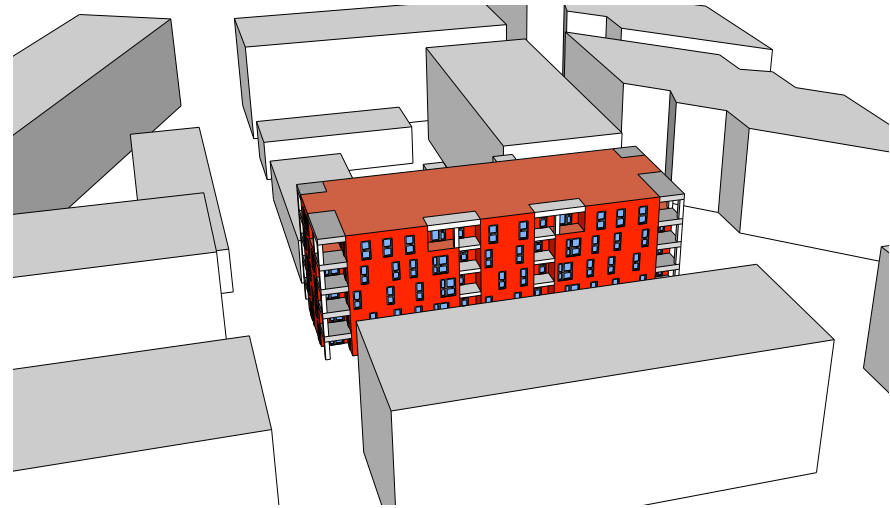
Mid-rise block of flats



Mid-rise block of flats

A 6-storeys block of 34 flats has been selected for modelling.

GIA: 3,202 m² (whole building)

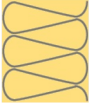








South-West elevation



North-East elevation

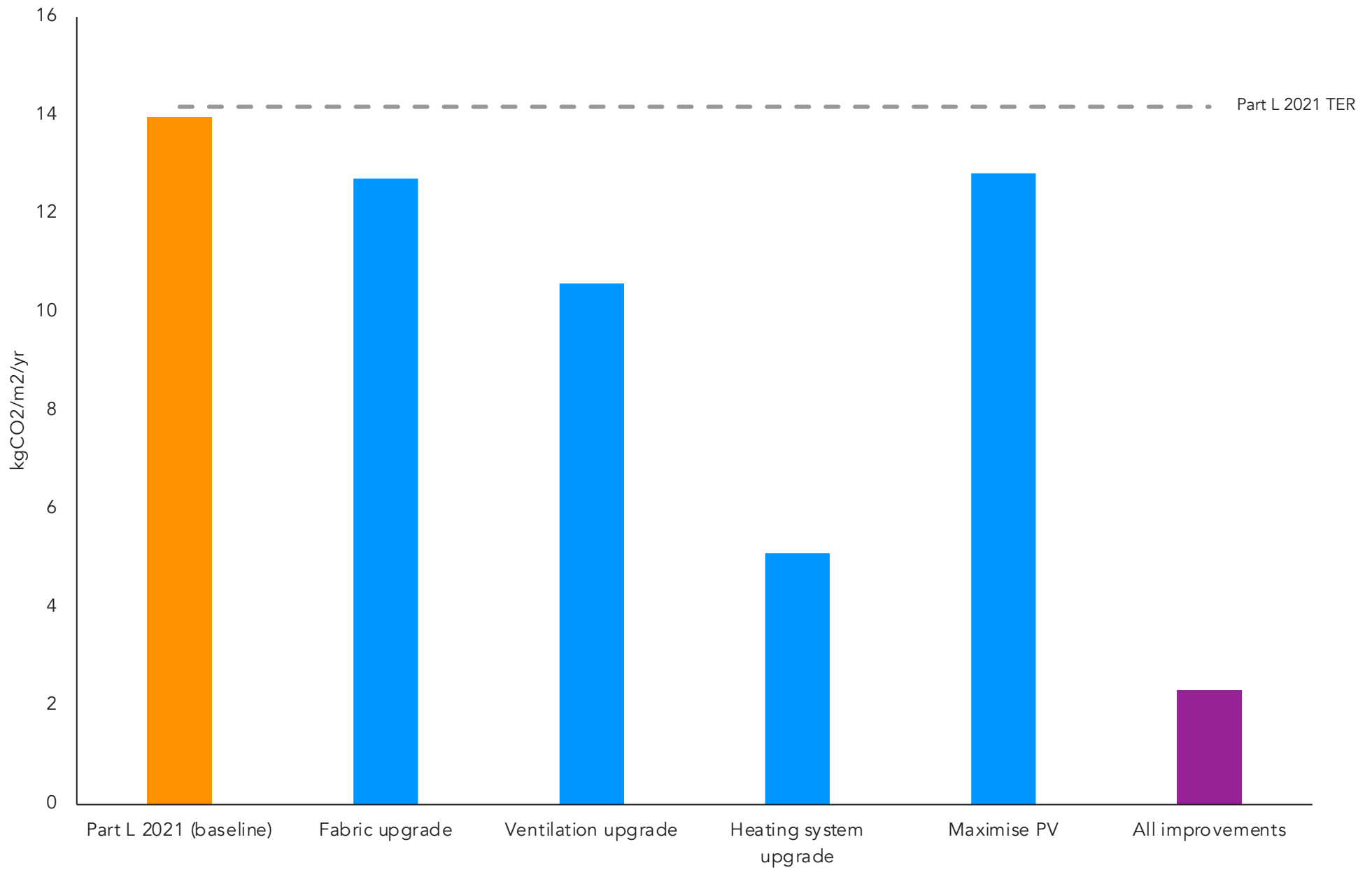
Modelling specifications | Mid rise block of flats

			Part L 2021 (Baseline)	Future Homes Standard (Option 1)	Fabric upgrade	Ventilation upgrade	Heating system upgrade	Maximise PV	All improvements
Building fabric and ventilation strategy	Floor Walls Roof (W/m ² K)		Part L 2021 compliant fabric	FHS compliant fabric	Low energy fabric	Part L 2021 compliant fabric	Part L 2021 compliant fabric	Part L 2021 compliant fabric	Low energy fabric
			0.12/0.15	0.10/0.13	0.10/0.12	0.12/0.15	0.12/0.15	0.12/0.15	0.10/0.12
			0.15	0.15	0.13	0.15	0.15	0.15	0.13
		0.15	0.14	0.10	0.15	0.15	0.15	0.10	
Windows (W) Doors (D) (W/m ² K)		Double glazing	Double glazing	Triple glazing	Double glazing	Double glazing	Double glazing	Double glazing	Triple glazing
		W - 1.2 D - 1.0	W - 1.2 D - 1.0	W - 0.8 D - 1.0	W - 1.2 D - 1.0	W - 1.2 D - 1.0	W - 1.2 D - 1.0	W - 1.2 D - 1.0	W - 0.8 D - 1.0
	Airtightness (m ³ /m ² h)		5	4	5	1	5	5	1
	Ventilation strategy		Natural ventilation with intermittent extract fans	Decentralised mechanical ventilation (dMEV) system	Natural ventilation with intermittent extract fans	MVHR 84% SFP <0.7W/l/s <2m external ducts	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	MVHR 84% SFP <0.7W/l/s <2m external ducts
Heating, hot water	Heating system		Gas combi boiler (55°C) 89%	Ambient loop ASHP (<45°C) 300%	Gas combi boiler (55°C) 89%	Gas combi boiler (55°C) 89%	Communal ASHP 300%	Gas combi boiler (55°C) 89%	Communal ASHP 300%
	Hot water heating system		No additional cylinder	200l cylinder 120mm jacket insulation 1.6 kWh/day	No additional cylinder	No additional cylinder	HIU 1.44kWh/day	No additional cylinder	HIU 1.44kWh/day
	Waste water heat recovery (WWHR)		Yes 36% System A	No	Yes 36% System A	Yes 36% System A	Yes 36% System A	Yes 36% System A	Yes 36% System A
Renewables	PV panels		15.0 kW	44.3 kW E/W concertina	15.0 kW	15 kW	0 kW	57.6 kW E/W concertina	57.6 kW E/W concertina

All results | Mid rise block of flats

	Part L 2021 (Baseline)	Future Homes Standard (Option 1)	Fabric upgrade	Ventilation upgrade	Heating system upgrade	Maximise PV	All improvements
Description	Part L 2021 notional assumptions	FHS notional assumptions	Improved U-values	MVHR Improved airtightness	Communal ASHP No PV	Maximum PV	Improved U-values MVHR Improved airtightness Communal ASHP Maximum PV
DER kgCO ₂ /m ² /yr	14.0	4.1	12.7	10.6	5.1	12.8	2.3
% DER < TER (Carbon emissions)	-	71%	10%	25%	64%	10%	84%
% DPER < TPER (Primary energy)	-	39%	8%	20%	29%	10%	61%
% DFEE < TFEE (Fabric energy efficiency)	-	3%	15%	7%	0%	0%	22%

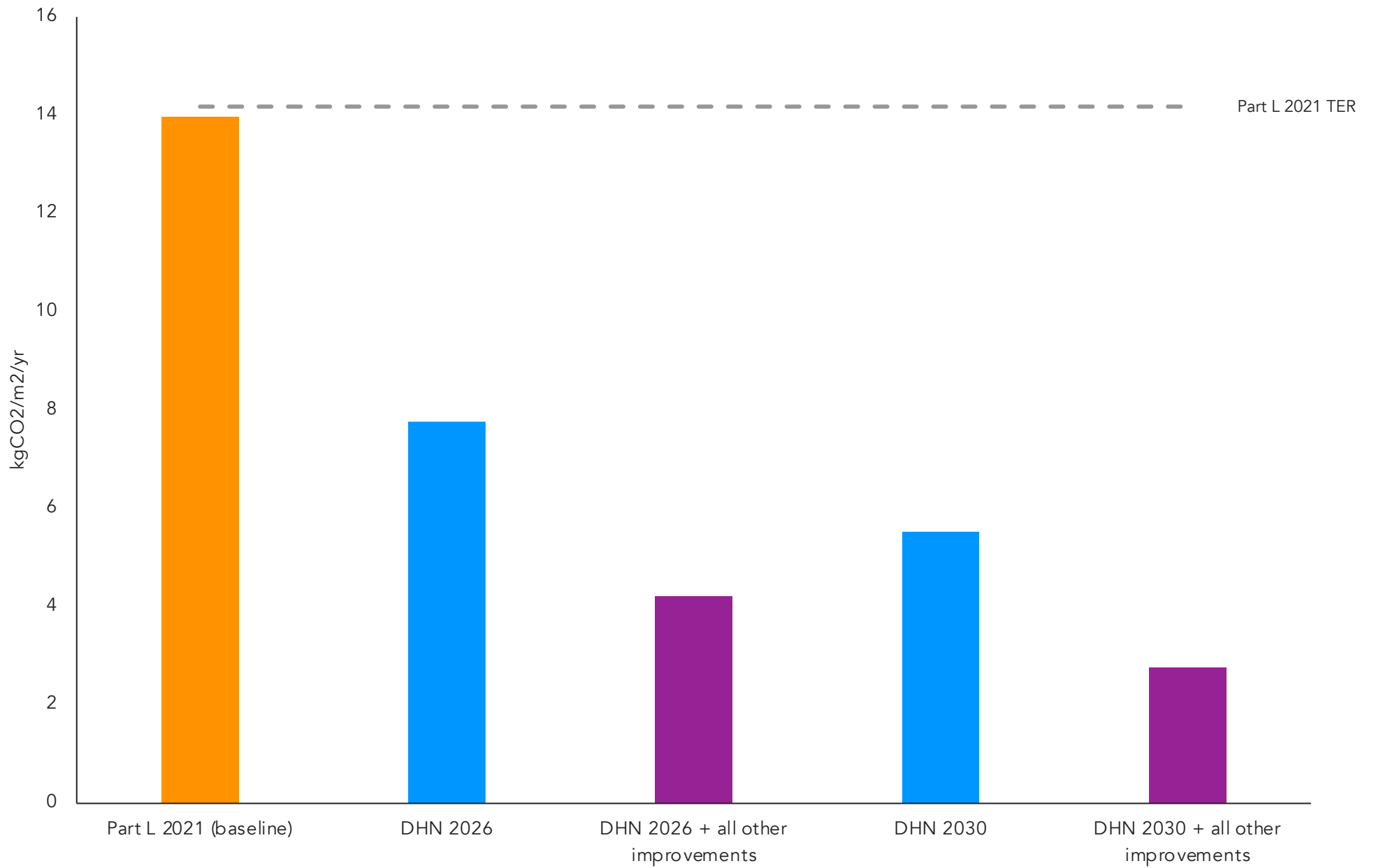
Results | Mid rise flats












DHN results | Mid rise block of flats

	Part L 2021 (Baseline)	DHN 2026	DHN 2026 + all other improvements	DHN 2030	DHN 2030 + all other improvements
Description	Part L 2021 notional assumptions	DHN 2026	Improved U- values MVHR Improved airtightness DHN 2026 Maximum PV	DHN 2030	Improved U- values MVHR Improved airtightness DHN 2030 Maximum PV
DER kgCO ₂ /m ² /yr	13.9	7.7	4.7	5.5	3.3
% DER < TER (Carbon emissions)	-	45%	70%	61%	80%
% DPER < TPER (Primary Energy)	-	1%	43%	21%	56%
% DFEE < TFEE (Fabric energy efficiency)	-	0%	22%	0%	22%

DHN Results | Mid rise flats



Policy compliant specifications | Mid-rise flats

			Part L 2021 (Baseline)	All improvements	70% TER reduction	100% TER reduction	100% TER reduction 10% TFEF reduction	100% TER reduction 10% TFEF reduction Offset unregulated
Building fabric and ventilation strategy 	Floor Walls Roof (W/m ² K) 	Part L 2021 compliant fabric 0.12/0.15 0.15 0.15	Low energy fabric 0.10/0.12 0.13 0.10	Part L 2021 compliant fabric 0.12/0.15 0.15 0.15	Part L 2021 compliant fabric 0.12/0.15 0.15 0.15	Part L 2021 compliant fabric 0.12/0.15 0.15 0.15	Part L 2021 compliant fabric 0.12/0.15 0.15 0.15	
	Windows (W) Doors (D) (W/m ² K) 	Double glazing W - 1.2 D - 1.0	Triple glazing W - 0.8 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Triple glazing W - 0.8 D - 1.0	Triple glazing W - 0.8 D - 1.0	
	Airtightness (m ³ /m ² h) 	5	1	5	5	5	5	
	Ventilation strategy	Natural ventilation with intermittent extract fans	MVHR 84% SFP <0.7W/l/s <2m external ducts	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	
	Heating, hot water 	Heating system 	Gas combi boiler (55°C) 89%	Communal ASHP 300%	Communal ASHP 300%	Communal ASHP 300%	Communal ASHP 300%	Communal ASHP 300%
Hot water heating system	No additional cylinder	HIU 1.44kWh/day	HIU 1.44kWh/day	HIU 1.44kWh/day	HIU 1.44kWh/day	HIU 1.44kWh/day		
Waste water heat recovery (WWHR) 	Yes 36% System A	Yes 36% System A	No	No	No	No		
Renewables 	PV panels 	15.0 kWp	57.6 kWp E/W concertina	45 kWp	57.6 kWp E/W concertina	57.6 kWp E/W concertina	57.6 kWp E/W concertina	
	Offsetting required? (tCO₂)	-	-	-	Yes	Yes	Yes	

Policy results | Mid-rise flats

	Part L 2021 (Baseline)	All improvements	70% TER reduction	100% TER reduction	100% TER reduction 10% TFEE reduction	100% TER reduction 10% TFEE reduction Offset unregulated
Description	Part L 2021 notional assumptions	Improved U-values MVHR Improved airtightness ASHP Maximum PV	ASHP No WWHR Additional PV	ASHP No WWHR Additional PV	Improved U-values Improved airtightness ASHP No WWHR Additional PV	Improved U-values Improved airtightness ASHP No WWHR Maximum PV
DER kgCO ₂ /m ² /yr	14.0	2.3	4.1	3.8	3.4	3.4
% DER < TER (Carbon emissions)	-	84%	71%	74%	76%	76%
Residual regulated tCO ₂ /yr	38.9	6.5	11.4	10.5	9.6	9.6
% DPER < TPER (Primary energy)	-	61%	40%	44%	48%	48%
% DFEE < TFEE (Fabric energy efficiency)	-	22%	0%	0%	12%	12%
Unreg tCO ₂ /yr	19.5	19.5	11.4	10.5	9.6	29.0
Total CO ₂ to offset (at £403/tCO ₂ /yr)	n/a	n/a	n/a	10.5	9.6	38.6

7.7

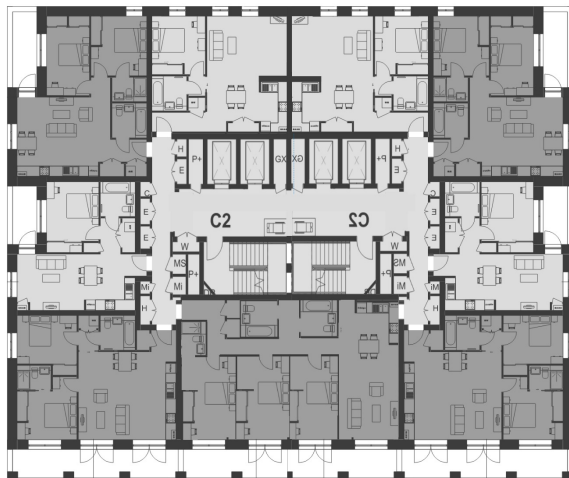
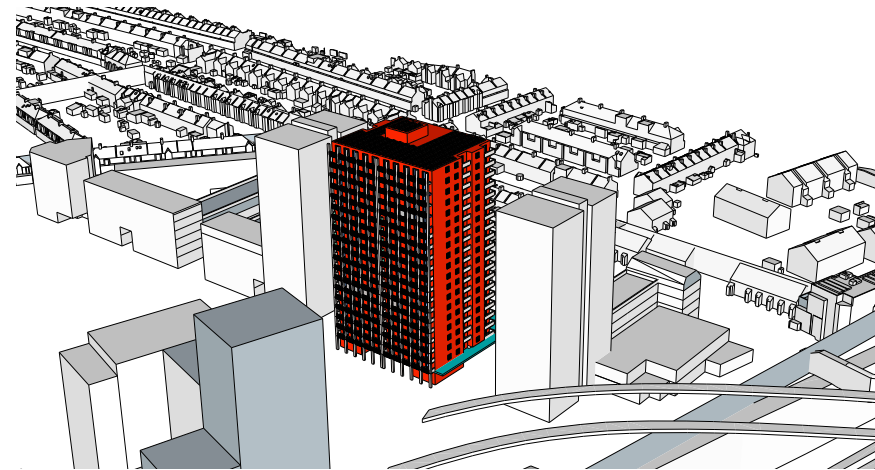
High-rise block of flats



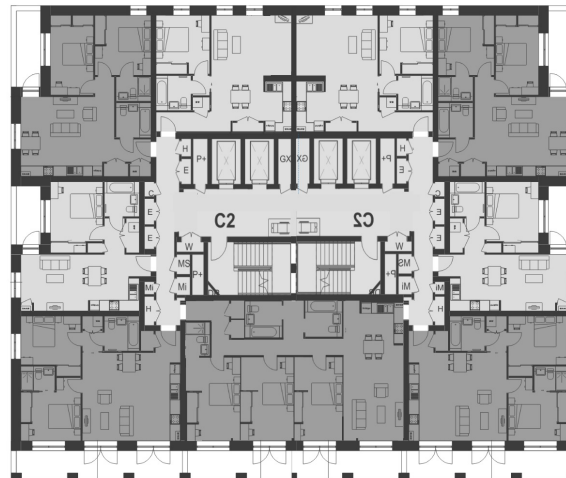
High rise block of flats

A 20 storey block of 180 flats has been selected for modelling.

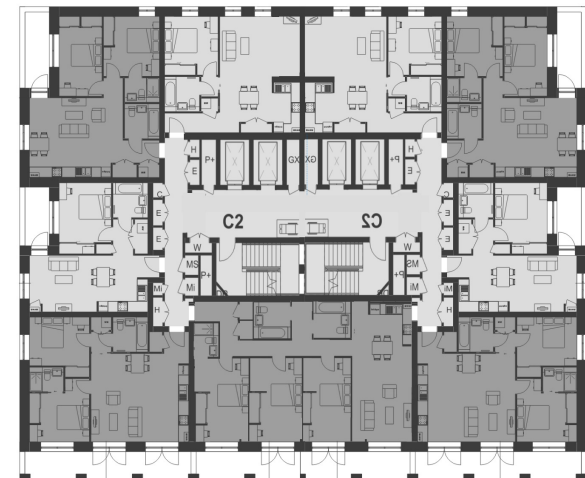
GIA: 15,541 m² (whole building)



Ground floor


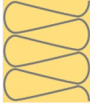









Mid floor



Top floor

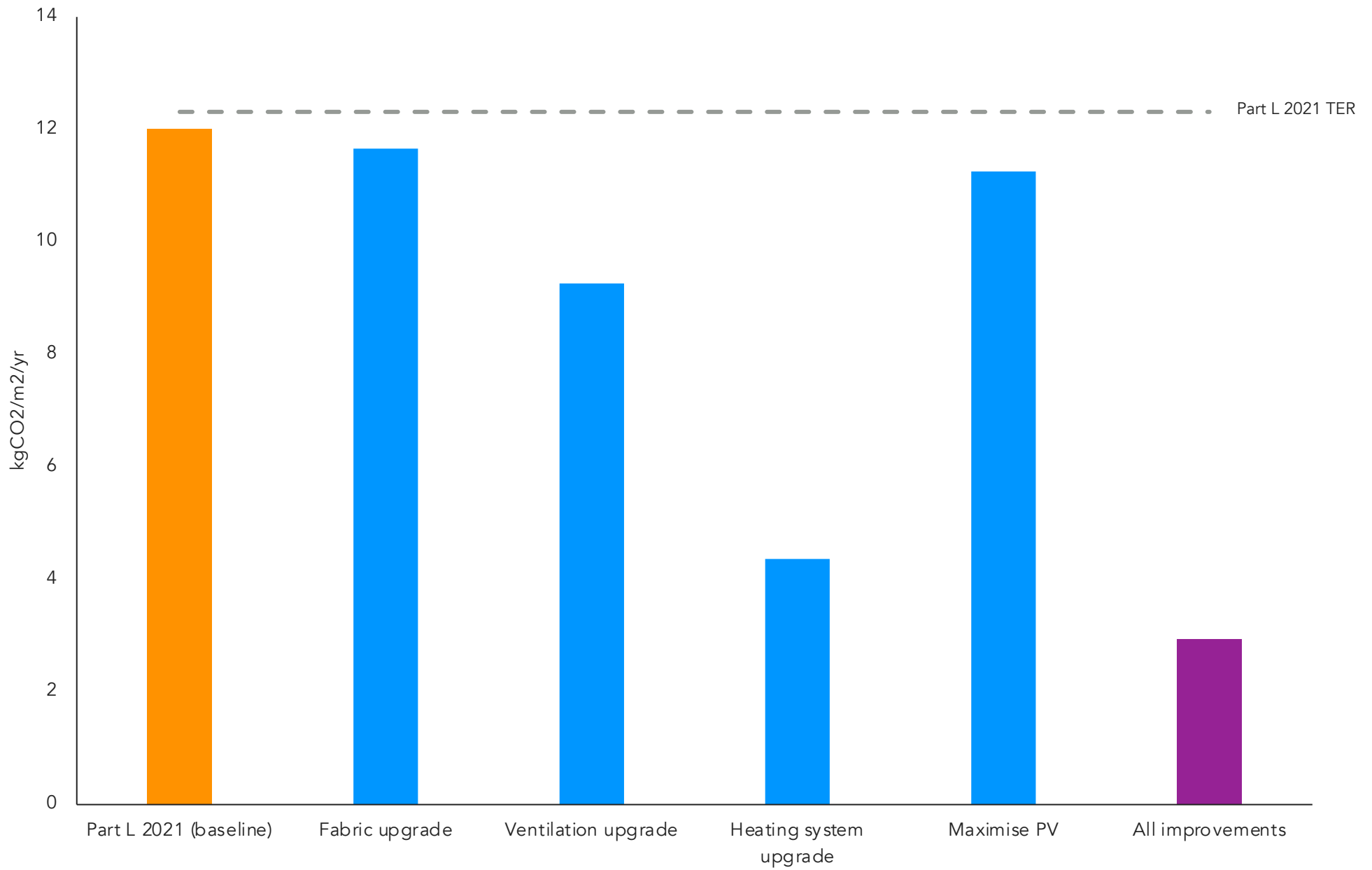
Modelling specifications | High Rise Block of Flats

		Part L 2021 (Baseline)	Future Homes Standard (Option 1)	Fabric upgrade	Ventilation upgrade	Heating system upgrade	Maximise PV	All improvements	
Building fabric and ventilation strategy 	Floor Walls Roof (W/m ² K) 	Part L 2021 compliant fabric 0.14 0.145 0.10	FHS compliant fabric 0.13 0.16 0.10	Low energy fabric 0.12 0.145 0.10	Part L 2021 compliant fabric 0.14 0.145 0.10	Part L 2021 compliant fabric 0.14 0.145 0.10	Part L 2021 compliant fabric 0.14 0.145 0.10	Low energy fabric 0.12 0.145 0.10	
	Windows (W) Doors (D) (W/m ² K) 	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Triple glazing W - 1.0 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Double glazing W - 1.2 D - 1.0	Triple glazing W - 1.0 D - 1.0
	Airtightness (m ³ /m ² h) 	5	4	5	1	5	5	5	1
	Ventilation strategy	Natural ventilation with intermittent extract fans	Decentralised mechanical ventilation (dMEV) system	Natural ventilation with intermittent extract fans	MVHR 84% SFP <0.7W/l/s	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	MVHR 84% SFP <0.7W/l/s
Heating, hot water 	Heating system 	Gas combi boiler (55°C)	Communal ASHP 300%	Gas combi boiler (55°C)	Gas combi boiler (55°C)	Communal ASHP 300%	Gas combi boiler (55°C)	Communal ASHP 300%	
	Hot water heating system	No additional cylinder	HIU 1.44kWh/day	No additional cylinder	No additional cylinder	HIU 1.44kWh/day	No additional cylinder	HIU 1.44kWh/day	
	Waste water heat recovery (WWHR) 	Yes 36%	No	Yes 36%	Yes 36%	Yes 36%	Yes 36%	Yes 36%	Yes 36%
Renewables 	PV panels 	5.5 kW	4.9 kW	5.5 kW	5.5 kW	0 kW	111.6 kW	111.6 kW	

Results | High Rise Block of Flats

	Part L 2021 (Baseline)	Future Homes Standard (Option 1)	Fabric upgrade	Ventilation upgrade	Heating system upgrade	Maximise PV	All improvements
Description	Part L 2021 notional assumptions	FHS notional assumptions	Improved U-values	MVHR Improved airtightness	Communal ASHP No PV	Maximum PV	Improved U-values MVHR Improved airtightness Communal ASHP Maximum PV
DER kgCO ₂ /m ² /yr	12.0	4.2	11.7	9.3	4.4	11.3	2.9
% DER < TER (Carbon emissions)	-	66%	5%	25%	65%	9%	76%
% DPER < TPER (Primary Energy)	-	35%	3%	18%	32%	9%	52%
% DFEE < TFEE (Fabric energy efficiency)	-	2%	6%	7%	0%	0%	13%

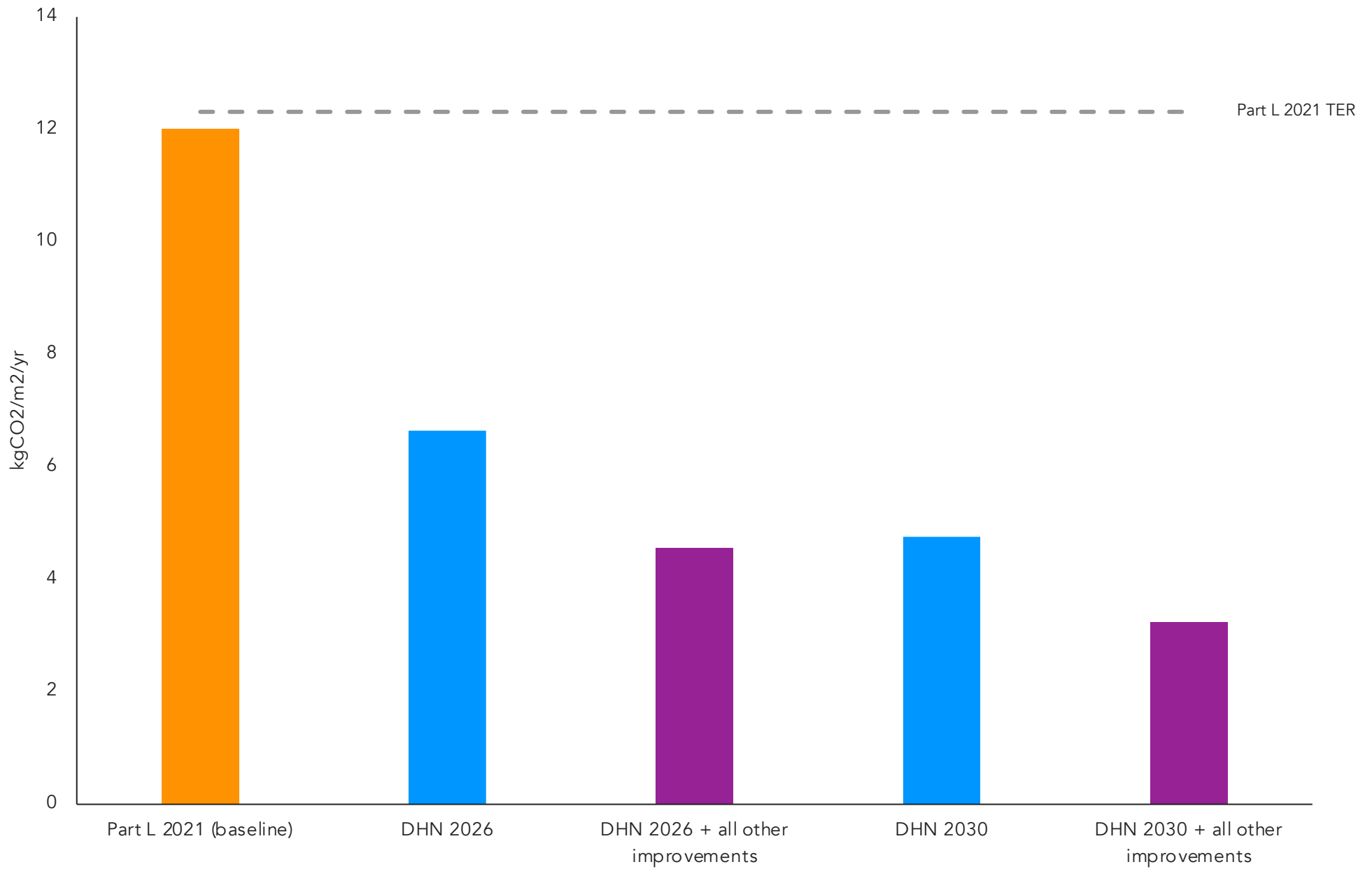
Results | High rise flats





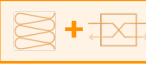






DHN results | High rise block of flats

	Part L 2021 (Baseline)	DHN 2026	DHN 2026 + all other improvements	DHN 2030	DHN 2030 + all other improvements
Description	Part L 2021 notional assumptions	DHN 2026	Improved U- values MVHR Improved airtightness DHN 2026 Maximum PV	DHN 2030	Improved U- values MVHR Improved airtightness DHN 2030 Maximum PV
DER kgCO ₂ /m ² /yr	12.0	6.7	4.6	4.8	3.2
% DER < TER (Carbon emissions)	-	46%	63%	61%	74%
% DPER < TPER (Primary Energy)	-	4%	32%	23%	46%
% DFEE < TFEE (Fabric energy efficiency)	-	0%	13%	0%	13%

DHN Results | High rise flats



Modelling specifications | High-rise flats

		Part L 2021 (Baseline)	All improvements	70% TER reduction	100% TER reduction	100% TER reduction 10% TFEF reduction	100% TER reduction 10% TFEF reduction Offset unregulated
Building fabric and ventilation strategy	 <p>Floor Walls Roof (W/m²K)</p>	Part L 2021 compliant fabric	Low energy fabric	Low energy fabric	Low energy fabric	Low energy fabric	Low energy fabric
		0.14	0.12	0.12	0.12	0.12	0.12
		0.145	0.145	0.145	0.145	0.145	0.145
	0.10	0.10	0.10	0.10	0.10	0.10	
 <p>Windows (W) Doors (D) (W/m²K)</p>	Double glazing	Triple glazing	Triple glazing	Triple glazing	Triple glazing	Triple glazing	
	W - 1.2 D - 1.0	W - 0.8 D - 1.0	W - 0.8 D - 1.0	W - 0.8 D - 1.0	W - 0.8 D - 1.0	W - 0.8 D - 1.0	
 <p>Airtightness (m³/m²h)</p>	 <p>5</p>	1	5	5	3	3	
Ventilation strategy	Natural ventilation with intermittent extract fans	MVHR 84% SFP <0.7W/l/s <2m external ducts	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	
Heating, hot water	 <p>Heating system</p>	Gas combi boiler (55°C) 89%	Communal ASHP 300%	Communal ASHP 300%	Communal ASHP 300%	Communal ASHP 300%	Communal ASHP 300%
	 <p>Hot water heating system</p>	No additional cylinder	HIU 1.44kWh/day	HIU 1.44kWh/day	HIU 1.44kWh/day	HIU 1.44kWh/day	HIU 1.44kWh/day
	 <p>Waste water heat recovery (WWHR)</p>	Yes 36% System A	Yes 36% System A	Yes 36% System A	Yes 36% System A	Yes 36% System A	Yes 36% System A
Renewables	 <p>PV panels</p>	15.0 kWp	111.6 kWp E/W concertina	111.6 kWp E/W concertina	111.6 kWp E/W concertina	111.6 kWp E/W concertina	111.6 kWp E/W concertina
 <p>Offsetting required? (tCO₂)</p>	-	-	-	Yes	Yes	Yes	

All results | High-rise flats

	Part L 2021 (Baseline)	All improvements	70% TER reduction	100% TER reduction	100% TER reduction 10% TFEE reduction	100% TER reduction 10% TFEE reduction Offset unregulated
Description	Part L 2021 notional assumptions	Improved U-values MVHR Improved airtightness ASHP Maximum PV	ASHP No WWHR Additional PV	ASHP No WWHR Additional PV	Improved U-values Improved airtightness ASHP No WWHR Additional PV	Improved U-values Improved airtightness ASHP No WWHR Maximum PV
DER kgCO ₂ /m ² /yr	12.0	2.9	3.5	3.5	3.5	3.5
% DER < TER (Carbon emissions)	-	76%	71%	71%	72%	72%
Residual regulated tCO ₂ /yr	143.9	35.2	42.3	42.3	41.4	41.4
% DPER < TPER (Primary energy)	-	52%	43%	43%	44%	44%
% DFEE < TFEE (Fabric energy efficiency)	-	13%	6%	6%	10%	10%
Unreg tCO ₂ /yr	82.0	82.0	82.0	82.0	82.0	82.0
Offset (£403/tCO ₂ /y over 30y)	n/a	n/a	n/a	42.3	41.4	123.4