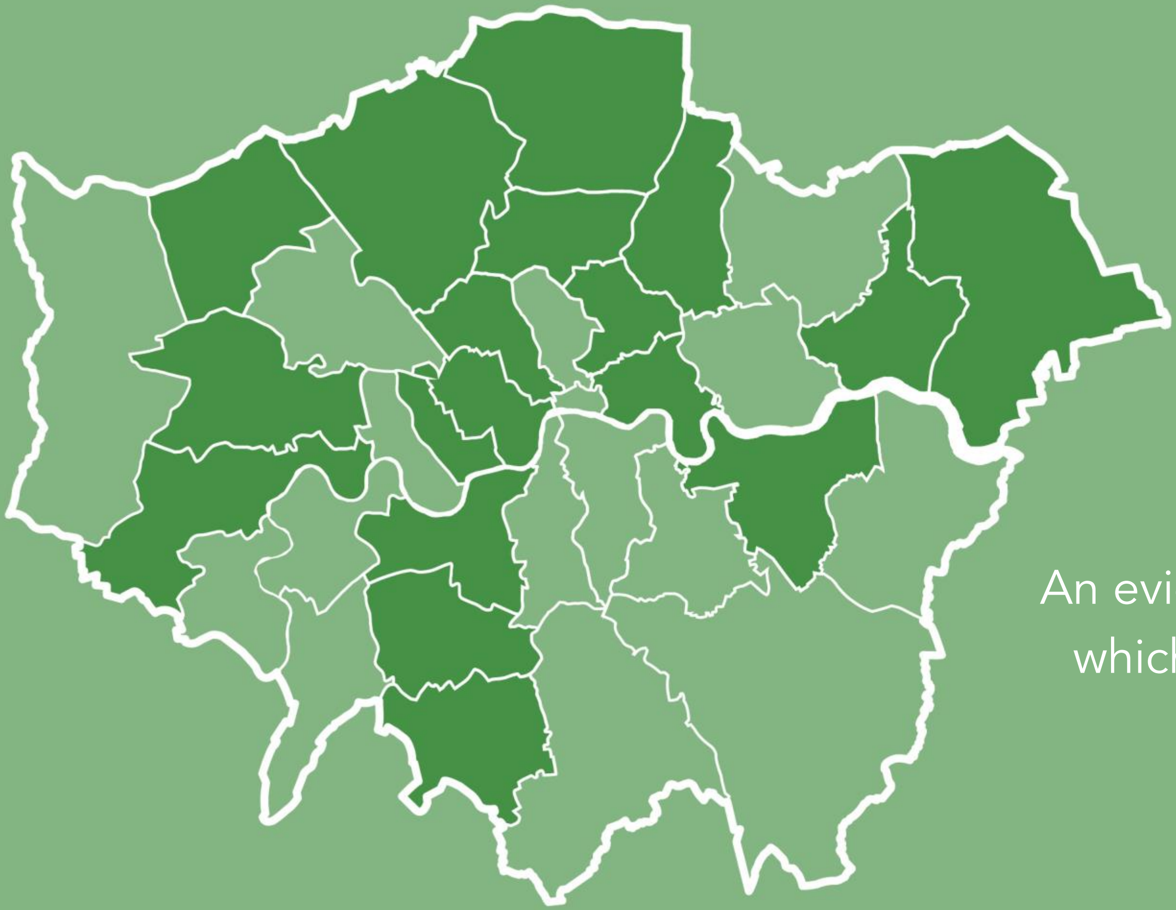


Delivering Net Zero

An evidence study to support planning policies which deliver Net Zero Carbon developments

Main report

May 2023 | Rev 4

Levitt Bernstein People.Design

Introba

INKLING

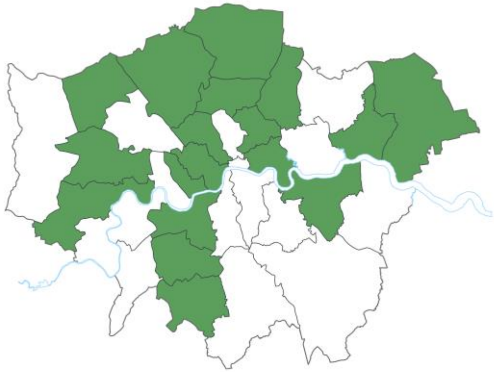
Currie & Brown

Etude

Client and consultant teams

The client team included the following 18 London boroughs:

Barking & Dagenham / Be First
Barnet
Camden
Ealing
Enfield
Greenwich
Hackney
Haringey
Harrow
Havering
Hounslow
Kensington and Chelsea
Merton
Sutton
Tower Hamlets
Waltham Forest
Wandsworth
Westminster



We wanted to thank all officers for their collaboration throughout this project. Energy and carbon policies rely heavily on the tools being used to evidence that they can be achieved (technically and financially). We are very grateful for the efforts made by everyone to understand the extensive (and sometimes confusing) energy and carbon modelling results we have shared.

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

Levitt Bernstein People.Design	Clare Murray Rania Kapitani Gina Windley
Introba	Clara Bagenal George Zeina Krayim Iraklis Stivachtaris
INKLING	Claire Das Bhaumik Susie Diamond Marcus Haydon
Currie & Brown	Adam MacTavish
Etude	Andrea Carvajal Ed Cremin Oyin Idowu Kate Millen Thomas Lefevre

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Contents

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Important note about this document, its purpose, its scope and its limitations

The main purpose of this document is to to constitute a technical evidence base to inform the policy making process for planning officers in the 18 London boroughs who participated in this study.

It considers two main indicative policy options in order to contribute to the development of a common and coherent policy direction, in conformity with the London Plan.

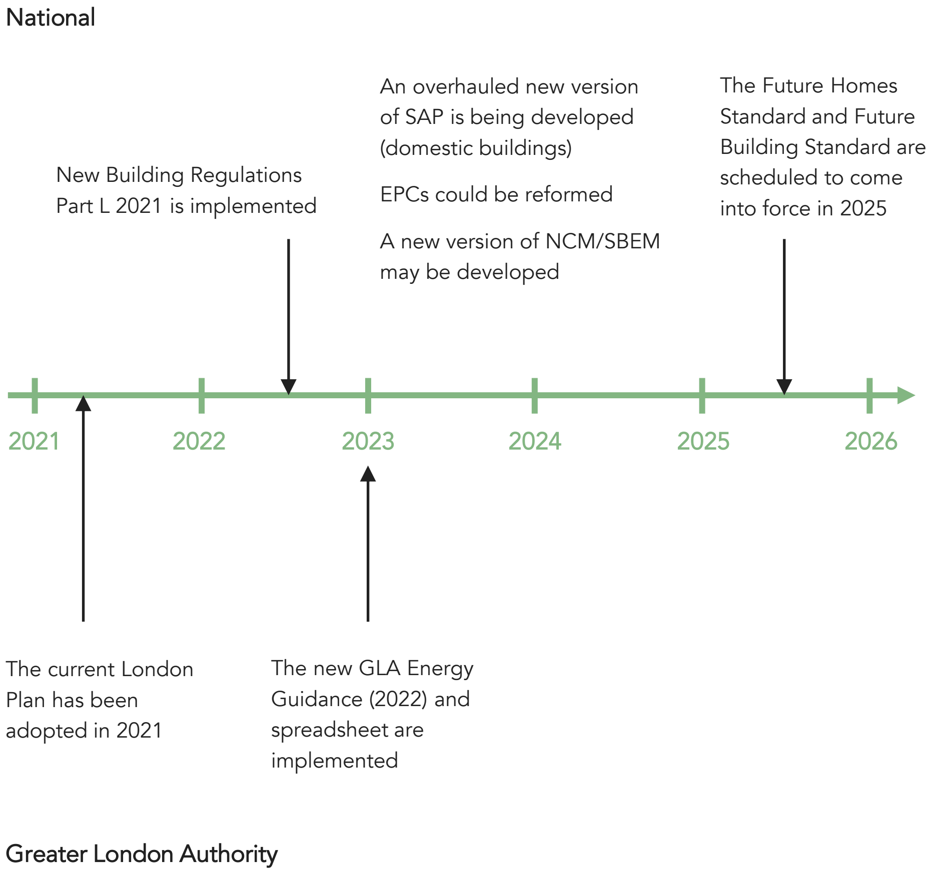
This document is about the future, not the past

This document was triggered by the latest edition of the building regulations for new buildings (Part L 2021) and the need for London boroughs to update their current energy and carbon planning policy targets. It also considers three scales of regulations/policy for which the landscape is likely to change in the next 3-4 years:

- **National level**: Part L 2021 has been introduced in 2022 and should be replaced by the Future Homes Standard and the Future Building Standard in 2025.
- **Regional level**: The GLA published new Energy Assessment Guidance in 2022. At the time of writing there is no plan to update the London Plan in the short to medium term.
- **London borough level**: each of the 18 London boroughs participating in this study are at different stages of the development of their Local Plan.

Scope and limitations

The scope of this study is to provide a robust evidence base in relation to energy use and carbon emission modelling for eight common building types in London. Although potential policy wording has been provided to assist planning policy officers in translating the technical findings into potential policy targets, this is not a policy document. It should not be used either as a criticism of current planning policy and/or to justify individual buildings' failure to comply with it. Finally, the recommendations do not limit what planning applications can deliver: some schemes will be able to go further.



New Building Regulations Part L 2021 is implemented

An overhauled new version of SAP is being developed (domestic buildings)

EPCs could be reformed

A new version of NCM/SBEM may be developed

The Future Homes Standard and Future Building Standard are scheduled to come into force in 2025

The current London Plan has been adopted in 2021

The new GLA Energy Guidance (2022) and spreadsheet are implemented

Figure 0.1 – Overview of potential changes to the national and regional policy landscape in the next 3 years

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1.0

The 2019 study

Towards Net Zero Carbon:

Achieving greater carbon reductions on site

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Summary of the 2019 study - *Towards Net Zero Carbon: Achieving greater carbon reductions on site*

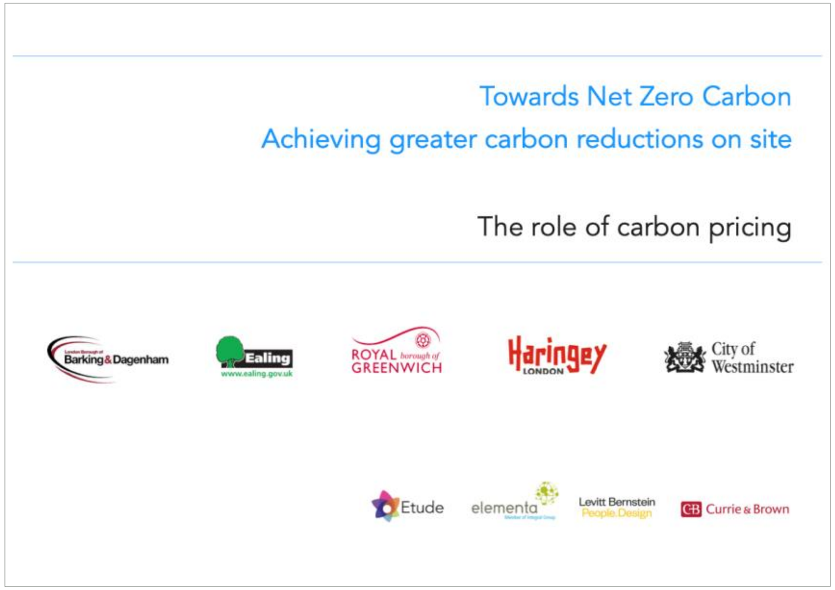
Greater carbon reduction on site are preferable to offsetting

In 2019, all London boroughs had a planning policy requiring new buildings to achieve a minimum 35% carbon reduction over Part L 2013 on-site complemented with a requirement to offset the residual regulated carbon emissions at a carbon price of £60-£95/tCO_2. Unfortunately, a few boroughs concluded from the applications they were receiving that not enough new buildings were seeking further carbon reduction on-site beyond the minimum requirement, and that carbon offsetting was relied on too heavily to achieve '*zero (regulated) carbon*'. Therefore, the London boroughs of Barking & Dagenham, Ealing, Greenwich, Haringey and the City of Westminster appointed Currie & Brown, Elementa, Levitt Bernstein and Etude in 2019 to investigate how the carbon offset price could be used to incentivise greater carbon reductions on-site.

Methodology and recommendations

Extensive energy and cost modelling on several types of domestic and non-domestic buildings was undertaken. Three building fabric scenarios and four heating systems were modelled, with and without PV panels for six building archetypes. The findings were used to understand the cost and carbon emission reductions associated with different combinations, and various offsetting pricing scenarios were then developed to incentivise on-site carbon emission reduction.

The study demonstrated that due to the decarbonisation of the electricity grid, for the same specifications, a greater improvement over Part L was achieved with no extra effort/cost (i.e. '60% is the new 35%'). The study also concluded that a carbon offset price of £60-£95/tCO_2 was not sufficient for local authorities to deliver the required carbon savings off-site. A price of at least £300/tCO_2 was recommended. A stepped carbon offset price was also proposed to discourage carbon offsetting as much as possible (please refer to the report's executive summary for further details). Finally, the team outlined a potential alternative to the Part L policy framework using Energy Use Intensity (EUI) and predictive energy modelling.

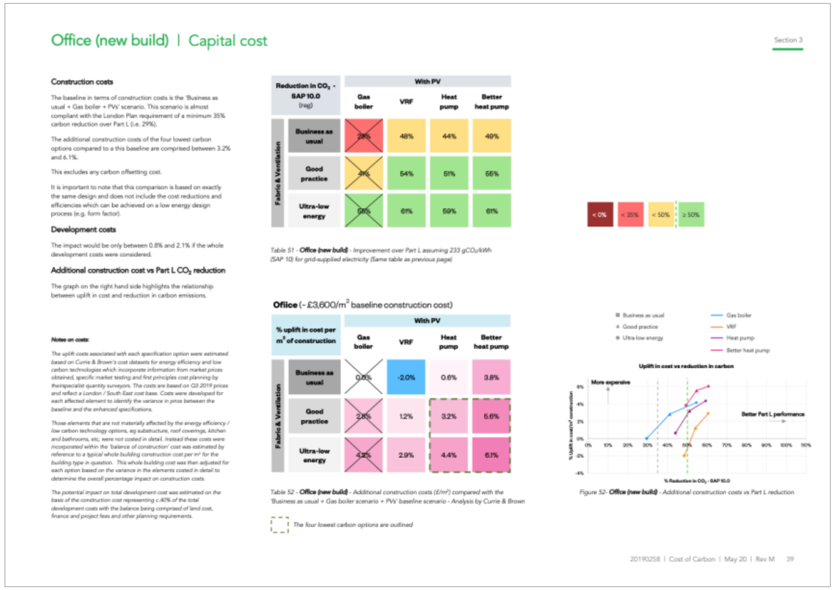


Towards Net Zero Carbon
Achieving greater carbon reductions on site

The role of carbon pricing

London Borough of Barking & Dagenham
Ealing www.ealing.gov.uk
ROYAL borough of GREENWICH
Haringey LONDON
City of Westminster

Etude
elementa
Levitt Bernstein People.Design
Currie & Brown



Office (new build) | Capital cost

Section 3

Construction costs

The baseline in terms of construction costs is the 'Business as usual + Gas boiler + PVs' scenario. This scenario is almost compliant with the London Plan requirement of a minimum 35% carbon reduction over Part L (i.e. 29%).

The additional construction costs of the four lowest carbon options compared to a this baseline are comprised between 3.2% and 6.1%.

This excludes any carbon offsetting cost.

It is important to note that this comparison is based on exactly the same design and does not include the cost reductions and efficiencies which can be achieved on a low energy design process (e.g. form factor).

Development costs

The impact would be only between 0.8% and 2.1% if the whole development costs were considered.

Additional construction cost vs Part L CO_2 reduction

The graph on the right hand side highlights the relationship between uplift in cost and reduction in carbon emissions.

Reduction in CO_2 - SAP 10.0 (reg)		With PV			
		Gas boiler	VRF	Heat pump	Better heat pump
Fabric & Ventilation	Business as usual	~~28%~~	48%	44%	49%
	Good practice	~~41%~~	54%	51%	55%
	Ultra-low energy	~~58%~~	61%	59%	61%

*Table 51 - **Office (new build)** - Improvement over Part L assuming 233 gCO_2/kWh (SAP 10) for grid-supplied electricity (Same table as previous page)*

🟥 < 0% | 🟥 < 35% | 🟨 < 50% | 🟩 ≥ 50%

Office (- £3,600/m^2 baseline construction cost)

% uplift in cost per m^2 of construction		With PV			
		Gas boiler	VRF	Heat pump	Better heat pump
Fabric & Ventilation	Business as usual	~~0.0%~~	-2.0%	0.6%	3.8%
	Good practice	~~2.8%~~	1.2%	3.2%	5.6%
	Ultra-low energy	~~4.2%~~	2.9%	4.4%	6.1%

*Table 52 - **Office (new build)** - Additional construction costs (£/m^2) compared with the 'Business as usual + Gas boiler scenario + PVs' baseline scenario - Analysis by Currie & Brown*

The four lowest carbon options are outlined

Notes on costs:

The uplift costs associated with each specification option were estimated based on Currie & Brown's cost datasets for energy efficiency and low carbon technologies which incorporate information from market prices obtained, specific market testing and first principles cost planning by theirspecialist quantity surveyors. The costs are based on Q3 2019 prices and reflect a London / South East cost base. Costs were developed for each affected element to identify the variance in price between the baseline and the enhanced specifications.

Those elements that are not materially affected by the energy efficiency / low carbon technology options, eg substructure, roof coverings, kitchen and bathrooms, etc, were not costed in detail. Instead these costs were incorporated within the 'balance of construction' cost was estimated by reference to a typical whole building construction cost per m^2 for the building type in question. This whole building cost was then adjusted for each option based on the variance in the elements costed in detail to determine the overall percentage impact on construction costs.

The potential impact on total development cost was estimated on the basis of the construction cost representing c.40% of the total development costs with the balance being comprised of land cost, finance and project fees and other planning requirements.

*Figure 52- **Office (new build)** - Additional construction costs vs Part L reduction*

20190258 | Cost of Carbon | May 20 | Rev M 39

Figure 1.1 – Extracts of 'Towards Net Zero Carbon – Achieving greater carbon reductions on site: the role of carbon pricing' undertaken in 2019.

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2.0

Summary and analysis of notable reports and evidence published since 2019

2.0 Summary and analysis of notable reports and evidence published since 2019

The last four years since the publication of the 2019 Towards Net Zero Carbon study have seen a significant number of changes at international, national, regional and local levels with new legislation, policy and guidance on Net Zero Carbon and new buildings. They are summarised in this section.

It also highlights emerging regulations and industry standards, as well as other important considerations, including fuel poverty and energy costs.

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2.1

New carbon reduction commitments since 2019

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The urgency is even greater now than it was in 2019: Net Zero by 2050 and carbon budgets

There is a climate emergency

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

National commitment

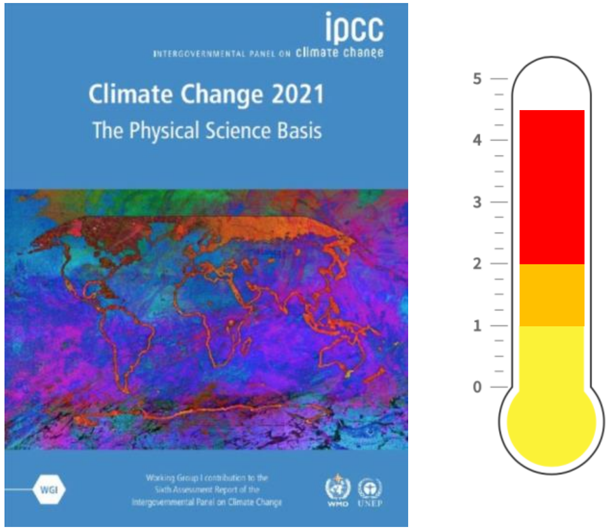
The UK's national commitment is set through the Climate Change Act 2008, which was updated in 2019. It legislates that the UK must be net zero carbon by 2050 and sets a system of carbon budgets to ensure that the UK does not emit more than its allowance in the next 27 years. This legal requirement is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

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

Achieving Net Zero Carbon

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

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



ipcc
INTERGOVERNMENTAL PANEL ON climate change
Climate Change 2021
The Physical Science Basis
Working Group I contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change

4-5°C the temperature rise we are likely to see if we continue on a **business as usual** path

1.5-2°C The maximum temperature rise above pre-industrial levels the IPCC recommends.

1°C The temperature rise already created

Figure 2.1 – Latest IPCC report and the associated targeted limit on global warming: 1.5-2°C

900,000 $MtCO_2$

Estimation of **remaining global carbon budget** (from 2020) for a chance of limiting temperature rises to below 1.7°C (Source: Tyndall Centre)

10-14 years

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

Figure 2.2 – The remaining global carbon budget is not significant. We need to reduce annual emissions sharply and quickly if we do not want to spend it in the next 10-14 years.

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The new London Net Zero pathway

Achieving Net Zero Carbon by 2030

The London Environment Strategy and the 1.5°C compatible Climate Action Plan, both published in 2018, set out pathways towards Net Zero London by 2050. However, in light of the science which has shown the need for urgent action, the Mayor of London has declared a climate emergency and has brought forward by 20 years the target for London to be Net Zero, which must now be achieved by 2030.

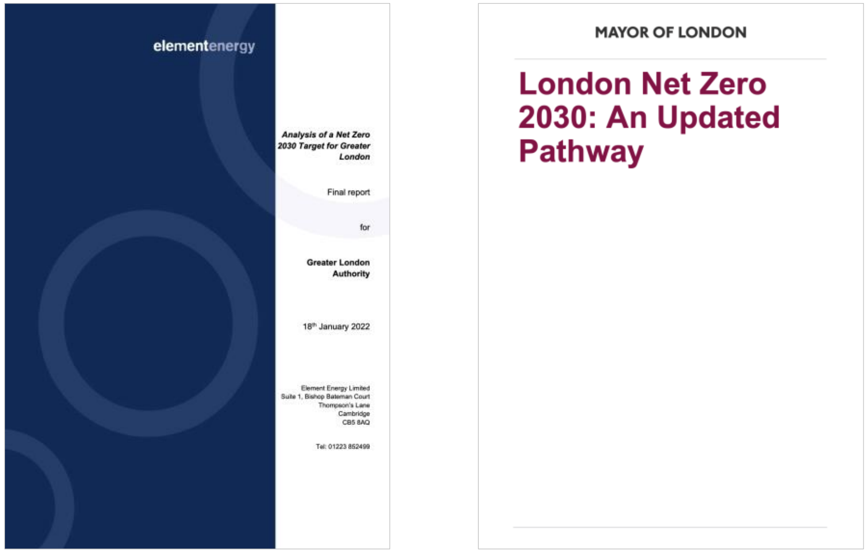
London Net Zero 2030: an updated pathway

The GLA has commissioned experts at Element Energy to analyse pathways for London to reach Net Zero by 2030. Their report '*Analysis of a Net Zero 2030 Target for Greater London*' was published in 2022 and explores four possible pathways that London could take. Based on this analysis, the Mayor of London adopted the **Accelerated Green pathway** as the preferred pathway for London. It now replaces the previous trajectory in the 1.5°C Plan.

The new London Net Zero pathway (Accelerated Green)

This pathway aims to reduce baseline emissions (30$MtCO_2$/yr in 2020) by more than 65% by 2030 down to 10$MtCO_2$/yr. Key features of this pathway for buildings include:

- 40% reduction in heat demand of buildings
- 200,000 homes retrofit each year, to achieve average EPC B or 65kWh/m^2/yr
- **Gas boilers in new developments banned by 2025**
- Gas boiler replacements banned by 2026 (with exceptions in areas expected to remain connected to the grid using biomethane)
- **2.2 million heat pumps by 2030, including 284,000 in 2028 alone, 60% of homes supplied with low carbon heat by 2030**
- **1.5GW of PV generation by 2030 and 3.9GW by 2050**



elementenergy

Analysis of a Net Zero 2030 Target for Greater London

Final report

for

Greater London Authority

18th January 2022

Element Energy Limited
Suite 1, Bishop Bateman Court
Thompson's Lane
Cambridge
CB5 8AQ

Tel: 01223 852499

MAYOR OF LONDON

London Net Zero 2030: An Updated Pathway

Figure 2.3 - Element Energy report: 'Analysis of a Net Zero 2030 Target for Greater London' (2022) and the GLA's response to the report: 'London Net Zero 2030: An Updated Pathway' (2022)

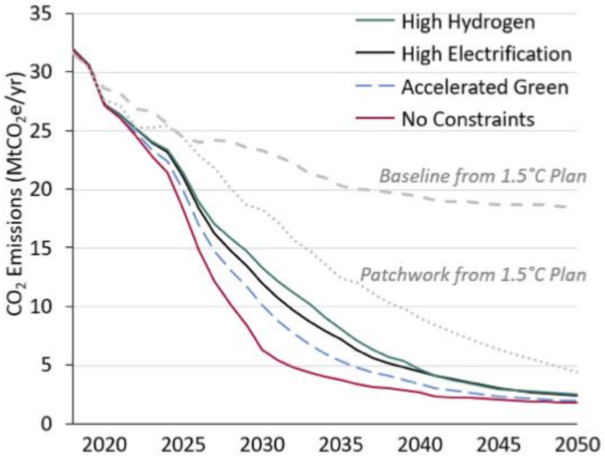


Figure 2.4 - Four pathways were considered by Element Energy and the Mayor of London adopted the 'Accelerated Green' pathway, shown above with a blue dotted line. It shows how decisive action is required over the next 10 years.

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The London boroughs' current climate change commitments

Most London boroughs have declared a climate emergency

30 of the 32 London boroughs and the City of London have declared a climate emergency. According to London Councils, as of January 2022, 22 boroughs have fully published Climate Action Plans (CAPs) and 6 boroughs have published drafts. A further 5 boroughs have CAPs in development, meaning that all boroughs have already published or intend to publish a Climate Action Plan.

Summary of commitments for new buildings

The key commitments of the CAPs relevant to new buildings include:

- All boroughs are committed to achieve the energy efficiency targets proposed by the London Plan as a minimum (i.e. 35% reduction over Part L 2013) and a few boroughs acknowledge the need to include Net Zero Carbon targets within the planning requirements. Furthermore, two boroughs are committed to explore exemplar energy efficiency solutions including Passivhaus, whilst two others indicate a commitment to Energy Use Intensity (EUI) targets for new dwellings.
- Although all boroughs show concern about the emissions generated by fossil fuels and mention the electrification of heat as part of their solutions for decarbonisation, only 5 CAPs pledge to prohibit the installation of gas boilers in new developments and only 1 commits to phasing out gas-fired CHPs.
- A requirement for new developments to include sources of low carbon energy is included in many CAPs with only one making a direct reference to air source heat pumps.
- Increasing solar capacity is highlighted in a few CAPs, however there is no direct link with a requirement for PV installation on new developments.

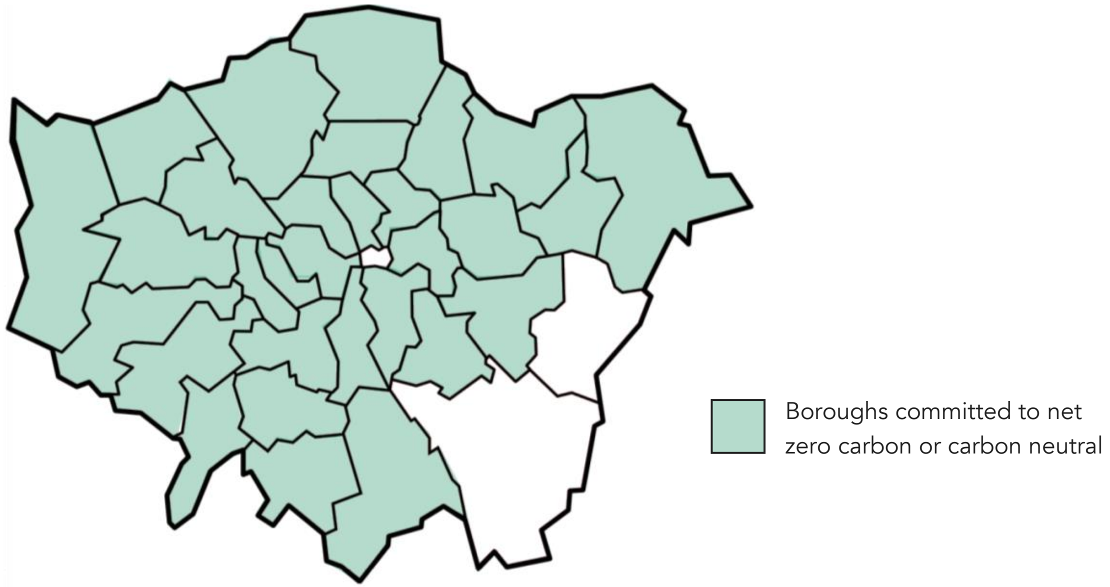
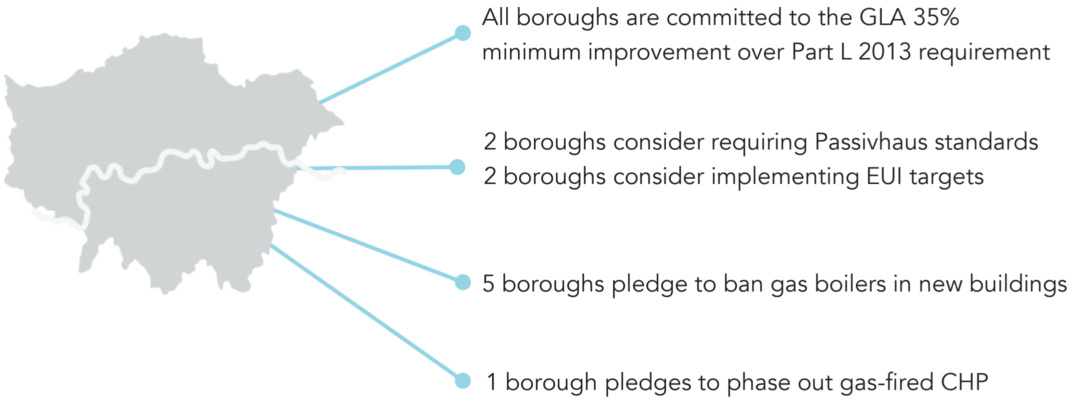


Figure 2.5 – The vast majority of London boroughs have declared a climate emergency


All boroughs are committed to the GLA 35% minimum improvement over Part L 2013 requirement

2 boroughs consider requiring Passivhaus standards
2 boroughs consider implementing EUI targets

5 boroughs pledge to ban gas boilers in new buildings

1 borough pledges to phase out gas-fired CHP

Figure 2.6 - Summary of key commitments relevant to new buildings included in the Climate Action Plans of the 18 participant London boroughs

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2.2

New building regulations: Part L 2021

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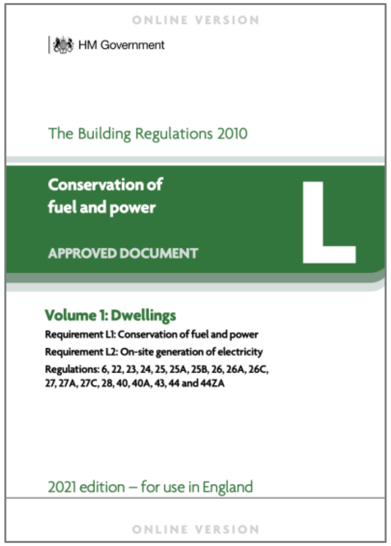
Part L1A 2021 for domestic buildings

Since the initial study was undertaken in 2019, Part L1A of the building regulations covering new dwellings has changed. The new regulations have come into force in 2022 and are estimated to reduce regulated CO_2 emissions by approximately 31% compared with the previous version of the building regulations (i.e. Part L1A 2013). Additionally, the SAP methodology used to calculate compliance for Part L has also been updated: SAP 10.2 has been released.

Main changes in Part L1A 2021

The list below summarises the key changes and new requirements set by Part L1A 2021:

- **Primary energy use** – This is a new requirement to comply with and 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. This is reported as kWh/m^2.year.
- **Carbon factors** – The carbon factors have been updated, and electricity has dropped to 0.136 $kgCO_2$/kWh which is 74% lower than the electricity carbon factor in Part L 2013 (i.e. 0.519 $kgCO_2$/kWh), and lower than gas (i.e. 0.210 $kgCO_2$/kWh). The implication is that electric modes of heating (e.g. heat pumps, direct electric) are now much 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 are assumed in the notional building.
- **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.



ONLINE VERSION

HM Government

The Building Regulations 2010

Conservation of fuel and power

APPROVED DOCUMENT

L

Volume 1: Dwellings

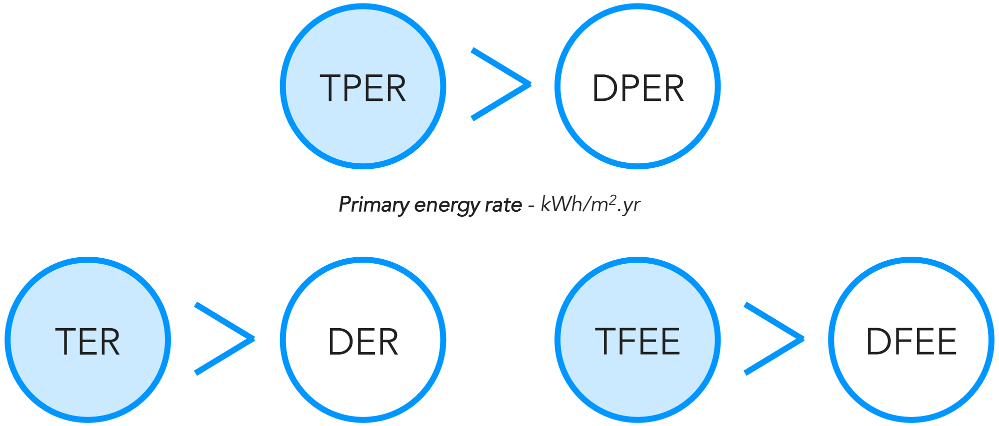
Requirement L1: Conservation of fuel and power
Requirement L2: On-site generation of electricity
Regulations: 6, 22, 23, 24, 25, 25A, 25B, 26, 26A, 26C, 27, 27A, 27C, 28, 40, 40A, 43, 44 and 44ZA

2021 edition – for use in England

ONLINE VERSION

Figure 2.6 - Part L 2021 – Conservation of fuel and power – Volume 1: Dwellings

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



Primary energy rate - kWh/m^2.yr

Target carbon emissions rate – $kgCO_2/m^2$.yr

Target fabric energy efficiency rate - kWh/m^2.yr

Figure 2.7 - New dwellings must comply with the energy and carbon requirements highlighted above.

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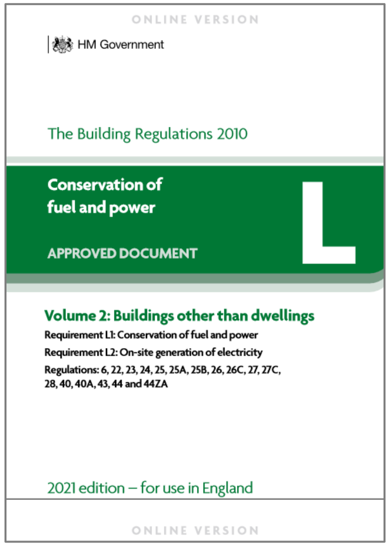
Part L2A 2021 for non-domestic buildings

Part L2A of the building regulations covering buildings other than dwellings has also been updated. The new regulations are estimated to reduce regulated CO_2 emission by approximately 27% compared to the previous version of the building regulations for new non-domestic buildings (Part L2A 2013).

Main changes in Part L2A 2021

The list below summarises the key changes and new requirements set by Part L2A 2021:

- **Primary energy use** – This is a new requirement to comply with. Primary energy use relates to how much energy is required by the new building; it is then converted (using primary energy factors) into primary energy. This is reported as kWh/m^2.year.
- **Carbon factors** – The carbon factors have been updated, and electricity has dropped to 0.136 $kgCO_2/kWh$ which is 74% lower than the electricity carbon factor in Part L 2013 (i.e. 0.519 $kgCO_{22}/kWh$), and lower than gas (i.e. 0.210 $kgCO_2/kWh$). The implication is that electric modes of heating (e.g. heat pumps, direct electric) are now much lower carbon than fossil fuel heating (e.g. gas boilers).
- **Revised "notional" building specification (TER)** – The assumptions used for the notional building to derive the Target Emission Rate (TER) have been revised. This includes uplifts to fabric performance, heating, hot water, ventilation, lighting and controls. PVs are also now included in the notional building if heat pumps are not used for heating.
- **Hot water demand** – New high and low classifications are applied to certain activity types. This dictates the performance, storage and circulation used in the notional.
- **Predictive energy modelling** – There is now a requirement for new non-domestic buildings over a certain size to predict operational energy at design stage, taking into account all metered loads, including unregulated energy.



ONLINE VERSION

HM Government

The Building Regulations 2010

Conservation of fuel and power

APPROVED DOCUMENT

L

Volume 2: Buildings other than dwellings

Requirement L1: Conservation of fuel and power

Requirement L2: On-site generation of electricity

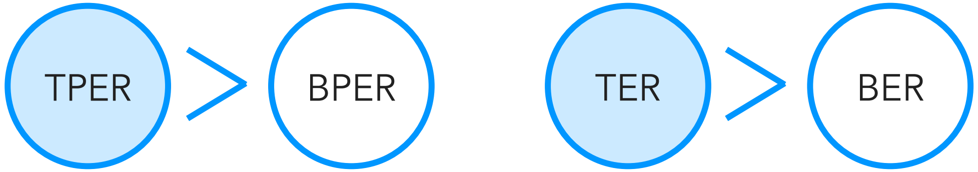
Regulations: 6, 22, 23, 24, 25, 25A, 25B, 26, 26C, 27, 27C, 28, 40, 40A, 43, 44 and 44ZA

2021 edition – for use in England

ONLINE VERSION

Figure 2.8 - Part L 2021 – Conservation of fuel and power – Volume 2: Buildings other than dwellings

Summary of key criteria (T = Target – B = Building)



Primary energy rate - kWh/m^2

Target carbon emissions rate – $kgCO_2/m^2$

Figure 2.9 - New buildings must comply with the energy and carbon requirements highlighted above.

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2.3

New policies, guidance and evidence bases published since 2019

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Guidance from the Climate Change Committee (CCC)

New buildings are currently adding to the problem

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

They create a future retrofit burden

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

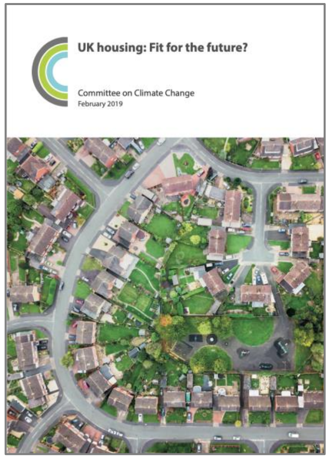
New buildings compliant with our climate change commitments

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

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

No offsetting… or a very limited role for it

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



UK housing: Fit for the future?

Committee on Climate Change
February 2019

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

Figure 2.10 - Extract from UK Housing: Fit for the Future? Committee on Climate Change, 2019.

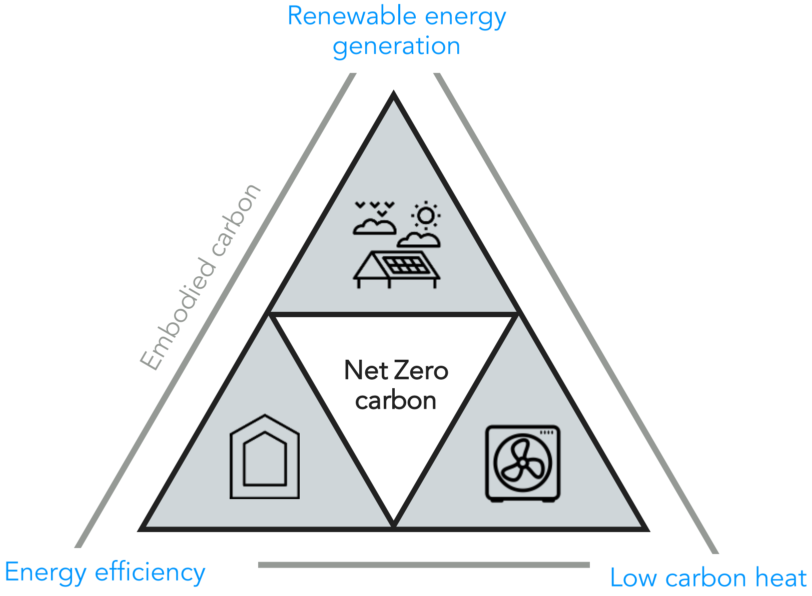


Figure 2.11 - For the Climate Change Committee, energy efficiency and low carbon heat represent two key pillars of future buildings compliant with our climate change commitments

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Current industry definition of Net Zero buildings

Industry definitions of Net Zero Carbon

A significant amount of work has been undertaken since 2019 to define and articulate the requirements of Net Zero carbon buildings. This includes the work undertaken and published by the Climate Change Committee (CCC), the Royal Institute of British Architects (RIBA), the Chartered Institute of Building Services (CIBSE), the UK Green Building Council (UKGBC), the Better Buildings Partnership (BBP), the Passivhaus Trust, the Good Homes Alliance (GHA) and the Low Energy Transformation Initiative (LETI).

Relevant reports and initiatives include:

- UKGBC Net Zero Carbon - A framework definition
- LETI Net Zero operational carbon one pager
- LETI Climate Emergency Design Guide
- WLCN - Carbon definitions for the built environment
- RIBA 2030 Climate Challenge.

The above documents and guidance are consistent in their approach, and all have similar metrics that include:

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

This study uses the current industry definition of Net Zero Carbon (refer to appendix for detailed definition).

Figure 2.12 - Industry publications on Net Zero

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Current industry definition of Net Zero buildings

A growing evidence base has led to an industry definition

The current definition of a Net Zero Carbon in operation for new buildings has been developed by UKGBC, LETI and BBP, and supported by the Good Homes Alliance, RIBA and CIBSE. In summary, it needs to achieve a low level of space heating demand and total energy use, cannot use fossil fuels on site and needs to generate renewable energy on-site to match its energy use on an annual basis.

1 - Energy efficiency

Buildings use energy for heating, hot water, ventilation, lighting, cooking, appliances and equipment. All energy use within the building must be considered (not only "regulated" energy use) and need to comply with a maximum value, the Energy Use Intensity (EUI) which varies depending on the building type and represents 'delivered energy' generally.

2 - Low carbon heat

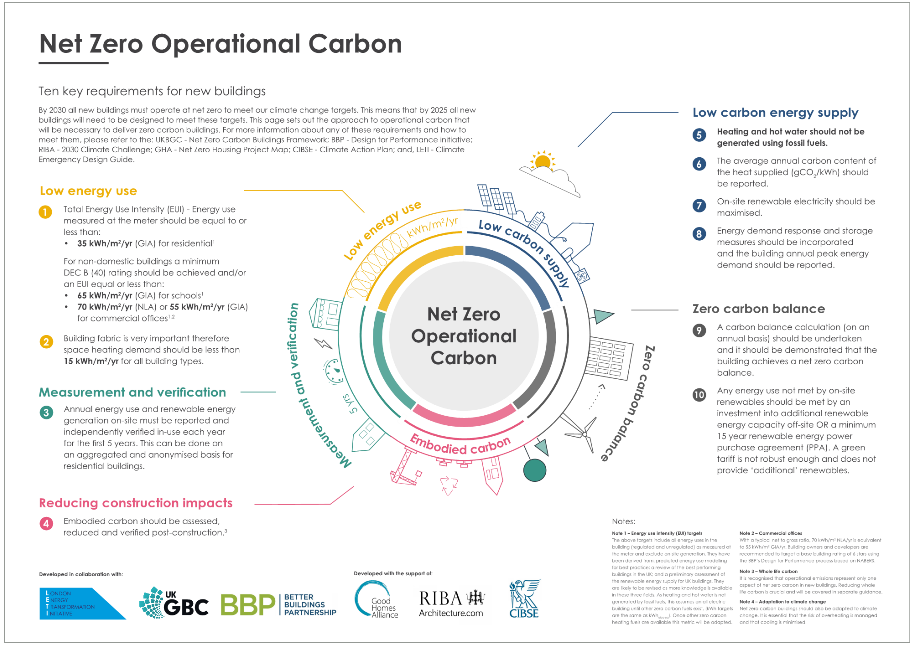
Low carbon heat is an essential feature of Net Zero Carbon buildings. All new buildings should be built with a low carbon heating system and must not connect to the gas network or, more generally, use fossil fuels on-site.

3 - Renewable energy generation

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

4 - Embodied carbon

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



Net Zero Operational Carbon

Ten key requirements for new buildings

By 2030 all new buildings must operate at net zero to meet our climate change targets. This means that by 2025 all new buildings will need to be designed to meet these targets. This page sets out the approach to operational carbon that will be necessary to deliver zero carbon buildings. For more information about any of these requirements and how to meet them, please refer to the: UKBGC - Net Zero Carbon Buildings Framework; BBP - Design for Performance initiative; RIBA - 2030 Climate Challenge; GHA - Net Zero Housing Project Map; CIBSE - Climate Action Plan; and, LETI - Climate Emergency Design Guide.

Low energy use

① Total Energy Use Intensity (EUI) - Energy use measured at the meter should be equal to or less than:
- **35 kWh/m²/yr** (GIA) for residential[1]

For non-domestic buildings a minimum DEC B (40) rating should be achieved and/or an EUI equal or less than:
- **65 kWh/m²/yr** (GIA) for schools[1]
- **70 kWh/m²/yr** (NLA) or **55 kWh/m²/yr** (GIA) for commercial offices[1,2]

② Building fabric is very important therefore space heating demand should be less than **15 kWh/m²/yr** for all building types.

Measurement and verification

③ Annual energy use and renewable energy generation on-site must be reported and independently verified in-use each year for the first 5 years. This can be done on an aggregated and anonymised basis for residential buildings.

Reducing construction impacts

④ Embodied carbon should be assessed, reduced and verified post-construction.[3]

Low carbon energy supply

⑤ **Heating and hot water should not be generated using fossil fuels.**

⑥ The average annual carbon content of the heat supplied (gCO_2/kWh) should be reported.

⑦ On-site renewable electricity should be maximised.

⑧ Energy demand response and storage measures should be incorporated and the building annual peak energy demand should be reported.

Zero carbon balance

⑨ A carbon balance calculation (on an annual basis) should be undertaken and it should be demonstrated that the building achieves a net zero carbon balance.

⑩ Any energy use not met by on-site renewables should be met by an investment into additional renewable energy capacity off-site OR a minimum 15 year renewable energy power purchase agreement (PPA). A green tariff is not robust enough and does not provide 'additional' renewables.

Notes:

Note 1 – Energy use intensity (EUI) targets
The above targets include all energy uses in the building (regulated and unregulated) as measured at the meter and exclude on-site generation. They have been derived from: predicted energy use modelling for best practice; a review of the best performing buildings in the UK; and a preliminary assessment of the renewable energy supply for UK buildings. They are likely to be revised as more knowledge is available in these three fields. As heating and hot water is not generated by fossil fuels, this assumes an all electric building until other zero carbon fuels exist. (kWh targets are the same as $kWh_{elec-eq}$). Once other zero carbon heating fuels are available this metric will be adapted.

Note 2 – Commercial offices
With a typical net to gross ratio, 70 kWh/m² NLA/yr is equivalent to 55 kWh/m² GIA/yr. Building owners and developers are recommended to target a base building rating of 6 stars using the BBP's Design for Performance process based on NABERS.

Note 3 – Whole life carbon
It is recognised that operational emissions represent only one aspect of net zero carbon in new buildings. Reducing whole life carbon is crucial and will be covered in separate guidance.

Note 4 – Adaptation to climate change
Net zero carbon buildings should also be adapted to climate change. It is essential that the risk of overheating is managed and that cooling is minimised.

Developed in collaboration with:

Developed with the support of:

Figure 2.13 - Ten key requirements for a Net Zero Operation Carbon - A summary

Developed by UKGBC, LETI and BBP, and supported by the Good Homes Alliance, RIBA and CIBSE.

An enlarged version of the adjacent definition can be found in section 13.1 (click on the image for a direct link)

2.4

Emerging regulations and industry standards

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The Future Homes Standard and the Future Building Standard

Another major update to the building regulations is on the way

It is expected that the next revision of Part L will be consulted on in mid-2023 and come into force in 2025. This future version of Part L (2025) will replace Part L 2021 and is referred to as:

- the Future Homes Standard for new domestic buildings.
- the Future Buildings Standard for new non-domestic buildings.

A new version of SAP is also expected to be introduced in 2025.

What can we expect from these future standards?

From a review of the documentation publicly available since 2019, further improvements are expected to be proposed.

Whilst the specifics are yet to be determined by DLUHC, and consulted on, 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.

There is still no clarity as to whether the standards will require compliance with new metrics though, and how evidence of compliance will be calculated in general.

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 information available to influence this study significantly.

However, it is important to note that any policy based on Part L 2021 will need to be revised within the next 3 years to make it relevant to Part L 2025.

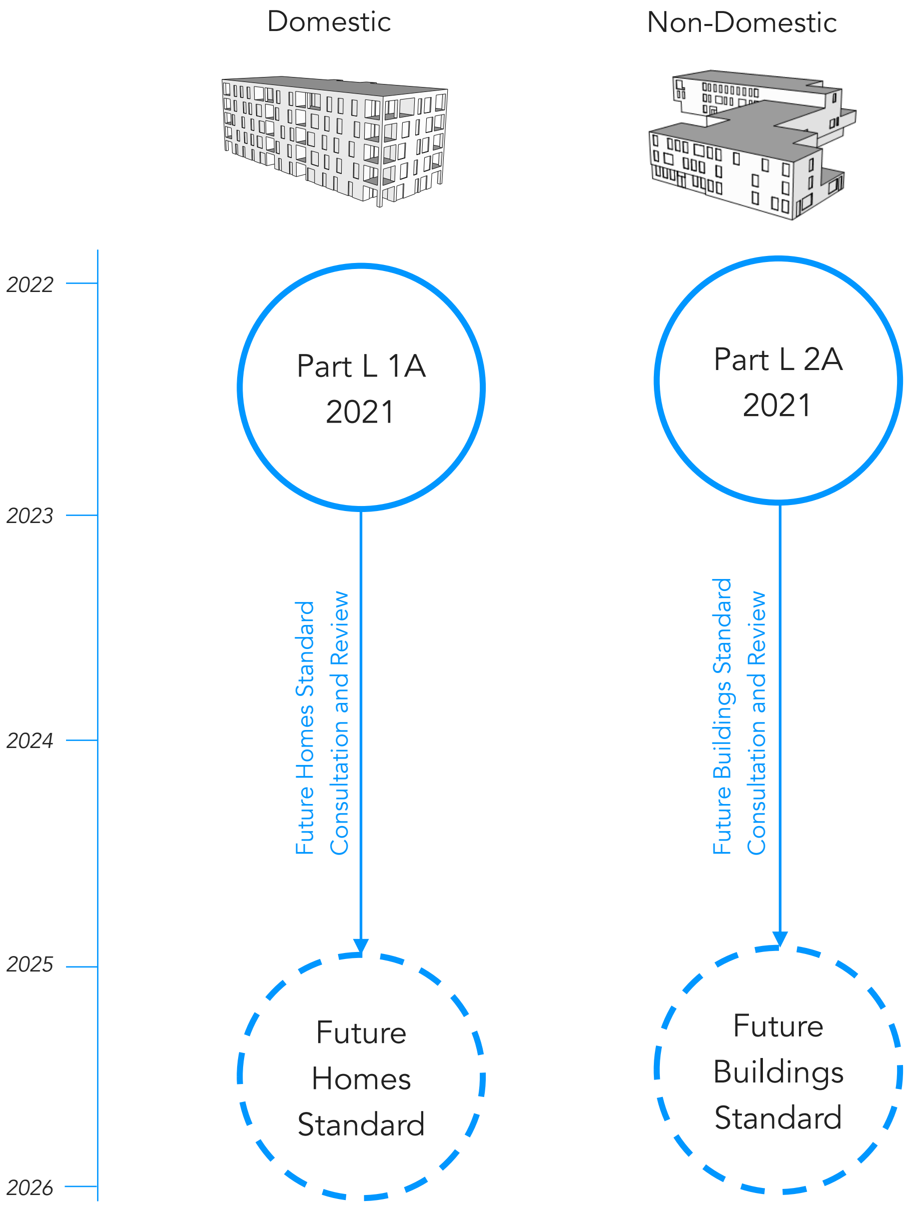

Figure 2.14 – Anticipated changes to Building Regulations in the next 3 years

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The Net Zero Carbon Buildings Standard

In 2022 various organisations including BBP, BRE, the Carbon Trust, CIBSE, IStructE, LETI, RIBA, RICS, and UKGBC have come together to develop a UK wide Net Zero Carbon Building Standard.

It will provide a rule book to robustly prove that built assets are net zero carbon and in line with the UK’s climate targets. It will be aligned with the UK's remaining carbon budget and other actions needed by the UK built environment to deliver decarbonisation in line with a 1.5°C pathway. It will also address Whole Life Carbon but not other social or environmental impacts such as air quality, health and wellbeing, resource scarcity, circular economy, biodiversity, ecology and flood risk.

It will provide clarity on how to assess new and existing buildings and determine whether they are Net Zero Carbon or not. In itself, it will not initially be a certification scheme. However, it is intended that this is developed from the NZCBS at a later date.

Sectors

The standard will seek to cover the following sectors, where there is enough data available to develop Net Zero targets and limits :

Homes, Offices, Schools, Logistics/Warehouses, Sport & Leisure, Retail, Higher Education, Healthcare, Science & Technology, Hotels, Commercial, Culture & Entertainment, Heritage and Data centres.

Timescales

This project started in May 2022, with various task and sector groups beginning work in September 2022. A ‘call for evidence’ programme asking for operational energy use and embodied carbon data to be submitted to the project, to support the development of net zero targets and limits was carried out from Nov 2022 to Jan 2023.

The aim is that a draft version of the Standard will be available for consultation in Summer 2023.

Figure 2.15 – The UK Net Zero Carbon Building Standard is currently being developed

The key metrics for the standard are:

- **Energy Use Intensity (EUI)** limits (kWh/m^{2}/yr)
- **Upfront (A1-A5) embodied carbon** (kg CO2/ m$^{2)}$)
- **Life cycle (A1-C4) embodied carbon limits** (kg CO_2/ m^{2})

Other metrics – such as space heating/cooling demand and peak load – are also to being considered.

Figure 2.16 – Key metrics likely to be used in the UK Net Zero Carbon Building Standard

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2.5

Other important considerations

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Energy cost crisis

A growing concern

Energy costs have always been a concern for those affected by fuel poverty and it is now a major issue for many Londoners.

The role of new buildings

There are three factors contributing to fuel poverty: energy prices (set by the market/energy suppliers), the household income and the dwelling's energy demand. The latter is the only criterion which can be positively influenced by the Local Plan and in particular by energy efficiency requirements for new buildings.

The two key benefits of energy efficiency

An energy efficient dwelling would help to reduce energy use in a sustainable way, which would in turn reduce energy costs. It would also make the temperature more stable, enabling a 'smart' heating system to make the most of flexible dynamic electricity prices. If electricity is used for heating, this benefit would be much more substantial with the use of 'Time of Use' tariffs.

The positive role of renewable energy generation on bills

The significant amount of PV generation on a Net Zero carbon building can and should benefit residents. A solar PV system can generate significant cost savings when electricity is used by residents on-site, and some revenues through the export of electricity to the grid.

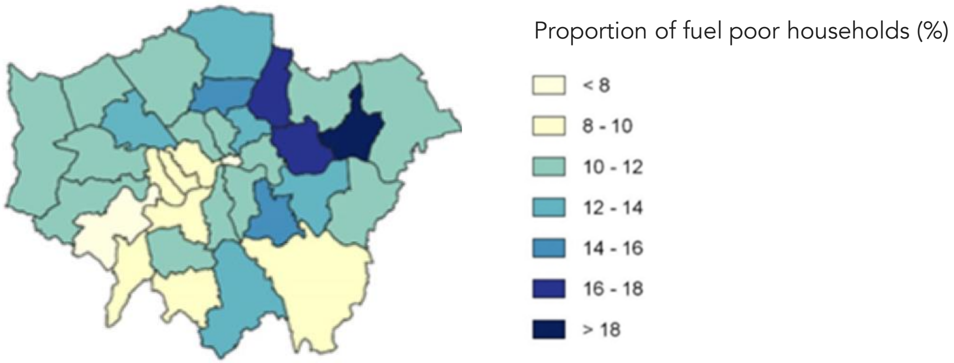

Figure 2.17 - Most London boroughs have high rates of fuel poverty (Source: Department for Business, Energy & Industrial Strategy, Fuel poverty sub regional statistics for 2020)

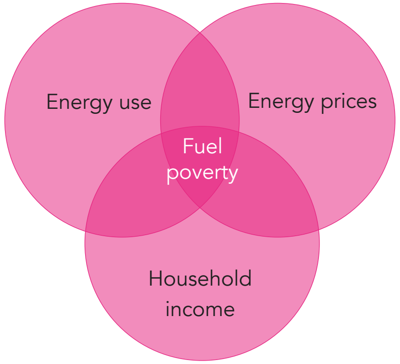

Figure 2.18 - The dwelling's energy use is one of the three key factors contributing to fuel poverty. Net Zero Carbon buildings would help to reduce it, contributing to the sustainable reduction in fuel poverty in London

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Embodied carbon and whole life carbon

Beyond operational energy and carbon

In order to reduce carbon emissions associated with new development across its estimated operational lifetime and beyond, emphasis must also be placed on the reduction of whole life carbon.

Whole Life Carbon

Whole life carbon brings together upfront embodied carbon, operational carbon, and carbon emissions associated with replacement and maintenance.

Embodied Carbon

Embodied carbon refers to the greenhouse gas emissions associated with the manufacture, transport, construction, repair, maintenance, replacement and deconstruction of all building elements. Upfront embodied carbon refers to the initial amount of embodied carbon associated with the building.

Why is Embodied Carbon important?

Both operational and embodied carbon must be reduced to address the climate crisis. Operational carbon is more closely monitored in current legislation and policy. However, embodied carbon must be drastically curtailed.

How do we define what good looks like?

There are currently no approved universal standard targets defined for embodied carbon however, LETI and RIBA targets have been aligned since May 2021, with best-practice performance for projects in the design phase considered to be a "C" rating, while a "B" is considered a robust stretch target for projects currently in the design phase.

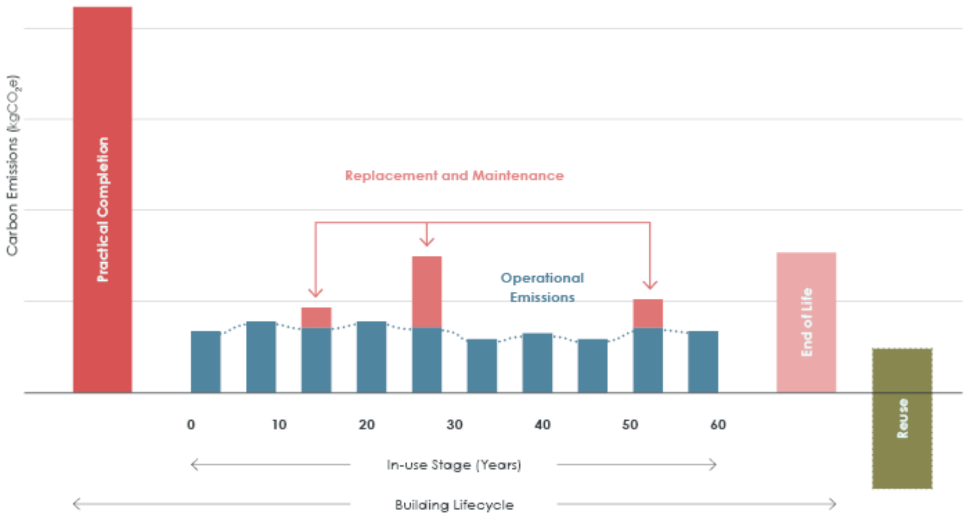
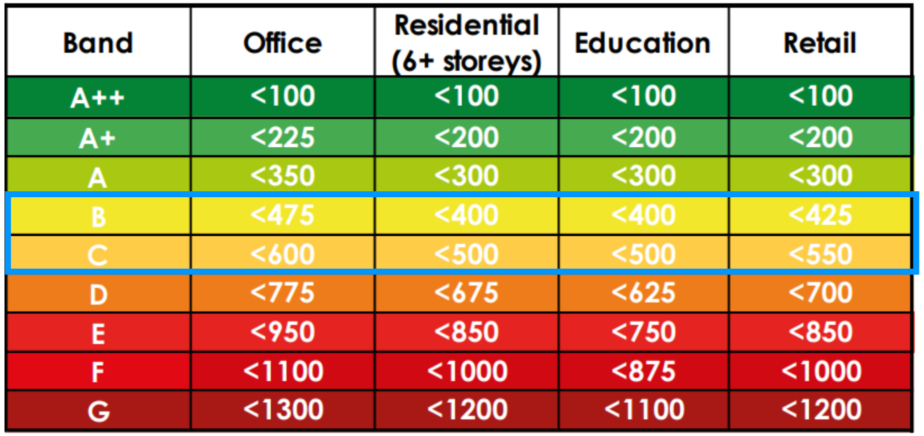


Figure 2.19 - Diagram showing the different components of whole life carbon (Source: LETI)



Band	Office	Residential (6+ storeys)	Education	Retail
A++	<100	<100	<100	<100
A+	<225	<200	<200	<200
A	<350	<300	<300	<300
B	<475	<400	<400	<425
C	<600	<500	<500	<550
D	<775	<675	<625	<700
E	<950	<850	<750	<850
F	<1100	<1000	<875	<1000
G	<1300	<1200	<1100	<1200

Figure 2.20 - Indicative targets for embodied carbon in $kgCO_2/m^2_{GIA}\cdot yr$ (Stages A1-5, excluding sequestration) (Source: LETI)

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3.0

New buildings: strategic planning policy options for London Boroughs

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3.0 New buildings: strategic planning policy options for London Boroughs

All buildings in England & Wales must comply with Part L 2021 of the Building Regulations. They set a minimum level of performance.

In order to deliver their climate commitments, local authorities can decide to go further and set their own energy and carbon targets. This section introduces two strategic policy directions that London boroughs could take:

- Policy option 1 which uses the Part L framework and Part L energy modelling to demonstrate compliance;
- Policy option 2 which uses a suite of energy-based policies and metrics, and predictive energy modelling to demonstrate compliance.

It sets out the key differences between these two options, as well as their applicability to minor applications and refurbishments.

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3.1

A confirmed ability for Local Authorities to set their own energy and carbon targets for new buildings

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London boroughs set their own energy and carbon requirements for new buildings

The role of local authorities in mitigating climate change in the UK and what they have been encouraged and allowed to do has changed over the years. Three distinct phases can be noted.

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

- The **Planning and Compulsory Purchase Act 2004** requires the local plan to ensure that development and use of land contribute to mitigation of climate change.
- The **Climate Change Act 2008** sets a clear direction for the UK. It obliges the government to set policy that will enable the UK to meet its carbon budgets.
- The **Planning and Energy Act 2008** empowers local plans to set "*reasonable requirements*" for new 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*".

2015-2019: deregulation and the misguided reliance on ambitious national standards

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

On 25th March 2015, a **Written Ministerial Statement (WMS)** sought to limit the freedom of LPAs to set their own standards until the introduction of zero carbon homes policy late in 2016. Until then LPAs were expected not to set conditions with requirements above CfSH level 4 (i.e. 19% improvement over Part L).

However, there has been no adoption of a zero carbon homes policy at a national level.

Since 2019: the turning point of Net Zero

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

At the same time, a very large number of local authorities, including many London boroughs declared a **climate and ecological emergency**.

An updated **NPPF** (National Planning Policy Framework) (2021) now expects the planning system to contribute to a "*radical reduction in greenhouse gas emissions*" (Para 148) and requires LPAs to take a proactive approach (Para 149). Further, the Government has confirmed that the Planning and Energy Act 2008 will not be amended. **The result of all this is that Councils are able to set local energy efficiency standards without falling foul of Government policy.** This has been confirmed by recent Planning Inspector reports (e.g. Dec 2022 for B&NES Council and Jan 2023 for Cornwall Council) which indicate that the WMS of 25 March 2015 is of limited relevance and that it has been superseded by subsequent events.

It should also be noted that in their **response to the Future Homes Standard consultation** in 2021, the Government stated the following:

"All levels of Government have a role to play in meeting the net zero target and local councils have been excellent advocates of the importance of taking action to tackle climate change. Local authorities have a unique combination of powers, assets, access to funding, local knowledge, relationships with key stakeholders and democratic accountability."

The above confirms the ability of London boroughs to set their own standards for new buildings as long as it can be demonstrated that they are technically feasible and that these policies consider the issue of viability and its impact on the delivery of new housing and other buildings.

Note: the Government's intention is to introduce National Development Management Policies (NDMPs). The consultation advised that 'A national policy on carbon measurement and reduction could set a baseline whilst enabling authorities to set further measures in their own plans based on parameters set in national policies, perhaps through an optional technical standard to allow for consistency and sound decision making'. Further details are not available at this moment in time.

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3.2

A choice between two strategic directions

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New buildings: two different strategic options for the 18 London boroughs to choose from

Adapting the current system or changing it?

London boroughs wishing to translate their climate ambitions into requirements for new buildings in the borough have the choice between two different strategic directions:

- **Policy option 1 consists of continuing to use the same system based on the Part L framework and adapting it to Part L 2021.** This system requires the applicant to use a Part L energy modelling software, and performance is measured against a single metric (i.e. % reduction in regulated carbon emissions over Part L 2021). This metric cannot be measured post-occupancy.
- **Policy option 2 is a new system focusing on absolute energy-based metrics**. It requires the applicant to use predictive energy modelling tools and methodologies. Performance is measured against a number of metrics (e.g. space heating demand, Energy Use Intensity), A significant advantage of the Energy Use Intensity (EUI) is that it can be measured post-occupancy as it generally aligns with 'energy at the meter'.

For a responsible use of the terminology 'Net Zero Carbon'

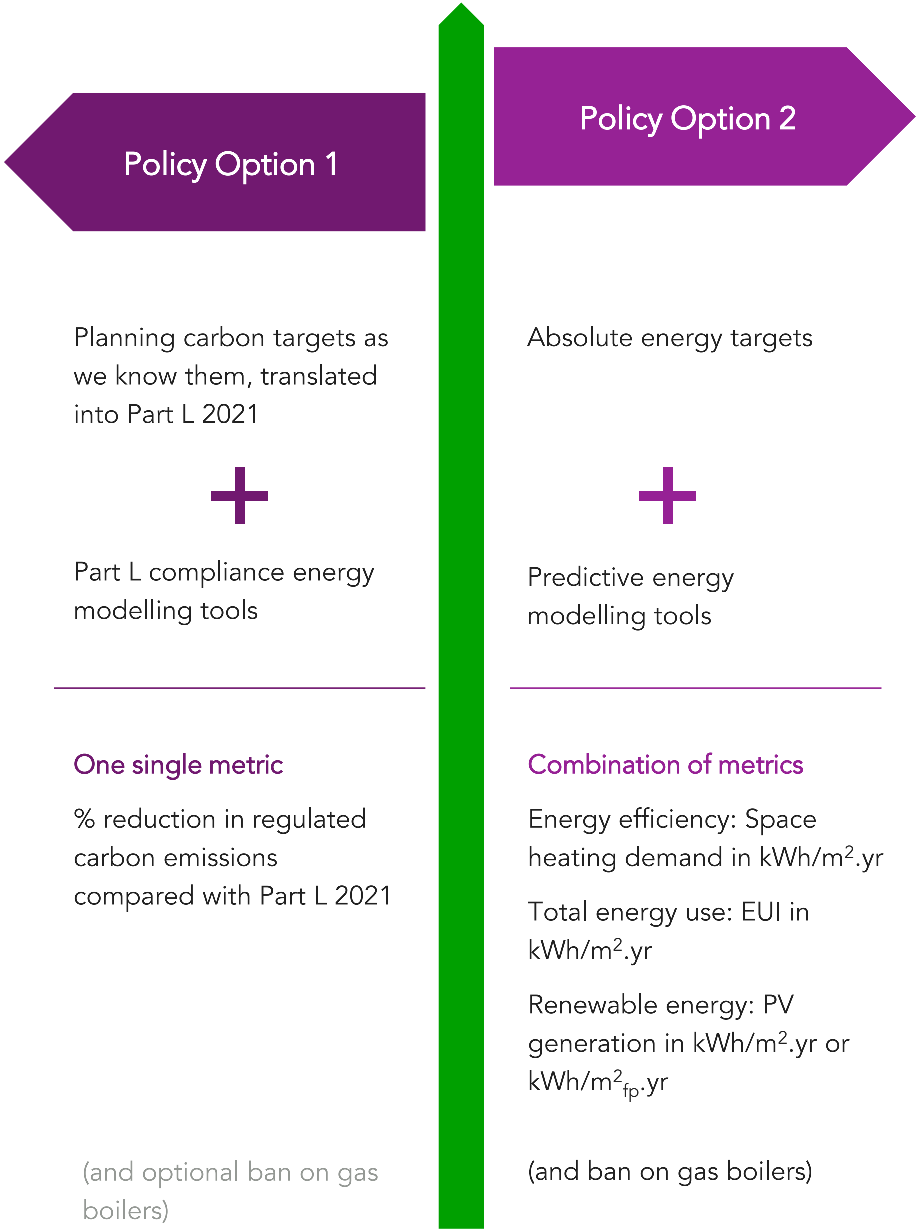
Both policy options seek to deliver 'Net Zero Carbon' new buildings. However, they refer to two different understandings of this term:

- **Policy option 1** generally only considers regulated energy use and allows carbon offsetting to play a significant role.
- **Policy option 2** considers all energy used in the building (except EV charging points) and seeks to achieve a balance between energy use and on-site renewable energy generation, only allowing offsetting to address a potential imbalance.

We strongly recommend that all London boroughs are clear and transparent about the definition of Net Zero Carbon they are using.

Options within each option

Different variations of each policy option are possible but for simplicity, this report considers the two main options.



Policy Option 1

Planning carbon targets as we know them, translated into Part L 2021

+

Part L compliance energy modelling tools

One single metric

% reduction in regulated carbon emissions compared with Part L 2021

(and optional ban on gas boilers)

Policy Option 2

Absolute energy targets

+

Predictive energy modelling tools

Combination of metrics

Energy efficiency: Space heating demand in kWh/m^2.yr

Total energy use: EUI in kWh/m^2.yr

Renewable energy: PV generation in kWh/m^2.yr or kWh/m$^2_{fp}$.yr

(and ban on gas boilers)

Figure 3.1 – Two types of approach are possible to go beyond the requirements of Part L 2021

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Building regulations form the foundations – Planning policy is a way to go further

Hierarchy of compliance

Compliance with Part L of the building regulations is mandatory for all developments. Planning policy (option 1 or 2) is then brought in to supplement regulation. Historically, building regulations Part L has always represented minimum compliance and planning policy pushed the ambition further. They also both focused on regulated carbon emissions. Therefore, planning policy could be relied upon to exceed regulation. For example, a 0% reduction in regulated CO_2 emissions would be building regulations compliant. London Plan policy would then then top it up to require a % improvement in CO_2 emissions (e.g. 35% reduction).

Introduction of new metrics and updates in Part L 2021

Part L has changed from one single criterion to a multi-criteria standard making it more complex and challenging to comply than in the past. In particular, the introduction of the primary energy metric for domestic and non-domestic buildings, and the updating of the target fabric energy efficiency (TFEE) metric for domestic buildings introduce key requirements. There is also a growing realisation in the building industry that planning policy may be more effective at delivering net zero carbon new buildings if it was to consider energy-based metrics rather than regulated carbon emissions. In summary:

1. With the introduction of Part L 2021, applicants and officers need to be satisfied that compliance with Part L 2021 will be achieved. This should be evidenced at planning stage.
2. Policy options 1 and 2 should be seen as two alternative ways to go beyond the minimum standards set by the building regulations in order to deliver net zero carbon buildings. The ability to effectively deliver this objective should be the most important considerations for each borough to inform their selection of policy option 1 or 2.

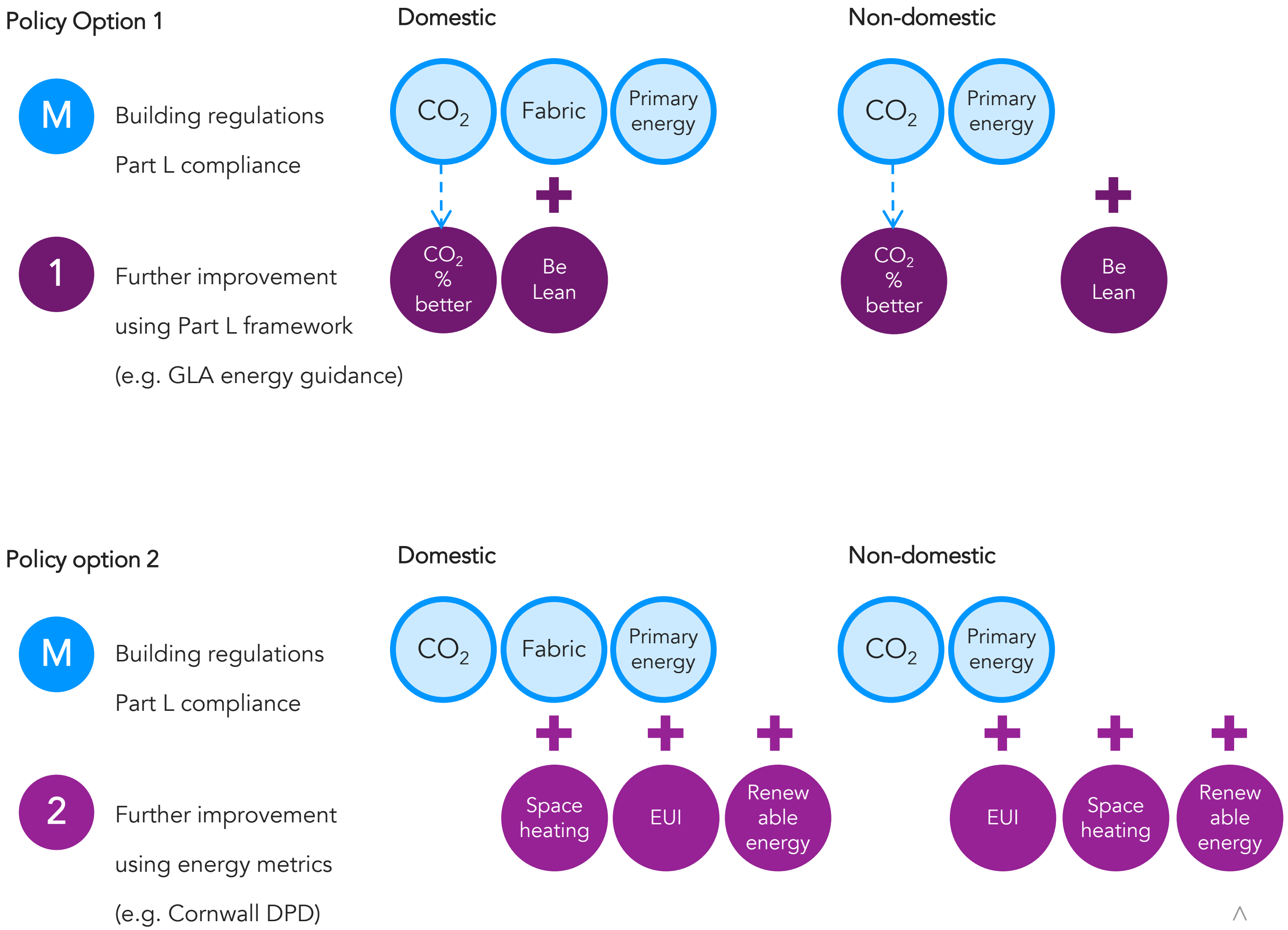

Figure 3.2 - Evidence of compliance with Part L of the building regulations should be evidenced at planning stage as it relies on compliance with several criteria.

Additional criteria can be set by planning policy to require the delivery of Net Zero Carbon new buildings.

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3.3

Introduction to Policy option 1:

Carbon improvement over the notional building using the Part L framework

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Policy option 1 | Carbon improvement over the notional building using the Part L framework

After the introduction of the 'Merton Rule'[1] and its adoption by the GLA in the London Plan and Mayor's first Energy Strategy in 2004, planning policy in London has sought to mitigate the impact of new buildings on climate change primarily through requirements to achieve quantified improvement over Part L of the building regulations. The London Plan, through its successive iterations (2008, 2011, 2016 and 2021), regularly updated these requirements and adapted them to successive versions of Part L of the building regulations (i.e. Part L 2010, Part L 2013, now Part L 2021).

Policy option 1 essentially carries on using this approach by adjusting the target (e.g. 35% improvement over Part L 2013) to Part L 2021 and ensuring that it is technically and financially viable for different typologies.

Local authorities using this framework

This is the approach currently adopted by the GLA in their latest energy assessment guidance.

Comment on the terminology 'Zero Carbon'

The Greater London Authority guidance on preparing energy assessments as part of planning applications (June 2022) states that:

"Major developments are required to achieve net zero-carbon by following the energy hierarchy (Policy SI 2). This means that regulated carbon emissions should be reduced so they are as close as possible to zero. Once on-site reductions have been maximised, the residual emissions should be offset via a payment into the relevant borough's carbon offset fund."

It is important to note that the definition of 'Zero Carbon' used by the London Plan therefore excludes 'unregulated' energy use and relies significantly on carbon offsetting, as illustrated by the adjacent diagram.

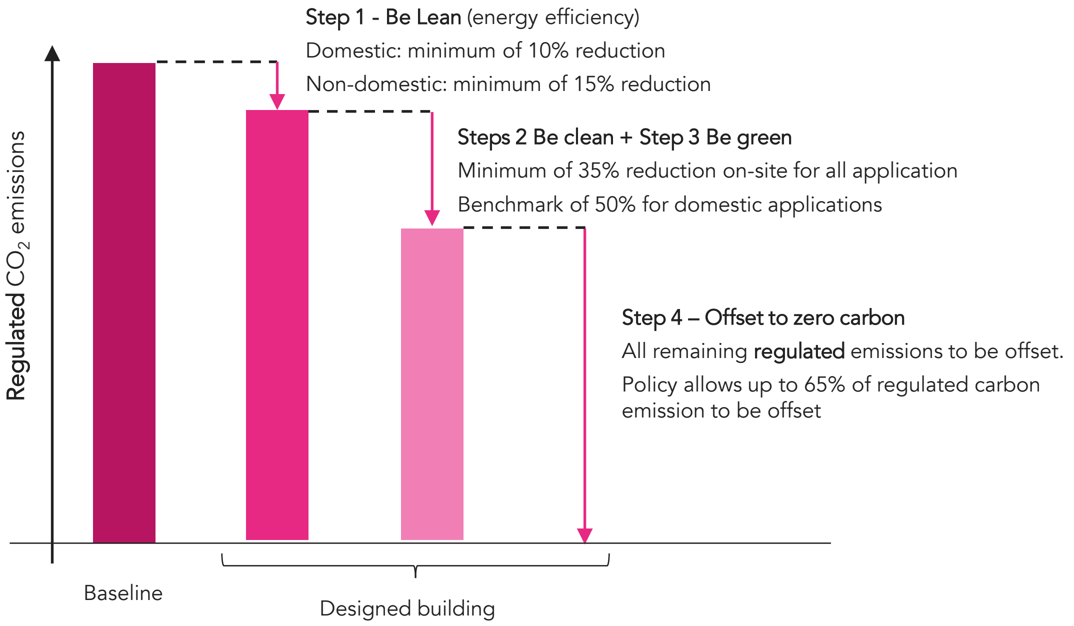
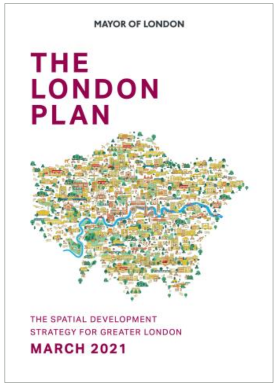


Figure 3.3 - The GLA Energy Assessment Guidance requires the above approach to carbon reduction for new buildings.

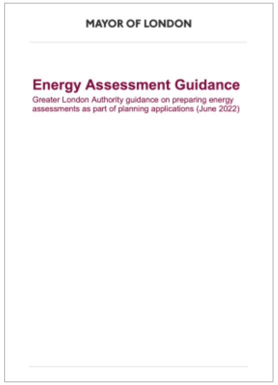


MAYOR OF LONDON

THE LONDON PLAN

THE SPATIAL DEVELOPMENT STRATEGY FOR GREATER LONDON
MARCH 2021

Figure 3.4 - GLA policy: London Plan's policy SI2 refers to Part L 2013 of the Building Regulations



MAYOR OF LONDON

Energy Assessment Guidance
Greater London Authority guidance on preparing energy assessments as part of planning applications (June 2022)

Figure 3.5 - GLA guidance: The GLA Energy Assessment Guidance (2022) is suggesting regulated carbon reductions targets against Part L 2021

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[1] *The 'Merton Rule' was a pioneering planning requirement for new developments to generate at least 10% of their energy requirements from renewable energy sources.*

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Policy option 1 | How does it work?

The same approach as Part L and a focus on regulated carbon

Policy option 1 uses the Part L calculation of regulated carbon emissions, which evaluates the performance of a proposed building comparing its performance to a baseline (i.e. the notional building) and express it as a percentage improvement over that baseline.

What is the 'notional' building?

The notional building has the same size, shape, orientation and up to a point, glazing proportions as the proposed building. In domestic developments, the notional building's fabric and services specifications are standardised and defined by the Part L notional building requirements. For non-domestic developments, the fabric specifications are also standardised, however the services specifications change according to the proposed building's services. For example, if the proposed building has a heat pump system, then the notional building will also be modelled as a heat pump system; and if it has a gas boiler, then the notional building also has a gas boiler. However notional building efficiencies and specifications are assumed. Therefore, the baseline (notional building) for non-domestic developments is "floating" as it is dependant on the proposed building services strategy.

Target (TER) and Dwelling/Building (BER/DER) Emission Rates

The baseline (notional building) emission rate is used to set the Target Emission Rate (TER), and the proposed building emission rate is known as the Dwelling or Building Emission Rate (DER or BER) respectively for domestic and non-domestic development..

The percentage improvement is calculated according to the formula below:

$$\frac{(\text{TER}) - (\text{DER/BER})}{(\text{TER})} \times 100\%$$

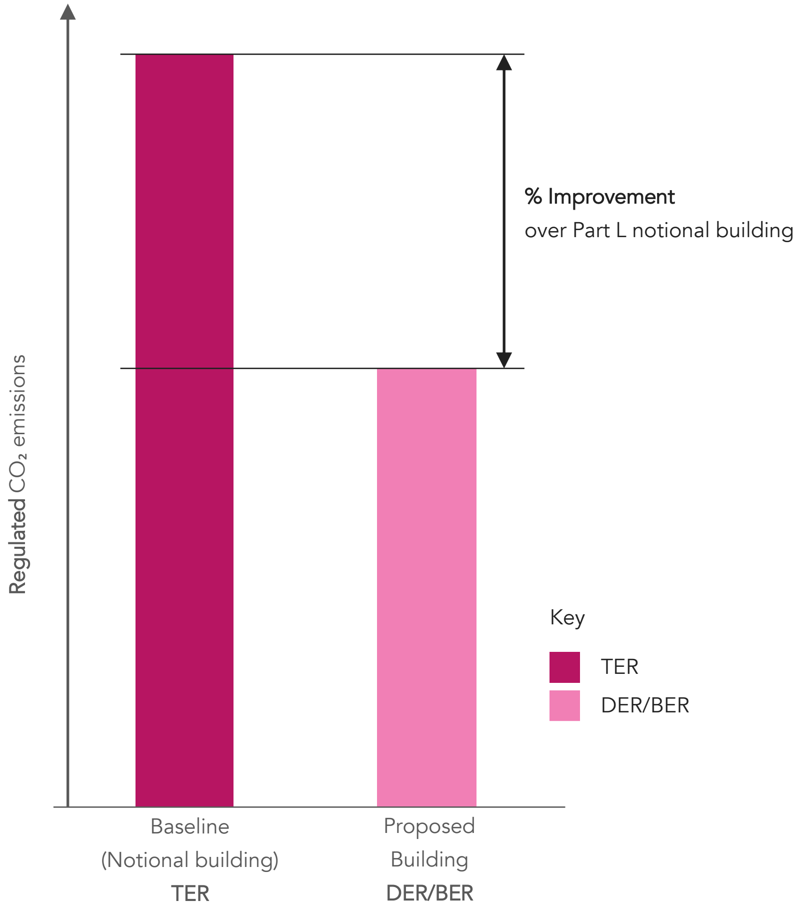

Figure 3.6 – The key metric in Policy option 1 is the % reduction in regulated carbon emissions against baseline, represented by the notional building, an 'equivalent building' with the same size and shape but with standardised proportions of windows and specifications.

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3.4

Introduction to Policy option 2:

Absolute energy performance targets

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Policy option 2 | Absolute energy performance targets

Policy option 2 for London boroughs is to introduce a Net Zero Carbon building policy in line with the emerging industry definition of Net Zero Carbon new buildings. This would require the introduction of the following requirements and energy performance metrics.

1. **No fossil fuels on-site**
   This would be consistent with the GLA's Accelerated Green Pathway which relies on banning new gas boilers.
2. **Space heating demand** (e.g. <15-20 kWh/m^2.yr).
   This would be consistent with the CCC's recommendations[1].
3. **Energy use intensity (EUI)** (e.g. <35 kWh/m^2.yr for domestic).
   This would be consistent with the current industry definition of Net Zero carbon new buildings in operation.
4. **Renewable energy generation** (e.g. to match the EUI or >100 kWh/m^2 $_{\text{footprint}}$.yr). This would incentivise more renewable energy generation on new buildings and a balance with energy use.
5. **Upfront embodied carbon**
   This is not covered by this report but should become a policy.

Local authorities using absolute energy performance targets

The list below includes the names of local authorities which have already published proposed policies consistent with option 2 above: Cornwall Council (Climate Emergency DPD), Bath & North East Somerset Council (Local Plan), London Borough of Newham (Local Plan), Greater Cambridge (Local Plan), Central Lincolnshire (Local Plan) London Borough of Merton, from 2025 (Local Plan).

GLA energy guidance (2022) and energy-based metrics

The GLA now requires applicants to report the Energy Use Intensity (EUI) and space heating demand of the development.

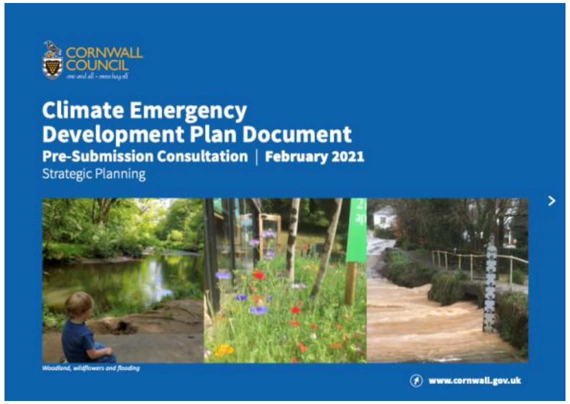
Newham London

NEW LOCAL PLAN | CLIMATE EMERGENCY

Operational energy and carbon evidence base

May 2022 | Rev H

Figure 3.7 - Evidence base for the London Borough of Newham's new Local Plan
https://www.newham.gov.uk/planning-development-conservation/newham-local-plan-refresh/4



CORNWALL COUNCIL

Climate Emergency Development Plan Document

Pre-Submission Consultation | February 2021

Strategic Planning

Woodland, wildflowers and flooding

www.cornwall.gov.uk

COMMITTEE STAGE VERSION

First Proposals

Greater Cambridge Local Plan

Figure 3.8 (Left) Cornwall Council Climate Emergency DPD and associated evidence base
https://www.cornwall.gov.uk/planning-and-building-control/planning-policy/adopted-plans/climate-emergency-development-plan-document/

Figure 3.9 (Right) Greater Cambridge New Local Plan
https://consultations.greatercambridgeplanning.org

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[1] *See the report 'The Future of Housing', Climate Change Committee, 2019*

[2] *See 2022 Energy Assessment guidance item 1.7*

Policy option 2 I How does it work?

An overarching policy

Policy option 2 would rely on an overarching policy requiring all new buildings to be designed and built to be Net Zero Carbon in operation. More specifically, it would introduce a number of associated policies on:

- **Space heating demand**
- Low carbon heat
- **Energy Use Intensity (EUI)**
- On-site renewable energy generation
- Assured energy performance (i.e. design and construction checks)
- Offsetting (as last resort)
- Embodied carbon policies (outside the scope of this report)

Space heating demand

Various design and specification decisions affect space heating demand including building form and orientation, insulation, air-tightness, windows and doors and the type of ventilation system. The Climate Change Committee recommends a space heating demand of less than 15-20 kWh/m^2/yr for new homes, therefore the policy requirement on space heating demand could be that all buildings should achieve a space heating demand of less than 15 kWh/m$^2_{GIA}$/yr.

Energy Use Intensity (EUI)

For new buildings to be compliant with our climate change targets, they need to use a total amount of energy which is small enough so that it can be generated entirely, on an annual basis, with renewable energy and low carbon resources. The EUI metric is also very beneficial as it can be measured post-construction, therefore helping to drive down the performance gap which is such a significant issue in the construction industry. The policy requirement on EUI could be that all buildings should achieve an Energy Use Intensity (EUI) of no more than a maximum (e.g. 35 kWh/m$^2_{GIA}$/yr for domestic).

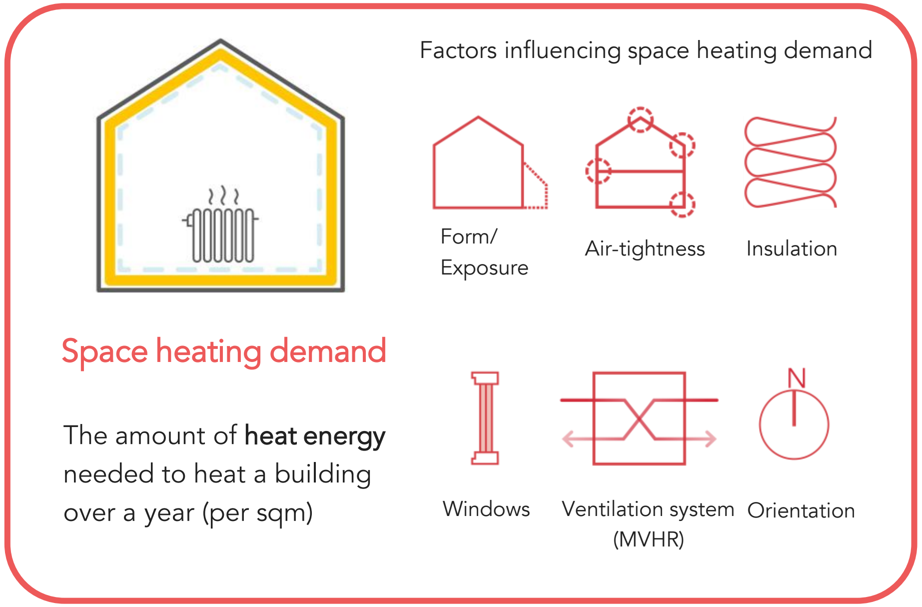

Figure 3.10 – The space heating demand metric

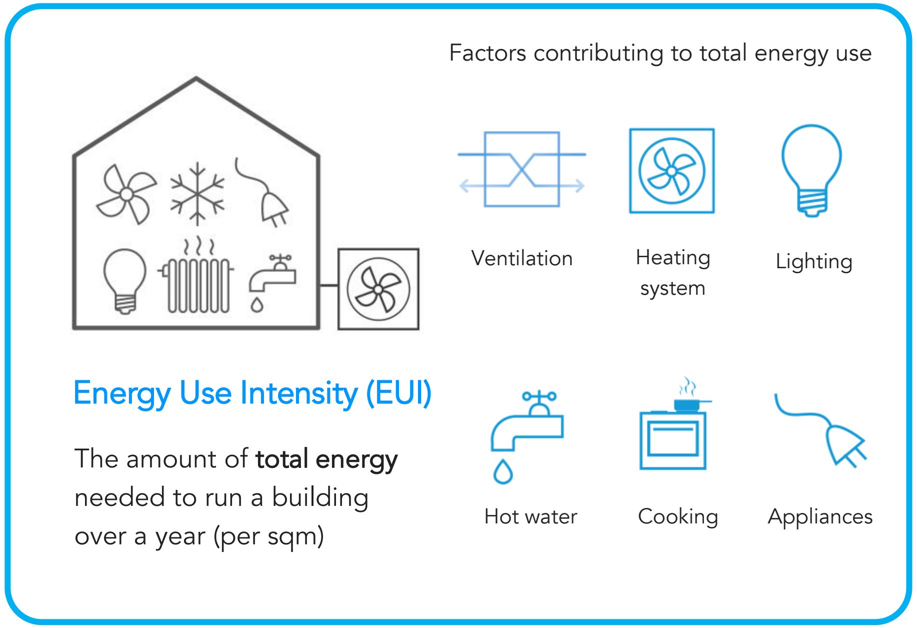

Figure 3.11 – The Energy Use Intensity (EUI) metric

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Policy option 2 | Energy Use Intensity (EUI): a simple, measurable metric

What is the EUI?

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

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

For communally heated dwellings/buildings heat 'at the meter' will need to be converted to heat energy (further information on this is provided later in the report).

What is included in the EUI?

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

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

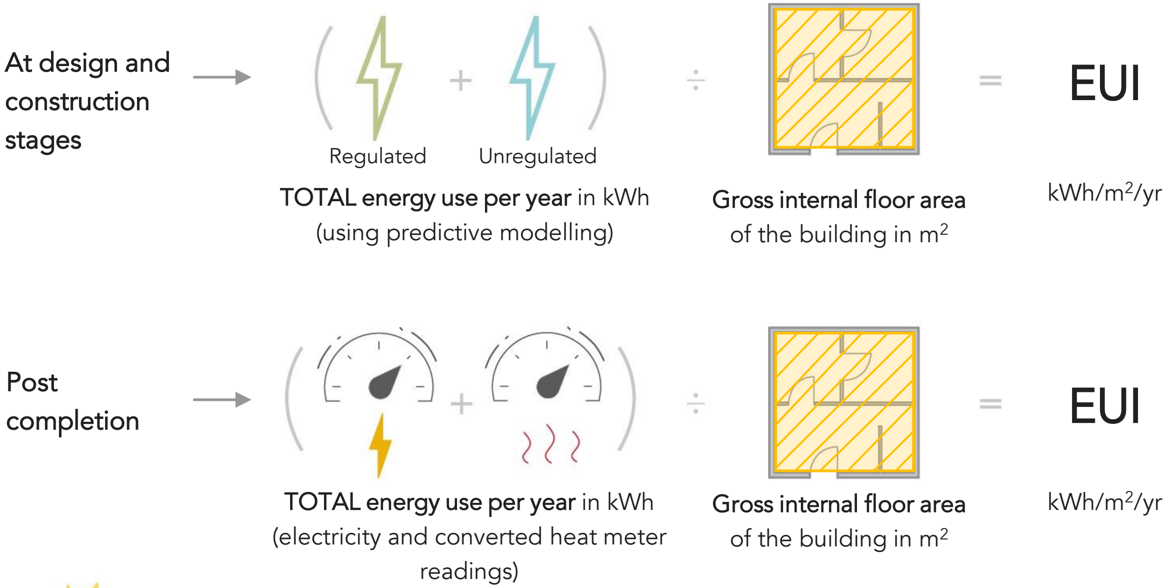

Figure 3.12 – The Energy Use Intensity (EUI) during design construction and post-completion

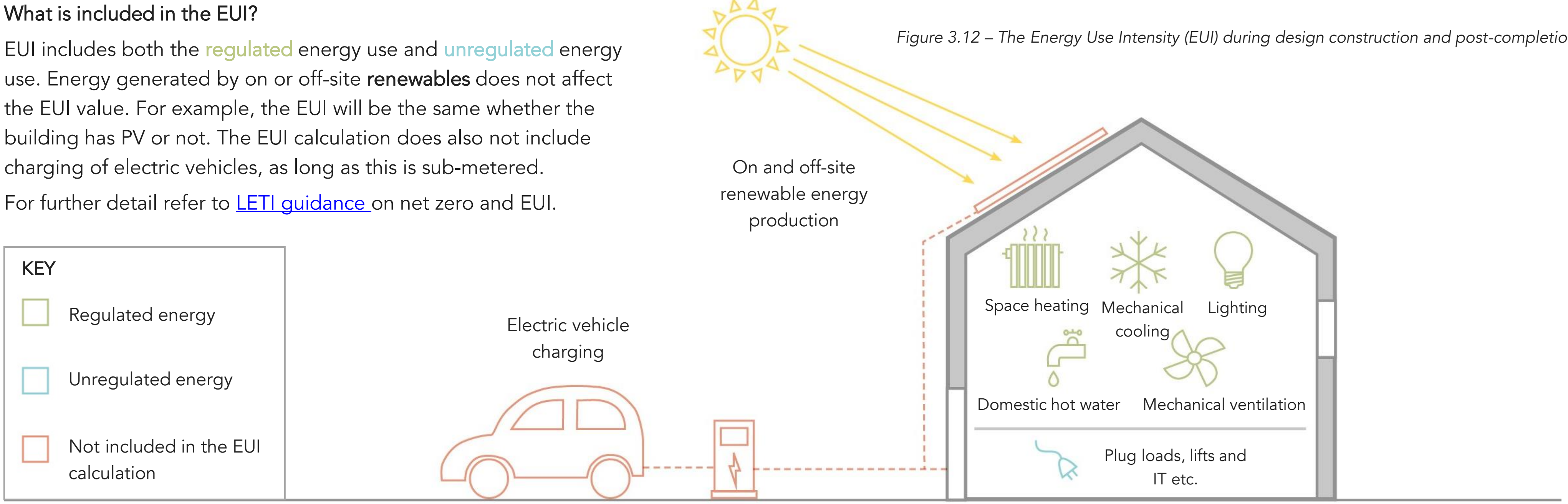

Figure 3.13 - What is included in the EUI?

Note: EUI should not be confused with Primary Energy which rely on the multiplicatio
to each fuel (similarly to carbon emissions which rely on the multiplication of energy

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Policy option 2 | Bath & North East Somerset | Policy and extracts of the Planning Inspector's report

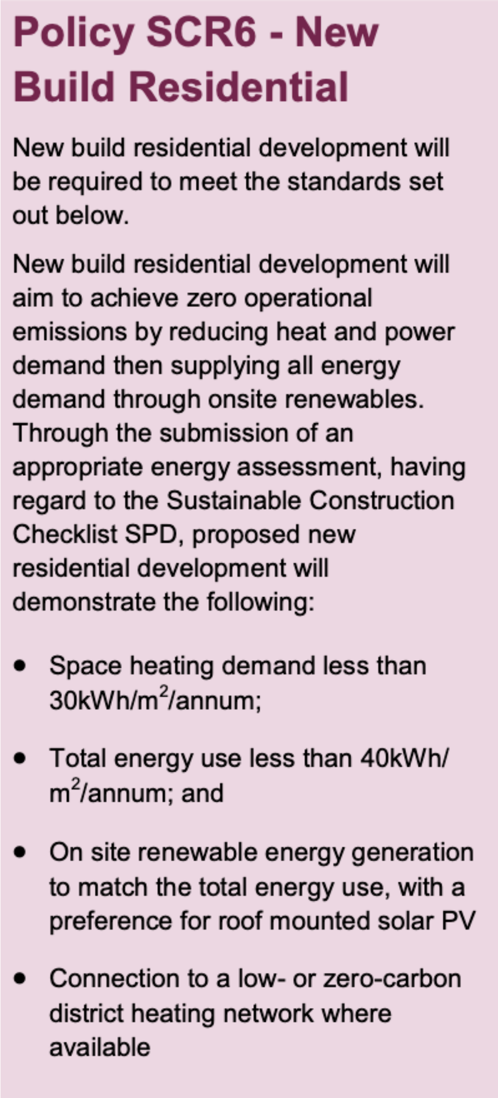
Bath and North East Somerset adopted their new policy in January 2023, becoming the first council in England to successfully adopt an energy-based net zero housing policy as part of its commitment to tackling the climate emergency.

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

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

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

Source: B&NES Council's website



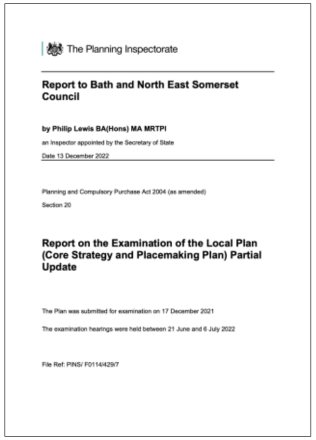
Policy SCR6 - New Build Residential

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

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

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

Figure 3.14 – Net Zero policy adopted by Bath & North East Somerset Council based on energy metrics



The Planning Inspectorate

Report to Bath and North East Somerset Council

by Philip Lewis BA(Hons) MA MRTPI

an Inspector appointed by the Secretary of State

Date 13 December 2022

Planning and Compulsory Purchase Act 2004 (as amended)

Section 20

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

The Plan was submitted for examination on 17 December 2021

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

File Ref: PINS/ F0114/429/7

Figure 3.15 – Selected extracts of the Planning Inspector's report on the examination of B&NES's Local Plan partial update (December 2022)

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

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

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

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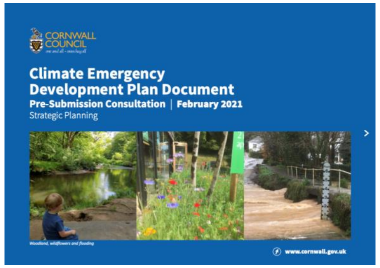
Policy option 2 I Cornwall Council I Policies and extracts of the Planning Inspector's report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Climate Emergency
Development Plan Document
Pre-Submission Consultation | February 2021
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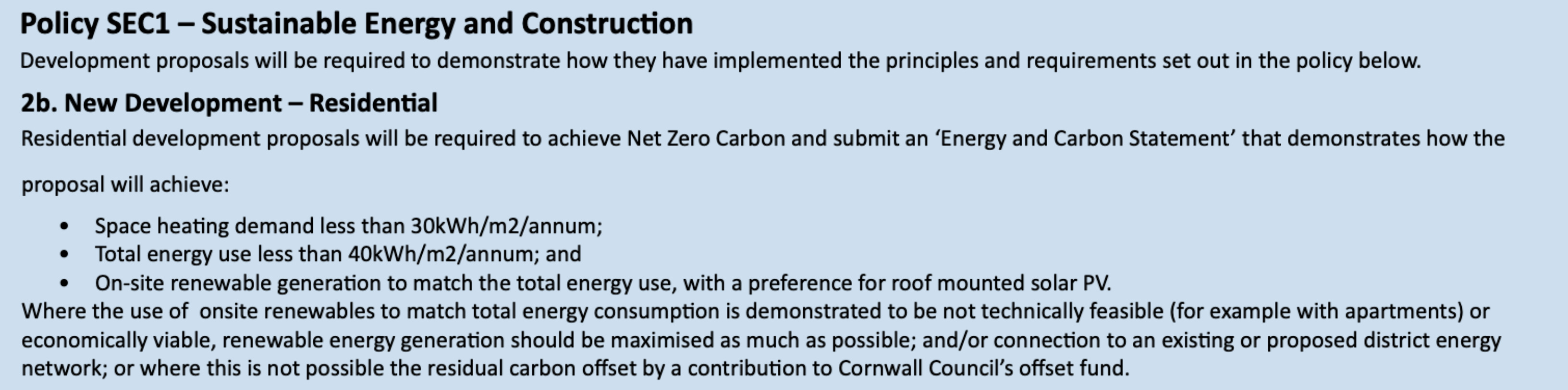
Figure 3.16 – Net Zero policy adopted by Cornwall Council based on energy metrics


Policy SEC1 – Sustainable Energy and Construction

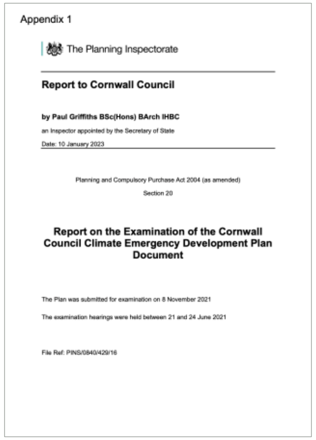
Development proposals will be required to demonstrate how they have implemented the principles and requirements set out in the policy below.

2b. New Development – Residential

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

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

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


Appendix 1

The Planning Inspectorate

Report to Cornwall Council

by Paul Griffiths BSc(Hons) BArch IHBC

an Inspector appointed by the Secretary of State

Date: 10 January 2023

Planning and Compulsory Purchase Act 2004 (as amended)
Section 20

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

The Plan was submitted for examination on 8 November 2021

The examination hearings were held between 21 and 24 June 2021

File Ref: PINS/0840/429/16

Figure 3.17 – Selected extracts of the Planning Inspector's report on the examination of Cornwall Council's Climate Emergency Development Plan Document (January 2023)

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

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

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

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

Conclusion

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

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3.5

Key considerations for selecting the right policy option for your borough

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Key difference 1 I A relative target (Policy option 1) or Absolute target (Policy option 2)

Validating performance against the targets

Policy option 1 is based on a required improvement over compliance with building regulations, determined using a baseline: the 'notional building'. The notional building has the same shape, orientation and, up to a point, the same glazing proportions as the actual proposed building design. For clarity, the notional building is fictional and is created by the compliance software only for building regulations purposes. The % improvement over a notional building is an intangible requirement that cannot be measured, whereas an absolute energy use target in kWh/m^2.yr (as per Policy option 2) can be checked against metered energy in the occupied building. This makes post-construction verification and learning from a feedback loop easier with the absolute target.

Incentivising better design

Improving the design of a building by reducing the extent of heat loss areas, the number of junctions, and by optimising elevation design are widely considered as essential components of an energy efficient design. However, comparing a development to its own notional building (Policy option 1) essentially neutralises the benefit of these measures and moreover does not penalise inefficient building designs. With an absolute target (Policy option 2), the benefits (or penalty) of changes to the building form and design are assessed and good design practice is rewarded.

Additional issues with changing carbon and primary energy factors

Policy option 1 relies on carbon emission factors and primary energy factors that introduce additional complexity.

Compliance with energy use metrics (Policy option 2) is only affected by changes in building design, and not by these wider 'system factors'.

%
improvement
over notional
building

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

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

- ✓ Is a 'physical' metric which can be measured
- ✓ Can be understood by all professionals, and most consumers
- ✓ Can be checked against in-use data

Figure 3.18 - The relative metric used by Policy option 1 (i.e. % improvement over Part L) has a number of unintended consequences which hinder the continuous improvement of building design, consumer trust and performance outcomes.

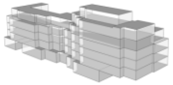
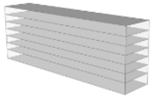
		Improvement over Part L (%) SAP	Space heating demand (kWh/m^2/yr) SAP	Space heating demand (kWh/m^2/yr) PHPP
High form factor		35%	18	26
Medium form factor		35%	15	20
Low form factor		37%	11	13

Figure 3.19 - A more efficient form is important for low energy buildings, but it is not rewarded by the notional building approach: with similar specifications (e.g. U-values) the performance against Part L (%) calculated by SAP for the three buildings above is broadly similar despite the fact that space heating demand is much smaller with a more efficient design.

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Key difference 2 | A single metric (Policy option 1) or a suite of metrics (Policy option 2)

A single metric for policy option 1

Policy option 1 uses a single performance metric: the reduction in regulated carbon emissions over the building regulations Part L limit expressed as a percentage (e.g. 35% better than Part L 2021). This amalgamates into one metric the building's efforts in terms of energy efficiency, low carbon heat and renewable energy generation.

A suite of metrics for policy option 2

Policy option 2 uses a set of metrics to separately measure each of the key attributes needed to achieve Net Zero:

- Space heating demand (kWh/m^2.yr) for energy efficiency
- Gas use (yes/no) for low carbon heat
- EUI (kWh/m^2.yr) for energy efficiency (including system efficiencies)
- Energy balance (kWh/m^2.yr) or total renewable energy generated ((kWh/m^2_{fp}.yr) for renewable energy generation.

Why a suite of metrics can be better for Net Zero?

Having a dedicated metric per key objective (e.g. space heating demand for fabric energy efficiency) 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 new building.

Energy, not CO_2, is the best metric

As the grid decarbonises, there is a real risk that looking only at the carbon emissions will dilute the differences between buildings. A move towards energy metrics would ensure the ability to distinguish and support good building design is maintained.

Regulated energy or total energy

Policy option 1 does not include CO_2 emissions from equipment and appliances. This represents approximately 50% of energy use in a low energy home.

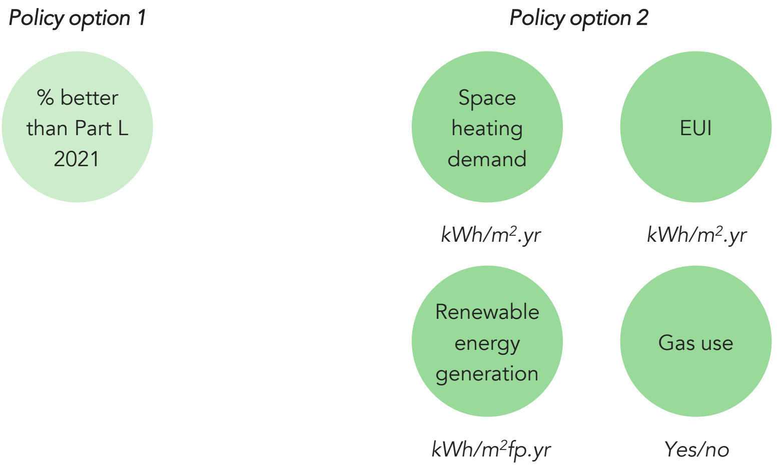

Figure 3.20 – Key metrics used in Policy options 1 and 2

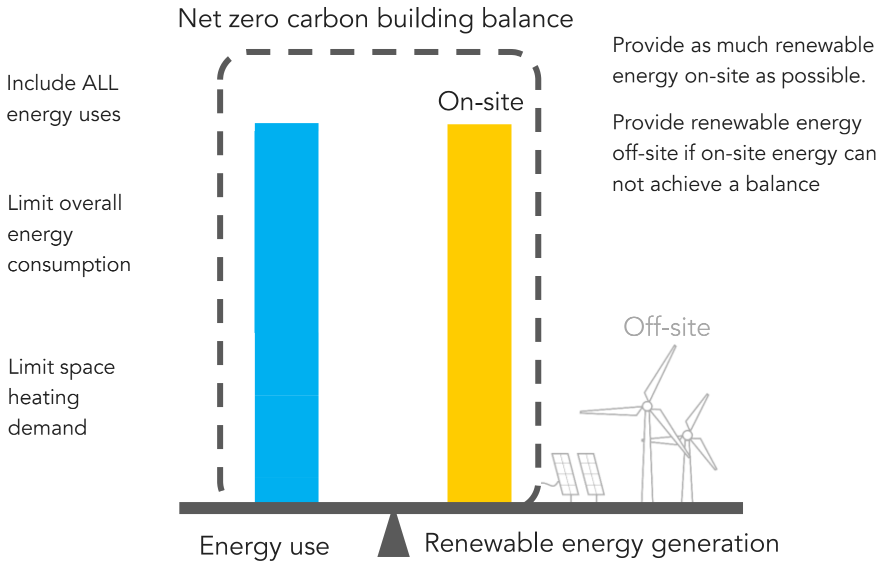

Figure 3.21 – How energy metrics help to deliver zero carbon buildings. The goal is simple and tangible – to achieve a balance between energy use and renewable energy generation on-site. The definition also includes the requirement to limit the energy required for space heating and limit overall energy use, which reduces the amount of renewable energy needed on-site.

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Key difference 3 | Part L energy modelling (Policy option 1) or Predictive energy modelling (Policy option 2)

Part L modelling for Policy option 1

SAP (domestic) and the National Calculation Methodology (NCM) (non domestic) are the calculation methodologies used to demonstrate compliance with Part L of the Building Regulations. SAP (Standard Assessment Procedure) is used through the associated SAP software and the NCM and (National Calculation Methodology) through SBEM and Dynamic Simulation Modelling (DSM) tools. Policy option 1 relies on the same tool.

However, until now, these Part L energy assessment methodologies were developed only to check compliance with Building Regulations. They were never meant to perform key functions that are required to deliver Net Zero carbon buildings, and most importantly they were not meant to predict future energy use accurately. This is a widely accepted fact in the industry which all stakeholders agree with.

It seems that when these tools were first mandated to be used at planning stage, approximately 15 years ago, it was to minimise the burden on applicants. A different and better type of energy modelling may be required if Net Zero Carbon buildings are to be delivered.

Predictive energy modelling for Policy option 2

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

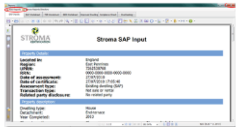
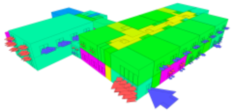
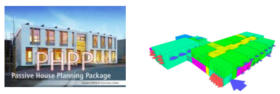
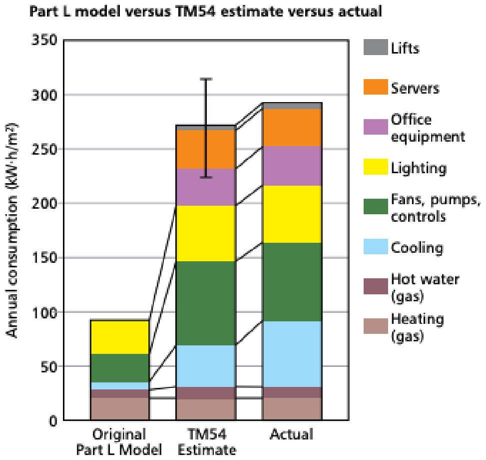
	Part L modelling	Predicted energy use modelling
Domestic	 SAP (Part L1A)	 PHPP
Non-domestic	 NCM (Part L2A)	 PHPP or DSM (TM54)

Figure 3.22 - There is a significant difference between Part L modelling currently used to demonstrate compliance with planning policy and predicted energy use modelling.



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

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

Figure 3.23 - Extracts of CIBSE Technical Memorandum 54 (TM54): Evaluating operational energy performance of buildings at the design stage

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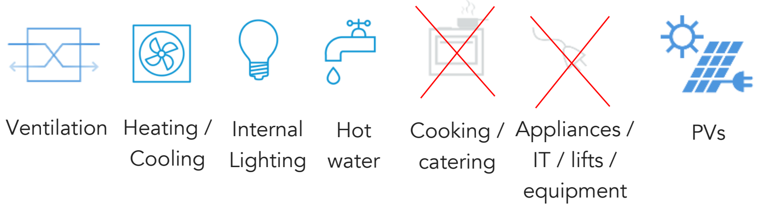
Key difference 3 I **Part L energy modelling** (Policy option 1) **or Predictive energy modelling** (Policy option 2)

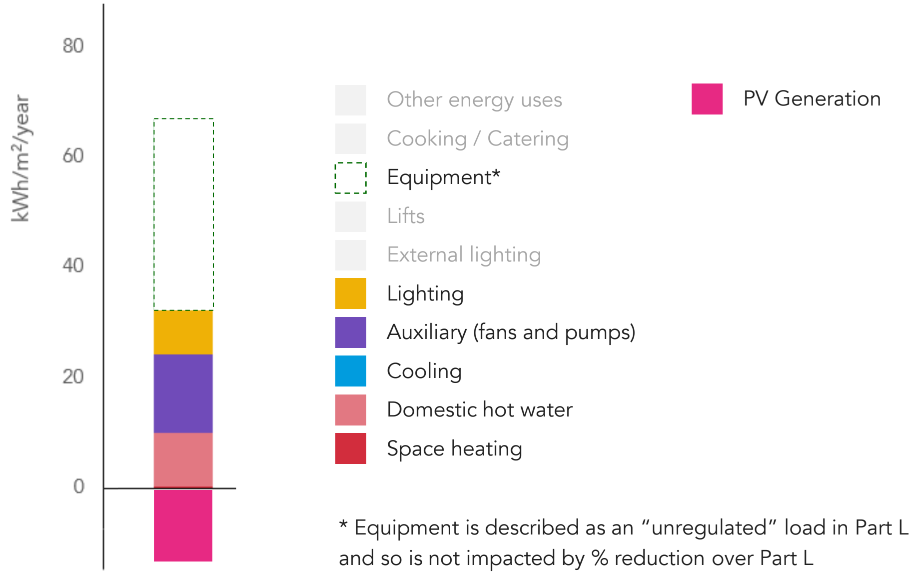
Policy Option 1

Part L compliance energy modelling

Energy use

Renewable generation





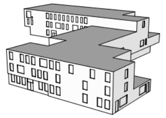
* Equipment is described as an "unregulated" load in Part L and so is not impacted by % reduction over Part L

Figure 3.24 – Energy uses assessed by a typical Part L compliance energy model

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

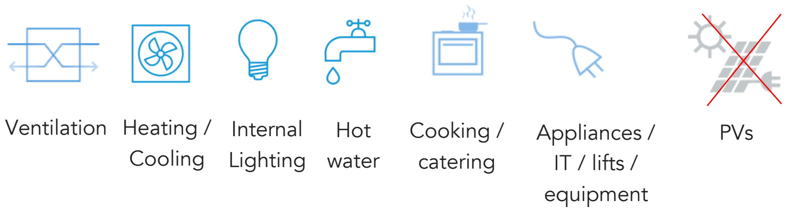
Policy Option 2

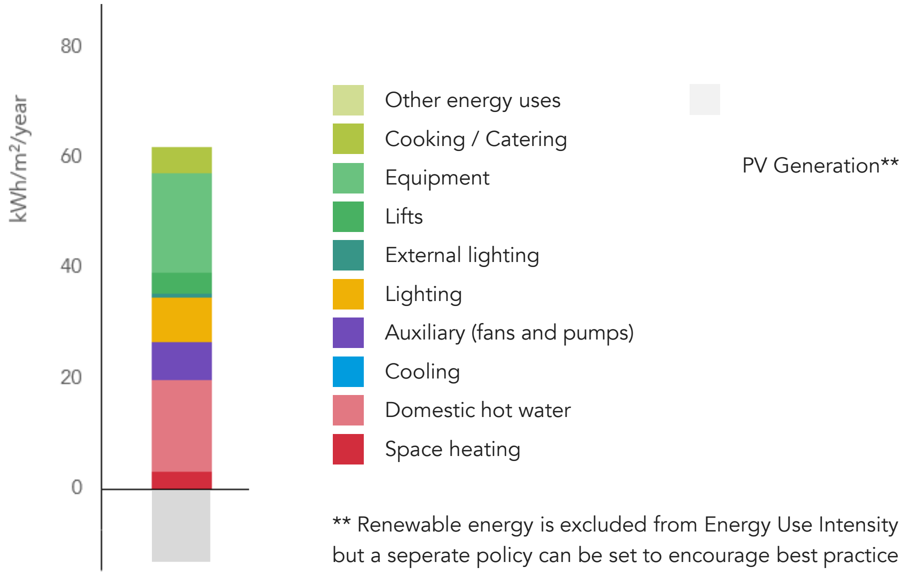
Predictive energy modelling



Energy use

Renewable generation





** Renewable energy is excluded from Energy Use Intensity but a seperate policy can be set to encourage best practice

Figure 3.25 – Energy uses assessed by a typical predictive energy model

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3.6

Minor applications and refurbishments

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Minor applications

Should minor applications be exempt from the requirements of Policy options 1 or 2?

The definition of a minor application

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

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

A minor application would therefore be one under these thresholds.

There is no technical reason to create an exemption

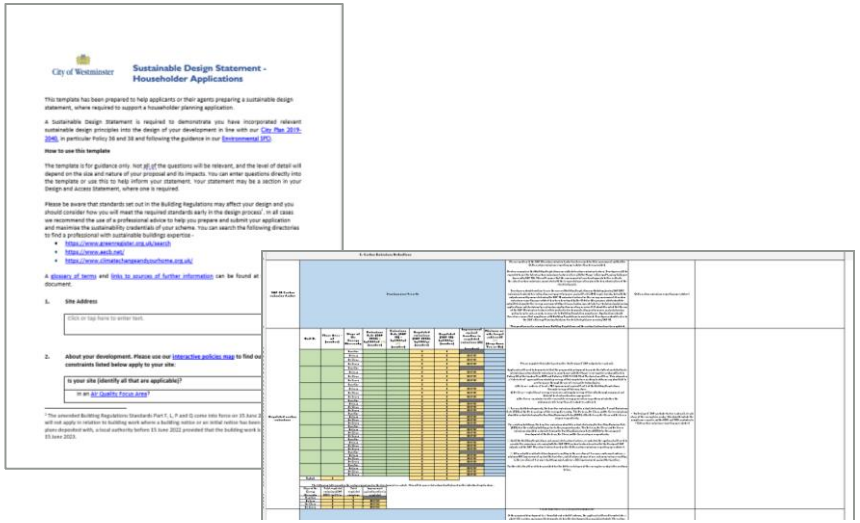
The implications of both policies in terms of design and construction (e.g. wall U-values, low carbon heat, PV renewable energy generation) are not different for minor applications, and it is not easier or more challenging to comply with Policy option 1 or 2 for them.

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

Simplifying reporting requirements

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

Developers of individual houses or commercial units or shops may also not have access to the resources needed to carry out predictive energy modelling (Policy option 2). An exemption may be envisaged for these very small developments but this exemption should be handled with care and restricted only to specific minor applications.



City of Westminster

Sustainable Design Statement - Householder Applications

This template has been prepared to help applicants or their agents preparing a sustainable design statement, where required to support a householder planning application.

A Sustainable Design Statement is required to demonstrate you have incorporated relevant sustainable design principles into the design of your development in line with our City Plan 2019-2040, in particular Policy 36 and 38 and following the guidance in our Environmental SPD.

How to use this template

The template is for guidance only. Not all of the questions will be relevant, and the level of detail will depend on the size and nature of your proposal and its impacts. You can enter questions directly into the template or use this to help inform your statement. Your statement may be a section in your Design and Access Statement, where one is required.

Please be aware that standards set out in the Building Regulations may affect your design and you should consider how you will meet the required standards early in the design process[1]. In all cases we recommend the use of a professional advice to help you prepare and submit your application and maximise the sustainability credentials of your scheme. You can search the following directories to find a professional with sustainable buildings expertise -

- https://www.greenregister.org.uk/search
- https://www.aecb.net/
- https://www.climatechangeandyourhome.org.uk/

A glossary of terms and links to sources of further information can be found at
document.

1. **Site Address**

Click or tap here to enter text.

2. **About your development. Please use our interactive policies map to find ou**
constraints listed below apply to your site:

Is your site (identify all that are applicable)?

In an Air Quality Focus Area?

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[1] The amended Building Regulations Standards Part F, L, P and Q come into force on 15 June 2
will not apply in relation to building work where a building notice or an initial notice has been
plans deposited with, a local authority before 15 June 2022 provided that the building work is
15 June 2023.

Figure 3.26 - Many boroughs have standard templates for minor applications for specific aspects of the application. A similar approach could be adopted for energy reporting for specific schemes less than a threshold number of homes or m^2 of commercial development.

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

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

.

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

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

Figure 3.27 – Examples of exemptions: the Community Infrastructure Levy (CIL)

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Existing buildings and refurbishments

This document focuses on new buildings, i.e. new constructed structures, as opposed to the renovation or refurbishment of existing structures. There are no technical reasons why Policy options 1 or 2 should not be applied to existing buildings and their refurbishment. In some cases, the framework of these policies could be used and the quantified targets left unchanged (e.g. major refurbishment). In some other cases, the targets may have to be changed. This review is however not within the scope of this report.

Change of use, conversions and major refurbishments

Where an existing building is being converted to a different use type, the performance of the converted property should not be worse than a new building of the same use type.

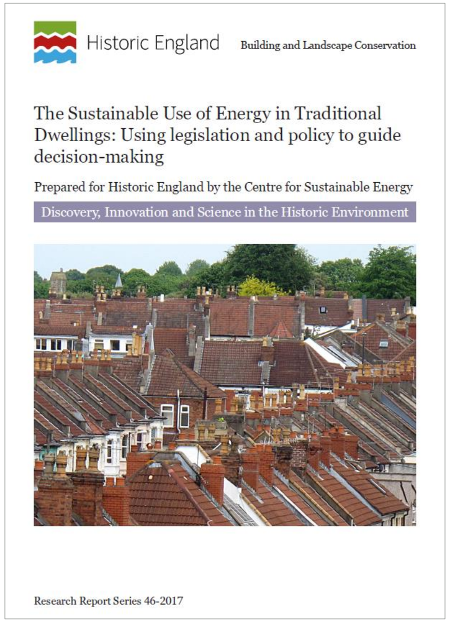
A major refurbishment would offer virtually the same opportunity as a new build in terms of energy efficiency, low carbon heat and renewable energy generation.

There is also a benefit, in carbon terms, of reusing existing buildings, especially the sub structure and superstructure where most of the embodied carbon in buildings is captured. It may be appropriate to incentivise reuse of existing structures financially, by not requiring offset payments to be made for residual carbon emissions.

Listed buildings, conservation areas, extensions and alterations

For heritage buildings, retrofit measures which reduce energy use and carbon emissions should be encouraged, as should the development of whole building energy improvement strategies.

For listed buildings, which will each need to be assessed on their individual merits, Historic England have published guidance on planning responsible retrofit of historic buildings which could be used as a reference for local policy. In conservation areas where buildings are not listed, some specific allowable solutions could be permitted. Supplementary guidance (e.g. on double or triple glazing, solar PVs, heat pumps), may help to dispel the current perception that they are simply not allowed anywhere.



Historic England Building and Landscape Conservation

The Sustainable Use of Energy in Traditional Dwellings: Using legislation and policy to guide decision-making

Prepared for Historic England by the Centre for Sustainable Energy

Discovery, Innovation and Science in the Historic Environment

Research Report Series 46-2017

Historic England

Energy Efficiency and Traditional Homes

Historic England Advice Note 14

Figure 3.28 - Historic England have published guidance for owners of heritage buildings and also for policy makers and planners on how to balance the need for improvements in energy performance with protection of heritage assets.

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4.0

Energy and cost modelling evidence base

Methodology, typologies and specifications

4.0 Energy and cost modelling evidence base I Methodology, typologies and specifications

Energy and cost modelling represent the core of this evidence base. Before presenting the extensive results of these analysis, this sections summarises the team's general approach to energy and cost modelling.

It explains which building archetypes were selected, and how different specifications were modelled.

It also introduces how heat networks were assessed in this study.

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4.1

Approach to energy and cost modelling

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Energy and cost modelling analysis | Purpose and archetype selection

Purpose of energy and cost modelling

Energy and cost modelling constitutes the core of this technical evidence base. Its purpose is to investigate how different building archetypes would perform against the metrics in Part L 2021, Policy option 1 and Policy option 2, using different combination of specifications. These results can then be used to inform the process of target setting by officers, and constitute the evidence that the associated policies are technically achievable. Finally, the cost modelling can be used to identify the additional cost of these policies above minimum building regulations compliance (Part L 2021).

Archetype selection

In order to undertake the energy and cost modelling for this technical evidence base, a number of domestic and non-domestic archetypes had to be identified and assessed.

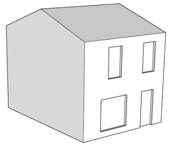
There is obviously a very wide rage of building types in London and within each building type an almost infinite variety of buildings. In discussions with the 18 London boroughs, we have identified 8 building archetypes: four domestic (i.e. terrace house, low-rise, medium-rise and high-rise apartment buildings) and four non-domestic (i.e. office, school, light industrial/warehouse and hotel).

We have then identified one building for each of these building types (see adjacent images). The building is obviously just an example and there are inherent limitations (e.g. a primary school was chosen for the 'schools' category, not a secondary school). However, it is very common for technical evidence bases to be based on selected buildings. It can always be expanded with more buildings/building types if required by one or several London boroughs.

24 different scenarios/combinations of specifications

24 different scenarios were modelled, combining different specifications in terms of fabric and ventilation, heating system and solar PVs. See section 4.2 and the appendix for further details.

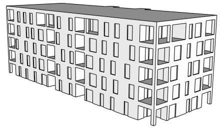
Domestic archetypes selected



Terrace house

95 sqm

This building represents the generic **Terrace house** new build typology

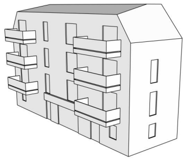


Mid-rise

5 storeys

3,200 sqm

This building represents the generic **Mid-rise apartment building** new build typology

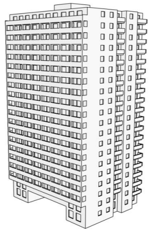


Low-rise

3/4 storeys

641 sqm

This building represents the generic **Low-rise apartment building**-new build typology



High-rise

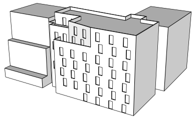
15 storeys

15,500 sqm

This building represents the generic **High-rise apartment building** new build typology

Please note that the findings will be very similar for a high-rise of 40-50 storeys

Non-domestic archetypes selected

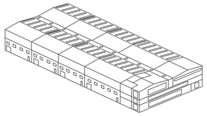


Office

7 storeys

4,000 sqm

This building represents the generic **office building** new build typology

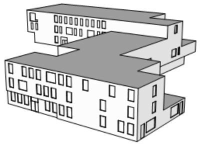


Industrial

2 storeys

9,000 sqm

This building represents the generic **industrial building** new build typology

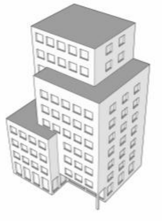


School

3/4 storeys

6,000 sqm

This building represents the generic **school building** new build typology



Hotel

11 storeys

3,900 sqm

This building represents the generic **hotel building** new build typology

Figure 4.1 – Graphical representation of the 8 buildings chosen as archetypes

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4.2

Specification scenarios modelled

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Energy and cost modelling analysis I Specifications modelled

Specification scenarios modelled

A fair and balanced set of specifications which considered various levels of performance for fabric and ventilation, heating systems and renewable energy provision were modelled. The performance of these scenarios ranged from 'business as usual' approaches to more ambitious 'ultra-low energy' levels. We selected three specific sets of building fabric, ventilation, heating and renewable energy specifications tailored to each archetype that would represent this spread of performance and be practical to build. An example for the mid-rise apartment building is provided in this section and the specific assumptions for all eight building archetypes are all available in section 12.0 Appendices.

Part L 2021 compliance modelling outputs

Each of theses 24 different scenarios were modelled for each of the 8 typologies using Part L 2021 accredited software based on SAP 10.2 for domestic buildings (i.e. Elmhurst Design SAP 1.7.25) and the NCM methodology for non-domestic buildings (i.e. EDSL's Tas and IES's VE). The following outputs were analysed regulated carbon emissions, primary energy use and FEE (Fabric Energy Efficiency).

Part L modelling outputs for Policy option 1

Results were analysed to investigate how the different cases would perform against the requirements of Policy option 1 in terms of:

- Regulated carbon emissions - % improvement over Part L 2021
- Regulated carbon emissions - 'Be Lean' performance

Predictive energy modelling outputs for Policy option 2

The buildings were also modelled using a predictive operational energy modelling tool: PHPP (10) for domestic buildings, EDSL's Tas and IES's VE using CIBSE TM54 methodology for non-domestic buildings. They were used to calculate the space heating demand (SHD) and Energy Use Intensity (EUI) for each scenario and each building.

Fabric and Ventilation	Heating system	Solar PVs
Business as usual*	Gas boiler	No
Good practice	Direct electric	High provision of PVs
Ultra-low energy	Less efficient heat pump	
	More efficient heat pump	

Table 4.1 - The 24 scenarios modelled are based on different permutations of the above parameters
** The 'Business as usual' scenarios is meant to represent the type of fabric and ventilation specifications that most applicants in London would consider 'standard' in the last 5-10 years.*

	1 Business as Usual*	2 Good Practice	3 Ultra Low Energy
Description	This scenario represents the type of energy efficiency performance most applicants are used to deliver.	This scenario represents an intermediate level of performance: better than business as usual but not as good as ultra low energy.	This scenario represents a feasible best practice level of performance, approximately equivalent to Passivhaus.
Floor U-Value (W/m^{2}K)	0.13	0.10	0.08
External wall U-Value (W/m^{2}K)	0.18	0.15	0.13
Roof U-Value (W/m^{2}K)	0.15	0.12	0.10
Soffit U-Value (W/m^{2}K)	N/A	N/A	N/A
Windows			
U-value (W/m^{2}K)	1.40	1.20	0.80
Windows g-value	0.4	0.5	0.5
External doors (W/m^{2}K)	N/A	N/A	N/A
Thermal bridging (W/m^{2}K)	Good practice (e.g. y-value ≃ 0.1 W/m^{2}K)	Better practice (e.g. y-value ≃ 0.07 W/m^{2}K)	Best practice (e.g. y-value ≃ 0.04 W/m^{2}K)
Air Permeability (m^3/m^2/hr)	3	3	<1
Ventilation system and design	Good quality MVHR Long ducts to outside	High quality MVHR Long ducts to outside	High quality MVHR Short ducts to outside
MVHR heat recovery efficiency	85%	90%	90%
MVHR specific fan power	0.8 W/l/s (SAP) 1.75 W/l/s (PHPP)	0.7 W/l/s (SAP) 1.25 W/l/s (PHPP)	0.6 W/l/s (SAP) 0.85 W/l/s (PHPP)

Table 4.2 - Example of the three different levels of fabric and ventilation efficiency considered. Although the same 'levels' are considered for each typology, the detailed fabric and ventilation specifications for each of these levels are specific to each typology. An example for the mid-rise apartment building can be found on the following pages. The full list of assumptions for each typology can be found in Appendix.

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Mid rise apartment building | Fabric & Ventilation

This table summarises the different energy efficiency assumptions modelled based on the three different fabric and ventilation scenarios.
The SAP Calculations assume a 5 story building.

NEW New input for SAP 10.2

	1 Business as Usual*	2 Good Practice	3 Ultra Low Energy
Description	This scenario represents the type of energy efficiency performance most applicants are used to deliver.	This scenario represents an intermediate level of performance: better than business as usual but not as good as ultra low energy.	This scenario represents a feasible best practice level of performance, approximately equivalent to Passivhaus.
Floor U-Value (W/m²K)	0.13	0.10	0.08
External wall U-Value (W/m²K)	0.18	0.15	0.13
Roof U-Value (W/m²K)	0.15	0.12	0.10
Soffit U-Value (W/m²K)	N/A	N/A	N/A
Windows U-value (W/m²K) Windows g-value	 1.40 0.4	 1.20 0.5	 0.80 0.5
External doors (W/m²K)	N/A	N/A	N/A
Thermal bridging (W/m²K)	Good practice (e.g. y-value ≃ 0.1 W/m²K)	Better practice (e.g. y-value ≃ 0.07 W/m²K)	Best practice (e.g. y-value ≃ 0.04 W/m²K)
Air Permeability (m³/m²/hr)	<3	<3	<1
Ventilation system and design	Good quality MVHR Long ducts to outside	High quality MVHR Long ducts to outside	High quality MVHR Short ducts to outside
MVHR heat recovery efficiency	85%	90%	90%
MVHR specific fan power	0.8 W/l/s (SAP) 1.75 W/l/s (PHPP)	0.7 W/l/s (SAP) 1.25 W/l/s (PHPP)	0.6 W/l/s (SAP) 0.85 W/l/s (PHPP)

Table 4.3 – Specifications assumed for each level of fabric and ventilation performance for the mid-rise apartment building

** The term 'Business as Usual' scenarios is meant to represent the type of fabric and ventilation specifications that most applicants in London would consider 'standard' for a mid-rise apartment building. For consistency it has not been changed compared with the initial 2019 study. We think that this approach is acceptable as 'Business as usual' has not changed significantly in terms of fabric and ventilation specifications*

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Notional building

Part L uses a notional building specification to generate the "baseline" (i.e. Target Emission Rate TER / Target Fabric Energy Efficiency TFEE / Target Primary Energy Rate TPER). This is a predefined set of performance values from building regulations Part L 2021. The values differ between domestic and non-domestic typologies.

Business as usual

The 'Business as usual' scenario is meant to represent the type of fabric and ventilation specifications that most applicants in London would consider 'standard' in the last 5-10 years. This scenario is unchanged from the 2019 study and is not intended to be a replica of the 'notional building' specification.

Why 'Business as usual' and not Notional building?

For consistency between the studies it has not been changed since 2019. We believe that this approach is acceptable and representative of 'Business as usual'.

	Notional building *(used in 2019 study)*	0 Notional building 2021 *(used in 2023 study)*	1 Business as usual
Description	This scenario represents the minimum energy efficiency performance required by Part L 2013 building regulations.	This scenario represents the minimum energy efficiency performance required by Part L 2021 building regulations.	This scenario represents the type of energy efficiency performance most applicants are used to deliver.
Floor U-Value (W/m^{2}K)	0.13	0.13	0.13
External wall U-Value (W/m^{2}K)	0.18	0.18	0.18
Roof U-Value (W/m^{2}K)	0.13	0.11	**0.15**
Soffit U-Value (W/m^{2}K)	N/A	N/A	N/A
Windows U-value (W/m^{2}K)* Windows g-value	 1.40 0.63	 1.20 0.63	 **1.40** **0.40**
External doors (W/m^{2}K)	N/A	N/A	N/A
Window area	As per design, windows are limited to 25% of the floor area	As per design, windows are limited to 25% of the floor area	**As per the design**
Thermal bridging (W/m^{2}K)	y-value ≃ 0.05 W/m^{2}K	y-value ≃ 0.05 W/m^{2}K	**Good practice (e.g. y-value ≃ 0.1 W/m^{2}K)**
Air Permeability (m^3/m^2/hr) at 50 Pa	5	5	**3**
Ventilation system and design	Natural ventilation with intermittent extract fans	Natural ventilation with intermittent extract fans	**Good quality MVHR** **Long ducts to outside**
MVHR heat recovery efficiency	N/A	N/A	**85%**
MVHR specific fan power	N/A	N/A	**0.8 W/l/s (SAP)** **1.75 W/l/s (PHPP)**

Table 4.4 - Mid-rise apartment example: this table compares the domestic notional building specification from building regulations Part L 2013 and 2021 with the 'business as usual' specification used in this report.

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Energy and cost modelling analysis | Heating systems modelled

Choosing which heating system to assess

Low carbon heat is one of the key pillars of Net Zero Carbon buildings and it is widely recognised that the industry is currently going through a paradigm shift. There is a move away from fossil fuel based heating systems to all electric systems (e.g heat pumps). This study looked to capture this necessary transition and its impact on carbon emissions and building energy use respectively.

There is however no 'one size fits all' low carbon heating system across all building archetypes, and there is a wide variety and complexity of heating systems available in the market. In selecting a heating system for new buildings, there are a series of pros and cons which must be considered (e.g. efficiency, space, cost, operation and maintenance, ownership, etc.) which will make a heating system more suited to some building archetypes than others.

We had to consolidate this into a reduced number of options which would be representative of new build projects in London. The heating systems considered (and summarised in the 'red' specifications table) are therefore different for each building archetype. It is important to note that the intention for selecting the heating systems proposed was to give a broad spectrum that would cover most systems typically seen in these archetypes. It is recognised that other heating systems not selected in this study may align with the performance metrics or targets suggested as part of the policy recommendations.

Why are gas boilers being considered as an option?

Gas boilers should not be used in new buildings anymore. However, the project team wanted to ensure an objective review of heating technologies that would be considered 'business as usual'. This was also important to ensure that the cost analysis was fair and representative of the current minimum building regulations compliance.

	A Gas boiler	B Direct electric	C Heat Pump System (less efficient) *Communal heat pump*	D Heat Pump System (more efficient) *Ambient loop heat pump/ Individual heat pump*
Description	Communal gas boiler supplying heat interface units in all flats	Direct electric and individual DHW tank	Communal air source heat pump supplying heat interface units in all flats	(1) communal air source heat pump OR ground loop supplying individual heat pumps through an ambient loop, or (2) individual air source heat pump system with DHW tank
Communal heating distribution and Distribution Loss Factor (DLF)	Flow and return temperature 70°C/50°C . Assumed DLF = 1.5	N/A	Flow and return temperature 60°C/40°C . Assumed DLF = 1.5	Ambient loop or N/A Assumed DLF = 1.0 or N/A
Heating emitters	LTHW radiators fed by HIU	Direct electric panel radiators	LTHW radiators fed by HIU	LTHW radiators fed by individual heat pump or warm air
Hot water system	HIU provides instantaneous hot water	80L hot water store with an immersion heater in each domestic unit	HIU provides instantaneous hot water	An 80L hot water store in each unit
Heating and hot water seasonal efficiency	93%	100%	190% space heating 210% water heating *Blended efficiencies for SAP models 1/2/3: 200% /201% / 204%*	330% space heating 280% water heating *Blended efficiencies for SAP models 1/2/3: 304% / 300% /293%*
Showers	2 showers – 8 l/min each	2 showers – 8 l/min each	2 showers – 8 l/min each	2 showers – 8 l/min each
Waste Water Heat Recovery	No WWHR assumed	No WWHR assumed	No WWHR assumed	No WWHR assumed
Internal lighting	30 light bulbs @ 5W and 95lW	30 light bulbs @ 5W and 95lW	30 light bulbs @ 5W and 95lW	30 light bulbs @ 5W and 95lW

Table 4.5 - Example of the four different heating systems considered for the mid-rise apartment building. Although the same number of systems are considered for each typology, the detailed heating system selection and specifications are specific to each typology.

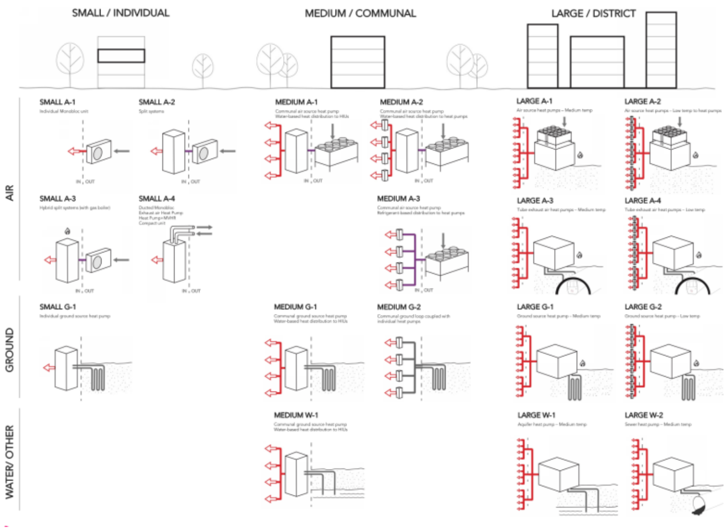

Figure 4.2 - Heat pumps are available in many different types and scales, from individual systems to large scale heat pumps (© Etude for the Greater London Authority). This study sought to select relevant solutions for each archetype, but more are possible.

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Mid rise apartment building | Building services

This table summarises the different heating system assumptions modelled based on the four different scenarios.

NEW New input for SAP 10.2

	A Gas boiler	B Direct electric*	C Less efficient Heat Pump System *Communal heat pump*	D More Efficient Heat Pump System *Communal heat pump*
Description	Communal gas boiler supplying heat interface units in all flats	Direct electric and individual hot water cylinder	Communal air source heat pump supplying heat interface units in all flats	Communal air source heat pump supplying heat interface units in all flats
Communal heating distribution and Distribution Loss Factor (DLF)	Flow and return temperature 70°C/50°C . Assumed DLF = 1.05	N/A	Flow and return temperature 65°C/50°C . Assumed DLF = 1.5	Flow and return temperature 65°C/50°C . Assumed DLF = 1.5
Heating emitters	LTHW radiators fed by HIU	Direct electric panel radiators	LTHW radiators fed by HIU	LTHW radiators fed by individual heat pump
Hot water system	HIU provides instantaneous hot water	180L hot water store with an immersion heater in each domestic unit	HIU provides instantaneous hot water	A 180L hot water store in each unit
Heating and hot water seasonal efficiency	93%	100%	190% space heating 210% water heating *Blended efficiencies for SAP models 1/2/3: 200% /201% / 204%*	330% space heating 280% water heating *Blended efficiencies for SAP models 1/2/3: 304% / 300% /293%*
Showers NEW	2 showers – 8 l/min each	2 showers – 8 l/min each	2 showers – 8 l/min each	2 showers – 8 l/min each
Waste Water Heat Recovery	No WWHR assumed	No WWHR assumed	No WWHR assumed	No WWHR assumed
Internal lighting	10 light bulbs @ 5W and 95lW	10 light bulbs @ 5W and 95lW	10 light bulbs @ 5W and 95lW	10 light bulbs @ 5W and 95lW

Table 4.6 – Specifications assumed for each type of heating system for the mid-rise apartment building

- *Please note that direct electric heating should be combined with an ultra-low level of energy use, delivered by an appropriate independently certified quality assurance standard, (e.g. Passivhaus). Otherwise, it introduces a significant risk of high energy bills for the occupants.*

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Energy and cost modelling analysis | Approach to PVs

Choosing which PV area to assess

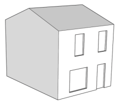
To ensure a robust and accurate evidence base for this study a PV feasibility study was undertaken for each building typology, which estimated the likely renewable energy generation from PV panels.

This page summarises its key conclusions, including the peak electrical generation output (kWp), the area of PV panels and the approximate percentage of total roof area used for PV panels.

The area for PVs and respective outputs, have been informed by similar projects, current and emerging PV panel outputs, and efforts to advocate for a 'good practice' practice' approach.

Detailed PV assumptions

Manufacturer	Longi Hi-MO6 Scientist 54 cell	Jinko - Tiger Neo N-type 72 cell
Power output, W	425	575
PV panel dimensions (mm):	1722 x 1134	1722 x 1134
PV panel efficiency:	22.5%	22.6%
Minimum distance to parapets:	Approx 0.6m	
Minimum distance to other roof structures:	Approx 1m	
Maximum overshading of PVs: *(allowable shading losses)*	10%	
Other electrical losses:	14%	

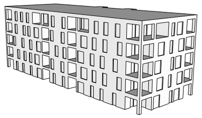


Terrace houses – 8 units

33.2 kWp

152 m² of PV panels

36% of roof area

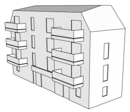


Mid-rise apartment building

54.5 kWp

250 m² of PV panels

33% of roof area

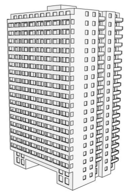


Low-rise apartment building

23.4 kWp

107 m² of PV panels

40% of roof area

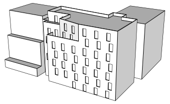


High-rise apartment building

38 kWp

170 m² of PV panels

21% of roof area



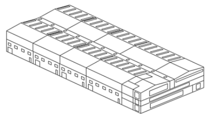
Office

54.8 kWp

432 m² of PV panels

70% of roof area

Max PV option

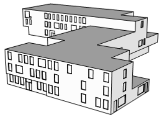


Industrial building

76.7 kWp

666 m² of PV panels

25% of roof area

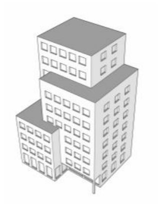


School

135.5 kWp

608 m² of PV panels

25% of roof area



Hotel

45 kWp

202 m² of PV panels

50% of roof area

Figure 4.3 – Summary of PV assumptions confirming total PV panel area and kWp output

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Mid rise apartment building | Photovoltaics (PVs)

This table summarises the different sizes of PV system assumed.

NEW New input for SAP 10.2

	Solar PVs
Description	This assumes a clear effort to design the roof in order to maximise the area of PVs.
Photovoltaic Panels (kWp)	55
Assumed area (Panel area)	250m^2
Tilt	10° (Horizontal)
Shading	Average/unknown
Battery capacity (kWh) NEW	N/A

Table 4.7 – Specifications assumed for the PV system

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4.3

Note on the assessment of heat networks in this study

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Connection to heat networks as a planning policy requirement

An important part of London's decarbonisation strategy for buildings in the last 15 years

Heat networks have been a central part of the GLA's and many London boroughs' strategy to decarbonise new and existing buildings in the last 15 years. Alongside efforts to improve energy efficiency of buildings and increase renewable energy generation, heat networks have been considered as one of the most important 'tools' available to planning officers to accelerate heat decarbonisation in London. Connection to district heating remains a policy requirement in the London Plan in Heat Network Priority Areas.

The London Plan gives heat networks priority in the 'heating hierarchy' and planning guidance seeks to ensure the delivery of good quality heat networks.

Heat network: clarification on terminology

For the purpose of this report, the term 'heat network' is to be understood as building heating systems going beyond the scale of an apartment building (which will be referred to as 'communal heating'). Heat networks connect several buildings together and to a low carbon heat source. Heat networks currently provide 2% of building heating requirements in the UK.

Scope of this report

This report shows how heat networks can be evaluated under Policy option 1 and 2. It does not include an assessment of the benefits and disadvantages of heat networks.

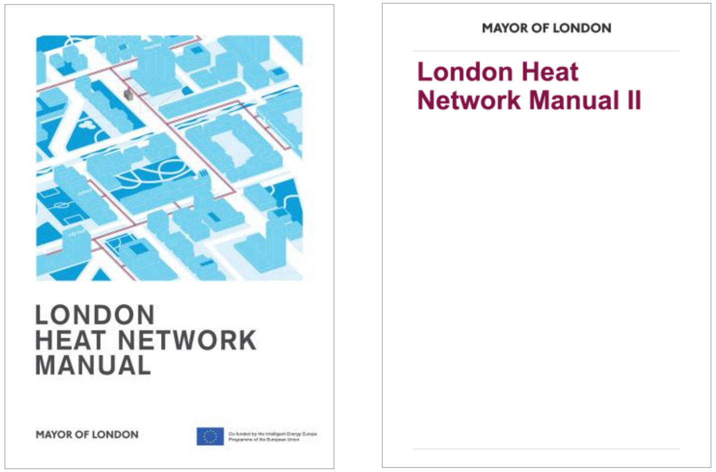
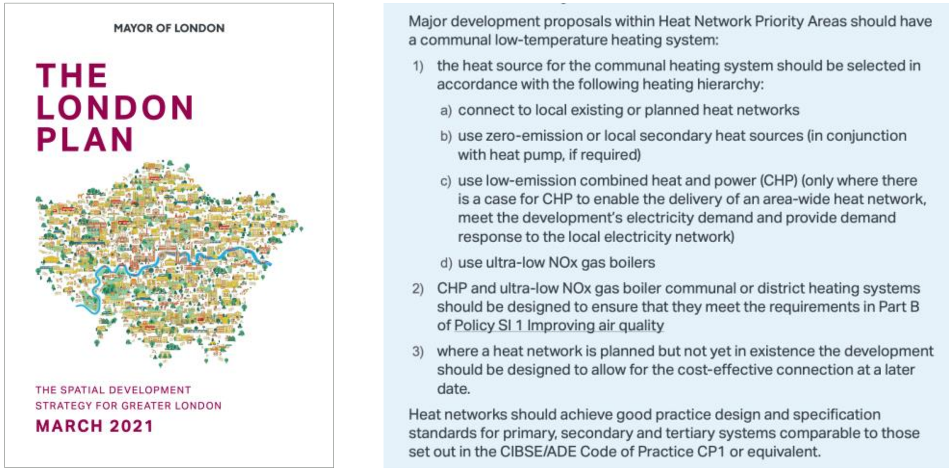


Figure 4.4 - The two versions of the London Heat Network Manuals published by the Greater London Authority in 2014 and 2021 seek to increase the quality of new heat networks in London



Major development proposals within Heat Network Priority Areas should have a communal low-temperature heating system:

1) the heat source for the communal heating system should be selected in accordance with the following heating hierarchy:
    a) connect to local existing or planned heat networks
    b) use zero-emission or local secondary heat sources (in conjunction with heat pump, if required)
    c) use low-emission combined heat and power (CHP) (only where there is a case for CHP to enable the delivery of an area-wide heat network, meet the development's electricity demand and provide demand response to the local electricity network)
    d) use ultra-low NOx gas boilers
2) CHP and ultra-low NOx gas boiler communal or district heating systems should be designed to ensure that they meet the requirements in Part B of Policy SI 1 Improving air quality
3) where a heat network is planned but not yet in existence the development should be designed to allow for the cost-effective connection at a later date.

Heat networks should achieve good practice design and specification standards for primary, secondary and tertiary systems comparable to those set out in the CIBSE/ADE Code of Practice CP1 or equivalent.

Figure 4.5 - The London Plan (2021) refers to Heat Network Priority Areas (which cover approximately half of London) including its entire central area, where heat networks are expected to be the favoured heating strategy. Connection to local or existing planned heat networks is then top of the list, without any clear reference to its carbon performance.

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Types of heat networks in London

One generic term, very different types of heat networks

The terms ‘district heating’ or ‘heat networks’ cover a wide range of realities in London. A review of the existing and planned heat networks showed a wide range of heat networks varying in terms of:

- **Heat generation**: e.g. gas-fired CHP, gas boilers, heat pumps, waste heat or Energy from Waste.
- **Status**: their growth may be complete or they may want to expand further.
- **Scale**, ranging from a few blocks to heat networks spanning over different London boroughs.
- **Supply temperature:** most heat networks operate at a temperature of 80°C or above but there is a drive towards lower temperatures.

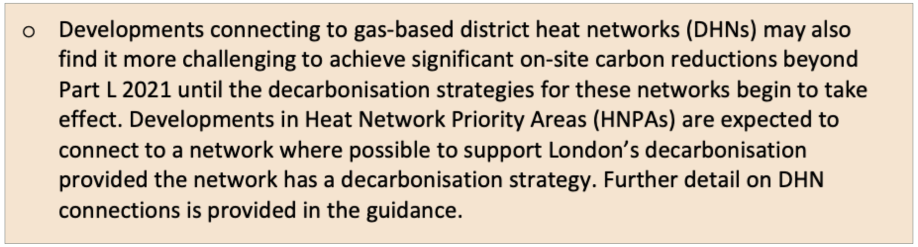
It is therefore not possible to model a ‘generic heat network’ in London. However, three conclusions emerged:

1. As the focus of this study is new buildings, we sought to model the type of networks which are seeking to expand as they are the ones to which the Council is likely to mandate connection to.

2. Energy from Waste systems (and particularly waste incineration plants) are currently considered by the UK Government as strategically important for management of municipal waste, with heat being a by product of this process. This was therefore considered as the first heat network scenario (DH1).

3. Some networks using fossil fuels (e.g. Olympic Park, Citigen) are seeking to grow and decarbonise. Therefore a heat network still using gas-fired CHP and boilers but relatively well advanced on its way to decarbonisation (40% heat pumps) was also modelled to see how it would perform. This was the second heat network scenario (DH2).

Figure 4.6 - The two types of heat networks assessed in the Towards Net Zero Carbon study



- **Developments connecting to gas-based district heat networks (DHNs) may also find it more challenging to achieve significant on-site carbon reductions beyond Part L 2021 until the decarbonisation strategies for these networks begin to take effect. Developments in Heat Network Priority Areas (HNPAs) are expected to connect to a network where possible to support London’s decarbonisation provided the network has a decarbonisation strategy. Further detail on DHN connections is provided in the guidance.**

Figure 4.7 - An extract from the GLA energy guidance cover note published in 2022, acknowledges the challenge associated with gas-based heat networks and requires them to have a decarbonisation strategy

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Heat networks case studies modelled in the Towards Net Zero Carbon study

DH1 I Energy from Waste

Figure 4.7 - Energy from Waste heat networks are centred around using heat that is produced by the process of waste incineration (above the North London Edmonton incinerator) distributing that heat to homes close to it or much further (Photograph: pxl.store/Alamy)

Generation mix	Indicative generation mix used by the BRE to derive carbon factor: 97% heat pump with heat recovered from waste combustion (COP of 10) and 3% back-up gas boilers (efficiency of 90%)
Approach to estimated carbon content of heat	Emissions associated with the incineration of waste in the carbon content of heat are disregarded.

Table 4.8 – Characteristics of DH1 assumed for the energy modelling

DH2 I Fossil fuel based heat network seeking to grow and decarbonise

Figure 4.8 - The vast majority of large existing heat networks burn fossil fuels in an Energy Centre (through CHPs and gas boilers). In order to decarbonise, they will seek to generate a growing proportion of their heat with heat pumps. DH2 represents a network targeting a 40% proportion of heat from heat pumps.

Generation mix (target)	Potential generation mix for a gas-fired CHP/ boilers significantly committed to decarbonisation: • **40% gas-fired CHP** • **20% gas-fired boilers** • **40% air source heat pump**
Approach to estimated carbon content of heat	Directly related to the generation mix and in particular the use of fossil fuels.

Table 4.9 – Characteristics of DH2 assumed for the energy modelling

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The scope of the heat network analysis in this study

Purpose of the heat networks analysis in the TNZC study

This report shows how heat networks can be evaluated under Policy option 1 and 2.

Analysis has been undertaken for:

- Two types of networks; DH1 which represents a network utilizing energy from waste and DH 2 a Legacy network seeking to decarbonise.
- a mid-rise apartment to understand what is required for domestic buildings.
- a school to understand what is required for non-domestic buildings.

The study uses generic carbon content of heat that are set out in SAP and NCM/SBEM, which vary for the different types of heat network. Carbon calculations are not based on actual forecast of the likely carbon content of heat of that network.

Exclusions

The main purpose of this report was not to consider heat networks in detail. The following exclusions were agreed with the London boroughs.

- This report does not include an assessment of the benefits and disadvantages of heat networks, or their costs/benefits.
- Assessment and comparison of various types of heat network (fossil fuel, heat pumps, waste heat and energy from waste) and non heat network solutions with net zero carbon standards.
- Detailed analysis on the feasibility of heat networks and further calculations to demonstrate how low carbon they are.
- Demonstrate how the GLA guidance can be used to expand higher carbon networks or enable the transition to low carbon networks.
- Analysis of new developments that may be next to an inefficient estate, building a larger case for this development to connect as a 'hub'.
- This report only looks at two types of network, a Legacy network seeking to decarbonise and a heat network from Energy from Waste. Other types of networks exist but have not been included.
- Only the mid-rise apartment was tested for domestic buildings and the school was tested for non-domestic, the other typologies in this report have not been tested.
- The testing carried out does not include sleeving.

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5.0

Energy modelling analysis for Part L 2021 compliance

5.0 Energy modelling analysis for Part L 2021 compliance

Before considering how Policy options 1 or 2 can go beyond the minimum requirements set by Part L 2021 it is important to assess and understand how the different archetypes and cases would perform against the different criteria of Part L 2021.

It will enable to identify, for each archetype, which combination of specifications are effectively no longer possible anyway and which ones would still comply, before further policies would apply another 'filter'.

Part L 2021 compliance for domestic buildings

5.1.1

Part L 2021 compliance for **terrace house**

5.1.2

Part L 2021 compliance for **low-rise apartment building**

5.1..3

Part L 2021 compliance for **mid-rise apartment building**

5.1.4

Part L 2021 compliance for **high-rise apartment building**

Part L 2021 compliance for non-domestic buildings

5.2.1

Part L 2021 compliance for **office building**

5.2.2

Part L 2021 compliance for **primary school**

5.2.3

Part L 2021 compliance for **industrial building**

5.2.4

Part L 2021 compliance for **hotel**

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How to read the tables in this section?

Developments must meet or exceed three criteria to pass Part L 2021, which are calculated based on the notional building: target primary energy rate (top right), target emission rate (bottom right) and, for residential developments, the target fabric energy efficiency (FEE) rate (bottom left). The tables created for each typology summarise how each case that has been modelled for this study would perform against these criteria. Cells in green or red indicate whether the scenario would pass or fail the Part L 2021 target. Percentages indicate how much the design either exceeds or fall short of the required target. Developments will not achieve Building Regulations compliance if they fail one or more of the three criteria.

Part L Compliance		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	🟥✕	🟥✕	🟥✕	🟥✕
	Good practice	🟥✕	🟥✕	🟩	🟩
	Ultra-low energy	🟩	🟩	🟩	🟩

Table 5.1 – Part L compliance - The 3 metrics combined and assessment of overall compliance

The summary table above brings together all criteria, summarising which of the scenarios would 'Fail' or 'Pass' Part L 2021 overall.

✕ Would not pass all 3 metrics of Part L 2021

Part L 2021 compliance

🟥 Fail

🟩 Pass

Fabric energy efficiency (FEE) metric

FEE SAP 10.2		
Fabric & ventilation	Business as usual	-14%
	Good practice	0%
	Ultra-low energy	31%

Table 5.2 – Performance of each case in terms of Fabric Energy Efficiency (FEE) against the Part L 2021 limit

Primary energy metric

Primary energy SAP 10.2 Part L (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	-17%	-39%	-12%	70%
	Good practice	-9%	-17%	16%	77%
	Ultra-low energy	22%	18%	33%	90%

Table 5.3 – Performance of each case in terms of Primary Energy against the Part L 2021 limit

CO_2 metric

Reduction in CO_2 - SAP 10.2 Part L (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	-14%	37%	58%	86%
	Good practice	-6%	49%	66%	90%
	Ultra-low energy	22%	67%	79%	96%

Table 5.4 – Performance of each case in terms of CO_2 against the Part L 2021 limit

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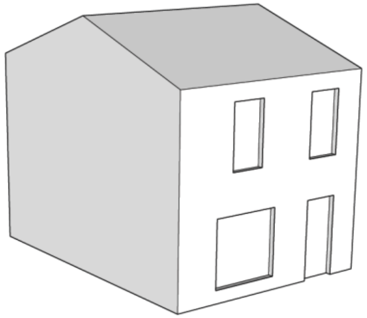
5.1

Part L 2021 compliance for domestic buildings

Return to contents >

5.1.1

Part L 2021 compliance for terrace house



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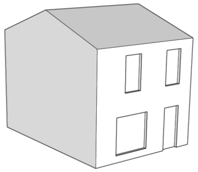
Terrace house | Compliance with Part L 2021



Part L compliance - The 3 metrics combined

	Part L Compliance	With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	🟥 ✗	🟥 ✗	🟥 ✗	🟥 ✗
	Good practice	🟩	🟩	🟩	🟩
	Ultra-low energy	🟩	🟩	🟩	🟩

Table 5.5 – Combination of compliance with the different metrics in Part L 2021 and assessment of overall compliance

Fabric energy efficiency incentivises good fabric

The fabric energy efficiency metric encourages 'good practice' and 'ultra-low energy' building fabric and ventilation systems.

✗	Would not pass all 3 metrics of Part L 2021

Part L 2021 compliance

🟥	Fail
🟩	Pass

	FEE SAP 10.2	
Fabric & ventilation	Business as usual	-16%
	Good practice	2%
	Ultra-low energy	20%

Table 5.6– Performance of each case in terms of FEE against the Part L 2021 limit

Primary energy metric has a minor effect

The use of the new primary energy metric incentivises improvements to the building fabric and/or the choice of heating and hot water system. Homes are therefore required to either have a better fabric when using fossil fuels or use a heat pump.

	Primary energy SAP 10.2 Part L (reg)	With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	-1%	-16%	62%	67%
	Good practice	20%	8%	72%	75%
	Ultra-low energy	43%	37%	83%	84%

Table 5.7 – Performance of each case in terms of Primary Energy against the Part L 2021 limit

CO_2 metric does very little

The CO_2 metric does not disincentivise the use of gas. It does little to ensure buildings reduce their carbon emissions further.

	Reduction in CO_2 - SAP 10.2 Part L (reg)	With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	4%	52%	92%	95%
	Good practice	23%	64%	98%	99%
	Ultra-low energy	45%	79%	103%	104%

Table 5.8 – Performance of each case in terms of CO_2 against the Part L 2021 limit

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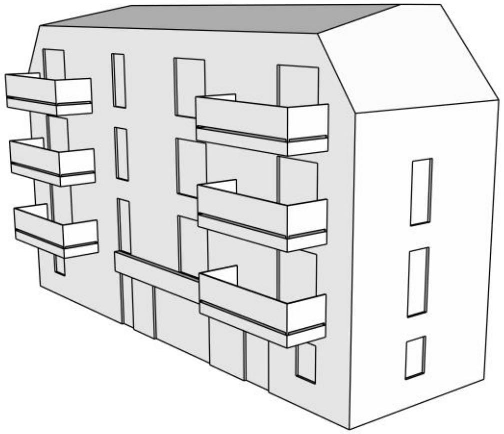
5.1.2

Part L 2021 compliance for low-rise apartment building



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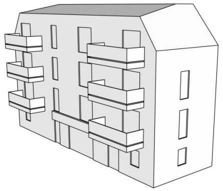
Low-rise apartment building | Compliance with Part L 2021



Part L compliance - The 3 metrics combined

Part L Compliance		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	✗	✗	✗	✗
	Good practice	🟩	🟩	🟩	🟩
	Ultra-low energy	🟩	🟩	🟩	🟩

Table 5.9 – Combination of compliance with the different metrics in Part L 2021 and assessment of overall compliance

Fabric energy efficiency incentivises good fabric

The fabric energy efficiency metric encourages 'good practice' and 'ultra-low energy' building fabric and ventilation systems.

Would not pass all 3 metrics of Part L 2021	Part L 2021 compliance	
✗	Fail	Pass

FEE SAP 10.2		
Fabric & ventilation	Business as usual	-14%
	Good practice	4%
	Ultra-low energy	28%

Table 5.10 – Performance of each case in terms of FEE against the Part L 2021 limit

Primary energy metric does very little

The use of the new primary energy metric does little to incentivise improvements to the building fabric and/or the choice of heating and hot water system. Only the direct electric system for the worst performing fabric is non-compliant.

Primary energy SAP 10.2 Part L (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	4%	-4%	14%	48%
	Good practice	20%	14%	30%	58%
	Ultra-low energy	42%	38%	51%	71%

Table 5.11 – Performance of each case in terms of Primary Energy against the Part L 2021 limit

CO_2 metric does very little

The CO_2 metric does not disincentivise the use of gas. It does little to ensure buildings reduce their carbon emissions further.

Reduction in CO_2 - SAP 10.2 Part L (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	7%	55%	67%	84%
	Good practice	22%	64%	75%	89%
	Ultra-low energy	43%	77%	86%	96%

Table 5.12 – Performance of each case in terms of CO_2 against the Part L 2021 limit

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5.1.3

Part L 2021 compliance for mid-rise apartment building

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Mid-rise apartment bulding | Compliance with Part L 2021

Part L compliance - The 3 metrics combined

Part L Compliance		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	✗	✗	✗	✗
	Good practice	🟩	🟩	🟩	🟩
	Ultra-low energy	🟩	🟩	🟩	🟩

Table 5.13 – Combination of compliance with the different metrics in Part L 2021 and assessment of overall compliance

Primary energy metric has a minor effect

The use of the new primary energy metric incentivises improvements to the building fabric and/or the choice of heating and hot water system. Homes are therefore required to either have a better fabric when using fossil fuels or use a heat pump.

Primary energy SAP 10.2 Part L (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	-2%	-12%	8%	38%
	Good practice	11%	2%	20%	45%
	Ultra-low energy	28%	22%	36%	54%

Table 5.15 – Performance of each case in terms of Primary Energy against the Part L 2021 limit

Fabric energy efficiency incentivises good fabric

The fabric energy efficiency metric encourages 'good practice' and 'ultra-low energy' building fabric and ventilation systems.

Would not pass all 3 metrics of Part L 2021

✗

Part L 2021 compliance

🟥 Fail

🟩 Pass

FEE SAP 10.2		
Fabric & ventilation	Business as usual	-11%
	Good practice	4%
	Ultra-low energy	26%

Table 5.14 – Performance of each case in terms of FEE against the Part L 2021 limit

CO_2 metric does very little

The CO_2 metric does not disincentivise the use of gas. It does little to ensure buildings reduce their carbon emissions further.

Reduction in CO_2 - SAP 10.2 Part L (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	1%	46%	57%	72%
	Good practice	13%	53%	62%	75%
	Ultra-low energy	29%	64%	72%	81%

Table 5.16 – Performance of each case in terms of CO_2 against the Part L 2021 limit

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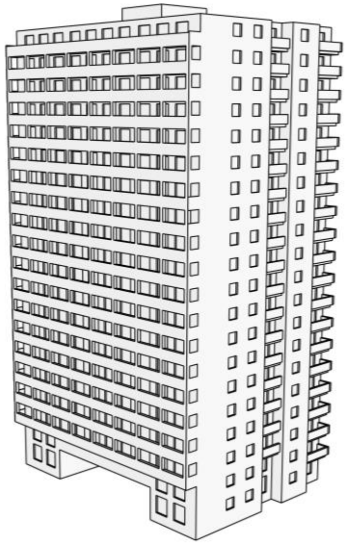
5.1.4

Part L 2021 compliance for high-rise apartment building



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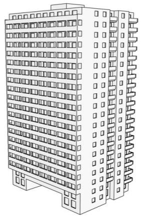
High-rise apartment building | Compliance with Part L 2021



Part L compliance - The 3 metrics combined

Part L Compliance		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	☒	☒	☒	☒
	Good practice	🟩	🟩	🟩	🟩
	Ultra-low energy	🟩	🟩	🟩	🟩

Table 5.17 – Combination of compliance with the different metrics in Part L 2021 and assessment of overall compliance

Fabric energy efficiency incentivises good fabric

The fabric energy efficiency metric encourages 'good practice' and 'ultra-low energy' building fabric and ventilation systems.

Part L 2021 compliance

- ☒ Would not pass all 3 metrics of Part L 2021
- 🟥 Fail
- 🟩 Pass

FEE SAP 10.2		
Fabric & ventilation	Business as usual	-12%
	Good practice	0%
	Ultra-low energy	8%

Table 5.18 – Performance of each case in terms of FEE against the Part L 2021 limit

Primary energy metric does very little

The use of the new primary energy metric does little to incentivise improvements to the building fabric and/or the choice of heating and hot water system. Only the direct electric system for the worst performing fabric is non-compliant.

Primary energy SAP 10.2 Part L (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	7%	-18%	9%	41%
	Good practice	20%	11%	28%	50%
	Ultra-low energy	29%	27%	37%	58%

Table 5.19 – Performance of each case in terms of Primary Energy against the Part L 2021 limit

CO_2 metric does very little

The CO_2 metric does not disincentivise the use of gas. It does little to ensure buildings reduce their carbon emissions further.

Reduction in CO_2 - SAP 10.2 Part L (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	6%	52%	60%	75%
	Good practice	16%	56%	65%	77%
	Ultra-low energy	24%	63%	69%	81%

Table 5.20 – Performance of each case in terms of CO_2 against the Part L 2021 limit

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5.2

Part L 2021 compliance for non-domestic buildings

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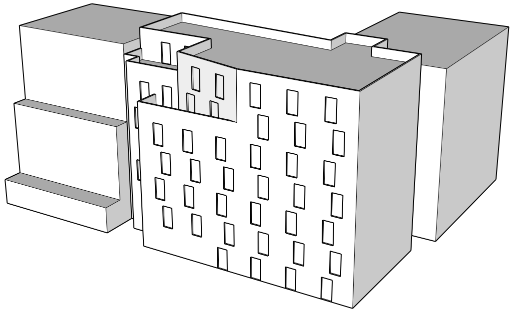
5.2.1

Part L 2021 compliance for office building



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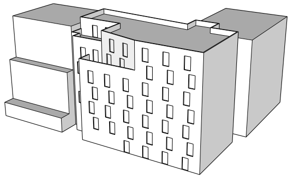
Office building I Compliance with Part L 2021



Part L compliance - The 2 metrics combined

Part L Compliance		With PV			
		Gas boiler	VRF	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	🟥 ✗	🟩	🟩	🟩
	Good practice	🟩	🟩	🟩	🟩
	Ultra-low energy	🟩	🟩	🟩	🟩

Table 5.21 – Combination of compliance with the different metrics in Part L 2021 and assessment of overall compliance

Metrics combined

Both building regulations metrics (primary energy and carbon) have been overlayed in the table above.

Our analysis shows that Part L2 2021 is not very effective at preventing fossil fuel heating from complying with building regulations or at encouraging better fabric, ventilation and heating systems.

Primary Energy and CO_2 metrics

Results show that all, except the 'Gas boiler' scenario under 'Business as usual' comply with the primary energy target.

Primary energy (with the 50% PV area) is not adding any incentives to increasing fabric or system performance, in addition to the CO_2 metric.

✗ Would not pass both metrics of Part L 2021

Part L 2021 compliance

🟥 Fail

🟩 Pass

Primary energy NCM - SAP 10.2 Part L (reg)		With PV			
		Gas boiler	VRF	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	-8%	15%	9%	16%
	Good practice	14%	31%	27%	32%
	Ultra-low energy	25%	33%	31%	33%

Table 5.22 – Performance of each case in terms of Primary Energy against the Part L 2021 limit

Reduction in CO_2 - NCM - SAP 10.2 Part L (reg)		With PV			
		Gas boiler	VRF	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	-22%	13%	6%	14%
	Good practice	7%	29%	25%	30%
	Ultra-low energy	26%	32%	30%	32%

PV area covering 50% of the building footprint area

Table 5.23 – Performance of each case in terms of CO_2 against the Part L 2021 limit

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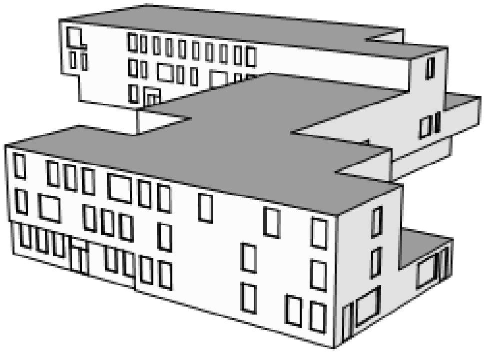
5.2.2

Part L 2021 compliance for primary school



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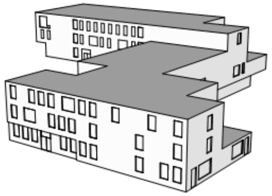
Primary school building | Compliance with Part L 2021



Part L compliance - The 2 metrics combined

Part L Compliance		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	🟩	🟩	🟩	🟩
	Good practice	🟩	🟩	🟩	🟩
	Ultra-low energy	🟩	🟩	🟩	🟩

Table 5.24 – Combination of compliance with the different metrics in Part L 2021 and assessment of overall compliance

Metrics combined

Both building regulations metrics (primary energy and carbon) have been overlayed in the table above.

Our analysis shows that Part L2 2021 is not very effective at preventing fossil fuel heating from complying with building regulations or at encouraging better fabric, ventilation and heating systems.

Primary Energy and CO_2 metrics

Results show that all proposed scenarios comply with the primary energy and carbon targets.

Would not pass both metrics of Part L 2021

✗

Part L 2021 compliance

🟥	🟩
Fail	Pass

Primary energy NCM - SAP 10.2 Part L (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	52%	21%	81%	83%
	Good practice	34%	13%	45%	45%
	Ultra-low energy	91%	85%	88%	88%

Table 5.25 – Performance of each case in terms of Primary Energy against the Part L 2021 limit

Reduction in CO_2 - NCM - SAP 10.2 Part L (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	27%	11%	75%	77%
	Good practice	26%	3%	40%	40%
	Ultra-low energy	636%	73%	83%	83%

PV area covering 25% of the building footprint area

Table 5.26 – Performance of each case in terms of CO_2 against the Part L 2021 limit

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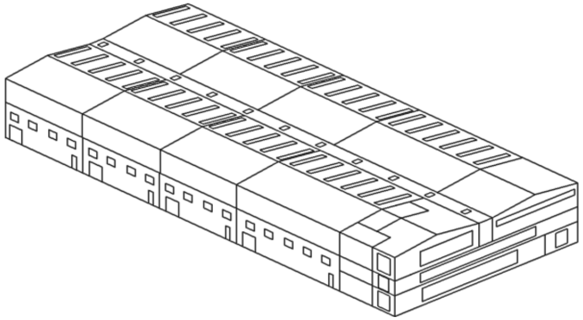
5.2.3

Part L 2021 compliance for industrial building



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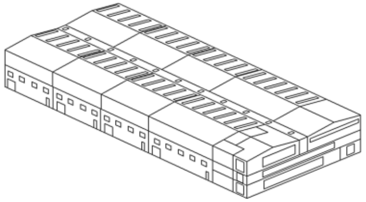
Industrial building | Compliance with Part L 2021



Part L compliance - The 2 metrics combined

Part L Compliance		With PV			
		Gas boiler	VRF	Four pipe chiller	Heat pump more efficient
Fabric & ventilation	Business as usual	🟥 ✗	🟩	🟩	🟩
	Good practice	🟥 ✗	🟩	🟩	🟩
	Ultra-low energy	🟩	🟩	🟩	🟩

Table 5.27 – Combination of compliance with the different metrics in Part L 2021 and assessment of overall compliance

Metrics combined

Both building regulations metrics (primary energy and carbon) have been overlayed in the table above.

Our analysis shows that Part L2 2021 is not very effective at preventing fossil fuel heating from complying with building regulations or at encouraging better fabric, ventilation and heating systems.

Primary Energy and CO_2 metrics

Results show that all proposed scenarios comply with the primary energy target, apart from gas boiler with 'Business as usual' and 'Good practice' fabrics.

For schemes with a gas boiler, the primary energy metric is incentivising the use of better fabric performance for the Industrial typology. For any scheme without a gas boiler, it does not incentivise the use of better fabric performance.

✗ Would not pass both metrics of Part L 2021

Part L 2021 compliance

🟥 Fail

🟩 Pass

Primary energy NCM - SAP 10.2 Part L (reg)		With PV			
		Gas boiler	VRF	Four pipe chiller	Heat pump more efficient
Fabric & ventilation	Business as usual	🟥 -5%	🟩 44%	🟩 42%	🟩 56%
	Good practice	🟥 -11%	🟩 44%	🟩 42%	🟩 56%
	Ultra-low energy	🟩 4%	🟩 47%	🟩 48%	🟩 63%

Table 5.28 – Performance of each case in terms of Primary Energy against the Part L 2021 limit

Reduction in CO_2 - NCM - SAP 10.2 Part L (reg)		With PV			
		Gas boiler	VRF	Four pipe chiller	Heat pump more efficient
Fabric & ventilation	Business as usual	🟩 0%	🟩 41%	🟩 40%	🟩 53%
	Good practice	🟩 6%	🟩 41%	🟩 40%	🟩 53%
	Ultra-low energy	🟩 21%	🟩 48%	🟩 46%	🟩 61%

Table 5.29 – Performance of each case in terms of CO_2 against the Part L 2021 limit

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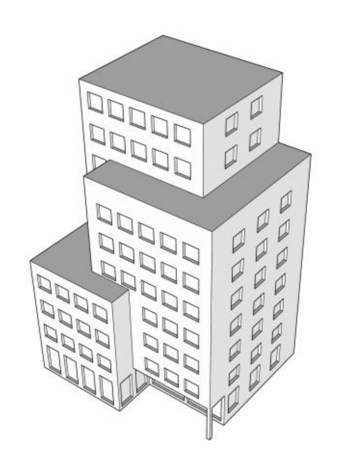
5.2.4

Part L 2021 compliance for hotel



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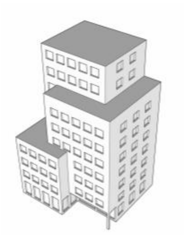
Hotel building I Compliance with Part L 2021



Part L compliance - The 2 metrics combined

	Part L Compliance	With PV			
		Gas boiler	Heat pump (220)	Heat pump (400/300)	Heat pump (450/300)
Fabric & ventilation	Business as usual	🟥 ✗	🟥 ✗	🟩	🟩
	Good practice	🟥 ✗	🟥 ✗	🟩	🟩
	Ultra-low energy	🟩	🟥 ✗	🟩	🟩

Table 5.30 – Combination of compliance with the different metrics in Part L 2021 and assessment of overall compliance

Metrics combined

Both building regulations metrics (primary energy and carbon) have been overlayed in the table above.

Our analysis shows that Part L2 2021 is not very effective at preventing fossil fuel heating from complying with building regulations or at encouraging better fabric, ventilation and heating systems.

Primary Energy and CO_2 metrics

Results show the same pattern of pass/fail as primary energy as for CO_2 emission reductions.

Primary energy (with the 50% PV area) does not add any incentive to increase fabric or system performance, in addition to the CO_2 metric.

✗	Would not pass both metrics of Part L 2021
🟥	Fail
🟩	Pass

Part L 2021 compliance

	Primary energy NCM - SAP 10.2 Part L (reg)	With PV			
		Gas boiler	Heat pump (220)	Heat pump (400/300)	Heat pump (450/300)
Fabric & ventilation	Business as usual	0%	-17%	8%	8%
	Good practice	3%	-13%	11%	11%
	Ultra-low energy	7%	-6%	17%	17%

Table 5.31 – Performance of each case in terms of Primary Energy against the Part L 2021 limit

	Reduction in CO_2 - NCM - SAP 10.2 Part L (reg)	With PV			
		Gas boiler	Heat pump (220)	Heat pump (400/300)	Heat pump (450/300)
Fabric & ventilation	Business as usual	-2%	-18%	7%	8%
	Good practice	2%	-13%	10%	11%
	Ultra-low energy	4%	-7%	16%	16%

Table 5.32 – Performance of each case in terms of CO_2 against the Part L 2021 limit

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6.0

Energy modelling analysis for Policy option 1 (Carbon improvement over the notional building using the Part L framework)

6.0 Energy modelling analysis for Policy option 1

Policy option 1 uses the Part L framework, and in particular its CO_2 metric to go beyond the requirements of Part L 2021 of the Building Regulations. Demonstration of compliance with these requirements is evidenced by the use of Part L modelling.

This section provides, for each archetype, the performance of each case against the CO_2 requirement of Part L 2021. This enables to see which cases comply with the 35% CO_2 reduction over Part L 2021 currently required by the GLA energy guidance (2022). It also enables to see which cases would not comply and which ones would perform significantly better.

Based on the findings of section 5.0, we can overlay compliance with all criteria in Part L 2021 with the CO_2 reduction over the Part L 2021 limit from this section. This enables to see whether and how planning policy option 1 would be successful at incentivising the design and construction of better buildings, which additional ‘filter’ Policy option 1 would effectively apply.

In terms of energy efficiency, this section also provides, for each archetype, the performance of each fabric and ventilation, against the ‘Be Lean’ requirement from the GLA.

A particular analysis on heat networks has also been undertaken to investigate how they are likely to perform under policy option 1.

Policy option 1 - Part L analysis for domestic buildings

6.1.1
Policy option 1 - Part L analysis for **terrace house**

6.1.2
Policy option 1 - Part L analysis for **low-rise apartment building**

6.1..3
Policy option 1 - Part L analysis for **mid-rise apartment building**

6.1.4
Policy option 1 - Part L analysis for **high-rise apartment building**

Policy option 1 - Part L analysis for non-domestic buildings

6.2.1
Policy option 1 - Part L analysis for **office building**

6.2.2
Policy option 1 - Part L analysis for **primary school**

6.2.3
Policy option 1 - Part L analysis for **industrial building**

6.2.4
Policy option 1 - Part L analysis for **hotel**

Policy option 1 - how are heat networks assessed and how do they perform?

Policy option 1 - summary

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How to read the tables in this section?

Most tables in this section indicate, , for each archetype, which carbon reduction over Part L 2021 is achieved by each combination of fabric and ventilation specifications and heating systems, all with PVs.

The results are colour coded using a clear key ranging from dark red (i.e. over the Part L 2021 CO_2 limit), through light red (better than the Part L 2021 CO_2 limit but not compliant with the 35% requirement) to dark green (>80% reduction over the Part L 2021 CO_2 limit).

Cases which comply with the 35% requirement are circled in blue on some tables.

Cases which do not comply with all Part L 2021 criteria are identified with a dark red cross.

Finally, separate tables indicate the likely 'Be Lean' performance of the three levels of fabric and ventilation.

Reduction in CO_2 - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	✗ 1%	✗ 46%	✗ 57%	✗ 72%
	Good practice	13%	53%	62%	75%
	Ultra-low energy	29%	64%	72%	81%

Table 6.1 – Performance of each case in terms of CO_2 against the Part L 2021 limit

Reduction in CO_2 - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	1%	46%	57%	72%
	Good practice	13%	53%	62%	75%
	Ultra-low energy	29%	64%	72%	81%

Table 6.2 – Performance of each case in terms of CO_2 overlaid with compliance with all Part L 2021 criteria

< 0%	< 35%	< 50%	< 60%	60-80%	> 80%	35% compliant

Figure 6.1 – Ranges of performance used to help the reader visualise the level of performance

✗ Would not pass all building regulations Part L 2021 metrics

Figure 6.2 – Graphical code to help the reader understand which cases would not be Part L compliant

Reduction in CO_2 - SAP 10.2 GLA (reg)		No PV
		Be Lean
Fabric & ventilation	Business as usual	-8%
	Good practice	7%
	Ultra-low energy	28%

Table 6.2 – Performance of the three levels of fabric and ventilation performance against the GLA's Be Lean requirement

< 10%	>= 10%

Figure 6.3 – Ranges of performance used to help the reader visualise the level of performance

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6.1

Policy option 1 - Part L analysis for domestic buildings

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Policy option 1 | Note on Waste Water Heat Recovery (WWHR) in domestic buildings

Under Part L 2021, waste water heat recovery (WWHR) systems have become embedded into the "notional specification" which is used to generate the Target Emission Rate (TER), i.e. the Part L 2021 CO_2 limit, and therefore the 'Be Lean' baseline.

Waste Water Heat Recovery in the 2019 study

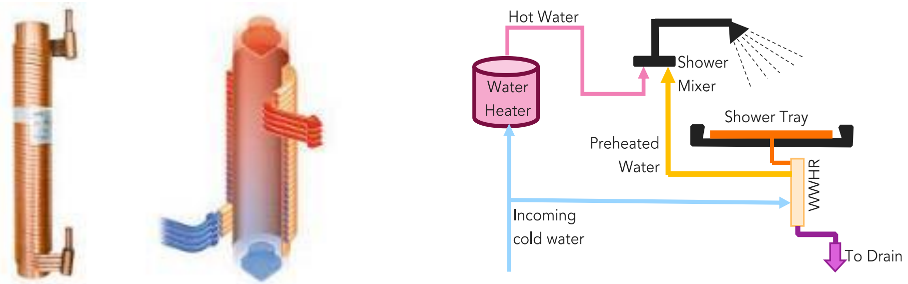
In the Cost of Carbon study (2019), WWHR was included in the 'more efficient heat pump' scenarios, the most efficient building services selection. However, as WWHR is now included in the TER and the 'Be Lean' baseline, we did not consider appropriate to have WWHR only in one of the building services scenarios. It was therefore removed from all building services scenarios.

What is the impact of WWHR in SAP calculations?

'Be Lean' calculations required by London Plan policy are based on the notional building specification (TER) set out in Part L 2021. Previously, the notional building in Part L 2013 did not include WWHR in the TER.

As WWHR has a significant effect on the calculations, a development could provide calculations that pass the 'Be Lean' requirement through including WWHR systems without improving the building fabric much beyond 'Business as Usual'. Furthermore, proposals with high-performance fabric and ventilation could be penalised for not including WWHR.

The adjacent graph illustrates this risk: the WWHR turns a scheme which would be worse than the 'Be Lean' baseline into one exceeding it by 9%, very close to the 10% 'Be Lean' requirement.



WWHR vertical pipe installation © Power pipe UK

WWHR example operation schematic

Figure 6.4 - What is WWHR and how does it work?
A WWHR system is a heat recovery device that recycles the heat energy from waste water. The technology can recover heat from any appliance or fitting that discharges hot water to the foul drains, such as a shower. The heat recovered is then used immediately to reduce the energy required to heat the shower water. WWHR tend to have no moving or active parts, recovering heat passively.

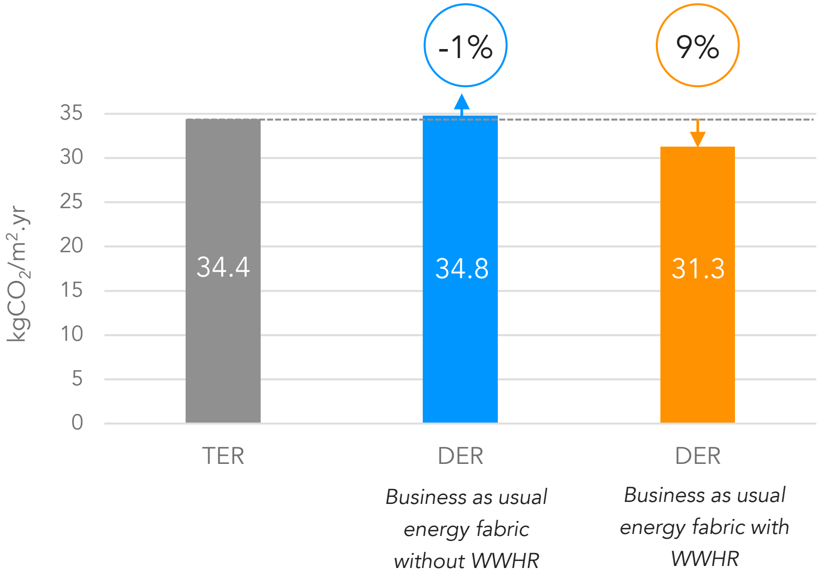


Figure 6.5 - The chart above shows the impact of WWHR on the GLA 'Be Lean' case in a mid-rise apartment building. A significantly greater reduction in CO_2 emissions is achieved when WWHR is included in the proposed building specification.

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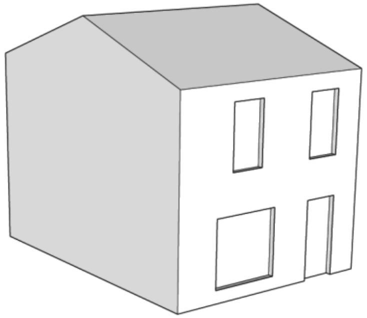
6.1.1

Policy option 1 - Part L analysis for terrace house



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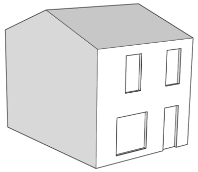
Terrace house | Policy option 1 | Improvement over Part L (regulated carbon emissions)

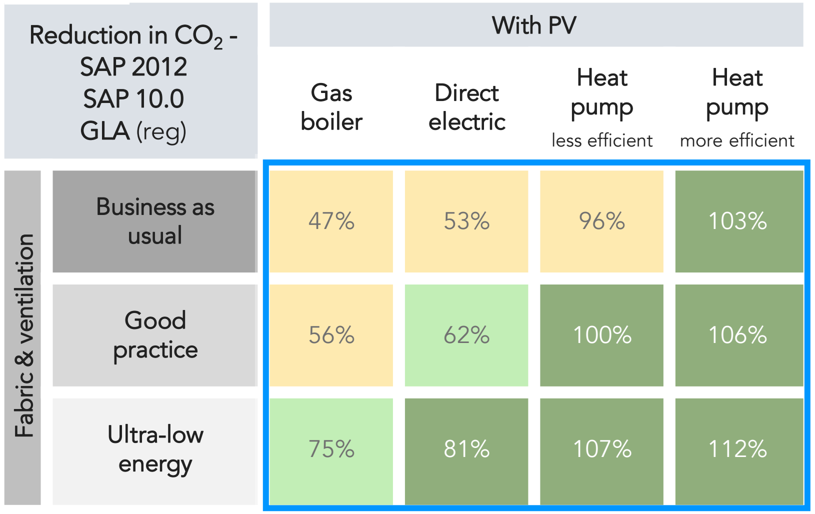


Findings of the 2019 study

London Plan policy of a 35% reduction in CO_2 emissions on-site on Part L 2013 (using SAP 10.0 emission factors) did not prevent the use of gas boilers. A more demanding requirement would incentivise heat pumps more.

35% compliant
< 0%
< 35%
< 60%
60-80%
> 80%

2019 study



Reduction in CO_2 - SAP 2012 SAP 10.0 GLA (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	47%	53%	96%	103%
	Good practice	56%	62%	100%	106%
	Ultra-low energy	75%	81%	107%	112%

Table 6.4 – Performance of each case in terms of CO_2 against the Part L 2013 baseline

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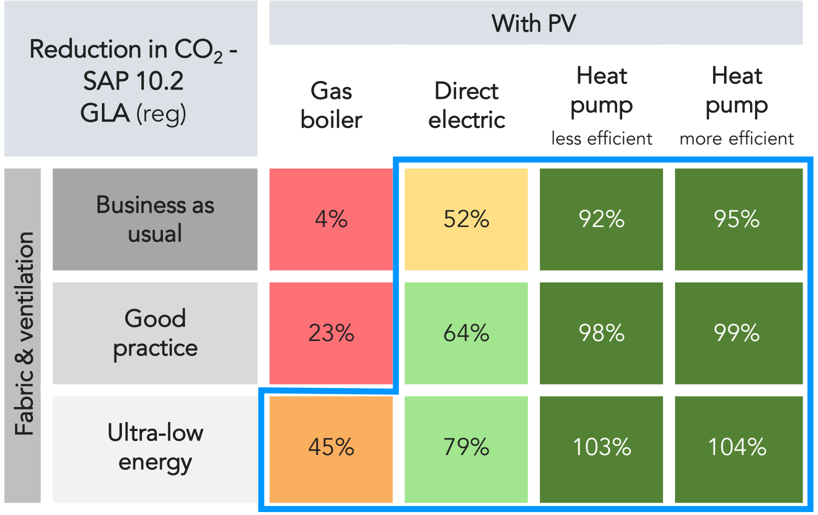
Findings of the 2023 study

A 35% improvement on Part L 2021 would not be effective at preventing the use of gas boilers. Also, it would not be sufficient to encourage developments to achieve further efficiencies through the fabric or heating system. A 50% 'benchmark' target improvement over Part L 2021 could be more effective in limiting applicants to direct electric or heat pumps, but an even more ambitious target would be required to drive further improvements to building fabric and ventilation. Direct electric should be combined with an appropriate performance standard, such as the Passivhaus standard).

35% compliant
< 0%
< 35%
< 50%
< 60%
60-80%
> 80%

2023 study



Reduction in CO_2 - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	4%	52%	92%	95%
	Good practice	23%	64%	98%	99%
	Ultra-low energy	45%	79%	103%	104%

Table 6.5 – Performance of each case in terms of CO_2 against the Part L 2021 baseline

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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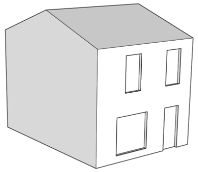
Terrace house | Policy option 1 | Improvement over Part L 2021 + Compliance with Part L 2021



Metrics combined

Part L compliance drives the ‘good practice’ and ‘ultra-low energy’ fabric specifications by ruling out a ‘business as usual’ level of fabric and ventilation performance.

The GLA's latest Energy Assessment Guidance (2022) sets an on-site 35% target improvement on Part L 2021. Our modelling results for this building type suggest that a 35% target would help to make it more challenging for a gas boiler scenario, however a benchmark 50% target would be even more effective.

A more ambitious target would incentivise even better designs and would be technically feasible.

Reduction in CO_2 - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	~~4%~~	~~52%~~	~~92%~~	~~95%~~
	Good practice	23%	64%	98%	99%
	Ultra-low energy	45%	79%	103%	104%

Table 6.6 – Performance of each case in terms of CO_2 overlaid with compliance with all Part L 2021 criteria

✗ Would not pass all 3 building regulations Part L 2021 metrics

< 0%	< 35%	< 50%	< 60%	60-80%	> 80%

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well

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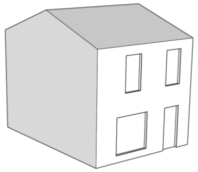
Terrace house I Policy option 1 I Be Lean



Findings of the 2019 study

All scenarios tested achieved a 10% reduction in emissions, therefore complying/exceeding the London Plan 'Be Lean' policy requirement.

For the terrace house, the Be Lean requirement was therefore not effective at incentivising more energy efficient fabric and ventilation specification.

🟥 < 10% 🟩 >= 10%

2019 study

	Reduction in CO$_2$ - SAP 2012 SAP 10.0 GLA (reg)	No PV Be Lean
Fabric & ventilation	Business as usual	10%
	Good practice	19%
	Ultra-low energy	37%

Table 6.7 – Performance of the three levels of fabric and ventilation performance against the Be Lean requirement (2019 study)

Findings of the 2023 study

A home with 'good practice' or 'ultra-low energy' fabric achieves greater than a 10% reduction in CO$_2$ from fabric and ventilation.

For the terrace house it also appears that the changes between each of the fabric specifications causes a large change in the result. This is less apparent in the other house typologies.

The inclusion of a waste water heat recovery (WWHR) system could allow even the 'business as usual' fabric scenario to meet the 10% reduction requirement. The inclusion of WWHR in schemes has the potential to mask the improvement or lack of improvement of the building fabric.

Using the Fabric Energy Efficiency indicator from Part L 2021 may be an alternative.

🟥 < 10% 🟩 >= 10%

2023 study

	Reduction in CO$_2$ - SAP 10.2 GLA (reg)	No PV Be Lean
Fabric & ventilation	Business as usual	-2%
	Good practice	18%
	Ultra-low energy	40%

Table 6.8 – Performance of the three levels of fabric and ventilation performance against the Be Lean requirement (2023 study)

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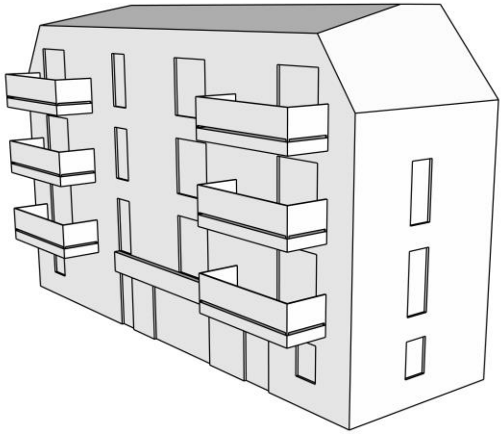
6.1.2

Policy option 1 - Part L analysis for low-rise apartment building



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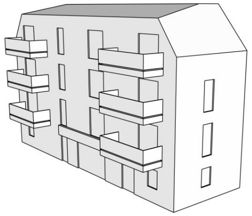
Low-rise apartment building | Policy option 1 | Improvement over Part L (regulated carbon emissions)



Findings of the 2019 study

London Plan policy of a 35% reduction in CO$_2$ emissions on-site on Part L 2013 (using SAP 10.0 emission factors) did not prevent the use of gas boilers, nor directly incentivise heat pumps.

35% compliant | < 0% | < 35% | < 60% | 60-80% | > 80%

2019 study

Reduction in CO$_2$ - SAP 2012 SAP 10.0 GLA (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	47%	53%	96%	103%
	Good practice	56%	62%	100%	106%
	Ultra-low energy	75%	81%	107%	112%

Table 6.9 – Performance of each case in terms of CO$_2$ against the Part L 2013 baseline

Findings of the 2023 study

A 35% improvement on Part L 2021 would not be effective at preventing the use of gas boilers. Also, it would not be sufficient to encourage developments to achieve further efficiencies through the fabric or heating system. A 50% 'benchmark' target improvement over Part L 2021 would be more effective in limiting applicants to direct electric or heat pumps, but an even more ambitious target would be required to drive further improvements to building fabric and ventilation. Direct electric should be combined with an appropriate performance standard, such as the Passivhaus standard).

35% compliant | < 0% | < 35% | < 50% | < 60% | 60-80% | > 80%

2023 study

Reduction in CO$_2$ - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	7%	55%	67%	84%
	Good practice	22%	64%	75%	89%
	Ultra-low energy	43%	77%	86%	96%

Table 6.10 – Performance of each case in terms of CO$_2$ against the Part L 2021 baseline

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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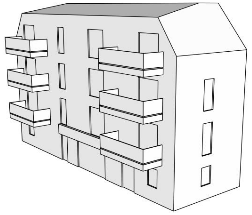
Low-rise apartment building | Policy option 1 | Improvement over Part L 2021 + Compliance with Part L 2021



Metrics combined

Part L compliance drives the 'good practice' and 'ultra-low energy' fabric specifications by ruling out a 'business as usual' level of fabric and ventilation performance.

The GLA's latest Energy Assessment Guidance (2022) sets an on-site 35% target improvement on Part L 2021. Our modelling results for this building type suggest that a 35% target would help to make it more challenging for a gas boiler scenario, however a benchmark 50% target would be even more effective.

A more ambitious target would incentivise even better designs and would be technically feasible.

Reduction in CO_2 - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	~~7%~~	~~55%~~	~~67%~~	~~84%~~
	Good practice	22%	64%	75%	89%
	Ultra-low energy	43%	77%	86%	96%

Table 6.11 – Performance of each case in terms of CO_2 overlaid with compliance with all Part L 2021 criteria

✗ Would not pass all 3 building regulations Part L 2021 metrics

< 0%	< 35%	< 50%	< 60%	60-80%	> 80%

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well

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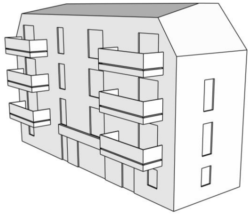
Low-rise apartment building | Policy option 1 | Be Lean



Findings of the 2019 study

The ‘good practice’ and ‘ultra-low energy’ fabric scenarios tested achieved greater than a 10% reduction in emissions, therefore exceeding the London Plan 'Be Lean' policy requirement. This requirement was therefore effective at encouraging energy efficiency improvements in the building fabric and ventilation specification.

🟥 < 10%	🟩 >= 10%

2019 study

Reduction in CO_2 - SAP 2012 SAP 10.0 GLA (reg)		No PV Be Lean
Fabric & ventilation	Business as usual	-4%
	Good practice	15%
	Ultra-low energy	33%

Table 6.12 – Performance of the three levels of fabric and ventilation performance against the Be Lean requirement (2019 study)

Findings of the 2023 study

Only a low-rise apartment building with ‘ultra-low energy’ fabric achieves greater than a 10% reduction in CO_2 from fabric and ventilation improvements, but it does it with a significant margin. There is a significant jump in results between the ‘good practice’ and ‘ultra-low energy’ fabric specifications, and the ‘good practice’ does not quite meet the 10% reduction. This suggests that the threshold for complying is somewhere between ‘good practice’ and ‘ultra-low energy’. The ‘Be Lean’ requirement is therefore effective at driving more energy efficient building fabric and ventilation specification.

The inclusion of a waste water heat recovery (WWHR) system could allow the ‘good practice’ fabric scenario to meet the 10% reduction requirement, but it is unlikely that it would allow the ‘business as usual’ specification to pass.

🟥 < 10%	🟩 >= 10%

2023 study

Reduction in CO_2 - SAP 10.2 GLA (reg)		No PV Be Lean
Fabric & ventilation	Business as usual	-8%
	Good practice	7%
	Ultra-low energy	28%

Table 6.13 – Performance of the three levels of fabric and ventilation performance against the Be Lean requirement (2023 study)

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6.1.3

Policy option 1 - Part L analysis for mid-rise apartment building

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Mid-rise apartment building | Policy option 1 | Improvement over Part L (regulated carbon emissions)

Findings of the 2019 study

London Plan policy of a 35% reduction in CO_2 emissions on-site on Part L 2013 (using SAP 10.0 emission factor) did not prevent the use of gas boilers. A more demanding requirement would incentivise heat pumps.

35% compliant	< 0%	< 35%	< 60%	60-80%	> 80%

2019 study

Reduction in CO_2 - SAP 2012 SAP 10.0 GLA (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	26%	40%	71%	87%
	Good practice	36%	51%	77%	91%
	Ultra-low energy	51%	66%	86%	96%

Table 6.14 – Performance of each case in terms of CO_2 against the Part L 2013 baseline

Findings of the 2023 study

A 35% improvement on Part L 2021 would be effective at preventing the use of gas boilers. However, it would not be sufficient to encourage developments to achieve further efficiencies through the fabric or heating system. A 50% 'benchmark' target improvement over Part L 2021 would be more effective in limiting applicants to direct electric or heat pumps, but an even more ambitious target would be required to drive further improvements to building fabric and ventilation. Direct electric should be combined with an appropriate performance standard, such as the Passivhaus standard).

35% compliant	< 0%	< 35%	< 50%	< 60%	60-80%	> 80%

2023 study

Reduction in CO_2 - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	1%	46%	57%	72%
	Good practice	13%	53%	62%	75%
	Ultra-low energy	29%	64%	72%	81%

Table 6.15 – Performance of each case in terms of CO_2 against the Part L 2021 baseline

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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Mid-rise apartment building | Policy option 1 | Improvement over Part L 2021 + Compliance with Part L 2021

Metrics combined

Part L compliance drives the 'good practice' and 'ultra-low energy' fabric specifications by ruling out a 'business as usual' level of fabric and ventilation performance.

The GLA's latest Energy Assessment Guidance (2022) sets an on-site 35% target improvement on Part L 2021. Our modelling results for this building type suggest that a 35% target would help to effectively rule out a gas boiler scenario.

A benchmark 50% target would be even more effective.

A more ambitious target would incentivise even better designs and would be technically feasible.

	Reduction in CO_2 - SAP 10.2 GLA (reg)	With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	~~1%~~	~~46%~~	~~57%~~	~~72%~~
	Good practice	13%	53%	62%	75%
	Ultra-low energy	29%	64%	72%	81%

Table 6.16 – Performance of each case in terms of CO_2 overlaid with compliance with all Part L 2021 criteria

✗ Would not pass all 3 building regulations Part L 2021 metrics

< 0%	< 35%	< 50%	< 60%	60-80%	> 80%

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well

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Mid-rise apartment building | Policy option 1 | Be Lean

Findings of the 2019 study

The ‘good practice’ and ‘ultra-low energy’ fabric scenarios tested achieved greater than a 10% reduction in emissions, therefore exceeding the London Plan 'Be Lean' policy requirement. This requirement was therefore effective at encouraging energy efficiency improvements in the building fabric and ventilation specification.

🟥 < 10% 🟩 >= 10%

2019 study

		No PV
Reduction in CO_2 - SAP 2012 SAP 10.0 GLA (reg)		Be Lean
Fabric & ventilation	Business as usual	🟥 4%
	Good practice	🟩 15%
	Ultra-low energy	🟩 29%

Table 6.17 – Performance of the three levels of fabric and ventilation performance against the Be Lean requirement (2019 study)

Findings of the 2023 study

A mi-rise apartment building with ‘good practice’ or ‘ultra-low energy’ fabric achieves greater than a 10% reduction in CO_2 from fabric and ventilation and comply with the ‘Be Lean’ requirement.

The inclusion of a waste water heat recovery (WWHR) system could allow the ‘business as usual’ fabric scenario to meet the 10% reduction requirement. The inclusion of WWHR in schemes has therefore the potential to mask the improvement or lack of improvement of the building fabric.

Using the Fabric Energy Efficiency indicator from Part L 2021 may be an alternative.

🟥 < 10% 🟩 >= 10%

2023 study

		No PV
Reduction in CO_2 - SAP 10.2 GLA (reg)		Be Lean
Fabric & ventilation	Business as usual	🟥 -1%
	Good practice	🟩 11%
	Ultra-low energy	🟩 27%

Table 6.18 – Performance of the three levels of fabric and ventilation performance against the Be Lean requirement (2023 study)

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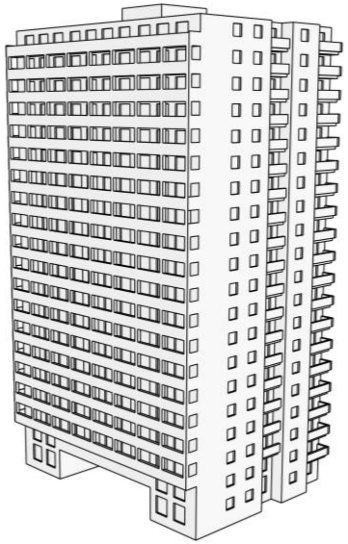
6.1.4

Policy option 1 - Part L 2021 analysis for high-rise apartment building



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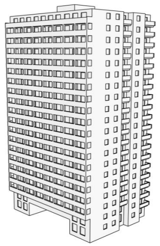
High-rise apartment building I Policy option 1 I Improvement over Part L (regulated carbon emissions)



Findings of the 2019 study

London Plan policy of a 35% reduction in CO$_2$ emissions on-site on Part L 2013 (using SAP 10.0 emission factor) prevented the use of gas boilers and partially incentivised heat pumps.

35% compliant	< 0%	< 35%	< 60%	60-80%	> 80%

2019 study

Reduction in CO$_2$ - SAP 2012 SAP 10.0 GLA (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	8%	25%	54%	69%
	Good practice	18%	35%	60%	72%
	Ultra-low energy	29%	47%	67%	75%

Table 6.19 – Performance of each case in terms of CO$_2$ against the Part L 2013 baseline

Findings of the 2023 study

A 35% improvement on Part L 2021 would not be effective at preventing the use of gas boilers. Also, it would not be sufficient to encourage developments to achieve further efficiencies through the fabric or heating system. A 50% 'benchmark' target improvement over Part L 2021 would be more effective in limiting applicants to direct electric or heat pumps, but an even more ambitious target would be required to drive further improvements to building fabric and ventilation. Direct electric should be combined with an appropriate performance standard, such as the Passivhaus standard).

35% compliant	< 0%	< 35%	< 50%	< 60%	60-80%	> 80%

2023 study

Reduction in CO$_2$ - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	6%	52%	60%	75%
	Good practice	16%	56%	65%	77%
	Ultra-low energy	24%	63%	69%	81%

Table 6.20 – Performance of each case in terms of CO$_2$ against the Part L 2021 baseline

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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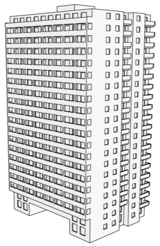
High-rise apartment building I Policy option 1 I Improvement over Part L 2021 + Compliance with Part L 2021



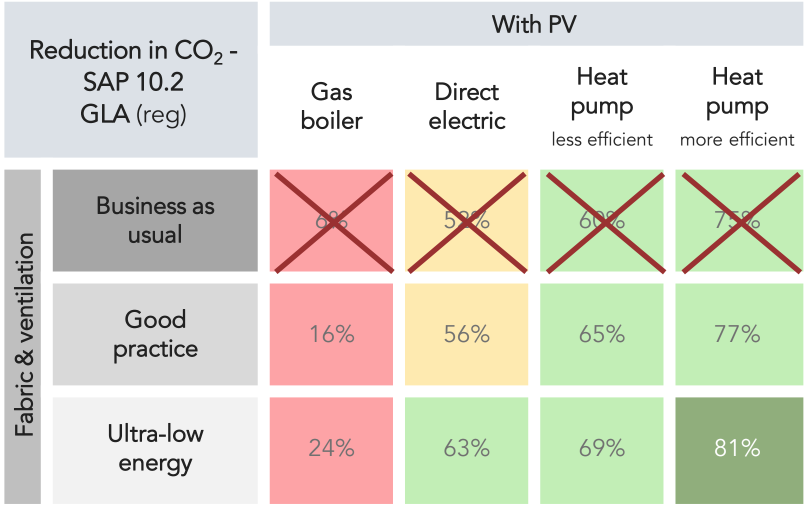
Metrics combined

Part L compliance drives the ‘good practice’ and ‘ultra-low energy’ fabric specifications by ruling out a ‘business as usual’ level of fabric and ventilation performance.

The GLA's latest Energy Assessment Guidance (2022) sets an on-site 35% target improvement on Part L 2021. Our modelling results for this building type suggest that a 35% target would help to effectively rule out a gas boiler scenario.

A benchmark 50% target would be even more effective.

A more ambitious target would incentivise even better designs and would be technically feasible.



Reduction in CO_2 - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	✗ 6%	✗ 52%	✗ 60%	✗ 75%
	Good practice	16%	56%	65%	77%
	Ultra-low energy	24%	63%	69%	81%

Table 6.21 – Performance of each case in terms of CO_2 overlaid with compliance with all Part L 2021 criteria

✗ Would not pass all 3 building regulations Part L 2021 metrics

< 0%	< 35%	< 50%	< 60%	60-80%	> 80%

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well

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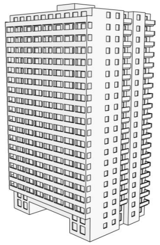
High-rise apartment building | Policy option 1 | Be Lean



Findings of the 2019 study

The 'good practice' and 'ultra-low energy' fabric scenarios tested achieved greater than a 10% reduction in emissions, therefore exceeding the London Plan 'Be Lean' policy requirement. This requirement was therefore effective at encouraging energy efficiency improvements in the building fabric and ventilation specification.

🟥 < 10% 🟩 >= 10%

2019 study

	Reduction in CO$_2$ - SAP 2012 SAP 10.0 GLA (reg)	No PV
		Be Lean
Fabric & ventilation	Business as usual	5%
	Good practice	15%
	Ultra-low energy	26%

Table 6.22 – Performance of the three levels of fabric and ventilation performance against the Be Lean requirement (2019 study)

Findings of the 2023 study

Only a high-rise building with 'ultra-low energy' fabric achieves greater than a 10% reduction in CO$_2$ from fabric and ventilation improvements. For the high-rise apartment building the 'good practice' does not quite meet the 10% reduction. This suggests that the threshold for complying is somewhere between 'good practice' and 'ultra-low energy'.

The inclusion of a waste water heat recovery (WWHR) system could allow the 'good practice' fabric scenario to meet the 10% reduction requirement, but it is unlikely that it would allow the 'business as usual' specification to pass. The inclusion of WWHR in schemes has the potential to mask the improvement or lack of improvement of the building fabric.

Using the Fabric Energy Efficiency indicator from Part L 2021 may be an alternative.

🟥 < 10% 🟩 >= 10%

2023 study

	Reduction in CO$_2$ - SAP 10.2 GLA (reg)	No PV
		Be Lean
Fabric & ventilation	Business as usual	-5%
	Good practice	6%
	Ultra-low energy	14%

Table 6.23 – Performance of the three levels of fabric and ventilation performance against the Be Lean requirement (2023 study)

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6.2

Policy option 1 - Part L 2021 analysis for non-domestic buildings

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Policy option 1 | Non-domestic buildings | Note on PV impact

The impact of PVs

It is clear from the results that the amount of photovoltaic panels (PV) provision included has a significant impact on the Part L performance of the non-domestic typologies analysed.

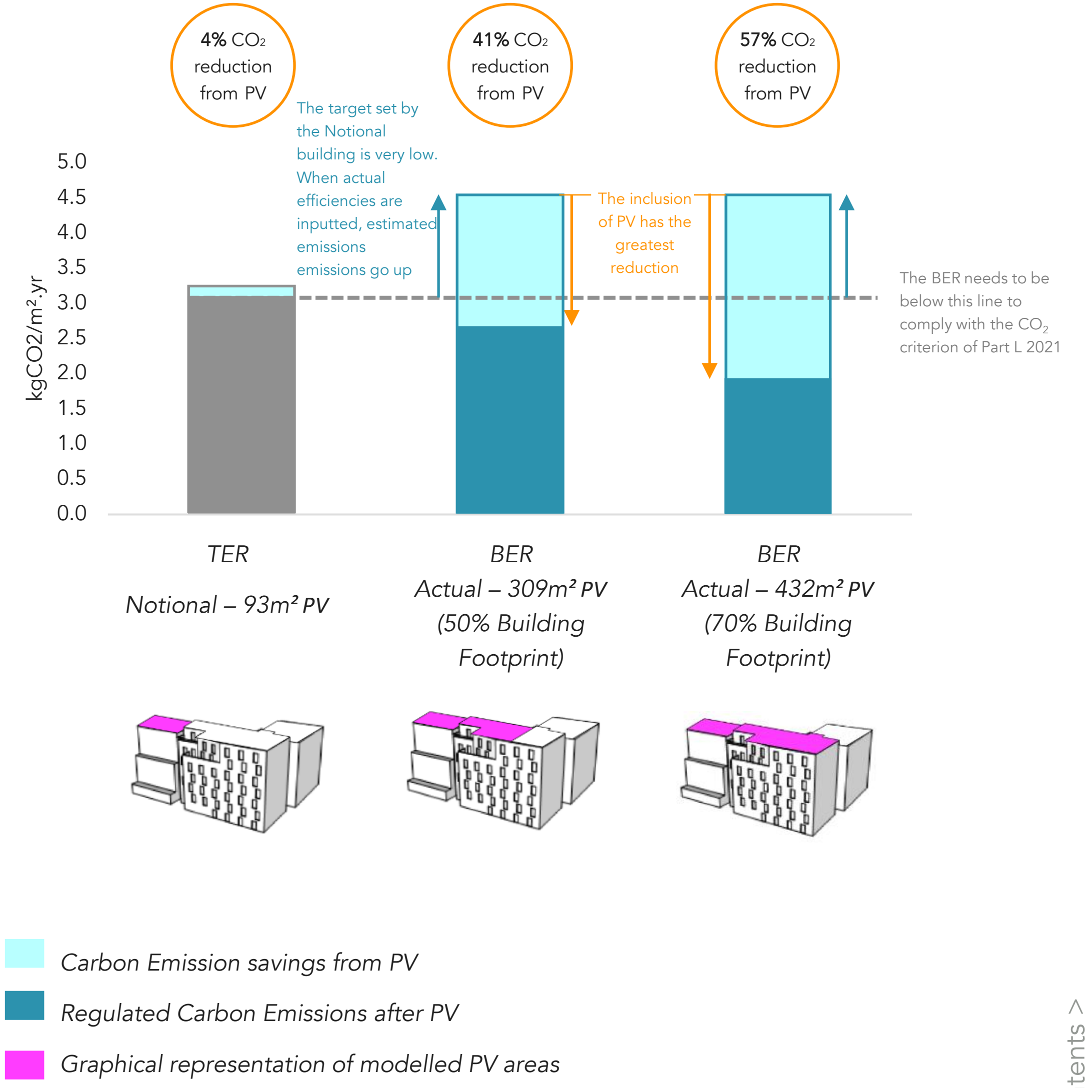
Further investigation has been undertaken to understand the impact of PVs in achieving the GLA 35% on-site reduction target. An example is therefore presented based on Scenario 1D for the office typology. This represents the ‘Business as usual’ fabric and ventilation specification, with the ‘Heat pump – More efficient’ system specification.

- The Notional building PV allowance contributes to 4% of the building’s emission rate as it only has 15% building footprint area of PV. This follows the allowance set by NCM based on the heat source being used for the building.
- The Actual building is based on 50% of the building footprint area being used for PV, and this reduced the building’s regulated carbon emissions by 41%. This scenario subsequently achieves a 14% on-site carbon emission reduction beyond Part L 2021.
- When the PV provision is increased to 70% of building footprint results in the Actual building and this reduced the building’s regulated carbon emissions by 57%. This scenario subsequently achieves a 38% on-site carbon emission reduction beyond Part L 2021.

As it can be seen, PVs appear to have a disproportionate impact on regulated CO_2 emissions estimated by Part L.

Other non-domestic typologies

The highly reactive nature of the Part L results to the quantity of PV provision included is reflected across all non-domestic typologies. Details of performance with and without PV for each are presented in the specific results sections for each building type.



The target set by the Notional building is very low. When actual efficiencies are inputted, estimated emissions emissions go up

The inclusion of PV has the greatest reduction

The BER needs to be below this line to comply with the CO_2 criterion of Part L 2021

Figure 6.6 - The above chart shows that regulated carbon emissions forming the Part L 2021 limit which new buildings have to comply with is very challenging: the emissions are very low. In the actual building, even when good/best practice specifications are assumed, the building’s emissions are estimated to be much higher, relying on PVs to comply. The example used above is the office building.

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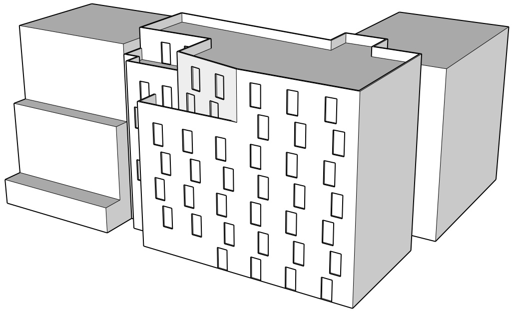
6.2.1

Policy option 1 - Part L analysis for office building



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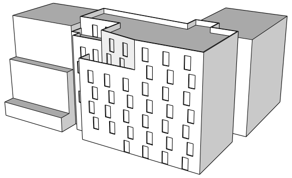
Office building I Policy option 1 I Improvement over Part L 2021 (regulated carbon emissions)



Findings of the 2019 study

All the scenarios, except for one, achieved the London Plan policy of a 35% reduction in CO_2 emissions on-site on Part L 2013 (using SAP 10.0 emission factors).

35% compliant	< 0%	< 35%	< 60%	60-80%	> 80%

2019 study

Reduction in CO_2 - NCM - SAP 10.0 GLA (reg)		With PV			
		Gas boiler	VRF	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	29%	48%	44%	49%
	Good practice	41%	54%	51%	55%
	Ultra-low energy	55%	61%	59%	61%

Table 6.24 – Performance of each case in terms of CO_2 against the Part L 2013 baseline

Findings of the 2023 study

Changes in the Part L 2021 methodology appear to significantly impact this building type. The modelling results suggest that none of the scenarios tested would achieve a 35% improvement on Part L 2021 of the Building Regulations, even with PVs covering 50% of the building footprint area. The highest improvement obtained was 32%. There is also limited improvement when comparing between electric heating scenarios, moving from 'Good practice' fabric and ventilation towards the better performing 'Ultra-low energy' level, therefore making Policy option 1 less effective at incentivising efficient fabric and ventilation design.

< 0%	< 35%	< 60%	60-80%	> 80%

2023 study

Reduction in CO_2 - NCM - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	VRF	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	-22%	13%	6%	14%
	Good practice	7%	29%	25%	30%
	Ultra-low energy	26%	32%	30%	32%

PV area covering 50% of the building footprint area

Table 6.25 – Performance of each case in terms of CO_2 against the Part L 2021 baseline

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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Office building I Policy option 1 I Improvement over Part L 2021 (A study on PV impact)

The impact of PVs is significant

The top table on the right shows results with PVs covering 50% of the building footprint area, an area equivalent to 300m^2.

The second table shows results with PVs covering 70% of the building footprint area, an area of 430m^2.

This highlights the impact of PV in carbon reduction performance, which may be the key difference between failing or complying with the 35% on-site carbon reduction requirement on Part L 2021.

This is likely to be due to the fact that the regulated emissions assessed by Part L 2021 modelling tools (e.g. heating) are now very small: PVs make more of an impact as the baseline is smaller.

Reduction in CO$_2$ - NCM - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	VRF	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	-22%	13%	6%	14%
	Good practice	7%	29%	25%	30%
	Ultra-low energy	26%	32%	30%	32%

Table 6.26 – Performance of each case in terms of CO$_2$ against the Part L 2021 baseline ***with the solar PV area covering 50% of the building footprint area***

Reduction in CO$_2$ - NCM - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	VRF	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	-1%	37%	30%	38%
	Good practice	28%	53%	49%	54%
	Ultra-low energy	47%	57%	55%	57%

Table 6.27 – Performance of each case in terms of CO$_2$ against the Part L 2021 baseline ***with the solar PV area covering 70% of the building footprint area***

35% compliant	< 0%	< 35%	< 60%	60-80%	> 80%

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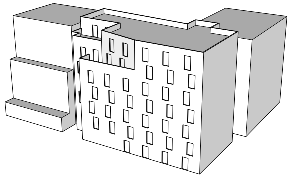
Office building | Policy option 1 | Improvement over Part L 2021 + Compliance with Part L 2021



Metrics combined

Both Building Regulation metrics (primary energy and carbon reduction) have been overlaid with the carbon reduction performance. All scenarios except the 'Gas boiler' scenario under 'Business as usual' are able to comply with Part L 2021, including those with poorer fabric/ventilation and system specifications.

None of the scenarios achieve the 35% on-site carbon reduction requirement on Part L 2021 with the PV area covering 50% of the building footprint.

Reduction in CO_2 - NCM - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	VRF	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	~~-22%~~	13%	6%	14%
	Good practice	7%	29%	25%	30%
	Ultra-low energy	26%	32%	30%	32%

PV area covering 50% of the building footprint area

Table 6.28 – Performance of each case in terms of CO_2 overlaid with compliance with all Part L 2021 criteria

✗ Would not pass both building regulations Part L 2021 metrics

< 0% | < 35% | < 60% | 60-80% | > 80%

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well

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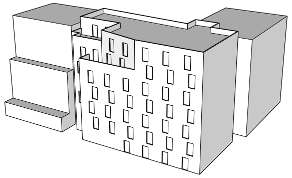
Office building | Policy option 1 | Be Lean



Findings of the 2019 study

The ‘good practice’ and ‘ultra-low energy’ fabric scenarios tested achieved a 15% reduction in emissions on Part L 2013 (assuming SAP 10.0 carbon factors), therefore meeting the London Plan 'Be Lean' policy requirement. This requirement was therefore effective at encouraging energy efficiency improvements in the building fabric and ventilation specification.

< 15% | >= 15%

2019 study

	Be Lean Reduction in CO_2 - NCM - SAP 10.0 GLA (reg)	No PV
		Gas baseline
Fabric & ventilation	Business as usual	5%
	Good practice	17%
	Ultra-low energy	31%

Table 6.29 – Performance of the three levels of fabric and ventilation performance against the Be Lean requirement (2019 study)

Findings of the 2023 study

The methodology set out in the GLA's Energy Assessment Guidance (2022) confirms a change in approach to Be Lean calculations for non-domestic buildings. Emission reductions are now required to be compared against a baseline with the same fuel and system type as the proposed ‘Be Green’ scenario, where previously the baseline for comparison remained the same for all scenarios. Since the proposed system scenarios have two different system types, the adjacent table has two columns representing the different baselines as a result of alternative proposed systems.

Based on the scenarios tested in this study, none of them achieve the required 15% improvement over the Part L 2021 required by ‘Be Lean’, even 'ultra-low energy fabric' (Passivhaus levels of efficiency) These results suggest that the ‘Be Lean’ requirement may be challenging to achieve for office buildings.

< 15% | >= 15%

2023 study

	Be Lean Reduction in CO_2 - NCM - SAP 10.2 GLA (reg)	No PV	
		Gas baseline	Heat pump/ VRF baseline
Fabric & ventilation	Business as usual	-58%	-43%
	Good practice	-29%	-26%
	Ultra-low energy	-11%	-22%

Table 6.30 – Performance of the three levels of fabric and ventilation performance against the Be Lean requirement (2023 study)

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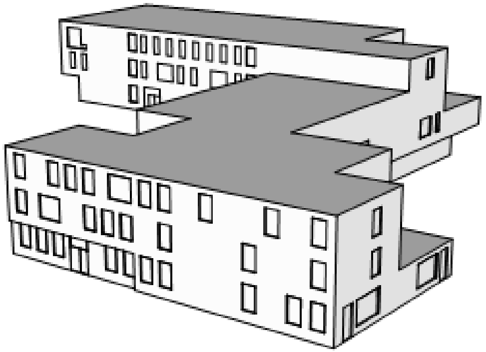
6.2.2

Policy option 1 - Part L analysis for primary school



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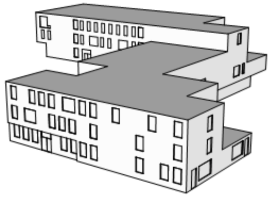
Primary school building | Policy option 1 | Improvement over Part L 2021 (regulated carbon emissions)



Findings of the 2019 study

All scenarios achieved the London Plan policy of a 35% reduction in CO_2 emissions on-site on Part L 2013 (using SAP 10.0 emission factors).

35% compliant

< 0%

< 35%

< 60%

60-80%

> 80%

2019 study

Reduction in CO_2 - NCM - SAP 10.0 GLA (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	46%	50%	58%	62%
	Good practice	43%	46%	47%	47%
	Ultra-low energy	51%	53%	53%	54%

Table 6.31 – Performance of each case in terms of CO_2 against the Part L 2013 baseline

Findings of the 2023 study

The modelling results suggest that some scenarios tested would achieve a 35% improvement on Part L 2021 of the Building Regulations with PVs covering 25% of the building footprint area: all those with heat pumps as well as the 'ultra-low energy' scenarios with 'gas boiler' and 'direct electric'.

The introduction of MVHR unfortunately penalises the % figures despite the absolute emissions being lower, which is one of the problem with a 'relative' approach to target setting.

Overall, Policy option 1 appears only partially effective at incentivising better and more efficient design solutions.

< 0%

< 35%

< 60%

60-80%

> 80%

2023 study

Reduction in CO_2 - NCM - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	27%	11%	75%	77%
	Good practice	26%	3%	40%	40%
	Ultra-low energy	63%	73%	83%	83%

PV area covering 25% of the building footprint area

Table 6.32 – Performance of each case in terms of CO_2 against the Part L 2021 baseline

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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Primary school building | Policy option 1 | Improvement over Part L 2021 | A study on PV impact

The impact of PVs is significant

The top table on the right shows results without any PVs modelled, where only the ultra-low energy scenarios comply with Building Regulations, and none achieve the 35% carbon reduction policy.

The second table shows results with PVs covering 25% of the building footprint area, an area of 600m^2.

This highlights the impact of PV in carbon reduction performance, which may be the key difference between failing or complying with the 35% on-site carbon reduction requirement on Part L 2021.

This is likely to be due to the fact that the regulated emissions assessed by Part L 2021 modelling tools (e.g. heating) are now very small: PVs make more of an impact as the baseline is smaller.

Reduction in CO_2 - NCM - SAP 10.2 GLA (reg)		No PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	-13%	-52%	-4%	-2%
	Good practice	-32%	-37%	-34%	-34%
	Ultra-low energy	5%	9%	9%	9%

*Table 6.33 – Performance of each case in terms of CO_2 against the Part L 2021 baseline **with no solar PV area***

Reduction in CO_2 - NCM - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	27%	11%	75%	77%
	Good practice	26%	3%	40%	40%
	Ultra-low energy	63%	73%	83%	83%

*Table 6.34– Performance of each case in terms of CO_2 against the Part L 2021 baseline **with the solar PV area covering 25% of the building footprint area***

< 0%
< 35%
< 60%
60-80%
> 80%

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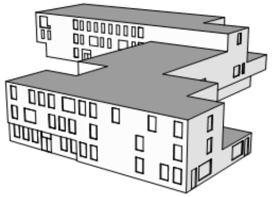
Primary school building | Policy option 1 | Improvement over Part L 2021 + Compliance with Part L 2021



Metrics combined

Both Building Regulation metrics (primary energy and carbon reduction) have been overlaid with the carbon reduction performance. All scenarios are able to comply with Part L 2021, including those with poorer fabric/ventilation and system specifications.

The 35% CO$_2$ reduction requirement on Part L 2021 would encourage better systems or better fabric but would fail to prevent gas boilers or a business as usual fabric if a heat pump was the heating system.

Finally, good practice specifications appear worse than business as usual just due to the fact that Part L 2021 fails to reward mechanical ventilation with heat recovery.

Reduction in CO$_2$ - NCM - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	27%	11%	75%	77%
	Good practice	26%	3%	40%	40%
	Ultra-low energy	63%	73%	83%	83%

PV area covering 25% of the building footprint area

Table 6.35 – Performance of each case in terms of CO$_2$ overlaid with compliance with all Part L 2021 criteria

✗ Would not pass both building regulations Part L 2021 metrics

< 0% | < 35% | < 60% | 60-80% | > 80%

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well

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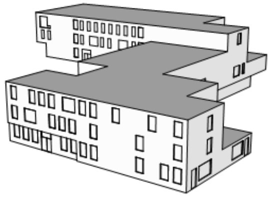
Primary school building | Policy option 1 | Be Lean



Findings of the 2019 study

None of the fabric and ventilation scenarios tested achieved a 15% reduction in emissions on Part L 2013 (assuming SAP 10.0 carbon factors), therefore they all failed the London Plan 'Be Lean' policy requirement. It was therefore ineffective at incentivising better levels of energy efficiency.

< 15% | >= 15%

2019 study

Be Lean Reduction in CO_2 - NCM - SAP 10.0 GLA (reg)		No PV
		Gas baseline
Fabric & ventilation	Business as usual	7%
	Good practice	0%
	Ultra-low energy	8%

Table 6.36– Performance of the three levels of fabric and ventilation performance against the Be Lean requirement (2019 study)

Findings of the 2023 study

The methodology set out in the GLA's Energy Assessment Guidance (2022) confirms a change in approach to Be Lean calculations for non-domestic buildings. Emission reductions are now required to be compared against a baseline with the same fuel and system type as the proposed 'Be Green' scenario, where previously the baseline for comparison remained the same for all scenarios. Since the proposed system scenarios have two different system types, the adjacent table has two columns representing the different baselines as a result of alternative proposed systems.

Based on the scenarios tested in this study, only one of them achieves the required 15% improvement over the Part L 2021 required by 'Be Lean'. These results suggest that the 'Be Lean' requirement may be challenging to achieve for school buildings.

< 15% | >= 15%

2023 study

Be Lean Reduction in CO_2 - NCM - SAP 10.2 GLA (reg)		No PV		
		Gas baseline	Direct electric baseline	Heat pump baseline
Fabric & ventilation	Business as usual	-12%	-17%	-11%
	Good practice	-27%	-53%	-34%
	Ultra-low energy	11%	17%	10%

Table 6.37 – Performance of the three levels of fabric and ventilation performance against the Be Lean requirement (2023 study)

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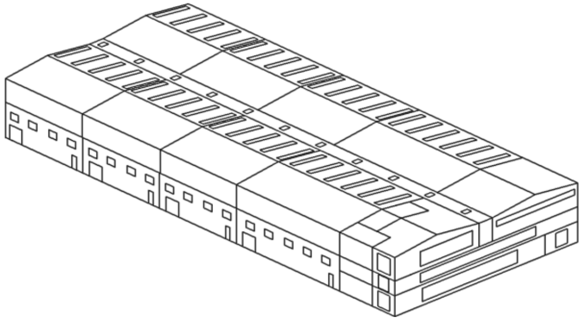
6.2.3

Policy option 1 - Part L analysis for industrial building



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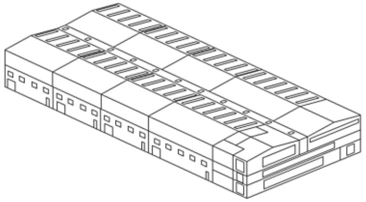
Industrial building I Policy option 1 I Improvement over Part L 2021 (regulated carbon emissions)



Findings of the 2023 study

The modelling results suggest that, except all gas boiler scenarios, all scenarios tested would achieve a 35% improvement on Part L 2021 of the Building Regulations with PVs covering 20% of the building footprint area.

There is however limited improvement across the electric heating scenarios as you move from 'Business as usual' fabric and ventilation towards the better performing 'Ultra-low energy' level, therefore making Policy option 1 ineffective at incentivising better and more efficient design solutions.

2023 study

Reduction in CO_2 - NCM - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	VRF	Four pipe chiller	Heat pump more efficient
Fabric & ventilation	Business as usual	0%	41%	40%	53%
	Good practice	6%	41%	40%	53%
	Ultra-low energy	21%	48%	46%	61%

PV area covering 20% of the building footprint area

Table 6.38 – Performance of each case in terms of CO_2 against the Part L 2021 baseline

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

< 0%	< 35%	< 60%	60-80%	> 80%

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Industrial building | Policy option 1 | Improvement over Part L 2021 (A study on PV impact)

The impact of PVs is significant

The top table on the right shows results without any PVs modelled, where none of the scenarios comply with Part L 2021, let alone the 35% carbon reduction policy.

The second table shows results with PVs covering 20% of the building footprint area, an area of 670m^2. All of the scenarios except the 'Gas boiler ones', achieve the 35% carbon reduction policy.

This highlights the impact of PV in carbon reduction performance, which may be the key difference between failing or complying with the 35% on-site carbon reduction requirement on Part L 2021.

This is likely to be due to the fact that the regulated emissions assessed by Part L 2021 modelling tools (e.g. heating) are now very small: PVs make more of an impact as the baseline is smaller.

Reduction in CO_2 - NCM - SAP 10.2 GLA (reg)		No PV			
		Gas boiler	VRF	Four pipe chiller	Heat pump more efficient
Fabric & ventilation	Business as usual	-47%	-10%	-11%	-8%
	Good practice	-72%	-17%	-18%	-18%
	Ultra-low energy	-56%	-10%	-12%	-10%

Table 6.39 – Performance of each case in terms of CO_2 against the Part L 2021 baseline ***with no solar PV area***

Reduction in CO_2 - NCM - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	VRF	Four pipe chiller	Heat pump more efficient
Fabric & ventilation	Business as usual	0%	41%	40%	53%
	Good practice	6%	41%	40%	53%
	Ultra-low energy	21%	48%	46%	61%

Table 6.40 – Performance of each case in terms of CO_2 against the Part L 2021 baseline ***with the solar PV area covering 20% of the building footprint area***

< 0%	< 35%	< 60%	60-80%	> 80%

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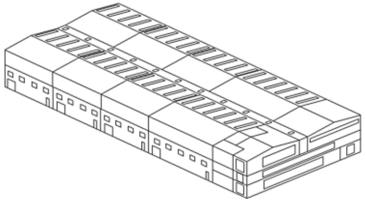
Industrial building | Policy option 1 | Improvement over Part L 2021 + Compliance with Part L 2021



Metrics combined

Both Building Regulation metrics (primary energy and carbon reduction) have been overlaid with the carbon reduction performance. All scenarios except the ‘Gas boiler’ scenario under ‘Business as usual’ and ‘Good practice’ are able to comply with Part L 2021, including those with poorer fabric/ventilation and system specifications.

It is clear that the 35% on-site carbon reduction requirement on Part L 2021 appears more stringent than Building Regulations for this typology and prevents the use of gas boilers.

However, as all electric scenarios comply with the 35% reduction target it fails to incentivise better fabric, ventilation or heating systems.

Reduction in CO$_2$ - NCM - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	VRF	Four pipe chiller	Heat pump more efficient
Fabric & ventilation	Business as usual	~~0%~~	41%	40%	53%
	Good practice	~~6%~~	41%	40%	53%
	Ultra-low energy	21%	48%	46%	61%

PV area covering 20% of the building footprint area

Table 6.41 – Performance of each case in terms of CO$_2$ overlaid with compliance with all Part L 2021 criteria

✗ Would not pass both building regulations Part L 2021 metrics

< 0%	< 35%	< 60%	60-80%	> 80%

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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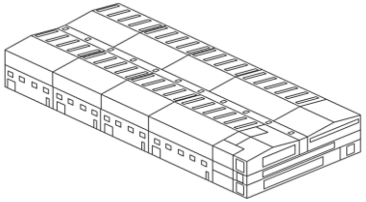
Industrial building I Policy option 1 I Be Lean



Findings of the 2023 study

The methodology set out in the GLA's Energy Assessment Guidance (2022) confirms a change in approach to Be Lean calculations for non-domestic buildings. Emission reductions are now required to be compared against a baseline with the same fuel and system type as the proposed 'Be Green' scenario, where previously the baseline for comparison remained the same for all scenarios. Since the proposed system scenarios have two different system types, the adjacent table has two columns representing the different baselines as a result of alternative proposed systems.

Based on the scenarios tested in this study, none of them achieve the required 15% improvement over the Part L 2021 required by 'Be Lean', even 'ultra-low energy fabric' (Passivhaus levels of efficiency) These results suggest that the 'Be Lean' requirement may be challenging to achieve for industrial buildings.

2023 study

Be Lean Reduction in CO_2 - NCM - SAP 10.2 GLA (reg)		No PV		
		Gas baseline	Elec & heat pump baseline	Heat pump baseline
			less efficient	more efficient
Fabric & ventilation	Business as usual	-4%	-11%	-11%
	Good practice	-2%	-17%	-19%
	Ultra-low energy	13%	-11%	-11%

🟥 < 15%

🟩 >= 15%

- *System A: Gas boiler*
- *System B: VRF (heat pump for space heating, direct electric DHW)*
- *System C: Four pipe chiller (heat pump for space heating, direct electric DHW)*
- *System D: Better heat pump (heat pump for space heating and DHW)*

Table 6.42 – Performance of the three levels of fabric and ventilation performance against the Be Lean requirement (2023 study)

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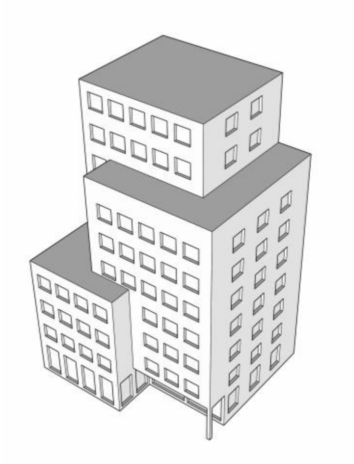
6.2.4

Policy option 1 - Part L analysis for hotel



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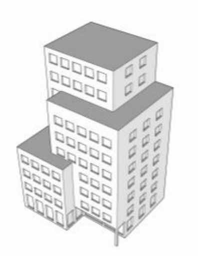
Hotel building I Policy option 1 I Improvement over Part L 2021 (regulated carbon emissions)



Findings of the 2019 study

All scenarios, except the ones using gas heating, achieved London Plan policy of a 35% reduction in CO_2 emissions on-site on Part L 2013 (using SAP 10.0 emission factors).

35% compliant | < 0% | < 35% | < 60% | 60-80% | > 80%

2019 study

Reduction in CO_2 - NCM - SAP 10.0 GLA (reg)		With PV			
		Gas boiler	Heat pump (220)	Heat pump (400/300)	Heat pump (450/300)
Fabric & ventilation	Business as usual	2%	45%	56%	56%
	Good practice	7%	48%	58%	58%
	Ultra-low energy	11%	51%	61%	61%

Table 6.43 – Performance of each case in terms of CO_2 against the Part L 2013 baseline

Findings of the 2023 study

The modelling results suggest that none of the scenarios tested would achieve a 35% improvement on Part L 2021 of the Building Regulations with PVs covering 50% of the building footprint area. The highest improvement obtained is 16%.

There is also limited improvement across the electric heating scenarios as you move from 'Business as usual' fabric and ventilation towards the better performing 'Ultra-low energy' level, therefore making Policy option 1 ineffective at incentivising better and more efficient design solutions.

< 0% | < 35% | < 60% | 60-80% | > 80%

2023 study

Reduction in CO_2 - NCM - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	Heat pump (220)	Heat pump (400/300)	Heat pump (450/300)
Fabric & ventilation	Business as usual	-2%	-18%	7%	8%
	Good practice	2%	-13%	10%	11%
	Ultra-low energy	4%	-7%	16%	16%

PV area covering 50% of the building footprint area

Table 6.44 – Performance of each case in terms of CO_2 against the Part L 2021 baseline

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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Hotel building | Policy option 1 | Improvement over Part L 2021 (A study on PV impact)

The impact of PVs is less significant for hotels

The top table on the right shows results without any PVs modelled.

The second table shows results with PVs covering 50% of the building footprint area, an area of 200m^2.

None achieve the 35% on-site carbon reduction requirement on Part L 2021 and the impact of PVs is less pronounced than it is for other typologies.

Reduction in CO_2 - NCM - SAP 10.2 GLA (reg)		No PV			
		Gas boiler	Heat pump (220)	Heat pump (400/300)	Heat pump (450/300)
Fabric & ventilation	Business as usual	-5%	-28%	-3%	-2%
	Good practice	-1%	-23%	1%	1%
	Ultra-low energy	2%	-17%	7%	7%

Table 6.45 – Performance of each case in terms of CO_2 against the Part L 2021 baseline ***with no solar PV area***

Reduction in CO_2 - NCM - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	Heat pump (220)	Heat pump (400/300)	Heat pump (450/300)
Fabric & ventilation	Business as usual	-2%	-18%	7%	8%
	Good practice	2%	-13%	10%	11%
	Ultra-low energy	4%	-7%	16%	16%

Table 6.46 – Performance of each case in terms of CO_2 against the Part L 2021 baseline ***with the solar PV area covering 20% of the building footprint area***

< 0%	< 35%	< 50%	< 60%	60-80%	> 80%

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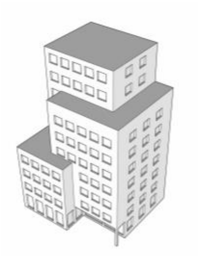
Hotel | Policy option 1 | Improvement over Part L 2021 + Compliance with Part L 2021



Metrics combined

Both Building Regulation metrics (primary energy and carbon reduction) have been overlaid with the carbon reduction performance. All scenarios except the 'Gas boiler' scenario under 'Business as usual' and all 'Heat pump 220% efficiency) are able to comply with Part L 2021, including those with poorer fabric/ventilation and system specifications.

None of the hotel scenarios would achieve the 35% on-site carbon reduction requirement on Part L 2021 with the PV area covering 50% of the building footprint.

Reduction in CO_2 - NCM - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	Heat pump (220)	Heat pump (400/300)	Heat pump (450/300)
Fabric & ventilation	Business as usual	☒ -2%	☒ -18%	7%	8%
	Good practice	2%	☒ -10%	10%	11%
	Ultra-low energy	4%	☒ -7%	16%	16%

PV area covering 50% of the building footprint area

Table 6.47 – Performance of each case in terms of CO_2 overlaid with compliance with all Part L 2021 criteria

☒ Would not pass both building regulations Part L 2021 metrics

< 0%	< 35%	< 60%	60-80%	> 80%

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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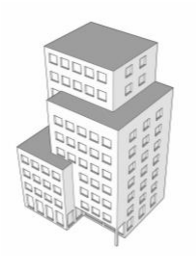
Hotel building I Policy option 1 I Be Lean



Findings of the 2019 study

None of the fabric and ventilation scenarios tested achieved a 15% reduction in emissions on Part L 2013 (assuming SAP 10.0 carbon factors), therefore they all failed the London Plan 'Be Lean' policy requirement. It was therefore ineffective at incentivising better levels of energy efficiency.

2019 study

	Be Lean Reduction in CO$_2$ - NCM - SAP 10.0 GLA (reg)	No PV
		Gas baseline
Fabric & ventilation	Business as usual	-4%
	Good practice	1%
	Ultra-low energy	5%

< 15% >= 15%

Table 6.48 – Performance of the three levels of fabric and ventilation performance against the Be Lean requirement (2019 study)

Findings of the 2023 study

The methodology set out in the GLA's Energy Assessment Guidance (2022) confirms a change in approach to Be Lean calculations for non-domestic buildings. Emission reductions are now required to be compared against a baseline with the same fuel and system type as the proposed 'Be Green' scenario, where previously the baseline for comparison remained the same for all scenarios. Since the proposed system scenarios have two different system types, the adjacent table has two columns representing the different baselines as a result of alternative proposed systems.

Based on the scenarios tested in this study, none of them achieve the required 15% improvement over the Part L 2021 required by 'Be Lean', even 'ultra-low energy fabric' (Passivhaus levels of efficiency) These results suggest that the 'Be Lean' requirement may be challenging to achieve for hotel buildings.

2023 study

	Be Lean Reduction in CO$_2$ - NCM - SAP 10.2 GLA (reg)	No PV	
		Gas baseline	Heat pump baseline
Fabric & ventilation	Business as usual	-1%	-4%
	Good practice	2%	0%
	Ultra-low energy	5%	7%

< 15% >= 15%

Table 6.49 – Performance of the three levels of fabric and ventilation performance against the Be Lean requirement (2023 study)

6.3

Policy option 1 - how are heat networks assessed and how do they perform?

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Policy option 1 | How are heat networks assessed in Part L?

District heat networks are considered within the Part L methodologies (i.e. SAP for domestic buildings and NCM/SBEM for non-domestic buildings). Key aspects of these methodologies include:

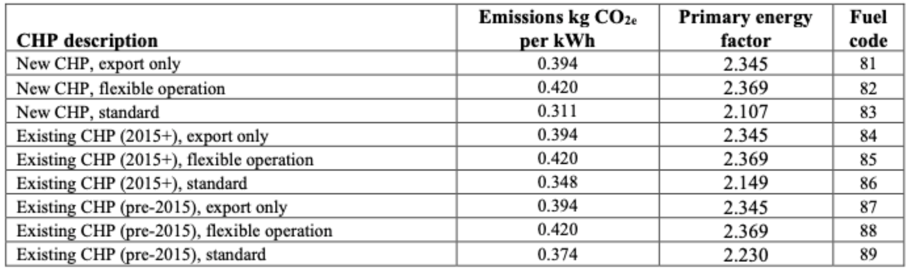
- A notional building that uses a heat network to calculate a target primary energy rate and a target carbon emissions rate. This baseline changes if buildings are connected to an existing heat network or to a new one and dependent on the type of heat generation used by the network.
- The Approved Document requires that the carbon emissions and primary energy figures for the heat delivered should be calculated for the proposed heat network using set fuel factors (gas and electricity) and the results compared against the notional baseline.
- The heat and electrical efficiencies for an existing network are stored in an official database; if it is not listed, these values should be obtained from operational records or the design specification.
- Efficiencies used are those from the heat generators, disregarding other factors, such as distribution losses, that can influence the efficiency of the system.

SAP 10.2 Consultation updates for heat networks

The outcome of the BEIS consultation in 2021 on heat networks was a set of 'adjustment factors' that are applied to the calculation for existing networks.

Part L 2021

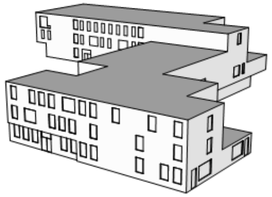
There has been no fundamental changes to the way in which heat networks are modelled in SAP in Part L 2013 compared to 2021. aside from the adjustment factors.



CHP description	Emissions kg CO$_{2e}$ per kWh	Primary energy factor	Fuel code
New CHP, export only	0.394	2.345	81
New CHP, flexible operation	0.420	2.369	82
New CHP, standard	0.311	2.107	83
Existing CHP (2015+), export only	0.394	2.345	84
Existing CHP (2015+), flexible operation	0.420	2.369	85
Existing CHP (2015+), standard	0.348	2.149	86
Existing CHP (pre-2015), export only	0.394	2.345	87
Existing CHP (pre-2015), flexible operation	0.420	2.369	88
Existing CHP (pre-2015), standard	0.374	2.230	89

Table 6.50 - Fuel factors in Part L 2021 that apply to electricity generated by CHP.

Policy option 1 | **School** | Part L assessment of DH1 and DH2



For non-domestic buildings, this report uses the School archetype to assess the performance of DH1, heat generated by an Energy from Waste plant and DH2, heat generated by a mix of heat sources including gas CHP, gas boilers and heat pumps.

Carbon emissions rate comparison

The graph on the bottom-right shows the comparative regulated emissions rates in $kgCO_2/m^2.yr$ for the Part L target (TER) and building emissions rates (BER) for the different scenarios being considered.

Comparison with non-district heating scenarios

The standard methodology applies different Part L baselines for the heat pump and district heating (DH) network scenarios, with a larger TER for the heat network. This larger TER allows buildings connected to the DH network to have worse performing fabric than those not connected whilst aiming to meet the same nominal % carbon reduction target.

Reduction in CO_2 NCM - SAP 10.2 GLA (reg)		With PV					
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient	DHN 1	DHN 2
Fabric & ventilation	Business as usual	27%	11%	75%	77%		
	Good practice	26%	3%	40%	40%		
	Ultra-low energy	63%	73%	83%	83%	112%	75%

Table 6.51 - Performance of each case in terms of CO_2 against the Part L 2021 baseline

Note that the automatic (within the Part L methodology) use of adjusted carbon factors, means that the performance of DH scenarios cannot be directly compared with the non- district heating scenarios

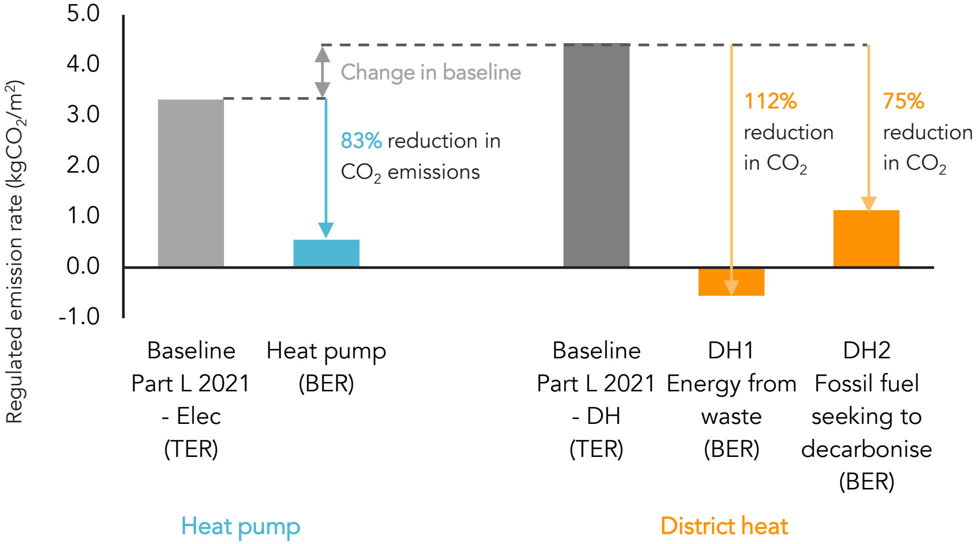


Figure 6.7 - Analysis of district heating and comparison with heat pump scenario: comparison of results from a heat pump (ground Source heat pump or ambient loop) and district heating scenarios.

DH2 scenario assumes a blended energy mix and does not account for 'sleeving'. The heat pump scenario includes direct electric point-of-use hot water to bathrooms and does not include water storage.

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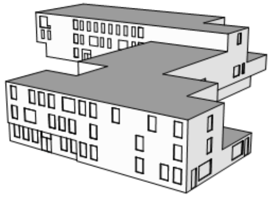
Policy option 1 | School | Part L assessment of DH1 and DH2



Emissions and primary energy figures have been calculated for each of the networks and compared against the notional baseline, assuming a fixed carbon emissions factor, as defined by the NCM.

Results

The results in the table on the top-right show the regulated CO_2 emissions ($kgCO_2/m^2.yr$) for the two district heating networks when modelled for the school archetype, along with those of the notional baseline in the NCM. The graph on the bottom right shows the regulated emissions compared to the better heat pump scenario.

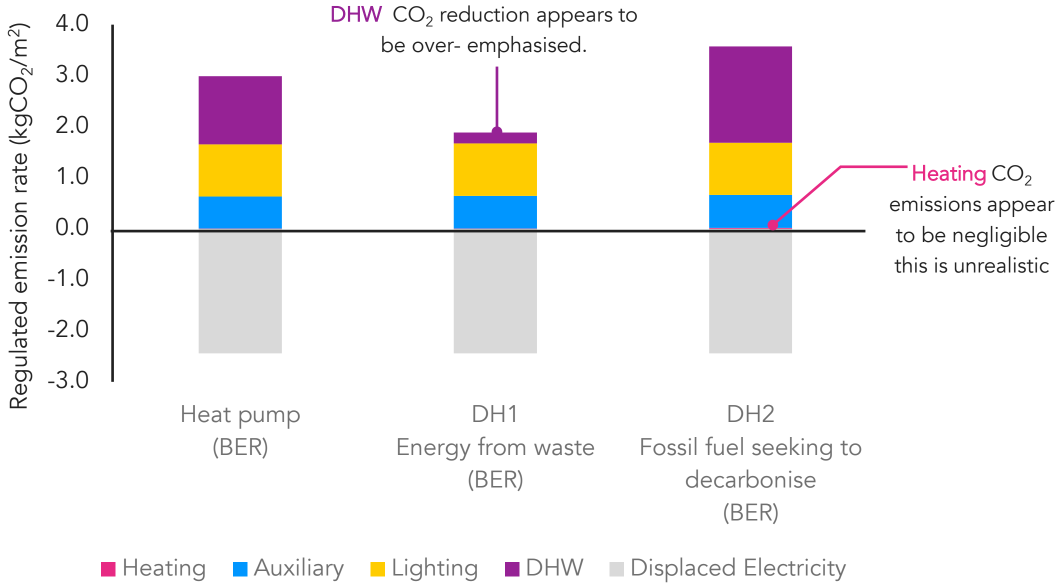
Heating in both DH scenarios has negligible CO_2 emissions, which seems unrealistic. There is a very wide variation in the DHW emissions between the scenarios, although the load is the same. The reductions for DH1 seem to be much greater than would be expected.

These results suggest the emissions from heating and hot water are not reliably accounted for by the NCM approved methodology.

	Notional	DH1	DH2
Heating	0.14	0.00	0.02
Cooling	0.00	0.00	0.00
Auxiliary	0.95	0.65	0.65
Lighting	1.04	1.02	1.02
DHW	3.41	0.22	1.89
Displaced elec	-1.11	-2.44	-2.44
Total	**4.44**	**-0.55**	**1.13**

Table 6.52 – Regulated carbon emission results for DH1 and DH2 compared with notional baseline.

CO_2 emissions ($kgCO_2/m^2.yr$) for the two district heating networks when modelled for the school archetype, along with those of the notional baseline.



DHW CO_2 reduction appears to be over- emphasised.

Heating CO_2 emissions appear to be negligible this is unrealistic

Figure 6.8 - Analysis of district heating and communal heat pump scenarios.

Modelling results from each district heating option compared with the 'heat pump-more efficient' scenario

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Policy option 1 | Mid-rise apartment building | Part L assessment of DH1 and DH2

For domestic buildings, using the mid-rise apartment building archetype as an example, the performance of the different types of heat networks has been analysed.

Carbon emissions rate comparison

The figures for both district heating scenarios have been compared against the 'heat pump' scenarios for the mid-rise apartment and results are shown in the adjacent table and graph.

Key points include:

- The Part L 2021 baseline remains relatively constant across the domestic calculations, therefore enabling a simple comparison between the different heating systems.
- DH1 (Energy from Waste) shows a significant reduction in regulated emissions, the best of all heating scenarios. The result appears logical given the very low carbon content of heat allocated to Energy from Waste in SAP 10.2.
- DH2 (Fossil fuel based heat network seeking to decarbonise) shows a reduction compared to the Part L baseline, but it performs only better than a gas boiler scenario and not as well as electrical heating scenarios. Again this appears logical as it is a blend between fossil fuels heating systems (i.e. gas boilers, gas CHP) and electrical heating systems (i.e. heat pumps).

Reduction in CO_2 SAP 10.2 GLA (reg)		With PV					
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient	DHN 1	DHN 2
Fabric & ventilation	Business as usual	1%	46%	57%	72%		
	Good practice	13%	53%	62%	75%		
	Ultra-low energy	29%	64%	72%	81%	101%	34%

Table 6.53 - Performance of each case in terms of CO_2 against the Part L 2021 baseline

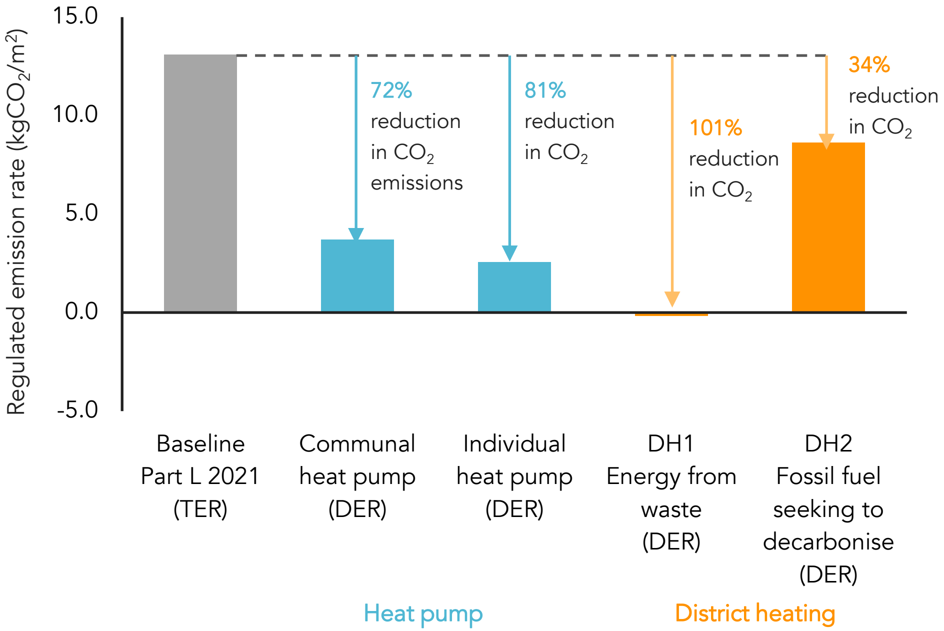

Figure 6.9 - Analysis of district heating and comparison with heat pump scenario

DH2 scenario assumes a blended energy mix and does not account for 'sleeving'. The heat pump scenarios do not include water storage, but a direct electric point-of-use hot eater to bathrooms.

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Policy option 1 | Mid-rise apartment building | Part L assessment of DH1 and DH2

Primary energy

This metric specifies the maximum primary energy use for a building in a year. Primary energy is defined in the assessment as being *'energy from renewable and non-renewable sources which has not undergone any conversion of transformation process'*.

The figures on the right summarise the results from the SAP 10.2 model and compare the calculated reduction in CO_2 emissions (top table) and the forecasted reduction in primary energy (bottom table) compared with the Part L 2021 baseline.

Key conclusions include.

- For all scenarios, the two measures, carbon emissions and primary energy, show reductions from the notional baseline that are in proportion with each other.
- DH1 (Energy from Waste) shows a significant reduction in primary energy, the best of all heating scenarios.
- DH2 (Fossil fuel based heat network seeking to decarbonise) shows a reduction compared to the Part L baseline and but it performs better in terms of primary energy, e.g. better than direct electric and the less efficient heat pump system. It still performs worse than the more efficient heat pump system.

Reduction in CO_2 SAP 10.2 GLA (reg)		With PV					
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient	DHN 1	DHN 2
Fabric & ventilation	Business as usual	1%	46%	57%	72%		
	Good practice	13%	53%	62%	75%		
	Ultra-low energy	29%	64%	72%	81%	101%	34%

Table 6.54 - Performance of each case in terms of CO_2 against the Part L 2021 baseline

Reduction in Primary energy SAP 10.2 Part L (reg)		With PV					
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient	DHN 1	DHN 2
Fabric & ventilation	Business as usual	-2%	-12%	8%	38%		
	Good practice	11%	2%	20%	45%		
	Ultra-low energy	28%	22%	36%	54%	100%	41%

Table 6.55 - Performance of each case in terms of Primary Energy against the Part L 2021 baseline

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Policy option 1 | The concept of 'sleeving'

What is 'sleeving'?

Sleeving is a term used to describe the theoretical allocation of some heat from a network to specific users. The principle is that new homes connecting to an existing network can be assumed to only use the heat generated by low carbon equipment that is added to meet the demand of those new homes.

Where the existing network uses fossil fuels and the new heat generation is from, say, heat pumps, then new homes added to the network are considered as only using the heat from the heat pumps and not from the fossil fuel plant.

At the time of writing, the GLA permits sleeving and is due to publish further guidance.

New low carbon heat for new buildings only - Implications

If sleeving is assumed, then without a separate strategy in place to decarbonise the supply for existing homes (i.e. replacing the original fossil fuel plant) existing homes will not decarbonise.

If London boroughs allow sleeving to be used when permitting new homes to be added to an existing fossil fuel led DH network, then they should **ensure that carbon emission reductions are not 'double counted'.** For example, If sleeving is used to permit new homes, then the London borough should not also declare that the DH network reduces the carbon emissions of existing homes.

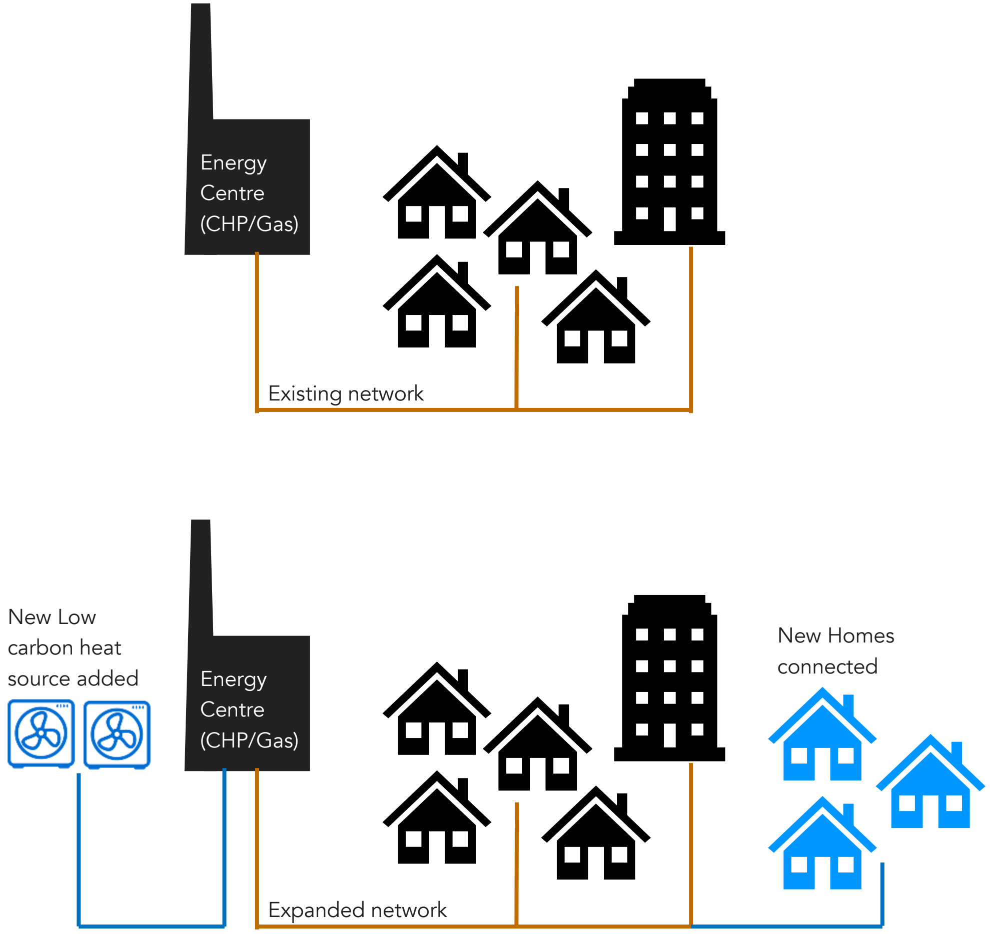

Figure 6.10 - The principle of 'sleeving' heat.

New homes are assumed to only take heat from new (low carbon) heat sources in the energy centre. Existing homes therefore do not decarbonise as none of the carbon emissions reduction are allocated to them unless the original fossil fuel plant is entirely replaced with a zero carbon alternative

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6.4

Policy option 1 - Summary

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Part L energy modelling for Policy option 1 | Domestic buildings | Summary of findings

Policy option 1 assumes that the Part L framework continues to be used to go beyond the minimum requirements of Building Regulations Part L 2021 in London.

The London Plan requires a 35% reduction in CO_2 emissions on-site relative to Part L 2013. The GLA's Energy Assessment Guidance published in 2022 advises that the same percentage improvement should now apply relative to Part L 2021 for domestic buildings.

Part L 2021 methodology for domestic buildings introduces a new range of requirements, assessed using a new government-approved SAP modelling methodology (SAP 10.2).

✕ Would not pass all three metrics of Building Regulations Part L 2021

< 0%	< 35%	< 50%	< 60%	60-80%	> 80%

In summary, domestic Part L modelling undertaken indicates the following

- This report finds that the GLA's new 35% improvement target against Part L 2021 appears broadly effective in encouraging applicants to use low-carbon energy sources, such as heat pumps, or ultra-low energy fabric combined with direct electric.
- Requiring a more ambitious level of on-site CO_2 reduction compared with Part L 2021 would however incentivise even better designs and would be technically feasible.
- In addition, it appears that the 'Be Lean' 10% fabric improvement requirement is now less effective at incentivising improvements to the building fabric than it did when it was applied to Part L 2013. This is partially because Part L 2021 now includes waste water heat recovery (WWHR) in the 'notional specification' of the target emission rate (TER). The use of the Fabric Energy Efficiency (FEE) metric in Part L 2021 may be a useful alternative.

Reduction in CO_2 - SAP 10.2 GLA(reg)		Terrace house				Low-rise apartment building				Mid-rise apartment building				High-rise apartment building			
		Gas boiler	Direct electric	Heat pump less efficient	Heat Pump more efficient	Gas boiler	Direct electric	Heat pump less efficient	Heat Pump more efficient	Gas boiler	Direct electric	Heat pump less efficient	Heat Pump more efficient	Gas boiler	Direct electric	Heat pump less efficient	Heat Pump more efficient
Fabric & ventilation	Business as usual	✕ 4%	✕ 52%	✕ 92%	✕ 95%	✕ 7%	✕ 55%	✕ 67%	✕ 84%	✕ 1%	✕ 46%	✕ 57%	✕ 72%	✕ 6%	✕ 52%	✕ 60%	✕ 75%
	Good practice	23%	64%	98%	99%	22%	64%	75%	89%	13%	53%	62%	75%	16%	56%	65%	77%
	Ultra-low energy	45%	79%	103%	104%	43%	77%	86%	96%	29%	64%	72%	81%	24%	63%	69%	81%

Table 6.56 - Performance of each case in terms of CO_2 against the Part L 2021 baseline

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Part L energy modelling for Policy option 1 I Non-domestic buildings I Summary of findings

Policy option 1 assumes that the Part L framework continues to be used to go beyond the minimum requirements of Building Regulations Part L 2021 in London.

The London Plan requires a 35% reduction in CO_2 emissions on-site relative to Part L 2013. The GLA's Energy Assessment Guidance published in 2022 advises that the same percentage improvement should now apply relative to Part L 2021 for non-domestic buildings.

Part L 2021 methodology for non-domestic buildings introduces a new range of requirements, assessed using a new government-approved NCM modelling methodology.

✗ Would not pass both metrics of Building Regulations Part L 2021

< 0%	< 35%	< 60%	60-80%	> 80%

In summary, domestic Part L modelling undertaken indicates the following

- The results indicate a large range of CO_2 emissions reductions depending on the building typology.
- The results of the modelling suggest that a 35% reduction beyond Part L 2021 is only achieved for two of the non-domestic building types investigated. This suggests that the 35% target is challenging to achieve in all non-domestic scenarios[1].
- Setting different policy targets across building types could be an appropriate solution.
- All results are highly reactive to the amount of PV provision, partially due to the fact that heating energy use tends to be significant underestimated.
- In addition, It has not been possible to achieve the 15% Be Lean reduction target in the majority of the scenarios investigated, even with typologies that have greater potential for CO_2 reductions.

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[1] *This would be consistent with the GLA Energy Assessment guidance item 2.2: '..benchmarks may be updated periodically to include additional building types to reflect improvements in performance over time'*

Reduction in CO_2 - NCM - SAP 10.2 GLA(reg)		School				Office				Industrial				Hotel			
		Gas boiler	Direct electric	Heat pump less efficient	Heat Pump more efficient	Gas boiler	VRF	Heat pump less efficient	Heat pump more efficient	Gas boiler	VRF	Four pipe chiller	Heat pump more efficient	Gas boiler	Heat pump (220)	Heat pump (400/300)	Heat pump (450/300)
Fabric & ventilation	Business as usual	27%	11%	75%	77%	✗ -22%	13%	6%	14%	✗ 0%	41%	40%	53%	✗ -2%	✗ -13%	7%	8%
	Good practice	26%	3%	40%	40%	7%	29%	25%	30%	✗ 6%	41%	40%	53%	2%	✗ -13%	10%	11%
	Ultra-low energy	63%	73%	83%	83%	26%	32%	30%	32%	21%	48%	46%	61%	4%	✗ -7%	16%	16%

Table 6.56 - Performance of each case in terms of CO_2 against the Part L 2021 baseline

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7.0

Energy modelling analysis for Policy option 2 (Absolute energy targets using predictive energy modelling)

7.0 Energy modelling analysis for Policy option 2

Policy option 2 uses energy-based metrics to go beyond the requirements of Part L 2021 of the Building Regulations. Demonstration of compliance with these requirements is evidenced by the use of predictive energy modelling.

This section provides, for each archetype, the performance of each case against two key energy-based metrics: space heating demand (SHD) and total energy use (also referred to as energy use intensity or EUI).

Based on the findings of section 5.0, we can overlay compliance with all criteria in Part L 2021 with these two energy-based metrics. This enables to see whether and how planning policy option 2 would be successful at incentivising the design and construction of better buildings.

A particular analysis on heat networks has also been undertaken to investigate how they are likely to perform under policy option 2.

Policy option 2 - Predictive energy analysis for domestic buildings

7.1.1

Policy option 2 – Predictive energy analysis for **terrace house**

7.1.2

Policy option 2 – Predictive energy analysis for **low-rise apartment building**

7.1..3

Policy option 2 – Predictive energy analysis for **mid-rise apartment building**

7.1.4

Policy option 2 – Predictive energy analysis for **high-rise apartment building**

Policy option 2 - Predictive energy analysis for non-domestic buildings

7.2.1

Policy option 2 – Predictive energy analysis for **office building**

7.2.2

Policy option 2 – Predictive energy analysis for **primary school**

7.2.3

Policy option 2 – Predictive energy analysis for **industrial building**

7.2.4

Policy option 2 – Predictive energy analysis for **hotel**

Policy option 2 - how are heat networks assessed and how do they perform?

Policy option 2 - summary

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How to read the tables in this section?

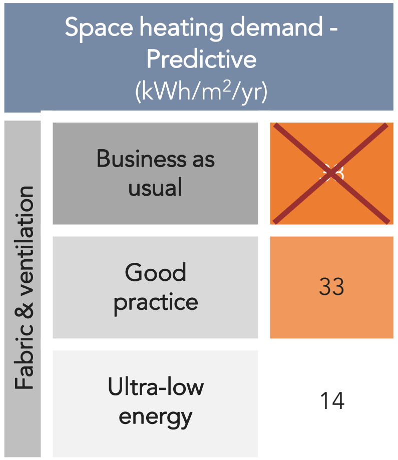
Most tables in this section indicate, for each archetype, which space heating demand and energy use intensity (EUI) are achieved by each combination of fabric and ventilation specifications and heating systems.

The results are colour coded using a clear key ranging from dark to light orange for space heating demand and from dark to light purple for energy use intensity EUI).

Cases which do not comply with all Part L 2021 criteria are identified with a dark red cross.

Space heating demand

Worst	Best



Fabric & ventilation	Space heating demand - Predictive (kWh/m²/yr)
Business as usual	✗ 38
Good practice	33
Ultra-low energy	14

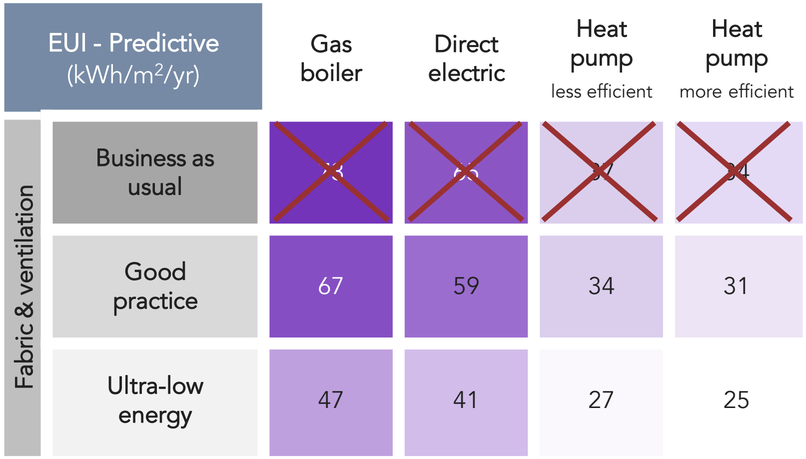
Table 7.1 - Performance of each case in terms of space heating demand

Would not pass all building regulations Part L 2021 metrics

Figure 7.1 – Graphical code to help the reader understand which cases would not be Part L compliant

Energy use intensity

Worst	Best



Fabric & ventilation	EUI - Predictive (kWh/m²/yr)	Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
	Business as usual	✗ 78	✗ 65	✗ 37	✗ 34
	Good practice	67	59	34	31
	Ultra-low energy	47	41	27	25

Table 7.2 - Performance of each case in terms of energy use intensity (EUI)

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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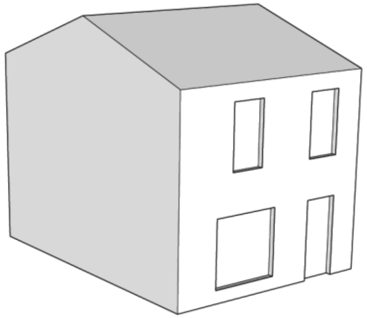
7.1

Policy option 2 - Predictive energy analysis for domestic buildings

Return to contents >

7.1.1

Policy option 2 - Predictive energy analysis analysis for terrace house



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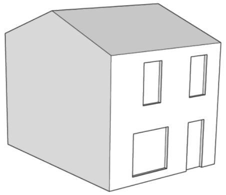
Terrace House | Policy option 2 | Predictive energy modelling (Space heating demand and EUI)



The space heating demand for the Terrace houses modelled varies from 38 (worst) down to 14 kWh/m^2.yr (best). The improvement between the Business-as-usual and Good practice cases is relatively marginal in comparison with the space heating demand improvement achieved by the Ultra-low energy case. The benefit of MVHR and best practice fabric specifications are clearly showing.

The Energy Use Intensity (EUI) of the terrace house covers all energy uses: space heating, domestic hot water, ventilation, lighting, equipment (cooking etc.) and appliances. The table shows a graduation of improvement as both the building fabric and heating systems become progressively more efficient. The estimated EUIs range from 73 (worst) down to 25 kWh/m^2/yr (best). As with the space heating demand, the difference between the Good practice and the Ultra-low energy is reflected in the EUI results.

The cases which generate the ideal compound result for both metrics are the two Ultra-low energy building fabric with heat pump scenarios. The heat pump cases use significantly less energy (i.e. lower EUIs) due to lower flow temperature requirements and better heating efficiencies.

Space heating demand

Worst | Best

		Space heating demand - Predictive (kWh/m^2/yr)
Fabric & ventilation	Business as usual	38
	Good practice	33
	Ultra-low energy	14

Table 7.3 - Performance of each case in terms of space heating demand

Energy use intensity

Worst | Best

	EUI - Predictive (kWh/m^2/yr)	Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	73	65	37	34
	Good practice	67	59	34	31
	Ultra-low energy	47	41	27	25

Table 7.4 - Performance of each case in terms of energy use intensity (EUI)

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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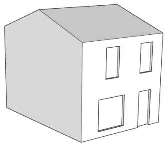
Terrace House | Policy option 2 | Predictive energy modelling results comparison across all cases



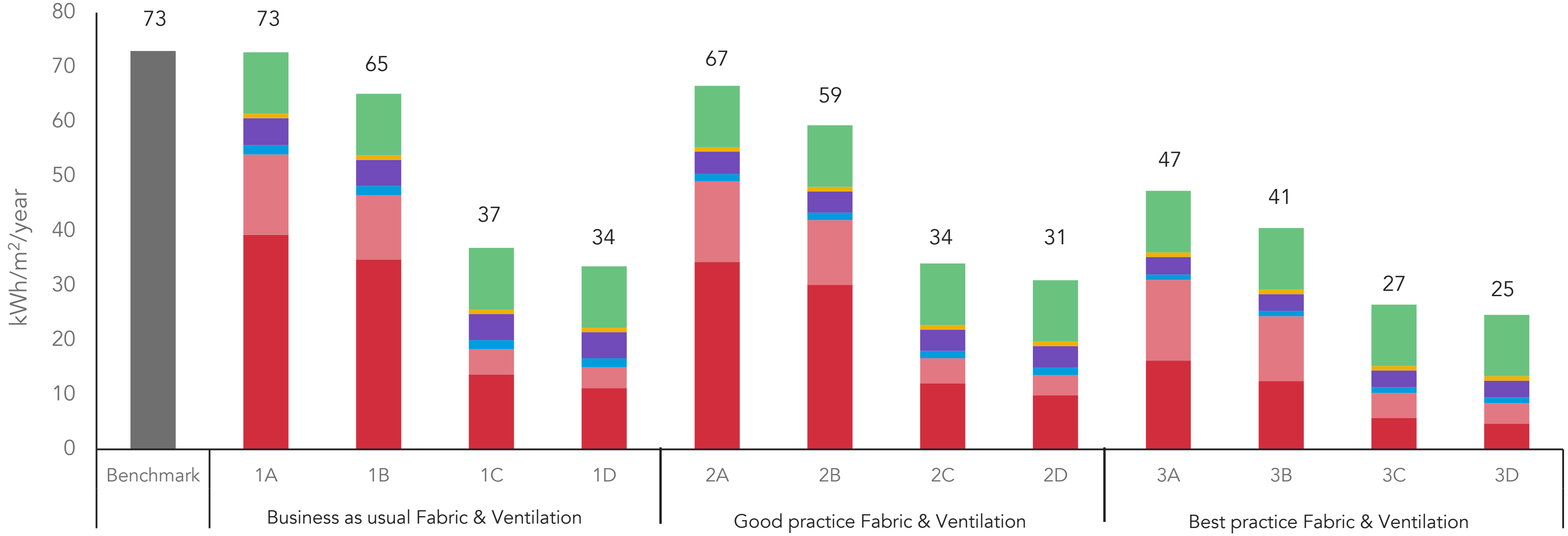


Figure 7.1 - Predictive energy modelling results: bar chart showing the detailed breakdown of energy use intensity (EUI) for each case

Detailed energy use breakdown (kWh/m².yr)		Bench mark	1A	1B	1C	1D	2A	2B	2C	2D	3A	3B	3C	3D
Other energy uses	🟩	73	-	-	-	-	-	-	-	-	-	-	-	-
Catering	🟩		-	-	-	-	-	-	-	-	-	-	-	-
Equipment	🟩		11	11	11	11	11	11	11	11	11	11	11	11
Lifts	🟩		-	-	-	-	-	-	-	-	-	-	-	-
External lighting	🟦		-	-	-	-	-	-	-	-	-	-	-	-
Lighting	🟨		1	1	1	1	1	1	1	1	1	1	1	1
Auxiliary (fans & pumps)	🟪		5	5	5	5	4	4	4	4	3	3	3	3
Cooling	🟦		2	2	2	2	2	2	2	2	2	2	2	2
Domestic hot water	🟥		15	12	5	4	15	12	5	4	15	12	5	4
Space heating	🟥		39	35	14	11	34	30	12	10	16	13	6	5

Table 7.5 – Predictive energy modelling results: detailed breakdown of energy use intensity (EUI) for each case

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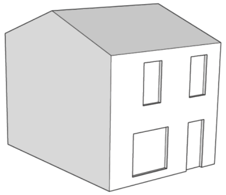
Terrace house l Policy option 2 l EUI + Compliance with Part L 2021



Metrics combined

This table shows how the space heating demand and EUI results would work in combination with Part L 2021 compliance.

- The 'good practice' and 'ultra-low energy' fabric specifications with the gas boiler case would be compliant with building regulations Part L 2021. They achieve an EUI of 67 and 47 kWh/m^2.yr respectively, so it could be ruled out if the EUI policy limit is lower than 47 kWh/m^2.yr.
- Additionally, the 'good practice' and 'ultra-low energy' and direct electric cases comply with Part L. They would achieve an EUI of between 59 and 41 kWh/m^2.yr respectively.

EUI - Predictive (kWh/m^2/yr)		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	~~73~~	~~65~~	~~37~~	~~34~~
	Good practice	67	59	34	31
	Ultra-low energy	47	41	27	25

Table 7.6 – Performance of each case in terms of Energy Use Intensity (EUI) overlaid with compliance with all Part L 2021 criteria

✗ Would not pass all three criteria of building regulations Part L 2021

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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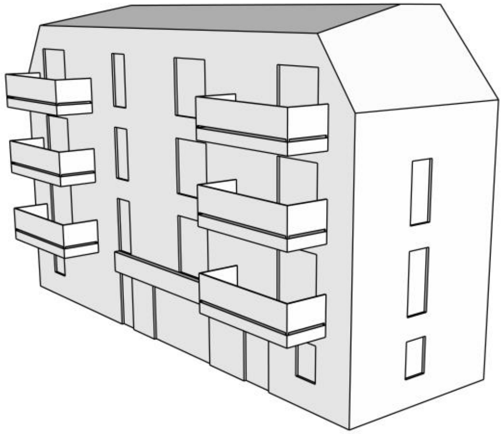
7.1.2

Policy option 2 - Predictive energy analysis for low-rise apartment building



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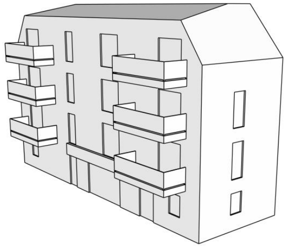
Low-rise apartment building | Policy option 2 | Predictive energy modelling (Space heating demand and EUI)



The space heating demand for the low-rise apartment building modelled varies from 35 (worst) down to 12 kWh/m²/yr (best). The improvement between the business-as-usual and good practice cases are relatively marginal in comparison to the space heating demand achieved in the ultra-low energy case. The benefit of MVHR and best practice fabric specifications are clearly showing.

The Energy Use Intensity (EUI) of the low-rise apartment building covers all energy uses: space heating, domestic hot water, ventilation, lighting, equipment (cooking, lift etc.) and appliances. The table shows a graduation of improvement as both the building fabric and heating systems become progressively more efficient. The estimated EUIs range from 71 (worst) down to 23 kWh/m²/yr (best).

As with the space heating demand, the difference between the good practice and the ultra-low energy is reflected in the EUI results. The case which generates the ideal compound result for both metrics is the Ultra-low energy building fabric with the more efficient heat pump.

Space heating demand

Worst	Best

	Space heating demand - Predictive (kWh/m²/yr)
Fabric & ventilation: Business as usual	35
Fabric & ventilation: Good practice	28
Fabric & ventilation: Ultra-low energy	12

Table 7.7 - Performance of each case in terms of space heating demand

Energy use intensity

Worst	Best

EUI - Predictive (kWh/m²/yr)	Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation: Business as usual	71	61	43	31
Fabric & ventilation: Good practice	65	54	39	28
Fabric & ventilation: Ultra-low energy	48	37	31	23

Table 7.8 - Performance of each case in terms of energy use intensity (EUI)

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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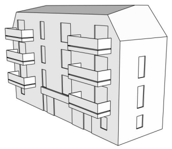
Low-rise apartment building | Policy option 2 | Predictive energy modelling results comparison across all cases



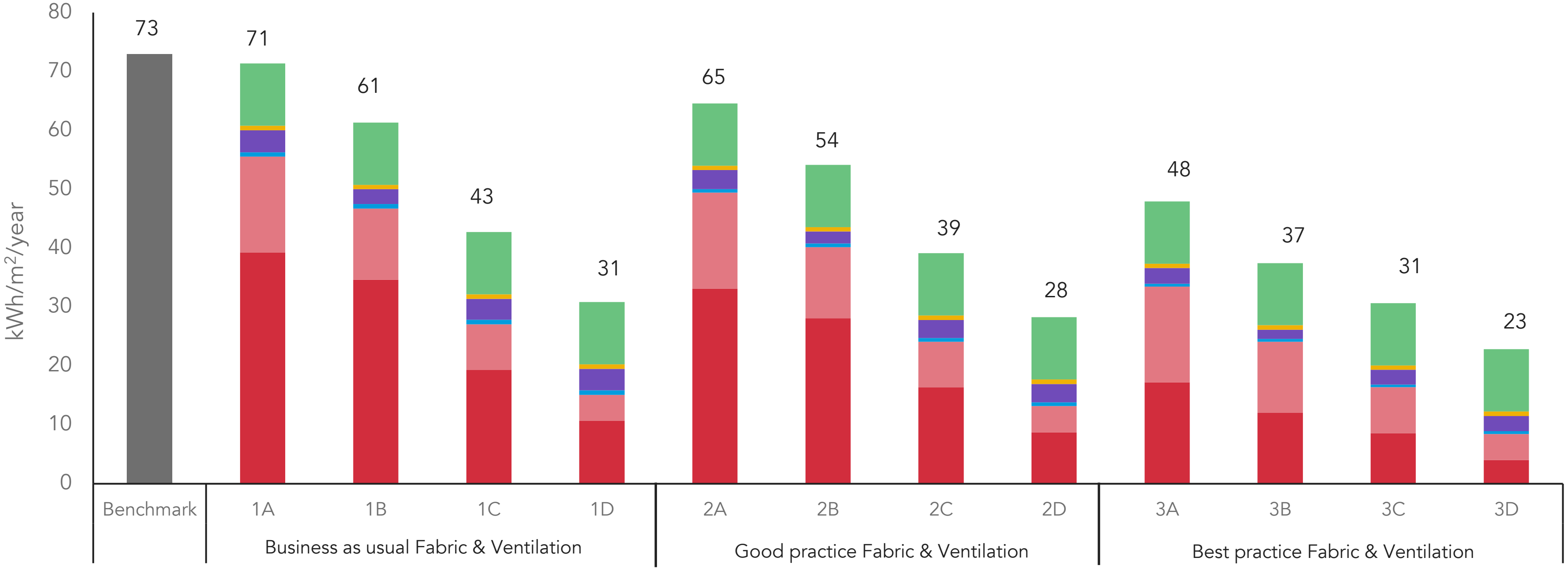


Figure 7.2 - Predictive energy modelling results: bar chart showing the detailed breakdown of energy use intensity (EUI) for each case

Detailed energy use breakdown (kWh/m².yr)		Bench mark	1A	1B	1C	1D	2A	2B	2C	2D	3A	3B	3C	3D
Other energy uses	🟩	73	-	-	-	-	-	-	-	-	-	-	-	-
Catering	🟩		-	-	-	-	-	-	-	-	-	-	-	-
Equipment	🟩		11	11	11	11	11	11	11	11	11	11	11	11
Lifts	🟩		-	-	-	-	-	-	-	-	-	-	-	-
External lighting	🟩		-	-	-	-	-	-	-	-	-	-	-	-
Lighting	🟨		1	1	1	1	1	1	1	1	1	1	1	1
Auxiliary (fans & pumps)	🟪		4	3	4	4	3	2	3	3	3	2	3	3
Cooling	🟦		-	-	-	-	-	-	-	-	-	-	-	-
Domestic hot water	🟥		16	12	8	4	16	12	8	4	16	12	8	4
Space heating	🟥		39	35	19	11	33	28	16	9	17	12	9	4

Table 7.9 – Predictive energy modelling results: detailed breakdown of energy use intensity (EUI) for each case

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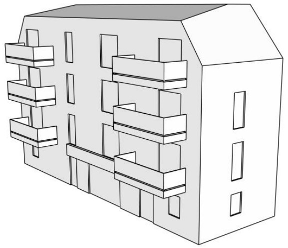
Low-rise apartment building | Policy option 2 | EUI + Compliance with Part L 2021



Metrics combined

This table shows how the space heating demand and EUI results would work in combination with Part L 2021 compliance.

- The 'good practice' and 'ultra-low energy' fabric specifications with the gas boiler case would be compliant with building regulations Part L 2021. They achieve an EUI of 65 and 48 kWh/m^2.yr respectively, so it could be ruled out if the EUI policy limit is lower than 48 kWh/m^2.yr.
- Additionally, the 'good practice' and 'ultra-low energy' and direct electric cases comply with Part L. They would achieve an EUI of between 54 and 37 kWh/m^2.yr respectively.

Fabric & ventilation	EUI - Predictive (kWh/m^2/yr)	Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
	Business as usual	~~71~~ ☒	~~60~~ ☒	~~43~~ ☒	~~32~~ ☒
	Good practice	65	54	39	28
	Ultra-low energy	48	37	31	23

Table 7.10 – Performance of each case in terms of Energy Use Intensity (EUI) overlaid with compliance with all Part L 2021 criteria

☒ Would not pass all three criteria of building regulations Part L 2021

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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7.1.3

Policy option 2 - Predictive energy analysis for mid-rise apartment building

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Mid-rise apartment building | Policy option 2 | Predictive energy modelling (Space heating demand and EUI)

The space heating demand for the mid-rise apartment building modelled varies from 28 (worst) down to 10 kWh/m²/yr (best). The improvement between the business-as-usual and good practice cases is relatively small in comparison to the space heating demand achieved in the ultra-low energy case. The benefit of MVHR and best practice fabric specifications are clearly showing.

The Energy Use Intensity (EUI) of the mid-rise apartment building covers all energy uses: space heating, domestic hot water, ventilation, lighting, equipment (cooking, lift etc.) and appliances. The table shows a graduation of improvement as both the building fabric and heating systems become progressively more efficient. The estimated EUIs range from 55 (worst) down to 26 kWh/m².yr (best).

As with the space heating demand, the difference between the good practice and the ultra-low energy is reflected in the EUI results. The cases which generates the ideal compound result for both metrics is the ultra-low energy building fabric with the more efficient heat pump system (e.g. communal heat pump with ambient loop). It leads to significantly lower EUIs due to better heating efficiencies, lower flow temperature requirements and less distribution losses.

Space heating demand

Worst	Best

	Space heating demand - Predictive (kWh/m²/yr)
Fabric & ventilation: Business as usual	28
Fabric & ventilation: Good practice	22
Fabric & ventilation: Ultra-low energy	10

Table 7.11 - Performance of each case in terms of space heating demand

Energy use intensity

Worst	Best

EUI - Predictive (kWh/m2/yr)	Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation: Business as usual	55	53	38	31
Fabric & ventilation: Good practice	49	48	35	29
Fabric & ventilation: Ultra-low energy	43	39	32	26

Table 7.12 - Performance of each case in terms of energy use intensity (EUI)

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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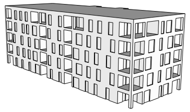
Mid-rise apartment building | **Policy option 2** | Predictive energy modelling results comparison across all cases



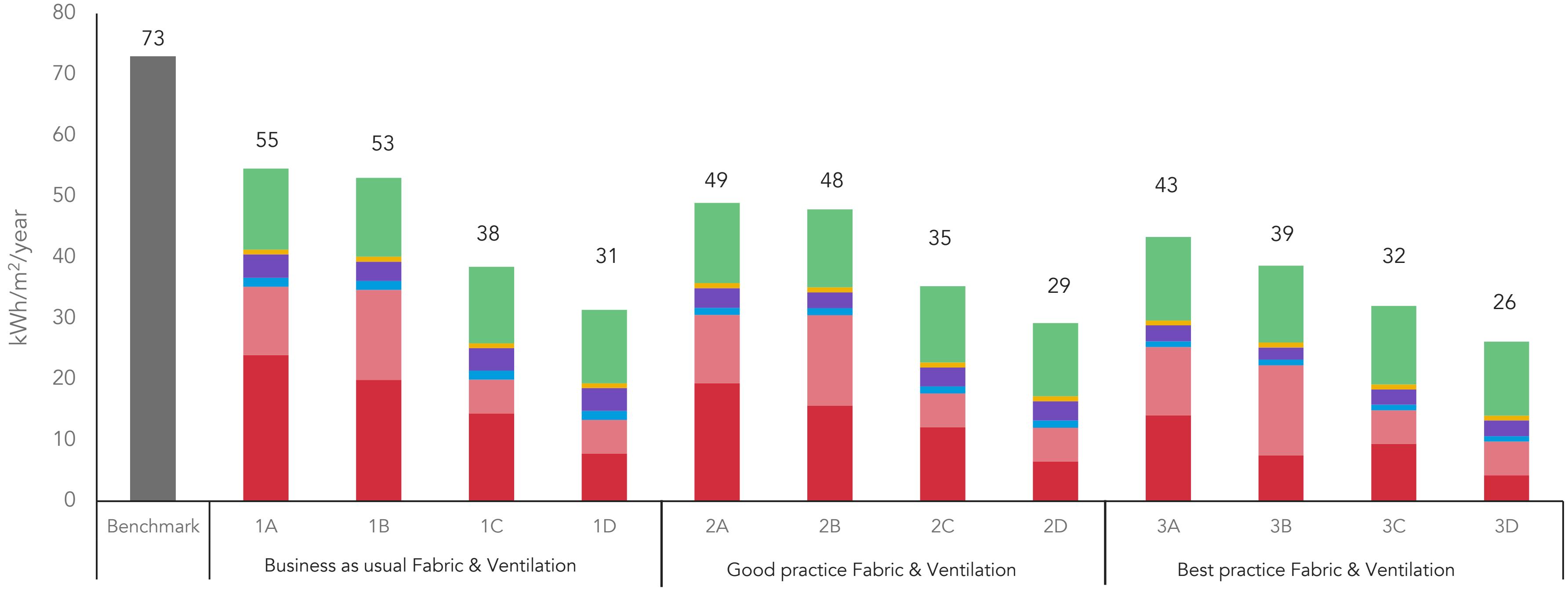


Figure 7.3 - Predictive energy modelling results: bar chart showing the detailed breakdown of energy use intensity (EUI) for each case

Detailed energy use breakdown (kWh/m^2.yr)		Benchmark	1A	1B	1C	1D	2A	2B	2C	2D	3A	3B	3C	3D
Other energy uses	🟩	73	-	-	-	-	-	-	-	-	-	-	-	-
Catering	🟩		-	-	-	-	-	-	-	-	-	-	-	-
Equipment	🟩		13	13	13	12	13	13	12	12	14	13	13	12
Lifts	🟩		-	-	-	-	-	-	-	-	-	-	-	-
External lighting	🟩		-	-	-	-	-	-	-	-	-	-	-	-
Lighting	🟨		1	1	1	1	1	1	1	1	1	1	1	1
Auxiliary (fans & pumps)	🟪		4	3	4	4	3	3	3	3	3	2	3	3
Cooling	🟦		1	1	1	1	1	1	1	1	1	1	1	1
Domestic hot water	🟥		11	15	6	6	11	15	6	6	11	15	6	6
Space heating	🟥		24	20	14	8	19	16	12	7	14	8	9	4

Table 7.13 – Predictive energy modelling results: detailed breakdown of energy use intensity (EUI) for each case

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Mid-rise apartment building | Policy option 2 | EUI + Compliance with Part L 2021

Metrics combined

This table shows how the space heating demand and EUI results would work in combination with Part L 2021 compliance.

- The ‘good practice’ and ‘ultra-low energy’ fabric specifications with the gas boiler case would be compliant with building regulations Part L 2021. They achieve an EUI of 49 and 43 kWh/m².yr respectively, so it could be ruled out if the EUI policy limit is lower than 43 kWh/m².yr.
- Additionally, the ‘good practice’ and ‘ultra-low energy’ and direct electric cases comply with Part L. They would achieve an EUI of between 48 and 39 kWh/m².yr respectively.

	EUI - Predictive (kWh/m2/yr)	Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	~~55~~ ✗	~~53~~ ✗	~~38~~ ✗	~~31~~ ✗
	Good practice	49	48	35	29
	Ultra-low energy	43	39	32	26

Table 7.6 – Performance of each case in terms of Energy Use Intensity (EUI) overlaid with compliance with all Part L 2021 criteria

✗ Would not pass all three criteria of building regulations Part L 2021

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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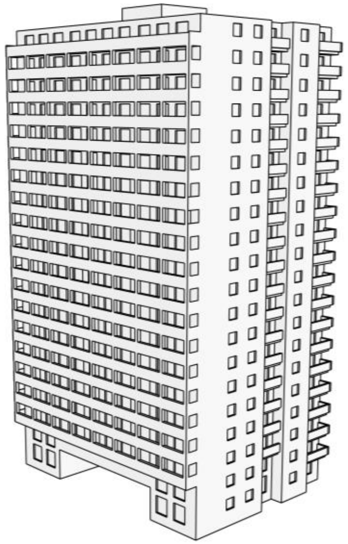
7.1.4

Policy option 2 - Predictive energy analysis for high-rise apartment building



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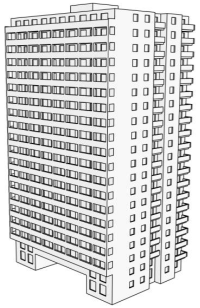
High-rise apartment building I Policy option 2 I Predictive energy modelling (Space heating demand and EUI)



The space heating demand for the high-rise apartment building modelled varies from 24 (worst) down to 10 kWh/m^2/yr (best). The improvement between the business-as-usual and good practice cases is relatively small in comparison to the space heating demand achieved in the ultra-low energy case. The benefit of MVHR and best practice fabric specifications are clearly showing.

The Energy Use Intensity (EUI) of the high-rise apartment building covers all energy uses: space heating, domestic hot water, ventilation, lighting, equipment (cooking, lift etc.) and appliances. The table shows a graduation of improvement as both the building fabric and heating systems become progressively more efficient. The estimated EUIs range from 45 (worst) down to 20 kWh/m^2/yr (best).

As with the space heating demand, the difference between the good practice and the ultra-low energy is reflected in the EUI results. The case which generates the ideal compound result for both metrics is the ultra-low energy building fabric with the communal heat pump with ambient loop. The introduction of an efficient heat pump system leads to significantly lower EUIs due to better heating efficiencies, lower flow temperature requirements and less distribution losses.

Space heating demand

Worst	Best

	Space heating demand - Predictive (kWh/m^2/yr)
Fabric & ventilation	
Business as usual	24
Good practice	20
Ultra-low energy	10

Table 7.15 - Performance of each case in terms of space heating demand

Energy use intensity

Worst	Best

EUI - Predictive (kWh/m^2/yr)	Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation				
Business as usual	45	42	30	24
Good practice	41	39	28	22
Ultra-low energy	36	32	25	20

Table 7.16 - Performance of each case in terms of energy use intensity (EUI)

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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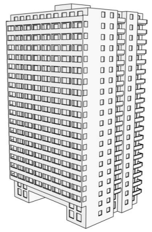
High-rise apartment building | Policy option 2 | Predictive energy modelling results comparison across all cases



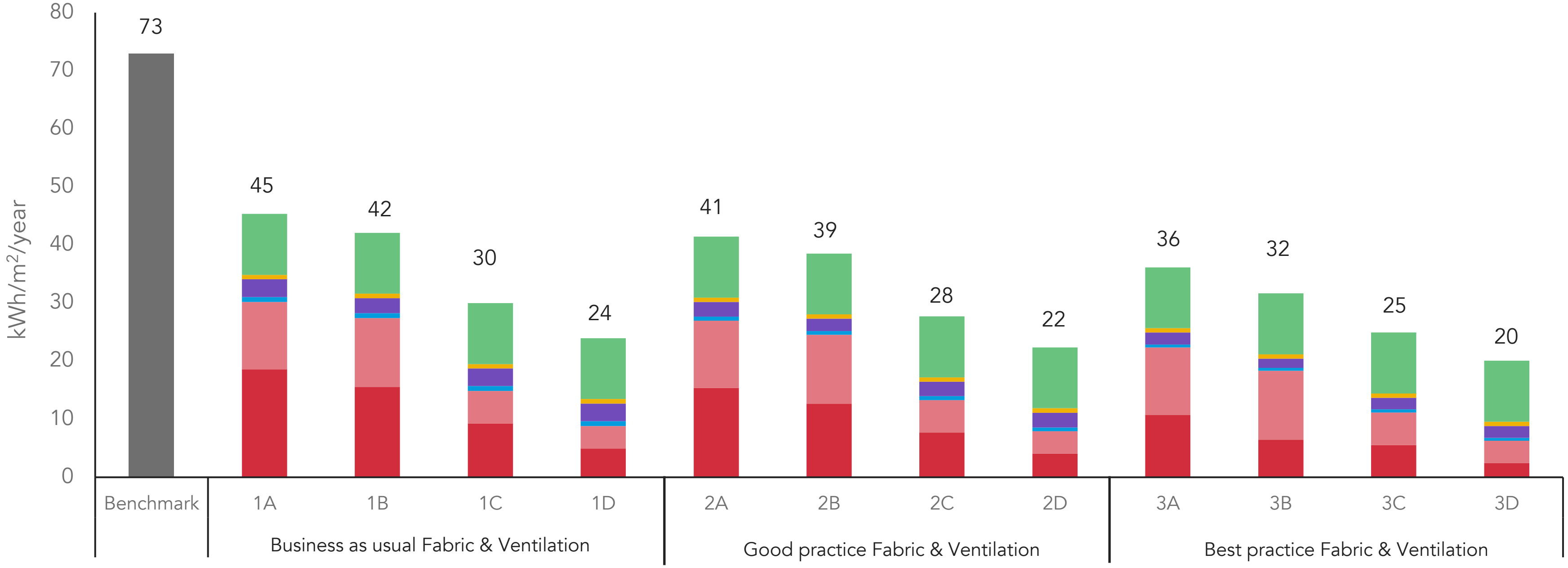


Figure 7.4 - Predictive energy modelling results: bar chart showing the detailed breakdown of energy use intensity (EUI) for each case

Detailed energy use breakdown (kWh/m².yr)		Bench mark	1A	1B	1C	1D	2A	2B	2C	2D	3A	3B	3C	3D
Other energy uses	🟩	73	-	-	-	-	-	-	-	-	-	-	-	-
Catering	🟩		-	-	-	-	-	-	-	-	-	-	-	-
Equipment	🟩		10	10	10	10	10	10	10	10	10	10	10	10
Lifts	🟩		-	-	-	-	-	-	-	-	-	-	-	-
External lighting	🟩		-	-	-	-	-	-	-	-	-	-	-	-
Lighting	🟨		1	1	1	1	1	1	1	1	1	1	1	1
Auxiliary (fans & pumps)	🟪		3	3	3	3	3	2	3	3	2	2	2	2
Cooling	🟦		1	1	1	1	1	1	1	1	1	1	1	1
Domestic hot water	🟥		12	12	6	4	12	12	6	4	12	12	6	4
Space heating	🟥		19	16	9	5	15	13	8	4	11	6	6	2

Table 7.17 – Predictive energy modelling results: detailed breakdown of energy use intensity (EUI) for each case

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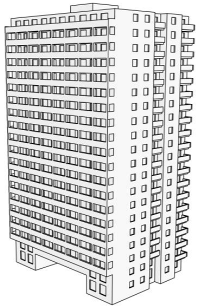
High-rise apartment building | Policy option 2 | EUI + Compliance with Part L 2021



Metrics combined

This table shows how the space heating demand and EUI results would work in combination with Part L 2021 compliance.

- The 'good practice' and 'ultra-low energy' fabric specifications with the gas boiler case would be compliant with building regulations Part L 2021. They achieve an EUI of 41 and 36 kWh/m^2.yr respectively, so it could be ruled out if the EUI policy limit is lower than 36 kWh/m^2.yr.
- Additionally, the 'good practice' and 'ultra-low energy' and direct electric cases comply with Part L. They would achieve an EUI of between 39 and 32 kWh/m^2.yr respectively.

	EUI - Predictive (kWh/m^2/yr)	Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	~~45~~	~~42~~	~~30~~	~~24~~
	Good practice	41	39	28	22
	Ultra-low energy	36	32	25	20

Table 7.18 – Performance of each case in terms of Energy Use Intensity (EUI) overlaid with compliance with all Part L 2021 criteria

✗ Would not pass all three criteria of building regulations Part L 2021

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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7.2

Policy option 2 - Predictive energy analysis for non-domestic buildings

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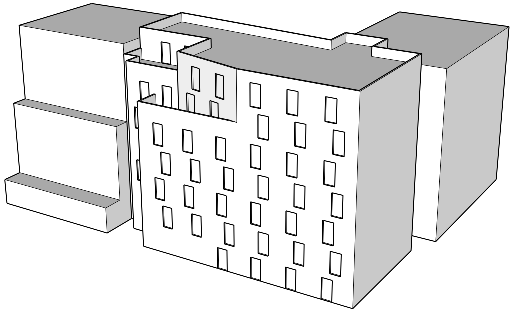
7.2.1

Policy option 2 - Predictive energy analysis for office building



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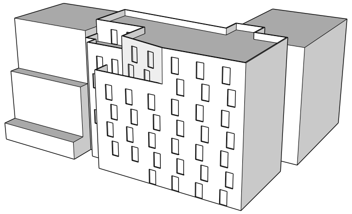
Office building I Policy option 2 I Predictive energy modelling (Space heating demand and EUI)



Space heating demand varies from 23 (worst) down to 4 kWh/m^2/yr (best). The benefit of better fabric and MVHR is clearly showing.

The estimated EUIs range from 104 (worst) down to 66 kWh/m^2/yr (best). The benefit of heat pumps over gas boilers is clear.

All results appear logical.

LETI design guidance recommends space heating demand of < 15 kWh/m^2/yr and an EUI of < 55 kWh/m^2/yr for offices. This would rule out the Business as usual case.

Space heating demand

Worst	Best

		Space heating demand - Predictive (kWh/m^2/yr)
Fabric & ventilation	Business as usual	23
	Good practice	12
	Ultra-low energy	4

Table 7.19 - Performance of each case in terms of space heating demand

Energy use intensity

Worst	Best

EUI - Predictive (kWh/m^2/yr)		Gas boiler	VRF	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	104	82	87	81
	Good practice	83	72	74	72
	Ultra-low energy	71	66	67	66

Table 7.20 - Performance of each case in terms of energy use intensity (EUI)

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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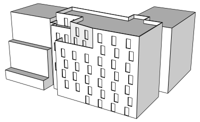
Office building | **Policy option 2** | Predictive energy modelling results comparison across all cases



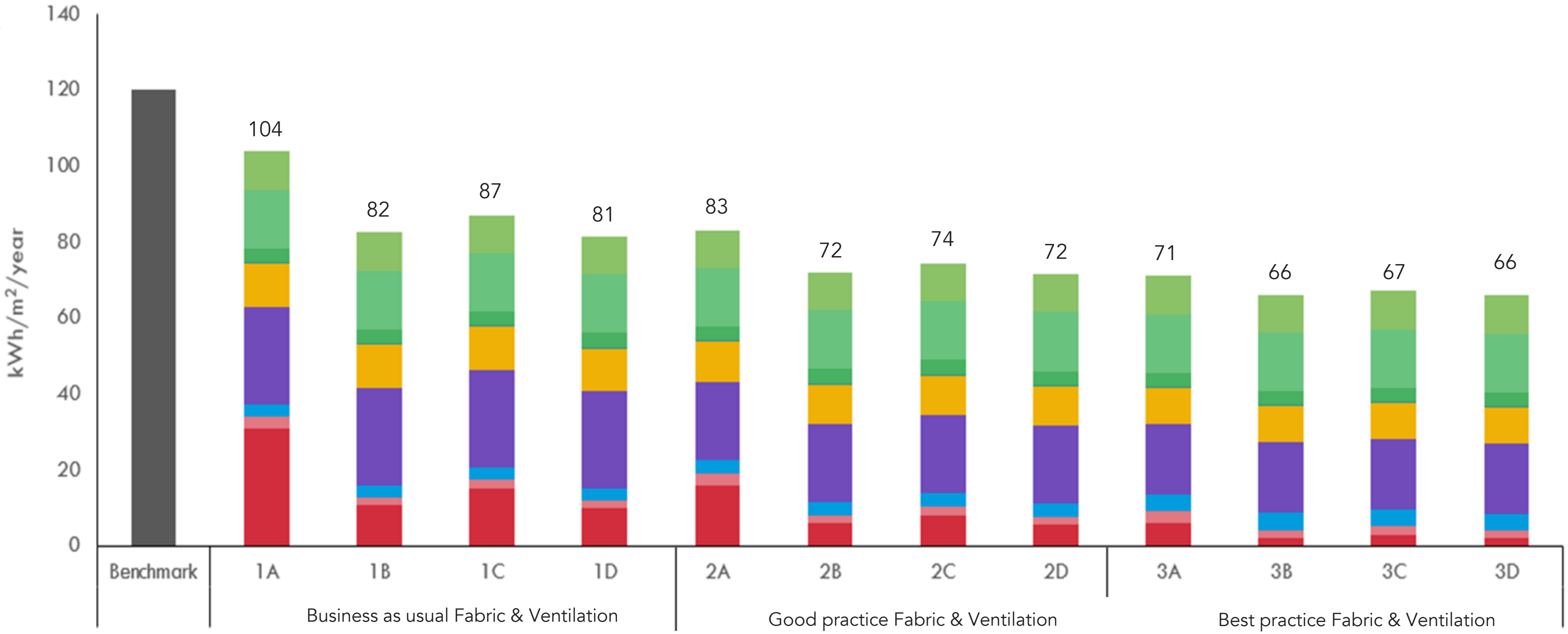


Figure 7.5 - Predictive energy modelling results: bar chart showing the detailed breakdown of energy use intensity (EUI) for each case

Detailed energy use breakdown (kWh/m².yr)		Bench mark	1A	1B	1C	1D	2A	2B	2C	2D	3A	3B	3C	3D
Other energy uses	🟩	120	-	-	-	-	-	-	-	-	-	-	-	-
Catering	🟩		-	-	-	-	-	-	-	-	-	-	-	-
Servers/IT hub	🟩		10	10	18	10	10	10	10	10	10	10	10	10
Equipment	🟩		15	15	15	15	15	15	15	15	15	15	15	15
Lifts	🟩		4	4	4	4	4	4	4	4	4	4	4	4
External lighting	🟩		0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Lighting	🟨		11	11	11	11	10	10	10	10	9	9	9	9
Auxiliary (fans & pumps)	🟪		26	26	26	26	21	21	21	21	19	19	19	19
Cooling	🟦		3	3	3	3	4	4	4	4	4	4	4	4
Domestic hot water	🟥		3	2	2	2	3	2	2	2	3	2	2	2
Space heating	🟥		31	11	15	10	16	6	8	5	6	2	3	2

Table 7.21 – Predictive energy modelling results: detailed breakdown of energy use intensity (EUI) for each case

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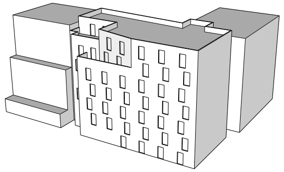
Office building | Policy option 2 | EUI + Compliance with Part L 2021



Metrics combined

The table shows the EUIs obtained from the predictive modelling results combined with Part L 2021 compliance.

One of the scenarios tested has failed to meet Part L and it correlates with the highest predicted EUIs.

Introducing a low EUI target would help to incentivise better fabric and ventilation.

Indicative SHD and EUI targets are introduced in the next section of the report.

	EUI - Predictive (kWh/m^2/yr)	Gas boiler	VRF	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	104 ✗	82	87	81
	Good practice	83	72	74	72
	Ultra-low energy	71	66	67	66

Table 7.22 – Performance of each case in terms of Energy Use Intensity (EUI) overlaid with compliance with all Part L 2021 criteria

✗ Would not pass both criteria of building regulations Part L 2021

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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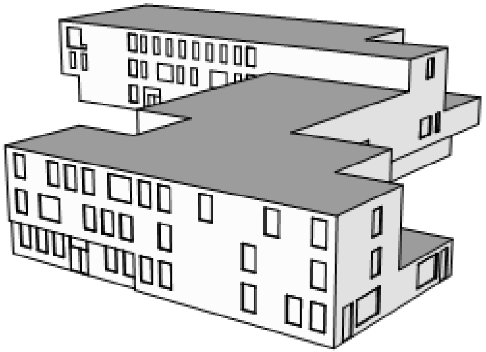
7.2.2

Policy option 2 - Predictive energy analysis for school



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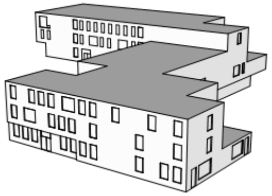
Primary school building | Policy option 2 | Predictive energy modelling (Space heating demand and EUI)



Space heating demand varies from 37 (worst) down to 4 kWh/m²/yr (best). The benefit of better fabric and MVHR is clearly showing.

The estimated EUIs range from 96 (worst) down to 57 kWh/m²/yr (best). The benefit of heat pumps over gas boilers or direct electric is clear, but it is diluted by the fact that DHW is provided by direct electric.

All results appear logical.

Space heating demand

Worst	Best

Fabric & ventilation	Space heating demand - Predictive (kWh/m²/yr)
Business as usual	37
Good practice	12
Ultra-low energy	4

Table 7.23 - Performance of each case in terms of space heating demand

Energy use intensity

Worst	Best

Fabric & ventilation EUI - Predictive (kWh/m2/yr)	Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Business as usual	96	92	65	64
Good practice	72	71	62	62
Ultra-low energy	60	60	57	57

Table 7.24 - Performance of each case in terms of energy use intensity (EUI)

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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Primary school building | **Policy option 2** | Predictive energy modelling results comparison across all cases

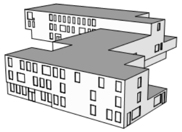

Figure 7.6 - Predictive energy modelling results: bar chart showing the detailed breakdown of energy use intensity (EUI) for each case

Detailed energy use breakdown (kWh/m².yr)		Bench mark	1A	1B	1C	1D	2A	2B	2C	2D	3A	3B	3C	3D
Other energy uses	🟨	100	-	-	-	-	-	-	-	-	-	-	-	-
Catering	🟩		5	5	5	5	5	5	5	5	5	5	5	5
Equipment	🟩		18	18	18	18	18	18	18	18	18	18	18	18
Lifts	🟩		4	4	4	4	4	4	4	4	4	4	4	4
External lighting	🟩		1	1	1	1	1	1	1	1	1	1	1	1
Lighting	🟧		9	9	9	9	8	8	8	8	7	7	7	7
Auxiliary (fans & pumps)	🟪		2	2	2	2	7	7	7	7	4	4	4	4
Cooling	🟦		-	-	-	-	-	-	-	-	-	-	-	-
Domestic hot water	🟥		17	17	17	17	17	17	17	17	17	17	17	17
Space heating	🟥		41	37	10	9	13	12	3	3	5	4	1	1

Table 7.25 – Predictive energy modelling results: detailed breakdown of energy use intensity (EUI) for each case

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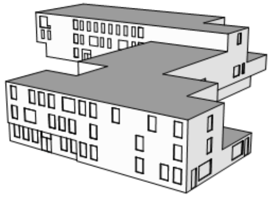
Primary school building I Policy option 2 I EUI + Compliance with Part L 2021



Metrics combined

The table shows the EUIs obtained from the predictive modelling results combined with Part L 2021 compliance.

None of the scenarios tested have failed to meet Part L. An EUI target could clearly help to drive the design and construction of better school buildings.

Indicative SHD and EUI targets are introduced in the next section of the report.

EUI - Predictive (kWh/m2/yr)		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	96	92	65	64
	Good practice	72	71	62	62
	Ultra-low energy	60	60	57	57

Table 7.26 – Performance of each case in terms of Energy Use Intensity (EUI) overlaid with compliance with all Part L 2021 criteria

✗ Would not pass both criteria of building regulations Part L 2021

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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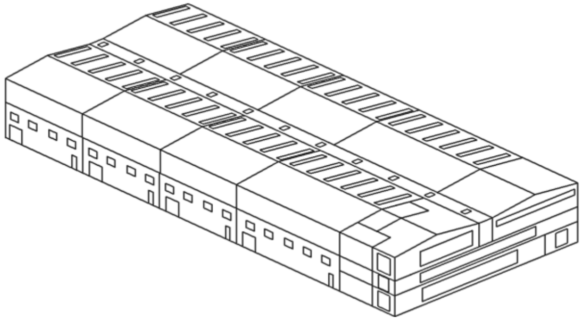
7.2.3

Policy option 2 - Predictive energy analysis for industrial building



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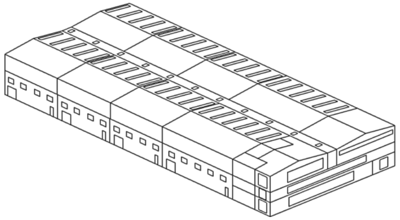
Industrial building I Policy option 2 I Predictive energy modelling (Space heating demand and EUI)



Space heating demand varies from 17 (worst) down to 10 kWh/m^2/yr (best). The benefit of better fabric and MVHR is clearly shown as you move towards better fabric performance.

The estimated EUIs range from 50 (worst) down to 27 kWh/m^2/yr (best). Fabric seems to have a greater impact on the Gas boiler scenarios due to the higher heating energy consumption, as results vary from 50 down to 36 kWh/m^2/yr. EUI results are very similar for VRF, Four pipe chiller and heat pump scenarios. The benefit of electric heating-over gas boilers is clear.

All results appear logical.

Space heating demand

Worst Best

		Space heating demand - Predictive (kWh/m^2/yr)
Fabric & ventilation	Business as usual	17
	Good practice	12
	Ultra-low energy	10

Table 7.27 - Performance of each case in terms of space heating demand

Energy use intensity

Worst Best

	EUI - Predictive (kWh/m^2/yr)	Gas boiler	VRF	Four pipe chiller	Heat pump more efficient
Fabric & ventilation	Business as usual	50	34	34	32
	Good practice	41	30	31	29
	Ultra-low energy	36	28	28	27

Table 7.28 - Performance of each case in terms of energy use intensity (EUI)

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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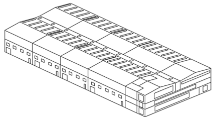
Industrial building | **Policy option 2** | Predictive energy modelling results comparison across all cases



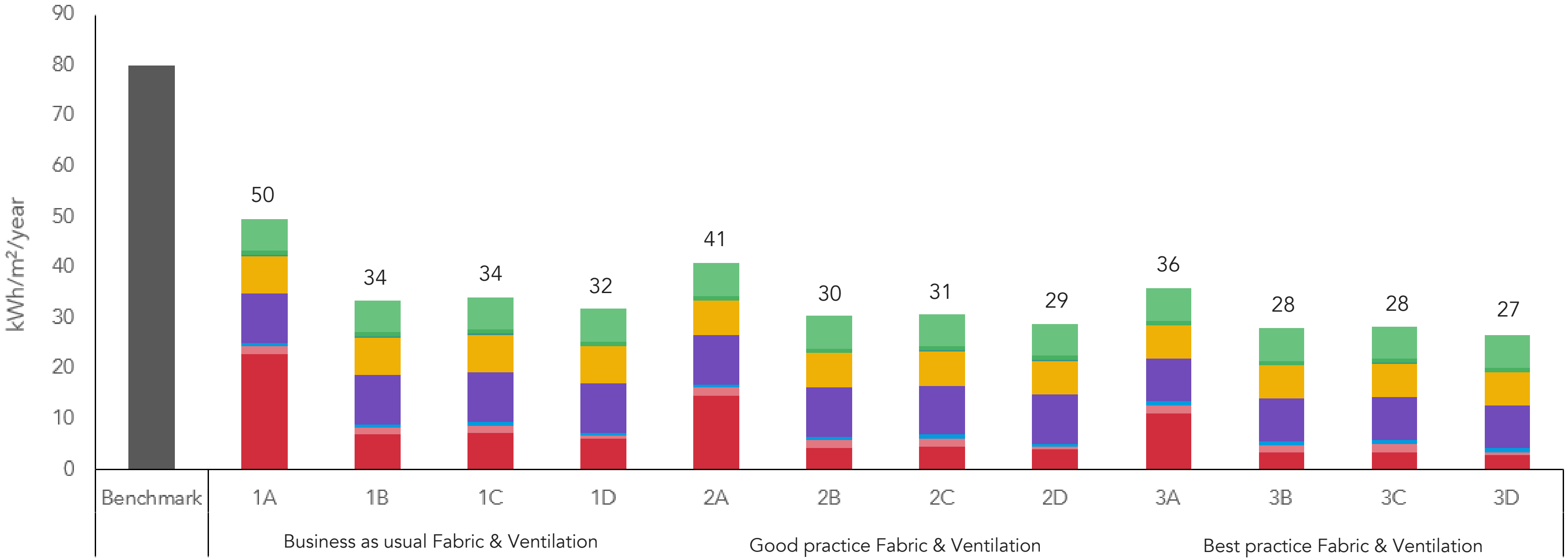


Figure 7.7 - Predictive energy modelling results: bar chart showing the detailed breakdown of energy use intensity (EUI) for each case

Detailed energy use breakdown (kWh/m².yr)		Bench mark	1A	1B	1C	1D	2A	2B	2C	2D	3A	3B	3C	3D
Other energy uses	🟩	80	-	-	-	-	-	-	-	-	-	-	-	-
Catering	🟩		-	-	-	-	-	-	-	-	-	-	-	-
Equipment	🟩		6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Lifts	🟩		0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
External lighting	🟦		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Lighting	🟨		7.4	7.4	7.4	7.4	6.7	6.7	6.7	6.7	6.5	6.5	6.5	6.5
Auxiliary (fans & pumps)	🟪		9.9	9.9	9.9	9.9	9.7	9.7	9.7	9.7	8.5	8.5	8.5	8.5
Cooling	🟦		0.5	0.5	0.7	0.5	0.6	0.6	0.8	0.6	0.7	0.7	0.9	0.7
Domestic hot water	🟥		1.5	1.5	1.5	0.5	1.5	1.5	1.5	0.5	1.5	1.5	1.5	0.5
Space heating	🟥		23.0	6.9	7.3	6.2	14.8	4.4	4.7	4.0	11.2	3.4	3.6	3.1

Table 7.29 – Predictive energy modelling results: detailed breakdown of energy use intensity (EUI) for each case

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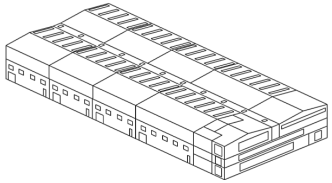
Industrial building I Policy option 2 I EUI + Compliance with Part L 2021



Metrics combined

The table shows the EUIs obtained from the predictive modelling results combined with Part L 2021 compliance.

Only two of the scenarios (both gas heated) have failed to meet Part L. An EUI target could clearly help to drive the design and construction of better industrial buildings.

Indicative SHD and EUI targets are introduced in the next section of the report.

	EUI - Predictive (kWh/m^2/yr)	Gas boiler	VRF	Four pipe chiller	Heat pump more efficient
Fabric & ventilation	Business as usual	~~50~~	34	34	32
	Good practice	~~41~~	30	31	29
	Ultra-low energy	36	28	28	27

Table 7.30 – Performance of each case in terms of Energy Use Intensity (EUI) overlaid with compliance with all Part L 2021 criteria

✗ Would not pass both criteria of building regulations Part L 2021

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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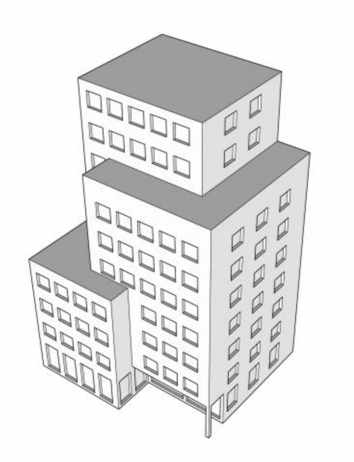
7.2.4

Policy option 2 - Predictive energy analysis for hotel



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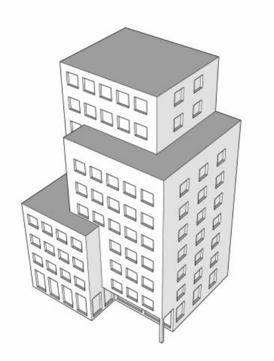
Hotel building I Policy option 2 I Predictive energy modelling (Space heating demand and EUI)



Space heating demand varies from 30 (worst) down to 15 kWh/m²/yr (best). The benefit of better fabric and ventilation is clearly showing

The estimated EUIs range from 233 (worst) down to 142 kWh/m²/yr (best). The benefit of heat pumps over gas boilers is clear.

All results appear logical.

Space heating demand

Worst	Best

	Space heating demand - Predictive (kWh/m²/yr)
Fabric & ventilation	
Business as usual	30
Good practice	24
Ultra-low energy	15

Table 7.31 - Performance of each case in terms of space heating demand

Energy use intensity

Worst	Best

EUI - Predictive (kWh/m²/yr)	Gas boiler	Heat pump (220)	Heat pump (400/300)	Heat pump (450/300)
Fabric & ventilation				
Business as usual	233	174	159	158
Good practice	222	166	152	152
Ultra-low energy	206	154	143	142

Table 7.32 - Performance of each case in terms of energy use intensity (EUI)

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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Hotel building | **Policy option 2** | Predictive energy modelling results comparison across all cases

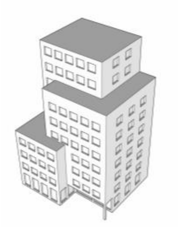

Figure 7.8 - Predictive energy modelling results: bar chart showing the detailed breakdown of energy use intensity (EUI) for each case

Detailed energy use breakdown (kWh/m^2.yr)		Bench mark	1A	1B	1C	1D	2A	2B	2C	2D	3A	3B	3C	3D
Other energy uses	🟩	340	-	-	-	-	-	-	-	-	-	-	-	-
Catering	🟩		71	71	71	71	71	71	71	71	71	71	71	71
Equipment	🟩		10	10	10	10	10	10	10	10	10	10	10	10
Lifts	🟩		5	5	5	5	5	5	5	5	5	5	5	5
External lighting	🟩		0	0	0	0	0	0	0	0	0	0	0	0
Lighting	🟨		12	12	12	12	11	11	11	11	10	10	10	10
Auxiliary (fans & pumps)	🟪		28	28	28	28	23	23	23	23	17	17	17	17
Cooling	🟦		1	1	1	1	1	1	1	1	1	1	1	1
Domestic hot water	🟥		74	23	32	23	74	23	32	23	74	23	32	23
Space heating	🟥		31	7	13	7	25	6	11	5	16	4	7	3

Table 7.33 – Predictive energy modelling results: detailed breakdown of energy use intensity (EUI) for each case

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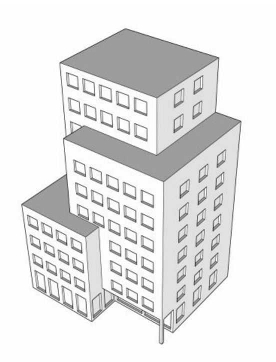
Hotel l Policy option 2 l EUI + Compliance with Part L 2021



Metrics combined

The table shows the EUIs obtained from the predictive modelling results combined with Part L 2021 compliance.

An EUI target could clearly help to drive the design and construction of better hotel buildings, incentivising both fabric and ventilation efficiency as well as better heating systems.

Indicative SHD and EUI targets are introduced in the next section of the report.

	EUI - Predictive ($kWh/m^2/yr$)	Gas boiler	Heat pump (220)	Heat pump (400/300)	Heat pump (450/300)
Fabric & ventilation	Business as usual	~~223~~	~~174~~	159	158
	Good practice	222	~~166~~	152	152
	Ultra-low energy	206	~~154~~	143	142

Table 7.34 – Performance of each case in terms of Energy Use Intensity (EUI) overlaid with compliance with all Part L 2021 criteria

✗ Would not pass both criteria of building regulations Part L 2021

Note: the above four heating options are not exhaustive. Other options (e.g. low carbon heat networks with low distribution losses) may perform well.

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7.3

Policy option 2 - how can heat networks be assessed using the EUI metric and how do they perform?

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Policy option 2 | How would EUIs work with heat networks?

Energy Use Intensity (EUI)

The EUI of a home or building is the total amount of energy it uses for all purposes in kWh/year, divided by the gross internal floor area (GIA) in m^2. The value of using this as a metric to measure energy performance is that it can be very easily checked. For a house or a flat or a school which has heating that only serves that home or building, the energy use is the sum of the utility bills.

However, where there is a heat network (or a communal heating system in general), it is less straightforward to assess the total energy used for that dwelling or building.

Boundary of the assessment

The usual definition of the EUI is the energy consumed within the site boundary. However, where that site or building is served by an energy centre that is outside the boundary, the system losses must be considered to understand the total energy required to deliver the heat to the end user.

Heat or energy for heat

If heat pumps are located in the energy centre, the efficiency of the heat generation also sits outside the site boundary. If the delivered heat is considered, rather than the energy used to generate it, the advantage of using a heat pump will not be captured by the EUI assessment.

The EUI will be the measured utility or energy supply to the energy centre – whether that is gas or electricity – divided by the total GIA of the properties served from the network. This though will give an average and will not distinguish better and worse performing buildings o. For a mixed use development, this could be very misleading. Some work will therefore be needed to develop a metering strategy that more accurately measures the actual energy use of users.

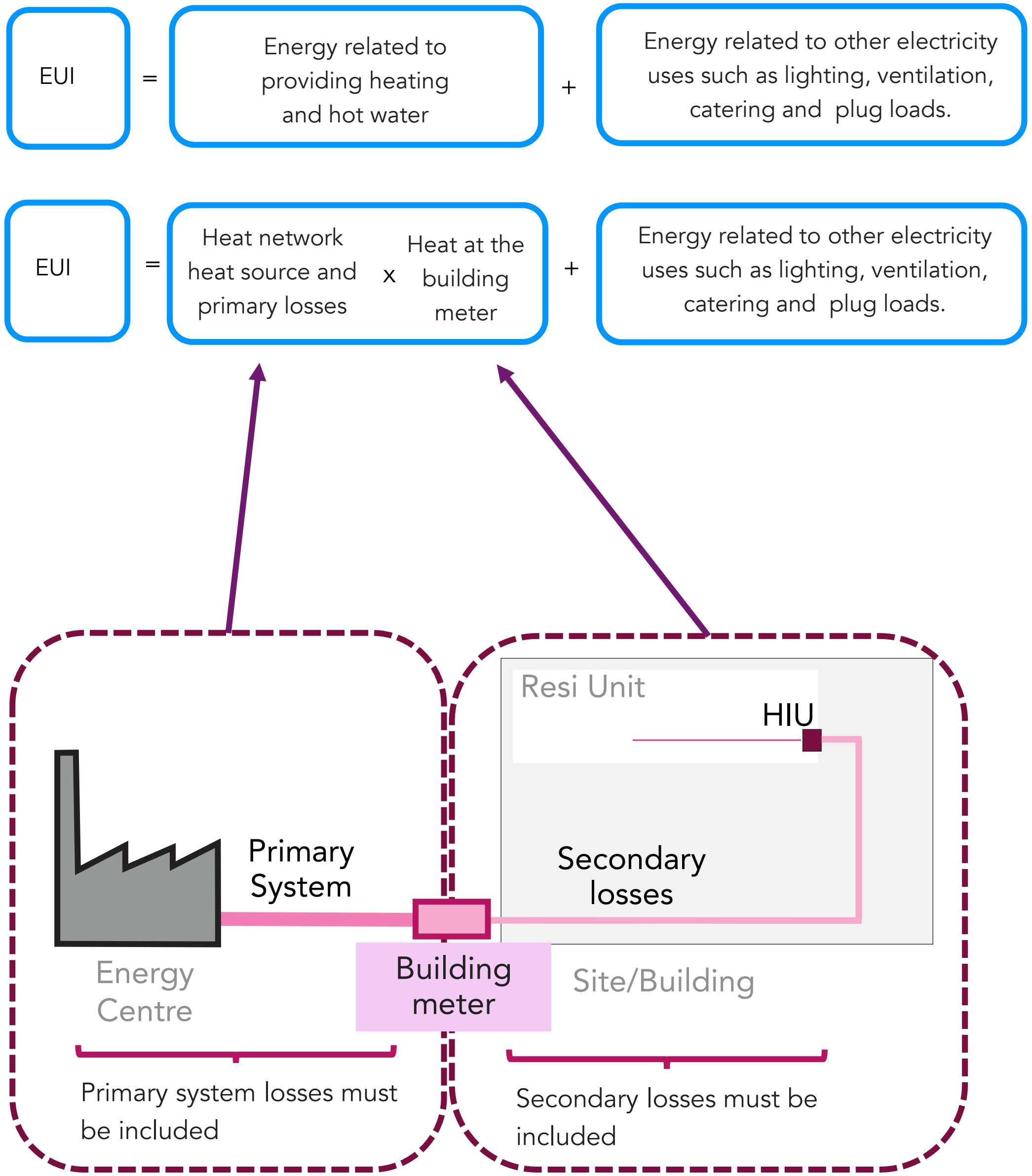

Figure 7.9 – Explanation of how EUIs can be calculated for heat networks

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Policy option 2 I How do you calculate EUI with a heat network?

Energy related to providing heating and hot water

Heat from a heat network is metered at the heat substation, usually on the upstream (energy centre) side. In domestic developments, the heat is also metered at the entry to each home, by the heat interface unit (HIU) if there is one. These meter readings need to be adjusted to account for the upstream (primary) system losses and the efficiency of the heat generation plant to derive an equivalent EUI value that is representative of the "Total Energy" used to deliver heat for heating and DHW to each dwelling.

The heat network provider would need to advise the primary system efficiency and losses to accurately assess the EUI.

For multi-residential blocks, the secondary losses can be measured by summing all of the HIU readings and subtracting that total from the main system meter reading – the difference will be the heat lost to the common areas and the ground inside the building or site boundary. These secondary losses can be applied as an average factor to all of the heat meter readings in that building to give the effective EUI required at the site boundary.

For single users, a house or a building like a school, the main system heat meter reading can be used as the EUI required at the site boundary.

The efficiencies and losses should be applied to the end use heat figure and then added to the electrical meter reading to get an overall EUI per building to compare to the policy target figure.

Energy related to providing heating and hot water

Electricity is always metered at the point of entry to a building or separately for each home. This meter reading can be used directly in the calculation of the EUI

Total EUI = Energy related to providing heating and hot water + Energy related to other electricity uses such as lighting, ventilation, catering and plug loads.

How do you calculate EUI with a heat network?

School

Heating & hot water metered at site boundary.

Electricity metered at site boundary.

Mid rise domestic

Heating & hot water metered at site boundary and sub metered at each home.

Electricity metered at each home.

Energy centre

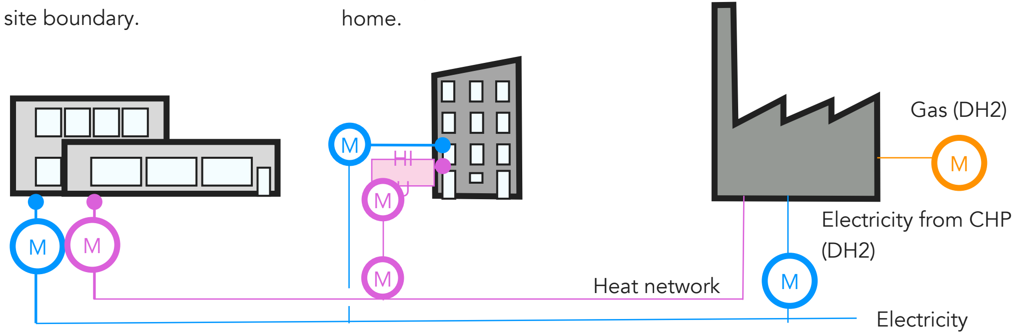

Figure 7.10 - The image above illustrates the metering strategy typically employed when delivering heat from a DH network and the metering strategy for electrical consumption. It should be recognised that where Combined Heat and Power generation is adopted, there will be a rebate due to the generation of electricity.

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Policy option 2 I Examples and target setting

Example with specific EUI targets

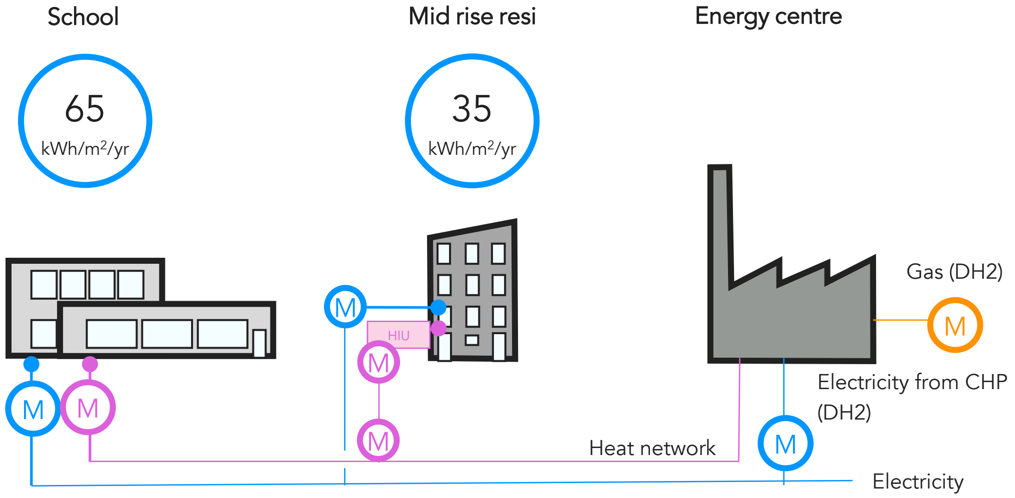
The targets set for EUI for each building and use type should be the same irrespective of the heating system that is proposed, so that all systems are compared with genuine equivalence.

For the heat network studies, only two typologies have been modelled, the mid-rise domestic building and the school. The target EUI recommended for each of these are:

Domestic - 35 kWh/m^2_{GIA}/yr.

School – 65 kWh/m^2_{GIA}/yr

These targets represent the total gas and electricity required to be used for each building type, at the energy centre. It is not the total of heat and electricity demand by the building or home. Whilst this difference seems complex, given the correct information from the heat network provider, it is a simple conversion to make. The following pages work through the two modelled examples and both network types to demonstrate the process of converting the heat demand to a corresponding energy consumption that can be used to assess the EUI.



Total EUI = Energy related to providing heating and hot water + Energy related to other electricity uses such as lighting, ventilation, catering and plug loads.

Figure 7.11 - To calculate the EUI associated with the all energy use required to power the buildings, and providing heating and DHW, the energy required to deliver this must be considered.

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Policy option 2 | School - worked example

This page shows a worked example of how the EUI could be calculated for the school based on a network using 110mm diameter primary pipework, 90°C flow temperature. The actual performance of each system will be individual to the system network characteristics, and these can be highly variable.

Example using 'ultra low energy' performance:

- Space heating demand of 4.3 kWh/m^2/yr
- Hot water demand of 16.7 kWh/m^2/yr,
- Secondary losses between the building heat meter and the school meter 10% of delivered heat. Heat at the building meter = 23.1 kWh/m^2/yr
- Electricity related to other electricity uses such as lighting, ventilation, catering and plug loads =38.9 kWh/m^2/yr

DH1 – Energy from Waste

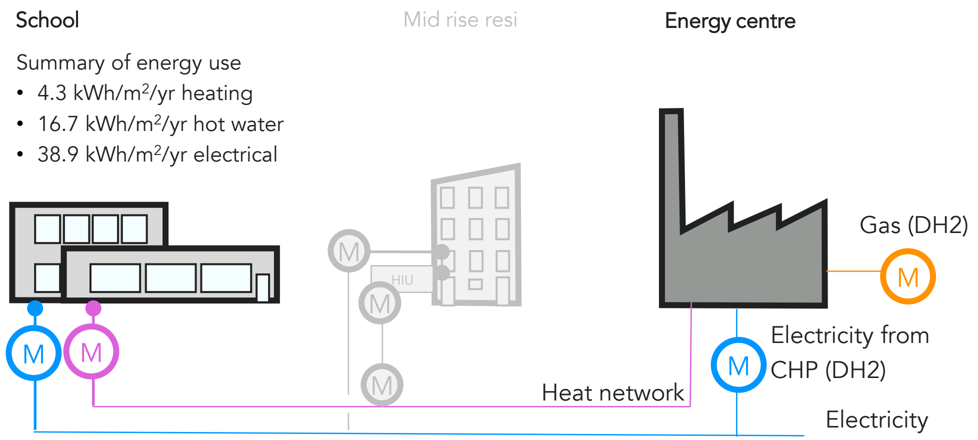
Assuming system performance characteristics as set out for DH1 and distribution losses of 50% for a system operating within 'good practice' parameters, the input energy to produce each kWh of heat output is 0.20kWh. Heat generation energy is therefore (23.1 x 0.2) = 4.6 kWh/m^2/yr

Total EUI = 4.6 + 38.9 = **43.5 kWh/m^2/yr**

DH2 - Fossil fuel based heat network seeking to grow and decarbonise

Assuming system performance characteristics and heat generation plant mix as set out for DH2 and distribution losses of 50% for a system operating within 'good practice' parameters, the input energy to produce each kWh heat output is 1.23 kWh. Heat generation energy is therefore (23.1 x 1.23) = 28.4 kWh/m^2/yr

Total EUI = 28.4 + 38.9 = **67.3 kWh/m^2/yr**



Summary of energy use

- 4.3 kWh/m^2/yr heating
- 16.7 kWh/m^2/yr hot water
- 38.9 kWh/m^2/yr electrical

Total EUI = Energy related to providing heating and hot water + Energy related to other electricity uses such as lighting, ventilation, catering and plug loads.

EUI (DHN 1) = 4.6 + 38.9 = 43.5 kWh/m^2/yr

EUI (DHN 2) = 28.4 + 38.9 = 67.3 kWh/m^2/yr

Figure 7.12 – Calculation of the EUI associated with the connection to heat networks DH1 or DH2

	EUI - Predictive (kWh/m2/yr)	Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient	DHN 1	DHN 2
Fabric & ventilation	Business as usual	96	92	65	64		
	Good practice	72	71	62	62		
	Ultra-low energy	60	60	57	57	44	67

Table 7.34 – EUI associated with DH1 and DH2 (ultra-low energy) compared with other heating systems

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Policy option 2 | Mid rise apartment building - worked example

This page shows a worked example of how the EUI could be calculated for the mid-rise apartment building based on a network using 110mm diameter primary pipework, 90°C flow temperature. The actual performance of each system will be individual to the system network characteristics, and these can be highly variable.

Using 'ultra low energy' performance:

Space heating demand of 7.6 kWh/m²/yr,

Hot water demand of 14.8 kWh/m²/yr,

Secondary losses between the building heat meter and the flat meter 10% of delivered heat. Heat at the building meter = 24.6 kWh/m²/yr

Electricity related to other electricity uses such as lighting, ventilation, catering and plug loads =16.3 kWh/m²/yr

DH1 – Energy from Waste

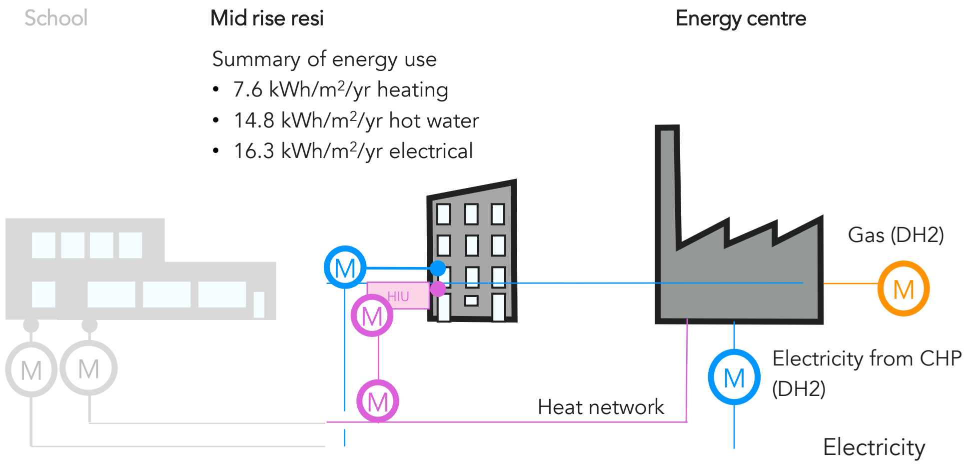
Assuming system performance characteristics as set out for DH1 and distribution losses of 50% for a system operating within 'good practice' parameters, the input energy to produce each kWh heat output is 0.20kWh. Heat generation energy is therefore (24.6 x 0.2) = 4.9 kWh/m²/yr

Total EUI = 4.9 + 16.3 = 21.2 kWh/m²/yr

DH2 - Fossil fuel based heat network seeking to grow and decarbonise

Assuming system performance characteristics and heat generation plant mix as set out for DH2 and distribution losses of 50% for a system operating within 'good practice' parameters, input energy to produce each kWh heat output is 1.23 kWh. Heat generation energy is therefore (24.6 x 1.23) = 30.3 kWh/m²/yr

Total EUI = 30.3 + 16.3 = 46.6 kWh/m²/yr



Total EUI = Energy related to providing heating and hot water + Energy related to other electricity uses such as lighting, ventilation, catering and plug loads.

EUI (DHN 1) = 4.9 + 16.3 = 21.2 kWh/m²/yr

EUI (DHN 2) = 30.3 + 16.3 = 46.6 kWh/m²/yr

Figure 7.13 – Calculation of the EUI associated with the connection to heat networks DH1 or DH2

	EUI - Predictive (kWh/m2/yr)	Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient	DHN 1	DHN 2
Fabric & ventilation	Business as usual	55	53	38	31		
	Good practice	49	48	35	29		
	Ultra-low energy	43	39	32	26	21	47

Table 7.35 – EUI associated with DH1 and DH2 (ultra-low energy) compared with other heating systems

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7.4

Policy option 2 - Summary

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Predictive energy modelling analysis for Policy option 2 | Domestic buildings | Summary of findings

Energy modelling using PHPP software was undertaken to estimate space heating demand and the total energy use (EUI) for the different domestic typologies.

- **Space heating demand seeks to improve energy efficiency.** As it can be seen from the adjacent table, the results are fairly consistent and would enable to use a particular level for policy (e.g. 15 or 20 kWh/m^2.yr in line with the recommendations of the CCC). The Terrace house has the widest range of space heating demand per floor area (GIA) relative to the other typologies and the high-rise apartment building has the narrowest.
- **Energy Use Intensity (EUI) seeks to reduce total energy use.** As it can be seen from the table below, the results are fairly consistent and would enable to use a particular level for policy (e.g. 35kWh/m^2.yr). The benefit of introducing a heat pump is clearest for the terrace house, reducing the EUI by 49% in the business-as-usual scenario and 43% for the ultra-low energy scenario.

Space heating demand – Predictive (kWh/m^2/yr)

Fabric & ventilation	Terrace	Low Rise	Mid Rise	High Rise
Business as usual	38	35	28	24
Good practice	33	28	22	20
Ultra-low energy	14	12	10	10

Table 7.36 – Summary of space heating demand results ranges for each domestic typology and each different level of fabric and ventilation specifications

Space heating demand

Worst	Best

Energy use intensity

Worst	Best

EUI - Predictive (kWh/m^2/yr)	Terrace House				Low rise apartment building				Mid rise apartment building				High rise apartment building			
Fabric & ventilation	Gas boiler	Direct electric	Heat pump less efficient	Heat Pump more efficient	Gas boiler	Direct electric	Heat pump less efficient	Heat Pump more efficient	Gas boiler	Direct electric	Heat pump less efficient	Heat Pump more efficient	Gas boiler	Direct electric	Heat pump less efficient	Heat Pump more efficient
Business as usual	73	65	37	34	71	61	43	31	55	53	38	31	45	42	30	24
Good practice	67	59	34	31	65	54	39	28	49	48	35	29	41	39	28	22
Ultra-low energy	47	41	27	25	48	37	31	23	43	39	32	26	36	32	25	20

Table 7.37 - Energy use intensity result ranges for each case of each domestic typology

Predictive energy modelling analysis for Policy option 2 I Non-domestic buildings I Summary of findings

Energy modelling using TAS and IES software in conjunction with CIBSE TM54 was undertaken to estimate space heating demand and the total energy use (EUI) for the different non-domestic typologies.

- **Space heating demand seeks to improve energy efficiency.** As it can be seen from the adjacent table, the results are fairly consistent and would enable to use a particular level for policy (e.g. 15 or 20 kWh/m^2.yr). The school and office typologies have the widest range of space heating demand per floor area (GIA) relative to the other typologies.
- **Energy Use Intensity (EUI) seeks to reduce total energy use.** As it can be seen from the table below, the range of results is very wide and would require specific EUI targets for the different typologies. The benefit of introducing a more efficient heat pump is clearest for the hotel which has the highest EUI.

Space heating demand – Predictive (kWh/m^2/yr)

		School	Office	Industrial	Hotel
Fabric & ventilation	Business as usual	37	23	17	30
	Good practice	12	12	12	24
	Ultra-low energy	4	4	10	15

Table 7.38 – *Summary of space heating demand results ranges for each non-domestic typology and each different level of fabric and ventilation specifications*

Space heating demand

Worst Best

Energy use intensity

Worst Best

EUI - Predictive (kWh/m^2/yr)		School				Office				Industrial				Hotel			
		Gas boiler	Direct electric	Heat pump less efficient	Heat Pump more efficient	Gas boiler	VRF	Heat pump less efficient	Heat pump more efficient	Gas boiler	VRF	Four pipe chiller	Heat pump more efficient	Gas boiler	Heat pump (220)	Heat pump (400/300)	Heat pump (450/300)
Fabric & ventilation	Business as usual	96	92	65	64	104	82	87	81	50	34	34	32	233	159	174	158
	Good practice	72	71	62	62	83	72	74	72	41	30	31	29	222	152	166	152
	Ultra-low energy	60	60	57	57	71	66	67	66	36	28	28	27	206	143	154	142

Table 7.39 - Energy use intensity result ranges for each case of each non-domestic typology

8.0

Comparison between modelling results for Policy options 1 and 2 and indicative targets for these policies

8.0 Comparison between modelling results for Policy options 1 and 2 and indicative targets

The main aim of this section is to derive some indicative policy suggestions, e.g.

- Policy option 1: buildings should achieve a minimum 65% CO_2 reduction.
- Policy option 2: buildings should achieve a space heating demand of less than 15 $kWh/m^2.yr$ and a minimum energy use intensity (EUI) of less than 35 $kWh/m^2.yr$.

Secondly, it enables a comparison between the likely effects that policy options 1 and 2 would have, i.e. which combination of specifications would find it more challenging to comply.

Comparison for domestic buildings

Comparison for non-domestic buildings

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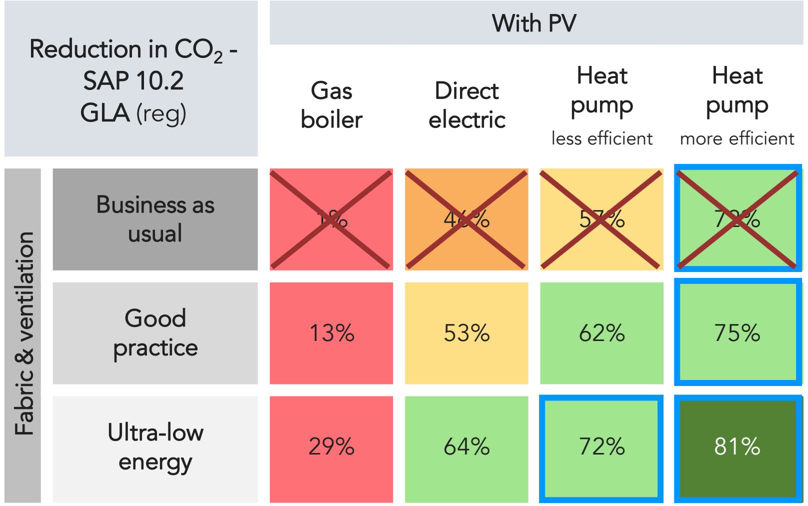
How to read the tables in this section

The tables in this section are the same as the ones shown earlier in the report for Policy option 1 (Section 6.0) and Policy option 2 (Section 7.0).

The only difference is the addition of blue rectangles to show which cases would comply with the indicative policy target suggested.

Policy option 1 (% over Part L)



	Reduction in CO_2 - SAP 10.2 GLA (reg)	With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	✗ 1%	✗ 46%	✗ 57%	✗ ☐ 72%
	Good practice	13%	53%	62%	☐ 75%
	Ultra-low energy	29%	64%	☐ 72%	☐ 81%

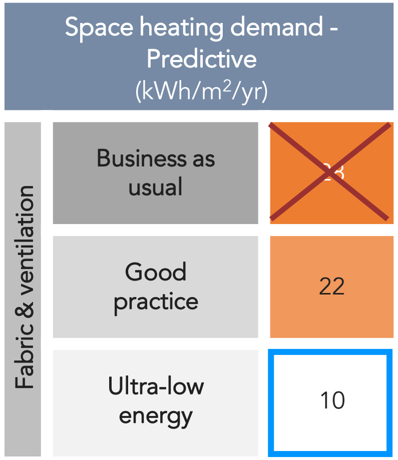
Table 8.1 – Performance of each case in terms of CO_2 overlaid with compliance with all Part L 2021 criteria and compliance with indicative policy target for option 1

✗ Would not pass all building regulations Part L 2021 metrics

☐ Compliant with proposed policy option

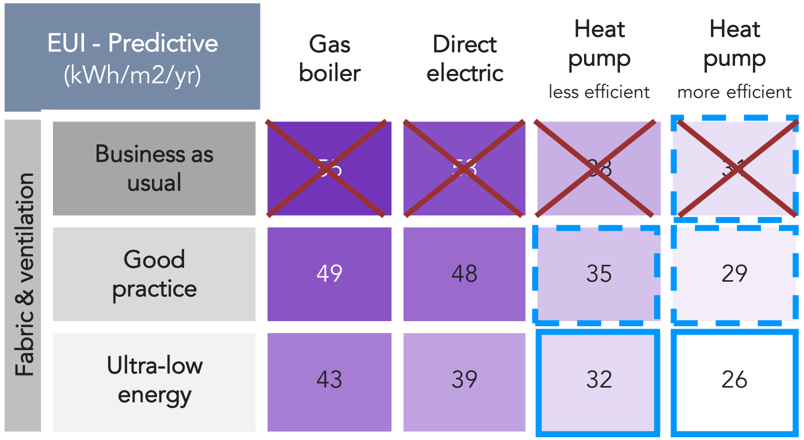
⬚ Compliant with one of two metrics

Policy option 2 (Space heating demand and EUI)



	Space heating demand - Predictive (kWh/m²/yr)	
Fabric & ventilation	Business as usual	✗ 28
	Good practice	22
	Ultra-low energy	☐ 10

Table 8.2 – Performance of each fabric and ventilation specification level in terms of space heating demand overlaid with compliance with the FEE criterion in Part L 2021 criteria and compliance with indicative policy target for option 2



	EUI - Predictive (kWh/m2/yr)	Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	✗ 55	✗ 53	✗ 38	✗ ⬚ 31
	Good practice	49	48	⬚ 35	⬚ 29
	Ultra-low energy	43	39	☐ 32	☐ 26

Table 8.3 – Performance of each case in terms of energy use intensity (EUI) overlaid with compliance with all criteria in Part L 2021 criteria and compliance with indicative policy target for option 2

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8.1

Comparison for domestic buildings

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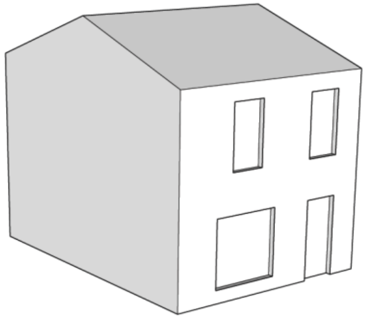
8.1.1

Comparison for terrace house



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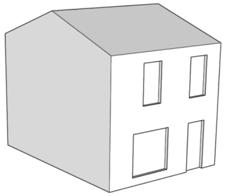
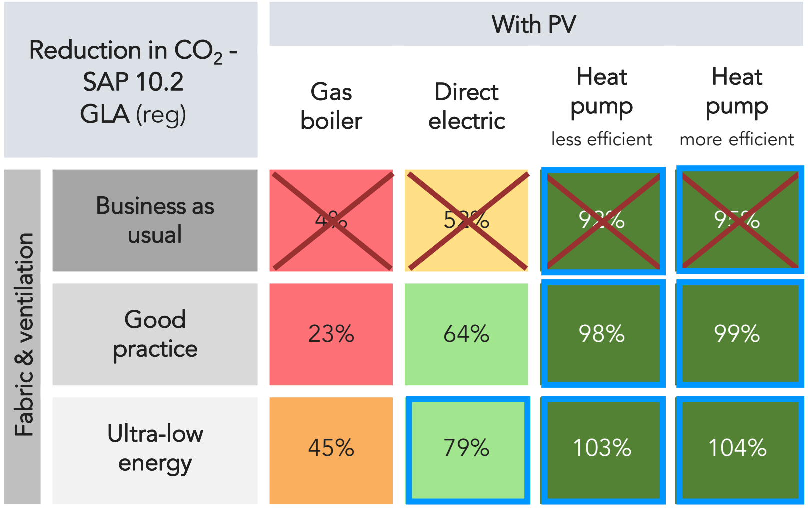
Terrace House | Policy Option 1 (% over Part L) **vs Option 2** (Space heating demand and EUI)



Policy option 1 (% over Part L)



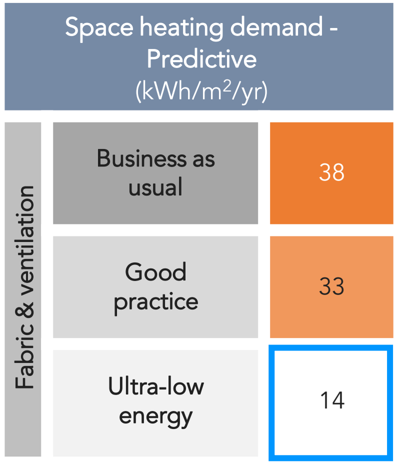
Reduction in CO_2 - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	4% ✗	52% ✗	92% ✗ ☐	95% ✗ ☐
	Good practice	23%	64%	98% ☐	99% ☐
	Ultra-low energy	45%	79% ☐	103% ☐	104% ☐

Table 8.4 – Performance of each case in terms of CO_2 overlaid with compliance with all Part L 2021 criteria and compliance with indicative policy target for option 1

Indicative policy requirement:

- **65% improvement over Part L 2021.**
- This threshold drives better energy efficiency by capturing the cases which marry good fabric requirements with efficient heating systems. It pushes schemes with direct electric to have an 'ultra-low energy' fabric and ventilation.
- It could be raised to 70% or even 75% for the terrace house but this would make it inconsistent with the 'high-rise' apartment building.

Policy option 2 (Space heating demand and EUI)

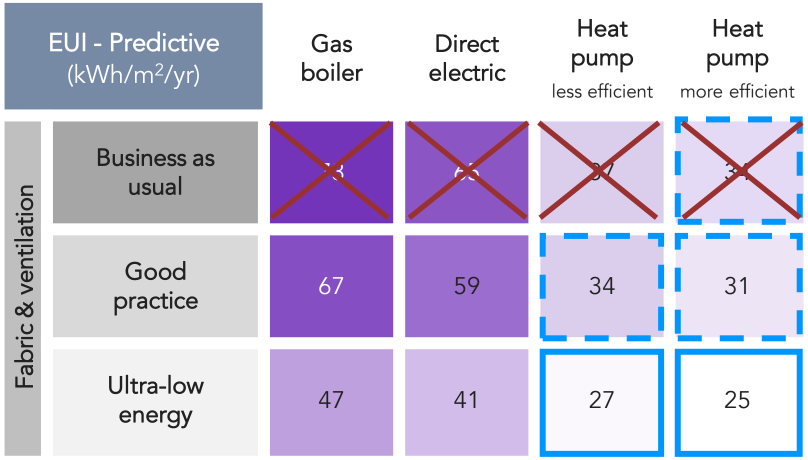


		Space heating demand - Predictive ($kWh/m^2/yr$)
Fabric & ventilation	Business as usual	38
	Good practice	33
	Ultra-low energy	14 ☐

Table 8.5 – Performance of each fabric and ventilation specification level in terms of space heating demand overlaid with compliance with the FEE criterion in Part L 2021 criteria and compliance with indicative policy target for option 2

Indicative policy requirement:

- **SHD < 15 kWh/m^2.yr**
- **EUI < 35 kWh/m^2.yr**
- These are in line with the industry definition of Net Zero Operational Carbon for residential buildings



EUI - Predictive ($kWh/m^2/yr$)		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	73 ✗	65 ✗	37 ✗	34 ✗ ⬚
	Good practice	67	59	34 ⬚	31 ⬚
	Ultra-low energy	47	41	27 ☐	25 ☐

Table 8.6 – Performance of each case in terms of energy use intensity (EUI) overlaid with compliance with all criteria in Part L 2021 criteria and compliance with indicative policy target for option 2

☐ Compliant with proposed policy option

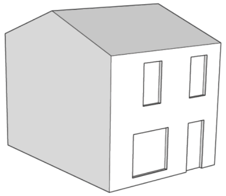
1 on the left

2 on the right

⬚ Compliant with one of two metrics

✗ Would not pass all 3 building regulations Part L 2021 metrics

Terrace House | Part L modelling vs Predictive energy modelling



⚑ **Space heating** appears to be significantly underestimated in Part L modelling, which means that changes to U-values, windows, airtightness will have less effect, thereby not encouraging better fabric and better design.

⚑ **Domestic hot water** appears to be significantly overestimated in Part L modelling. As heat pumps are generally less efficient when producing hot water, this negatively affects their performance and may reduce the difference between a 'less efficient' and a 'more efficient' heat pump system.

⚑ Part L has a simple and standardised calculation for estimating **'unregulated' energy use** (shown dashed in graph). This is hugely overestimated given that this only covers the cooking and appliances, with no estimation for plug loads. The overestimation of unregulated loads means that it can become daunting to include them in dwelling calculations and any attempt to offset them or balance them with renewable energy appears expensive.

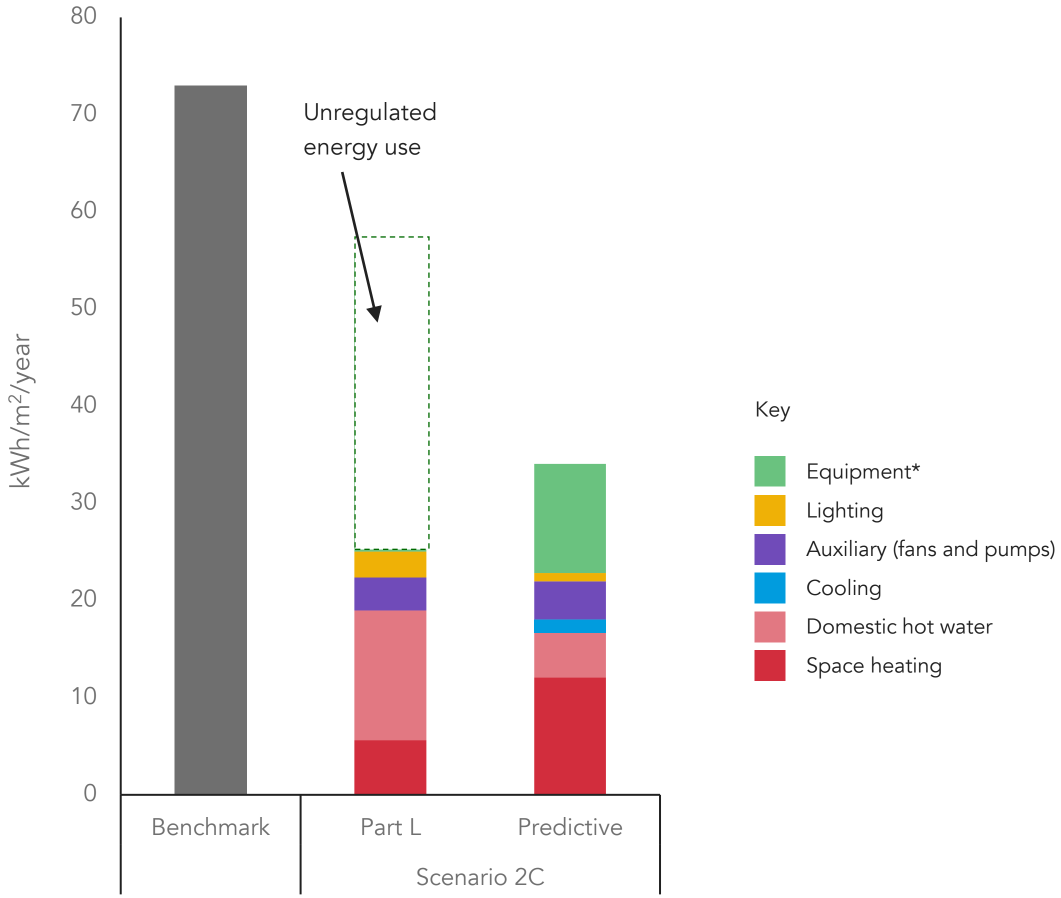


Figure 8.1 – Comparison between the results of the Part L energy model and the Predictive energy model, per separable energy use, for a typical 'good practice' scenario with a heat pump

** Note that the Part L equipment (cooking and appliances) is not currently an output from SAP 10.2 software.*

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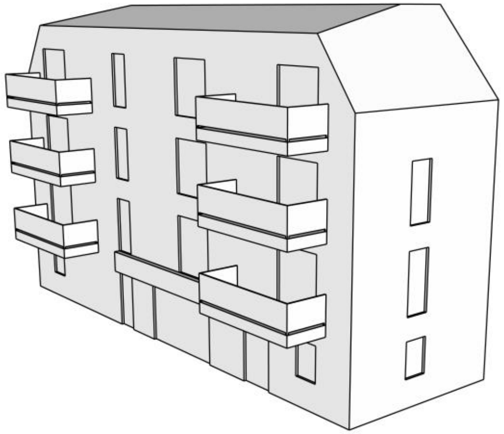
8.1.2

Comparison for low-rise apartment building



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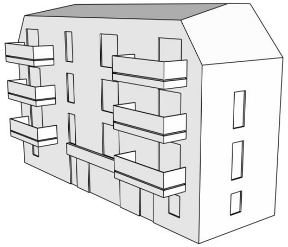
Low-rise apartment building | **Policy Option** 1 (% over Part L) **vs Option 2** (Space heating demand and EUI)



☐ Compliant with proposed policy option

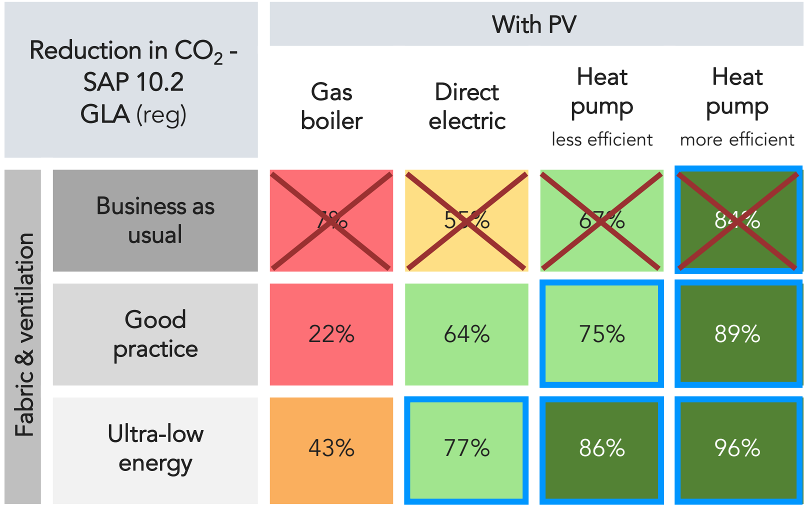
1 on the left

2 on the right

⬚ Compliant with one of two metrics

✗ Would not pass all 3 building regulations Part L 2021 metrics

Policy option 1 (% over Part L)



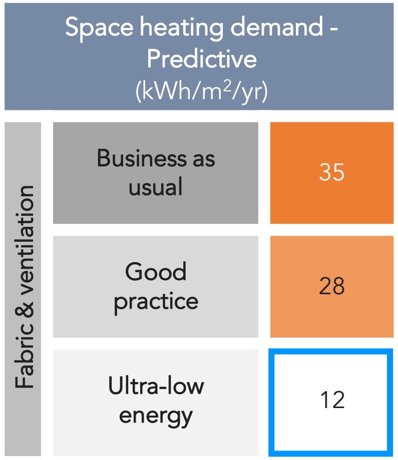
Reduction in CO_2 - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	✗ 7%	✗ 55%	✗ 67%	☐ ✗ 84%
	Good practice	22%	64%	☐ 75%	☐ 89%
	Ultra-low energy	43%	☐ 77%	☐ 86%	☐ 96%

Table 8.7 – Performance of each case in terms of CO_2 overlaid with compliance with all Part L 2021 criteria and compliance with indicative policy target for option 1

Indicative policy requirement:

- **65% improvement over Part L 2021.**
- This threshold drives better energy efficiency by capturing the cases which marry good fabric requirements with efficient heating systems. It pushes schemes with direct electric to have an 'ultra-low energy' fabric and ventilation (or more PVs).
- It could be raised to 70% or even 75% for the low-rise apartment building but this would make it inconsistent with the 'high-rise' apartment building.

Policy option 2 (Space heating demand and EUI)

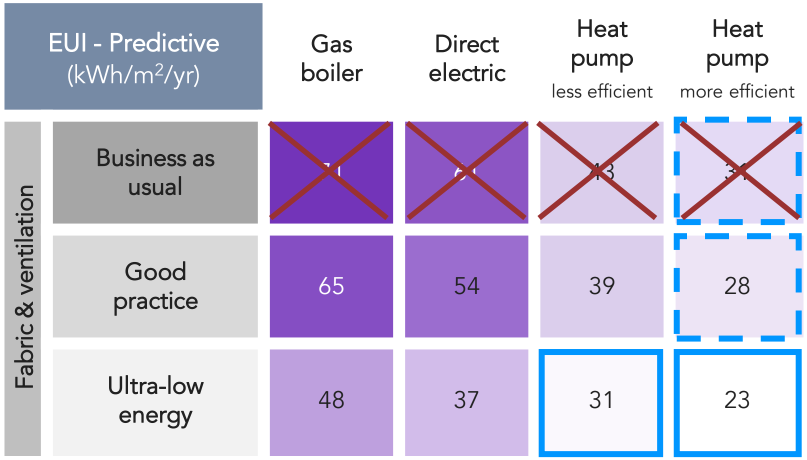


		Space heating demand - Predictive (kWh/m²/yr)
Fabric & ventilation	Business as usual	35
	Good practice	28
	Ultra-low energy	☐ 12

Table 8.8 – Performance of each fabric and ventilation specification level in terms of space heating demand overlaid with compliance with the FEE criterion in Part L 2021 criteria and compliance with indicative policy target for option 2

Indicative policy requirement:

- **SHD < 15 kWh/m².yr**
- **EUI < 35 kWh/m².yr**
- These are in line with the industry definition of Net Zero Operational Carbon for residential buildings



EUI - Predictive (kWh/m²/yr)		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	✗ 71	✗ 61	✗ 43	⬚ ✗ 31
	Good practice	65	54	39	⬚ 28
	Ultra-low energy	48	37	☐ 31	☐ 23

Table 8.9 – Performance of each case in terms of energy use intensity (EUI) overlaid with compliance with all criteria in Part L 2021 criteria and compliance with indicative policy target for option 2

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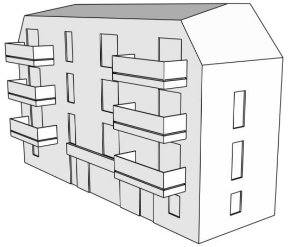
Low-rise apartment building | Part L modelling vs Predictive energy modelling



Space heating appears to be significantly underestimated in Part L modelling, which means that changes to U-values, windows, airtightness will have less effect, thereby not encouraging better fabric and better design.

Domestic hot water appears to be grossly overestimated in Part L modelling. As heat pumps are generally less efficient when producing hot water, this negatively affects their performance and may reduce the difference between a 'less efficient' and a 'more efficient' heat pump system.

Part L has a simple and standardised calculation for estimating **'unregulated' energy use** (shown dashed in graph). This is hugely overestimated given that this only covers the cooking and appliances, with no estimation for plug loads. The overestimation of unregulated loads means that it can become daunting to include them in dwelling calculations and any attempt to offset them or balance them with renewable energy appears expensive.

The '**regulated'** (heating, hot water, lighting, auxiliary) portion of the energy use in Part L, exceeds even the total energy use (including unregulated loads – equipment) for the predictive model.

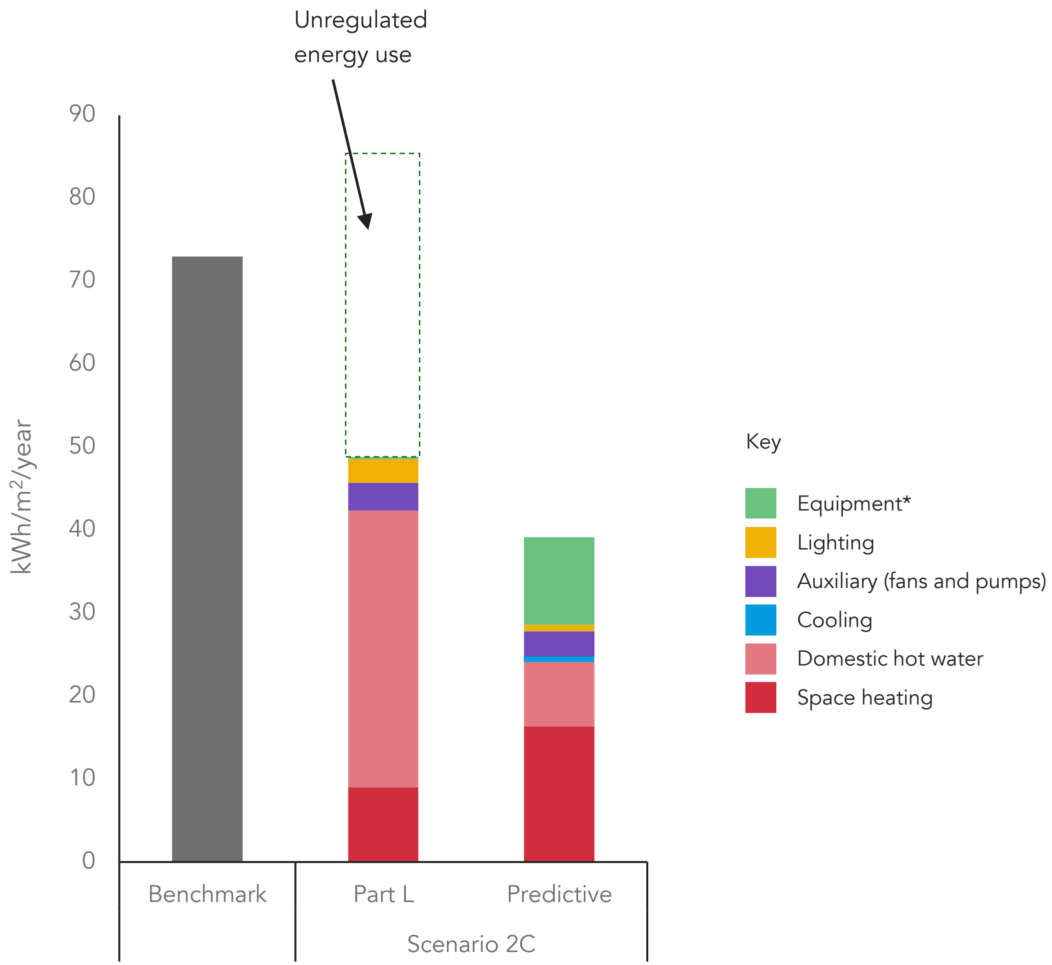


Figure 8.2 – Comparison between the results of the Part L energy model and the Predictive energy model, per separable energy use, for a typical 'good practice' scenario with a heat pump

** Note that the Part L equipment (cooking and appliances) is not currently an output from SAP 10.2 software.*

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8.1.3

Comparison for mid-rise apartment building

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Mid-rise apartment building I **Policy Option** 1 (% over Part L) **vs Option 2** (Space heating demand and EUI)

☐ Compliant with proposed policy option

1 on the left

2 on the right

⬚ Compliant with one of two metrics

✗ Would not pass all 3 building regulations Part L 2021 metrics

Policy option 1 (% over Part L)

Reduction in CO_2 - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	✗ 1%	✗ 46%	✗ 57%	☐ ✗ 72%
	Good practice	13%	53%	62%	☐ 75%
	Ultra-low energy	29%	64%	☐ 72%	☐ 81%

Table 8.10 – Performance of each case in terms of CO_2 overlaid with compliance with all Part L 2021 criteria and compliance with indicative policy target for option 1

Indicative policy requirement:

- **65% improvement over Part L 2021.**
- This threshold drives better energy efficiency by capturing the cases which marry good fabric requirements with efficient heating systems. It pushes schemes with direct electric to have an even better level of fabric and ventilation performance than 'ultra-low energy' or more PVs.
- It could be raised to 70% for the mid-rise apartment building but this would make it inconsistent with the 'high-rise' apartment building.

Policy option 2 (Space heating demand and EUI)

	Space heating demand - Predictive (kWh/m²/yr)
Fabric & ventilation	
Business as usual	28
Good practice	22
Ultra-low energy	☐ 10

Indicative policy requirement:

- **SHD < 15 kWh/m^2.yr**
- **EUI < 35 kWh/m^2.yr**
- These are in line with the industry definition of Net Zero Operational Carbon for residential buildings

Table 8.11 – Performance of each fabric and ventilation specification level in terms of space heating demand overlaid with compliance with the FEE criterion in Part L 2021 criteria and compliance with indicative policy target for option 2

EUI - Predictive (kWh/m2/yr)		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	✗ 55	✗ 53	✗ 38	⬚ ✗ 31
	Good practice	49	48	⬚ 35	⬚ 29
	Ultra-low energy	43	39	☐ 32	☐ 26

Table 8.12 – Performance of each case in terms of energy use intensity (EUI) overlaid with compliance with all criteria in Part L 2021 criteria and compliance with indicative policy target for option 2

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Mid-rise apartment building I Part L modelling vs Predictive energy modelling

Space heating appears to be significantly underestimated in Part L modelling, which means that changes to U-values, windows, airtightness will have less effect, thereby not encouraging better fabric and better design.

Domestic hot water appears to be grossly overestimated in Part L modelling. As heat pumps are generally less efficient when producing hot water, this negatively affects their performance and may reduce the difference between a 'less efficient' and a 'more efficient' heat pump system.

Part L has a simple and standardised calculation for estimating **'unregulated' energy use** (shown dashed in graph). This is hugely overestimated given that this only covers the cooking and appliances, with no estimation for plug loads. The overestimation of unregulated loads means that it can become daunting to include them in dwelling calculations and any attempt to offset them or balance them with renewable energy appears expensive.

The **'regulated'** (heating, hot water, lighting, auxiliary) portion of the energy use in Part L, exceeds even the total energy use (including unregulated loads – equipment) for the predictive model.

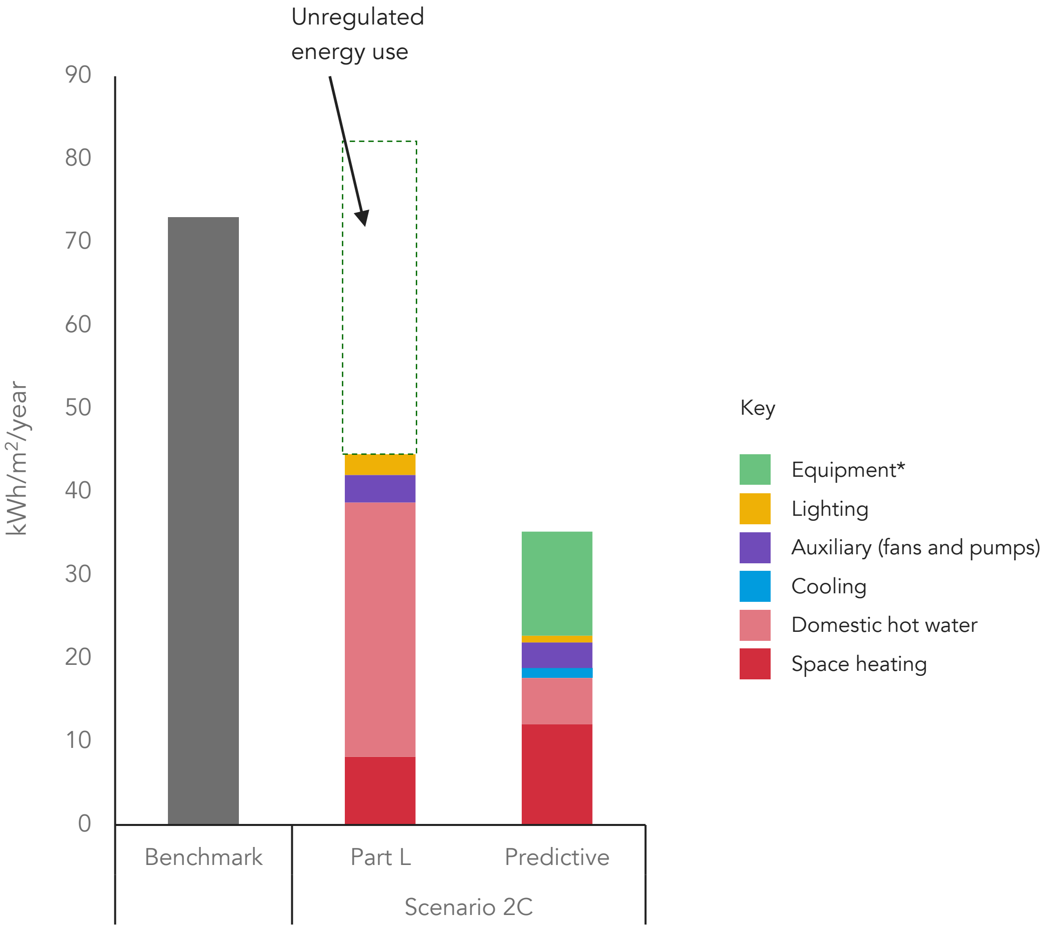

Figure 8.3 – Comparison between the results of the Part L energy model and the Predictive energy model, per separable energy use, for a typical 'good practice' scenario with a heat pump

** Note that the Part L equipment (cooking and appliances) is not currently an output from SAP 10.2 software.*

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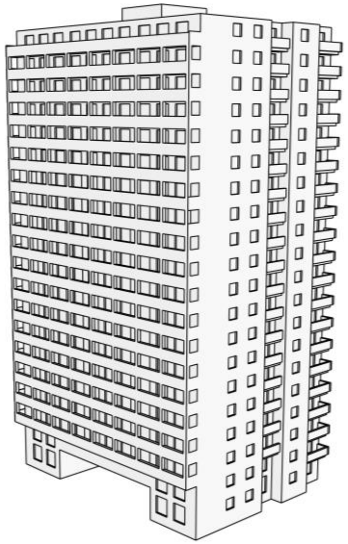
8.1.4

Comparison for high-rise apartment building



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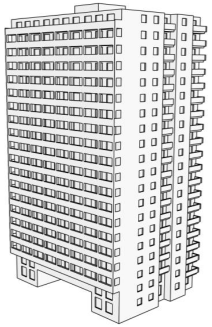
High-rise apartment building l **Policy Option** 1 (% over Part L) **vs Option 2** (Space heating demand and EUI)



☐ Compliant with proposed policy option

1 on the left

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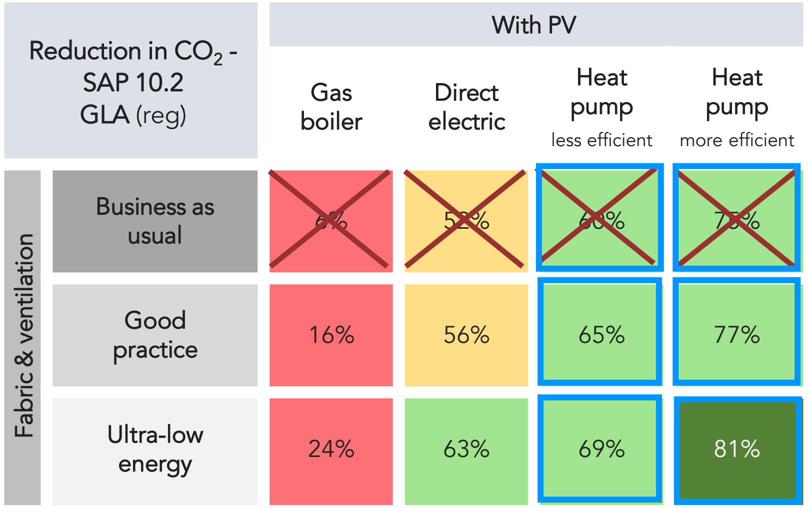
⬚ Compliant with one of two metrics

✗ Would not pass all 3 building regulations Part L 2021 metrics

Policy option 1 (% over Part L)



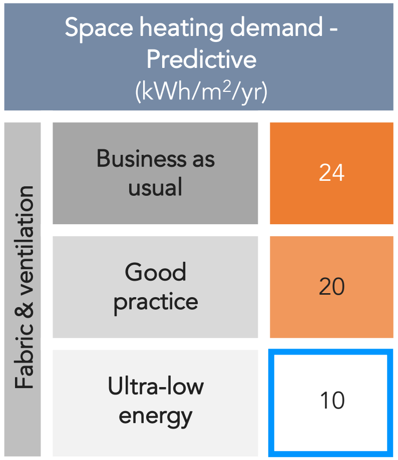
Reduction in CO$_2$ - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	~~6%~~	~~52%~~	~~60%~~	~~75%~~
	Good practice	16%	56%	65%	77%
	Ultra-low energy	24%	63%	69%	81%

Table 8.13 – Performance of each case in terms of CO$_2$ overlaid with compliance with all Part L 2021 criteria and compliance with indicative policy target for option 1

indicative policy requirement:

- **65% improvement over Part L 2021.**
- This threshold drives better energy efficiency by capturing the cases which marry good fabric requirements with efficient heating systems. It pushes schemes with direct electric to have an even better level of fabric and ventilation performance than 'ultra-low energy'.
- Setting the threshold at 70% would be too restrictive in terms of heating system, making it virtually impossible to comply with direct electric or a 'less efficient' heating system.

Policy option 2 (Space heating demand and EUI)

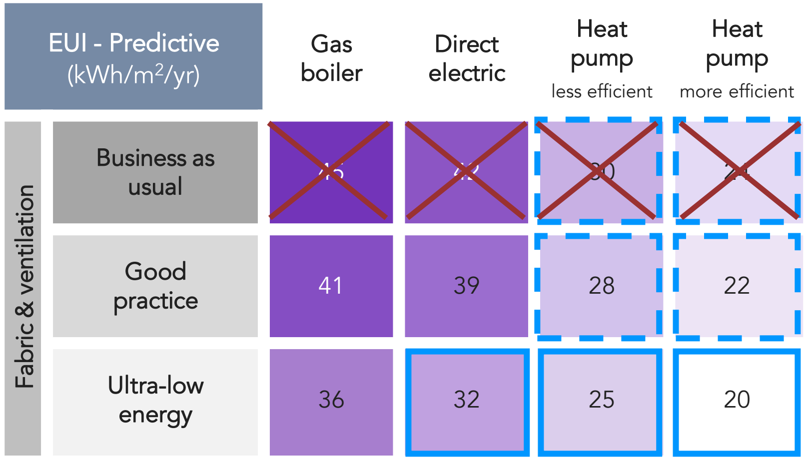


		Space heating demand - Predictive (kWh/m^2/yr)
Fabric & ventilation	Business as usual	24
	Good practice	20
	Ultra-low energy	10

Indicative policy requirement:

- **SHD < 15 kWh/m^2.yr**
- **EUI < 35 kWh/m^2.yr**
- These are in line with the industry definition of Net Zero Operational Carbon for residential buildings

Table 8.14 – Performance of each fabric and ventilation specification level in terms of space heating demand overlaid with compliance with the FEE criterion in Part L 2021 criteria and compliance with indicative policy target for option 2



EUI - Predictive (kWh/m^2/yr)		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	~~45~~	~~42~~	~~30~~	~~24~~
	Good practice	41	39	28	22
	Ultra-low energy	36	32	25	20

Table 8.15 – Performance of each case in terms of energy use intensity (EUI) overlaid with compliance with all criteria in Part L 2021 criteria and compliance with indicative policy target for option 2

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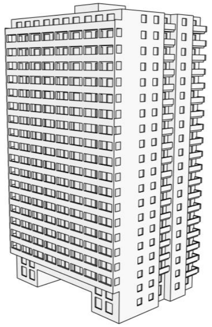
High-rise apartment building | Part L modelling vs Predictive energy modelling



Space heating appears to be significantly underestimated in Part L modelling, which means that changes to U-values, windows, airtightness will have less effect, thereby not encouraging better fabric and better design.

Domestic hot water appears to be grossly overestimated in Part L modelling. As heat pumps are generally less efficient when producing hot water, this negatively affects their performance and may reduce the difference between a 'less efficient' and a 'more efficient' heat pump system.

Part L has a simple and standardised calculation for estimating **'unregulated' energy use** (shown dashed in graph). This is hugely overestimated given that this only covers the cooking and appliances, with no estimation for plug loads. The overestimation of unregulated loads means that it can become daunting to include them in dwelling calculations and any attempt to offset them or balance them with renewable energy appears expensive.

The **'regulated'** (heating, hot water, lighting, auxiliary) portion of the energy use in Part L, exceeds even the total energy use (including unregulated loads – equipment) for the predictive model.

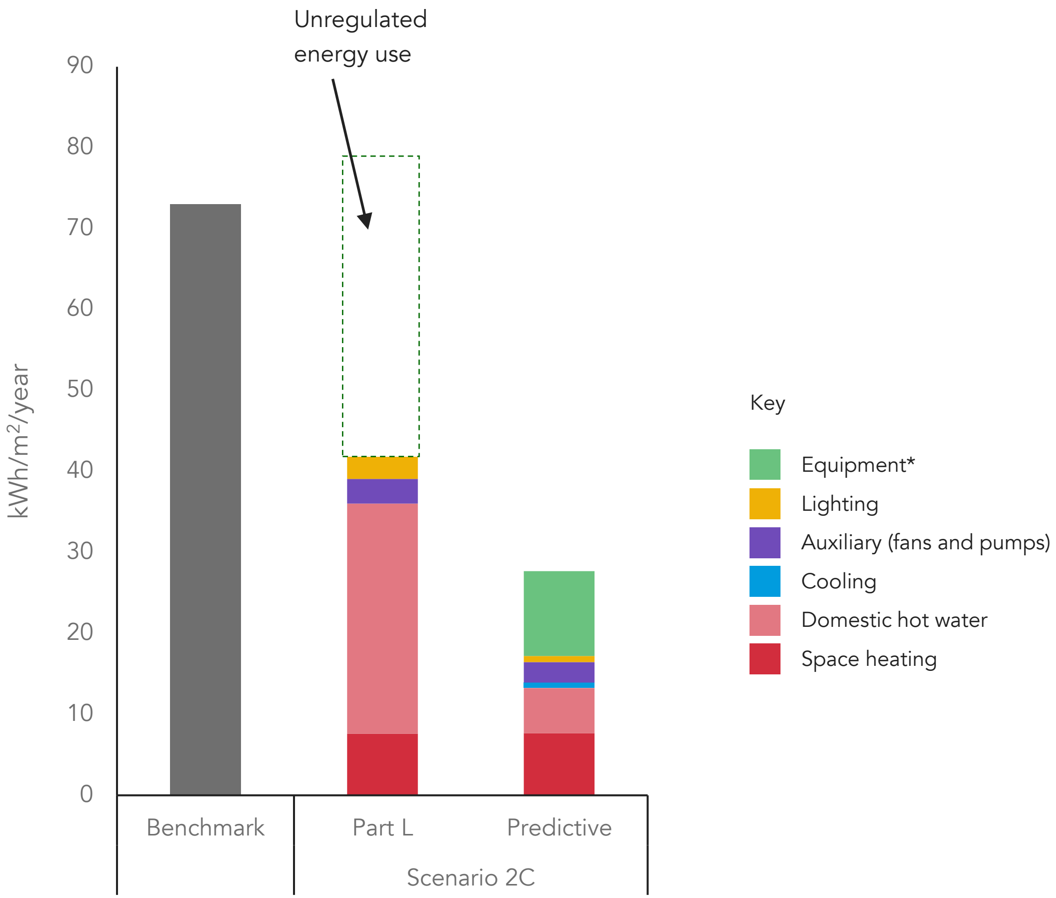


Figure 8.4 – Comparison between the results of the Part L energy model and the Predictive energy model, per separable energy use, for a typical 'good practice' scenario with a heat pump

** Note that the Part L equipment (cooking and appliances) is not currently an output from SAP 10.2 software.*

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8.2

Comparison for non-domestic buildings

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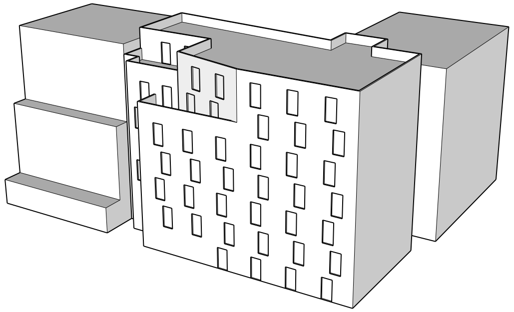
8.2.1

Comparison for office building



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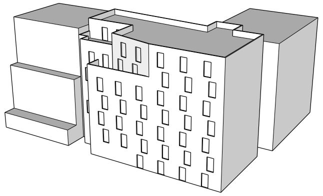
Office building I **Policy Option** 1 (% over Part L) **vs Option 2** (Space heating demand and EUI)



☐ Compliant with proposed policy option

1 on the left

2 on the right

⬚ Compliant with one of two metrics

✕ Would not pass both building regulations Part L 2021 metrics

Policy option 1 (% over Part L)

Reduction in CO$_2$ - NCM - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	VRF	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	✕ -22%	13%	6%	14%
	Good practice	7%	☐ 29%	☐ 25%	☐ 30%
	Ultra-low energy	☐ 26%	☐ 32%	☐ 30%	☐ 32%

PV area covering 50% of the building footprint area

Table 8.16 – Performance of each case in terms of CO$_2$ overlaid with compliance with all Part L 2021 criteria and compliance with indicative policy target for option 1

Indicative policy requirement:

- **25% improvement over Part L 2021.**
- It enables 'good practice' and 'ultra-low energy' levels of fabric and ventilation to comply with various types of electric heating systems.
- Unfortunately, a gas heating system would still be possible with an 'ultra-low energy' fabric and ventilation. Other policy mechanisms are recommended to prevent new fossil fuel heating systems to be granted planning permission.

Policy option 2 (Space heating demand and EUI)

	Space heating demand - Predictive (kWh/m^2/yr)
Fabric & ventilation	
Business as usual	23
Good practice	⬚ 12
Ultra-low energy	☐ 4

Indicative policy requirement:

- **SHD < 15 kWh/m^2.yr**
- **EUI < 70 kWh/m^2.yr**
- The EUI is higher than the 55 kWh/m^2.yr suggested by LETI for office buildings. The LETI target indicates what can be achieved in use whereas this evidence base seeks to set a reasonable minimum target.

Table 8.17 – Performance of each fabric and ventilation specification level in terms of space heating demand overlaid with compliance with the FEE criterion in Part L 2021 criteria and compliance with indicative policy target for option 2

	EUI - Predictive (kWh/m^2/yr)	Gas boiler	VRF	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	✕ 104	82	87	81
	Good practice	83	72	74	72
	Ultra-low energy	71	☐ 66	☐ 67	☐ 66

Table 8.18 – Performance of each case in terms of energy use intensity (EUI) overlaid with compliance with all criteria in Part L 2021 criteria and compliance with indicative policy target for option 2

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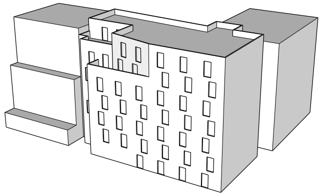
Office building | Part L modelling vs Predictive energy modelling



Space heating appears to be significantly underestimated in Part L modelling, which means that changes to U-values, windows, airtightness will have limited effect, thereby not encouraging better fabric and better design.

Part L estimates **'unregulated' energy use** (shown dashed in graph) but does not include it in the reported emissions and energy metrics. Policy Option 1 would therefore have no effect on it. The predictive modelling allows greater scrutiny of equipment loads and has found that equipment energy use is likely to be much lower than Part L calculates. This goes some way to explaining the very low space heating load, as equipment heat gains in the spaces act to suppress the heating load.

The predictive modelling has found that the **auxiliary (fans and pumps)** energy use is likely to be much higher than is assumed by Part L.

Benchmark total - the best practice benchmark for total energy use in offices is 120kWh/m²/yr. This figure is almost twice the EUI estimated by the predictive model. This shows that an energy model would always show how much energy a building could use if it was managed perfectly. Although some might say the estimate is unrealistic, it is a useful target to have when a building is being operated: it shows how low energy use could be.

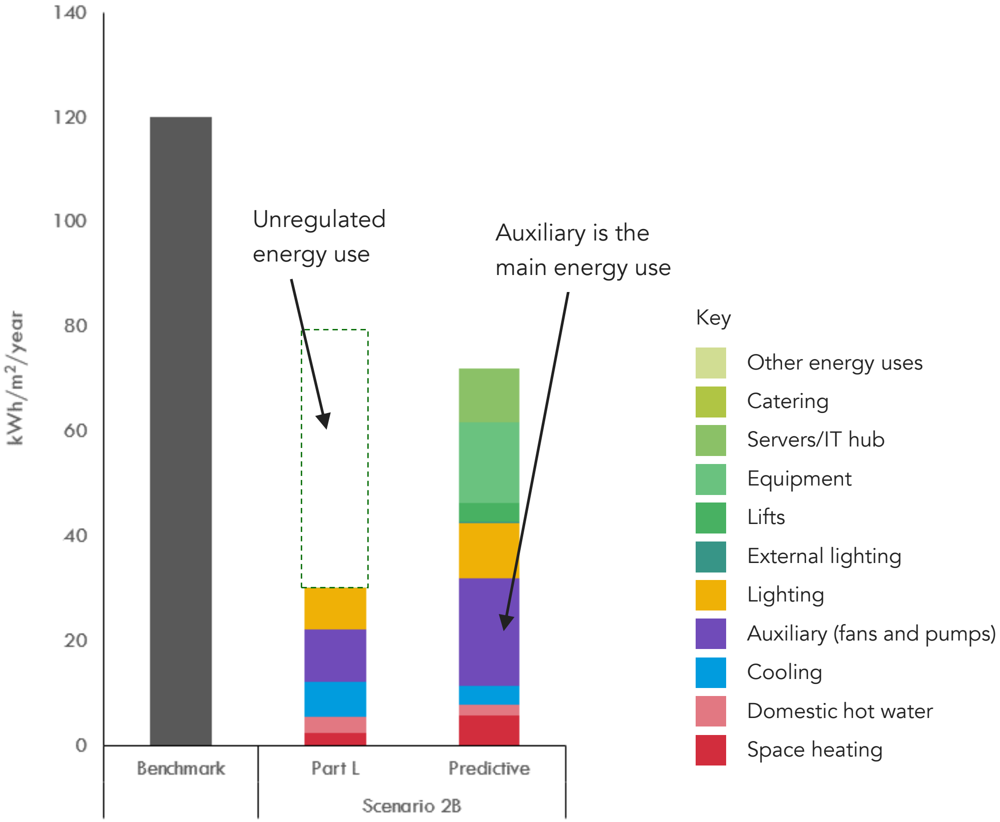


Figure 8.5 – Comparison between the results of the Part L energy model and the Predictive energy model, per separable energy use, for a typical 'good practice' scenario with a heat pump

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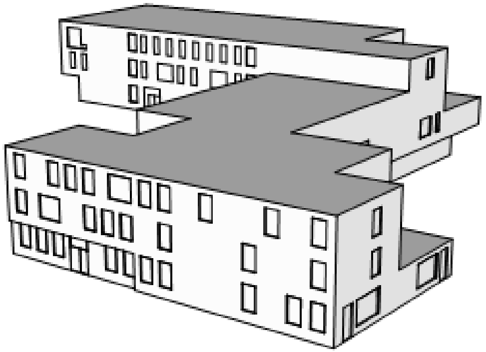
8.2.2

Comparison for primary school



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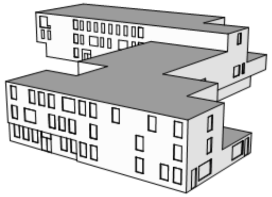
Primary school building | **Policy Option 1** (% over Part L) **vs Option 2** (Space heating demand and EUI)



☐ Compliant with proposed policy option

1 on the left

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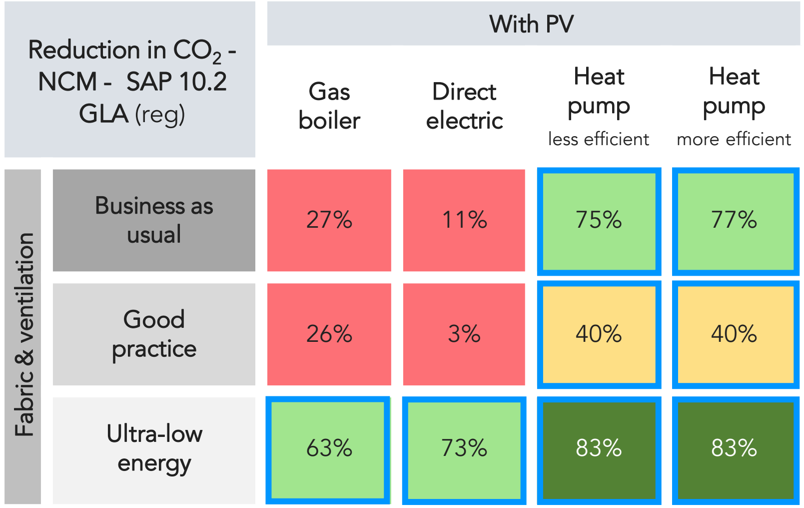
⬚ Compliant with one of two metrics

✗ Would not pass both building regulations Part L 2021 metrics

Policy option 1 (% over Part L)



	Reduction in CO_2 - NCM - SAP 10.2 GLA (reg)	With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	27%	11%	75%	77%
	Good practice	26%	3%	40%	40%
	Ultra-low energy	63%	73%	83%	83%

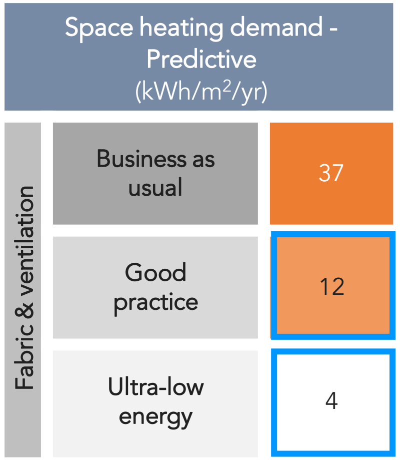
PV area covering 25% of the building footprint area

Table 8.19 – Performance of each case in terms of CO_2 overlaid with compliance with all Part L 2021 criteria and compliance with indicative policy target for option 1

Indicative policy requirement:

- **35% improvement over Part L 2021.**
- Heat pump scenarios can comply relatively easily and direct electric would only comply with an 'ultra-low energy' fabric and ventilation.
- Unfortunately, a gas heating system would still be possible with an 'ultra-low energy' fabric and ventilation. Other policy mechanisms are recommended to prevent new fossil fuel heating systems to be granted planning permission.

Policy option 2 (Space heating demand and EUI)

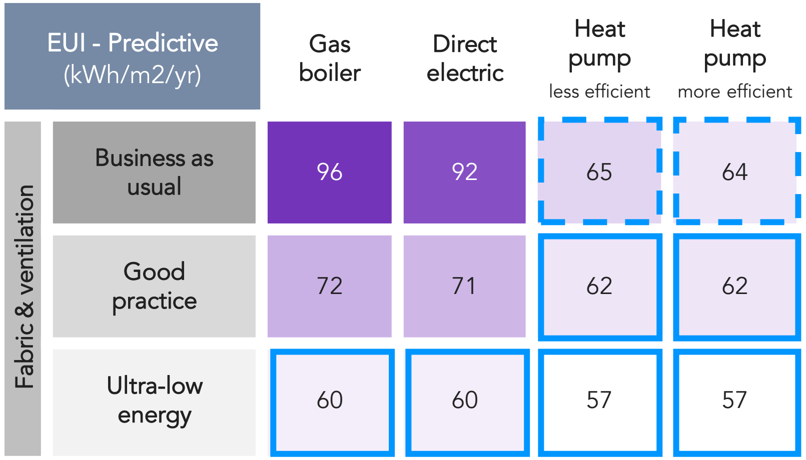


		Space heating demand - Predictive (kWh/m²/yr)
Fabric & ventilation	Business as usual	37
	Good practice	12
	Ultra-low energy	4

Indicative policy requirement:

- **SHD < 15 kWh/m².yr**
- **EUI < 65 kWh/m².yr**
- These are in line with the industry definition of Net Zero Operational Carbon for school buildings

Table 8.20 – Performance of each fabric and ventilation specification level in terms of space heating demand overlaid with compliance with the FEE criterion in Part L 2021 criteria and compliance with indicative policy target for option 2



	EUI - Predictive (kWh/m2/yr)	Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	96	92	65	64
	Good practice	72	71	62	62
	Ultra-low energy	60	60	57	57

Table 8.21 – Performance of each case in terms of energy use intensity (EUI) overlaid with compliance with all criteria in Part L 2021 criteria and compliance with indicative policy target for option 2

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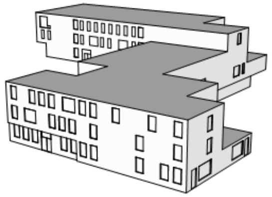
Primary school building | Part L modelling vs Predictive energy modelling



Space heating appears to be significantly underestimated in Part L modelling, which means that changes to U-values, windows, airtightness will have limited effect, thereby not encouraging better fabric and better design.

Part L estimates **'unregulated' energy use** (shown dashed in graph) but does not include it in the reported emissions and energy metrics. Policy Option 1 would therefore have no effect on it. The predictive modelling allows greater scrutiny of equipment loads and has found that equipment energy use is likely to be lower than Part L calculates. This goes some way to explaining the very low space heating load, as equipment heat gains in the spaces act to suppress the heating load.

The combination of the above and the overestimation of fan power means that **MVHR** could be discouraged using Policy Option 1. The predictive modelling has found that the auxiliary energy use is likely to be much lower than is assumed by Part L, meaning that ventilation systems that are overall more efficient will be incentivised.

Benchmark total - the best practice benchmark used is 100 kWh/m²/yr., which approximately aligns with the proposed performance level stated for primary schools in the the Green Construction Board research on energy efficiency for BEIS' Buildings Mission 2030. This is around half the CIBSE good practice benchmark data for existing school buildings, which is not considered appropriate as it is 10 years old, probably backward looking, and not transparent about what is included.

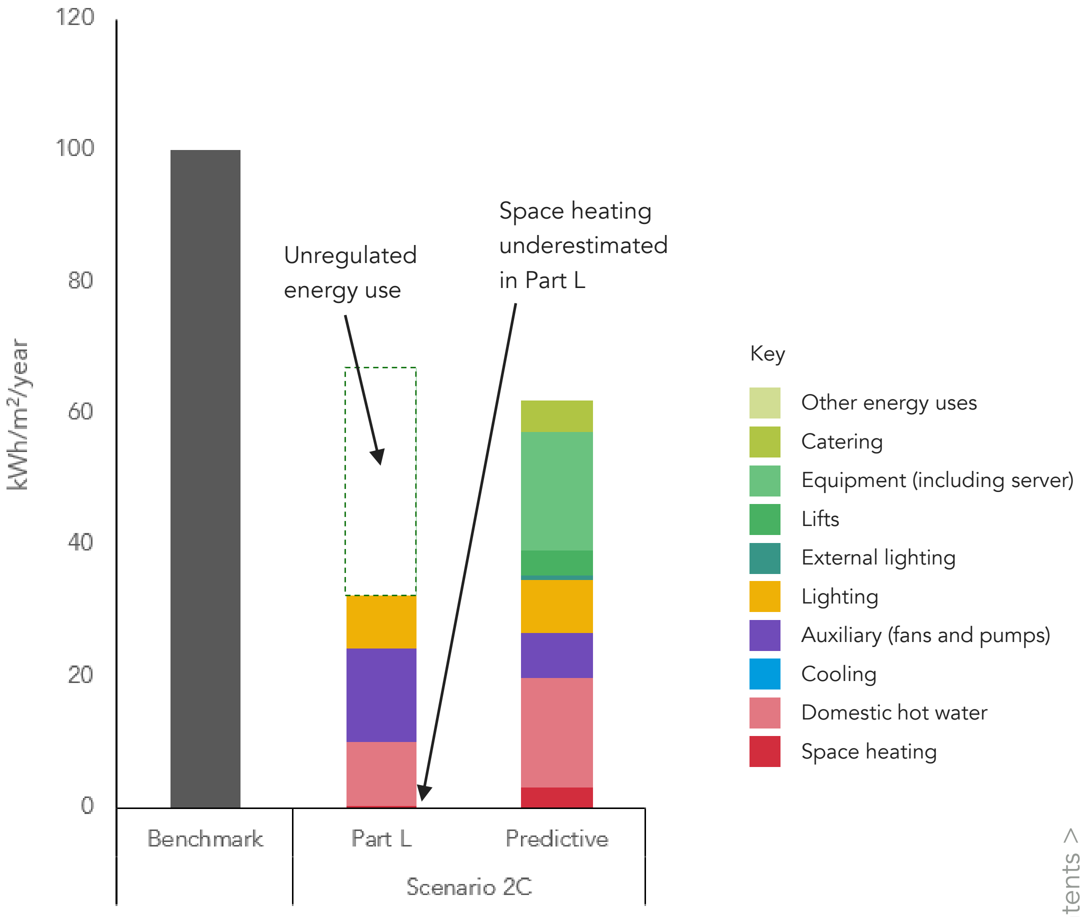


Figure 8.6 – Comparison between the results of the Part L energy model and the Predictive energy model, per separable energy use, for a typical 'good practice' scenario with a heat pump

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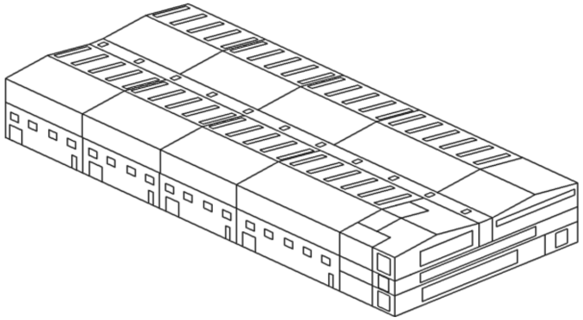
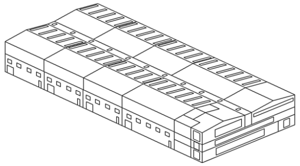
8.2.3

Comparison for industrial building



Industrial building I Policy Option 1 (% over Part L) **vs Option 2** (Space heating demand and EUI)



Policy option 1 (% over Part L)

Reduction in CO$_2$ - NCM - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	VRF	Four pipe chiller	Heat pump more efficient
Fabric & ventilation	Business as usual	✗ 0%	41%	40%	☐ 53%
	Good practice	✗ 6%	41%	40%	☐ 53%
	Ultra-low energy	21%	☐ 48%	☐ 46%	☐ 61%

PV area covering 20% of the building footprint area

Table 8.22 – Performance of each case in terms of CO$_2$ overlaid with compliance with all Part L 2021 criteria and compliance with indicative policy target for option 1

Indicative policy requirement:

- **45% improvement over Part L 2021.**
- An efficient heat pump scenario can comply relatively easily but other forms of electric heating would only comply with an 'ultra-low energy' fabric and ventilation.

Policy option 2 (Space heating demand and EUI)

Space heating demand - Predictive (kWh/m^2/yr)		
Fabric & ventilation	Business as usual	17
	Good practice	☐ 12
	Ultra-low energy	☐ 10

Indicative policy requirement:

- **SHD < 15 kWh/m^2.yr**
- **EUI < 35 kWh/m^2.yr**
- These are in line with the industry definition of Net Zero Operational Carbon.

Table 8.23 – Performance of each fabric and ventilation specification level in terms of space heating demand overlaid with compliance with the FEE criterion in Part L 2021 criteria and compliance with indicative policy target for option 2

EUI - Predictive (kWh/m^2/yr)		Gas boiler	VRF	Four pipe chiller	Heat pump more efficient
Fabric & ventilation	Business as usual	✗ 50	⬚ 34	⬚ 34	⬚ 32
	Good practice	✗ 40	☐ 30	☐ 31	☐ 29
	Ultra-low energy	36	☐ 28	☐ 28	☐ 27

Table 8.24 – Performance of each case in terms of energy use intensity (EUI) overlaid with compliance with all criteria in Part L 2021 criteria and compliance with indicative policy target for option 2

☐ Compliant with proposed policy option

1 on the left

2 on the right

⬚ Compliant with one of two metrics

✗ Would not pass both building regulations Part L 2021 metrics

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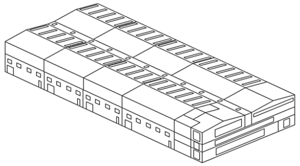
Industrial building | Part L modelling vs Predictive energy modelling



Space heating appears to be significantly underestimated in Part L modelling, which means that changes to U-values, windows, airtightness will have limited effect, thereby not encouraging better fabric and better design.

Equipment gains (i.e unregulated energy) appears to be very significantly overestimated in the Part L modelling, when compared to the equipment energy use in the predictive energy modelling, therefore leading to much lower space heating demand and energy consumption.

DHW appears to be significantly overestimated in the Part L modelling.

Part L estimates **'unregulated' energy use** (shown dashed in the graph) but does not use it so Policy Option 1 would have no effect on them.

Benchmark building – has an EUI of 80 kWh/m².yr, which is almost double the predictive energy modelling EUI. The benchmark building uses both electricity and gas, therefore cannot be taken as a like for like comparison with our modelled scenario. Furthermore, we have modelled a light operation industrial unit, however the nature of operation in industrial buildings can vary massively thus have different EUIs.

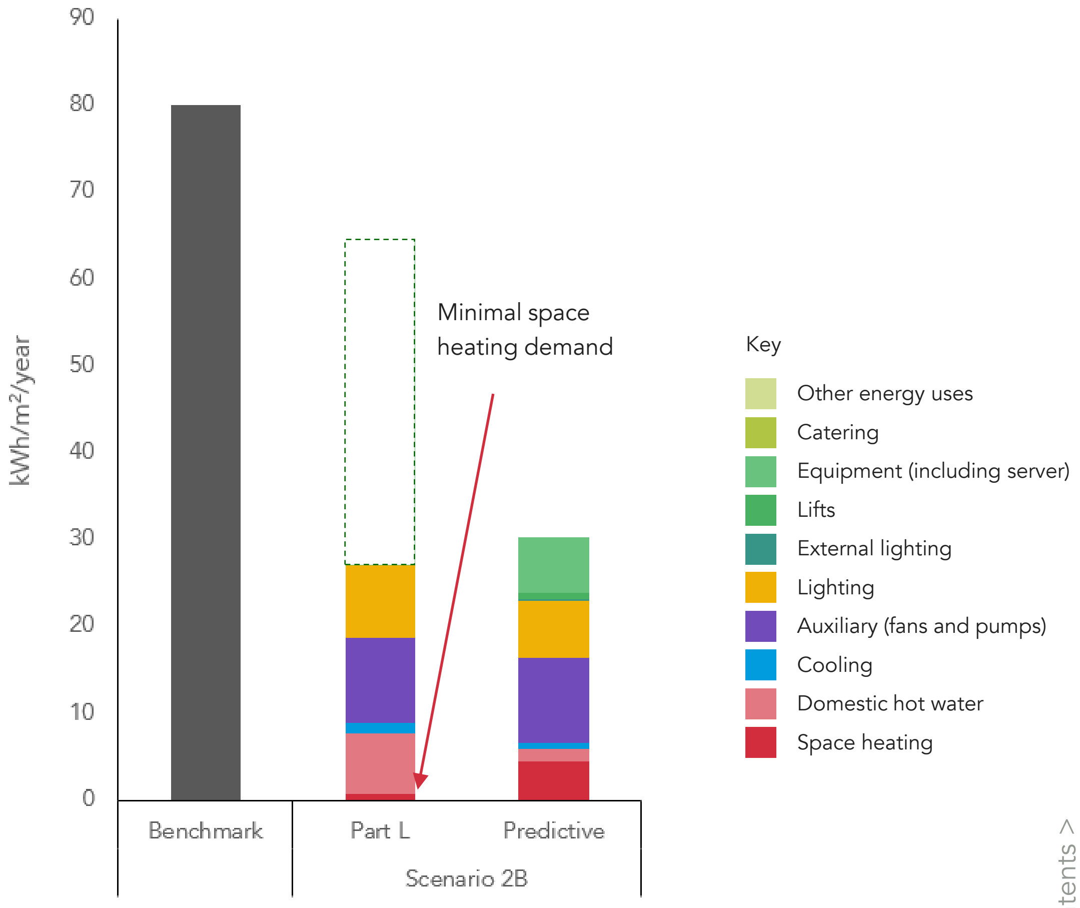


Figure 8.7 – Comparison between the results of the Part L energy model and the Predictive energy model, per separable energy use, for a typical 'good practice' scenario with a heat pump

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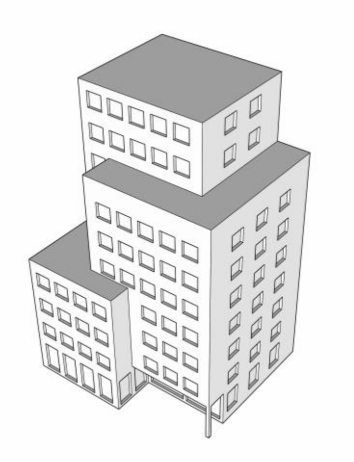
8.2.4

Comparison for hotel



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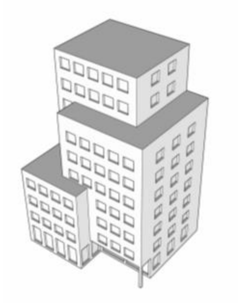
Hotel building I Policy Option 1 (% over Part L) **vs Option 2** (Space heating demand and EUI)



☐ Compliant with proposed policy option

1 on the left

2 on the right

⬚ Compliant with one of two metrics

✕ Would not pass both building regulations Part L 2021 metrics

Policy option 1 (% over Part L)

Reduction in CO$_2$ - NCM - SAP 10.2 GLA (reg)		With PV			
		Gas boiler	Heat pump (220)	Heat pump (400/300)	Heat pump (450/300)
Fabric & ventilation	Business as usual	-2%	-13%	7%	8%
	Good practice	2%	-13%	10%	11%
	Ultra-low energy	4%	-7%	16%	16%

PV area covering 50% of the building footprint area

Table 8.25 – Performance of each case in terms of CO$_2$ overlaid with compliance with all Part L 2021 criteria and compliance with indicative policy target for option 1

Indicative policy requirement:

- **10% improvement over Part L 2021.**
- This would enable 'good practice' and 'ultra-low energy' fabric and ventilation combined with heat pump scenarios to comply.

Policy option 2 (Space heating demand and EUI)

		Space heating demand - Predictive (kWh/m^2/yr)
Fabric & ventilation	Business as usual	30
	Good practice	24
	Ultra-low energy	15

Indicative policy requirement:

- **SHD < 15 kWh/m^2.yr**
- **EUI < 160 kWh/m^2.yr**
- These are in line with the industry definition of Net Zero Operational Carbon, although the particular hotel modelled in this evidence base is a high-energy use type.

Table 8.26 – Performance of each fabric and ventilation specification level in terms of space heating demand overlaid with compliance with the FEE criterion in Part L 2021 criteria and compliance with indicative policy target for option 2

	EUI - Predictive (kWh/m^2/yr)	Gas boiler	Heat pump (220)	Heat pump (400/300)	Heat pump (450/300)
Fabric & ventilation	Business as usual	233	174	159	158
	Good practice	222	166	152	152
	Ultra-low energy	206	154	143	142

Table 8.27 – Performance of each case in terms of energy use intensity (EUI) overlaid with compliance with all criteria in Part L 2021 criteria and compliance with indicative policy target for option 2

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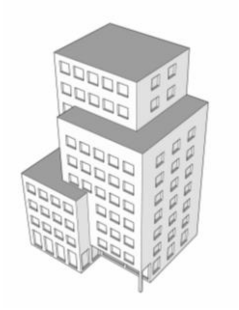
Hotel building | Part L modelling vs Predictive energy modelling



- **Catering loads** are very dominant in the predictive model yet have little bearing on building design and are likely, at planning stage, to be indicative estimates based on CIBSE benchmarks.

- **DHW loads** dominate the Part L assessment. Lower demand assumptions (based on CIBSE benchmarks) and cooler storage/supply temperatures result in lower energy use in predictive model.

- **Benchmark total** - the CIBSE best practice benchmark for total energy use in hotels is 340kWh/m²/yr. This figure is 10 years old, was probably backward looking then, and is not transparent about what is included, but is twice the EUI estimated by the predictive model.

- **Space heating** is significantly underestimated in Part L modelling, which means that changes to U-values, windows, airtightness will have little effect, thereby not encouraging better fabric and better design.

- Part L estimates **'unregulated' energy use** (shown dashed in graph) but does not include it in the reported emissions and energy metrics. Policy Option 1 would therefore have no effect on it. The predictive modelling allows greater scrutiny of equipment loads and has found that equipment energy use (excluding catering loads) is likely to be much lower than Part L calculates.

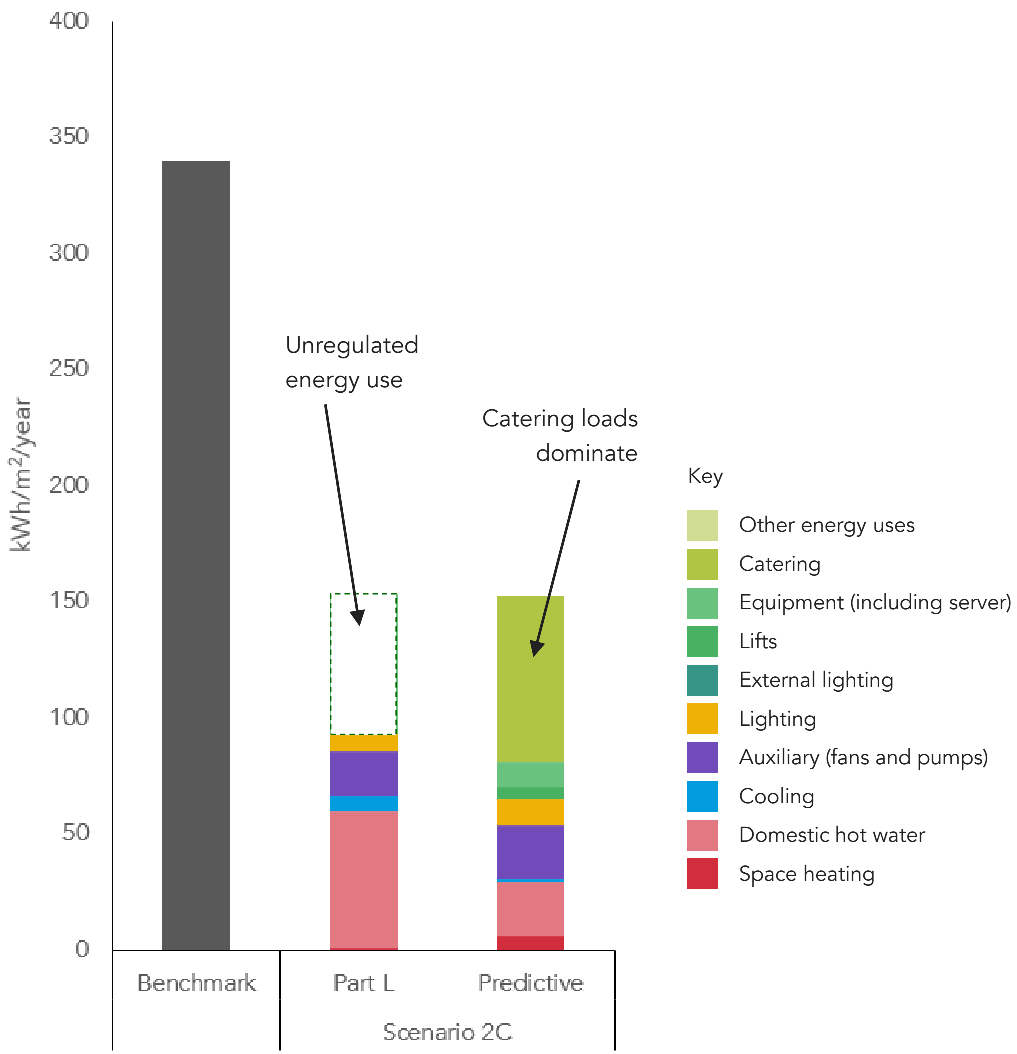


Figure 8.8 – Comparison between the results of the Part L energy model and the Predictive energy model, per separable energy use, for a typical 'good practice' scenario with a heat pump

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8.3

Additional analysis on heat networks - conclusion

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How would heat networks perform under Policy options 1 and 2?

Purpose of the TNZC study

The main aim of the TNZC study is to establish an evidence base to inform and support the development of new energy and carbon policies for new buildings in each of the 18 London Boroughs.

Heat networks are a key part of current GLA policy for heating, so it was necessary, as part of the study, to investigate how they would perform under Policy option 1, and to explain how they would be assessed (and perform) using Policy option 2.

Summary of conclusions

- Because the carbon content of grid electricity has rapidly reduced and heat pumps have become the first choice for local heating systems, the reduction in emissions that may be delivered by heat networks should be re-evaluated against this new baseline.
- Part L 2021 energy modelling used for Policy option 1 assess DH1 (Energy from Waste) favourably but not DH2, particularly in terms of carbon. It performs worse than a local heat pump system, which seems logical.
- It is possible to evaluate the performance of heat networks using the EUI metric (Policy option 2), with the additional information from the network providers. Including heat generating plant efficiencies and actual predicted system losses.
- Distribution losses are an inevitable feature of all heat networks. These system losses should be evaluated for each application, rather than estimated based on a factor of the heat delivered.

	Reduction in CO$_2$ – SBEM (reg)	With PV					
		Gas boiler	Direct electric	Heat Pump less efficient	Heat pump more efficient	DHN 1	DHN 2
Fabric & ventilation	Business as usual	27%	11%	75%	77%		
	Good practice	26%	3%	40%	40%		
	Ultra-low energy	63%	73%	83%	83%	112%	75%

Table 8.28 – Policy option 1: performance of DH1 and DH2 (assuming an ultra-low energy building) in terms of CO$_2$ compared with all other cases

	EUI - Predictive (kWh/m2/yr)	Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient	DHN 1	DHN 2
Fabric & ventilation	Business as usual	96	92	65	64		
	Good practice	72	71	62	62		
	Ultra-low energy	60	60	57	57	44	67

Table 8.29 – Policy option 2: performance of DH1 and DH2 (assuming an ultra-low energy building) in terms of energy use intensity (EUI) compared with all other cases

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9.0

Cost modelling

9.0 Cost modelling

What would be the likely impact of these different combination of specifications on capital (construction) costs? And on the energy costs that residents would have to pay?

This section, prepared by Currie & Brown, seeks to provide these answers and forms part of this evidence base.

As always with costs, it is important to understand how these assessments were undertaken as well as their limitations. In particular:

- The costs models are based on the buildings modelled. Although the trends and orders of magnitude are expected to be broadly similar for other buildings within the same archetype, variations are possible.
- The 'cost reference scenario' or 'baseline' has been chosen to represent a set of specifications which would comply with Part L 2021.
- Annual domestic energy costs are highly sensitive to utility prices which have been very volatile. This section has been included in this evidence base to illustrate that more efficient and better buildings would benefit residents' energy bills too. It should not be relied upon to accurately predict a particular building's future energy bills.

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How to read tables in this section?

These tables indicate, for each archetype, the comparative construction costs of each combination of specifications compared to a ‘cost reference scenario’ or ‘baseline’ selected on the basis that it is Part L 2021 compliant.

The costs are shown as savings (shades of blue) or additional costs (shades of pink), and they are indicated both in % and £/m^2.

A red cross has been added over the scenarios which would not comply with Part L 2021 of the building regulations.

✗ Would not pass all criteria of building regulations Part L 2021

Low-rise apartment (~ £2,500/m^2 baseline construction cost)

% uplift in cost per m^2 of construction		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	~~-2.4%~~	~~-4.6%~~	~~-0.3%~~	~~2.3%~~
	Good practice	0.0%	-2.3%	2.1%	4.7%
	Ultra-low energy	2.4%	0.2%	4.5%	7.1%

Table 9.1 – Relative costs (%) of each case compared to the ‘0’ baseline, overlaid with compliance with all Part L 2021 criteria and

£/m^2 of construction		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	~~-£59~~	~~-£116~~	~~-£9~~	~~-£57~~
	Good practice	£0	-£57	£51	£117
	Ultra-low energy	£61	£4	£112	£178

Table 9.2 – Relative costs (£/m^2) of each case compared to the ‘0’ baseline, overlaid with compliance with all Part L 2021 criteria and

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9.1

Capital cost modelling

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Cost methodology and impact of inflation since 2019 cost assessment

Costing approach

The uplift costs associated with each specification option were estimated based on Currie & Brown's cost datasets for energy efficiency and low carbon technologies which incorporate information from market prices, specific market testing and first principles cost planning by their specialist quantity surveyors.

The costs are based on Q4 2022 prices and reflect a London cost base inclusive of overheads, profit and preliminaries.

Costs were developed for each affected element to identify the variance in price between the baseline and the enhanced specifications. Those elements that are not materially affected by the energy efficiency / low carbon technology options, e.g substructure, roof coverings, kitchen and bathrooms, etc, were not costed in detail. Instead, these costs were incorporated within the 'balance of construction' cost estimated by reference to a typical whole building construction cost per m^2 for the building type in question. This whole building cost was then adjusted for each option based on the variance in the elements costed in detail to determine the overall percentage impact on construction costs.

Inflation

Overall cost inflation in London between Q2 2019 (first Towards Net Zero Carbon study) and Q4 2022 (this update) is c.12% based on published tender price indices which also reflect Currie & Brown's experience of average tender returns over this period.

Inflation is driven by a wide range of factors, predominantly materials pricing, but also wage inflation and reflects a combination of supply shortages, exchange rates, and wider inflation across the UK and global economy. Materials pricing indices show more significant inflation for some products notably aggregates (over 60%) and insulation (30%). We have therefore applied element specific inflation rates accordingly as follows: flat roofs (25%), heating and heat distribution (25%), windows (30%).

Some products, notably photovoltaics, are experiencing more significant short-term cost 'spikes' due to short term stock availability. However, we do not believe these elevated rates will be sustained beyond the short term (6-9 months) and so have excluded from this analysis on the basis that they will not be in place when new policies are implemented.

Future projection

Notwithstanding the currently high levels of economic instability and associated uncertainties in economic forecasting, some indicative levels of future inflation are shown below suggesting that it is likely that overall construction cost inflation in years 2023-25 will be under 5% per year. This industry average figure masks a reasonable degree of variability in demand for different sectors with strong activity in the public sector from a backlog of public projects currently in procurement and a weakening in demand in the commercial (particularly office) market.

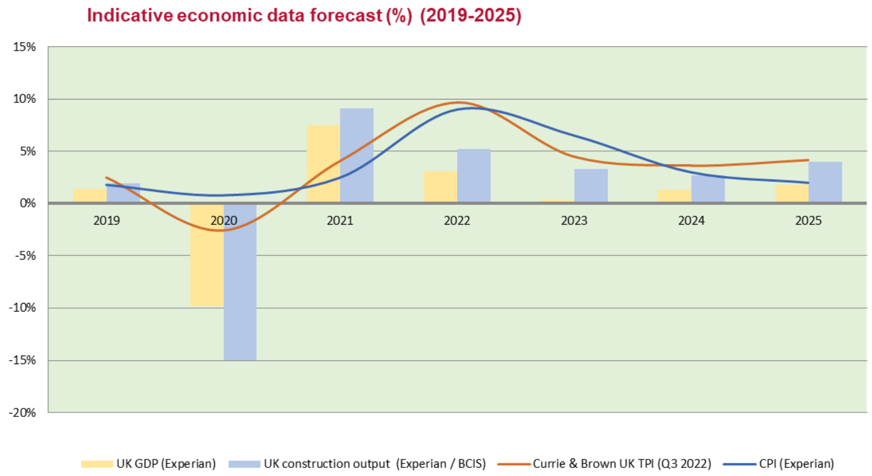

Figure 9.1 - Inflation projection to 2025

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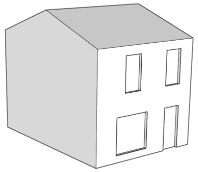
Terrace house | Capital costs



Cost analysis shows that the Good practice standard with gas is similar in cost to a BAU fabric with a heat pump.

The ultra-low energy fabric is c.3% more expensive than the Good Practice specification largely a result of the costs of the higher specification walls, floor and windows.

The introduction of a heat pump or better heat pump adds around 1.5-2.5% to the capital cost while direct electric heating and hot water systems are c.2% less expensive than gas boiler option.

There is potential to reduce the capital costs of the heat pumps for the ultra-low energy standards if units of a smaller capacity can be specified (ie <5kW). However, there are relatively few of these systems available.

✗ Would not pass all 3 building regulations Part L 2021 metrics

Terrace house (~ £2,020/m² baseline construction cost)

% uplift in cost per m² of construction		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	~~-1.6%~~	~~-3.6%~~	~~-0.2%~~	~~0.7%~~
	Good practice	0.0%	-2.0%	1.4%	2.3%
	Ultra-low energy	3.0%	1.0%	4.4%	5.3%

Table 9.1 – Relative costs (%) of each case compared to the '0' baseline, overlaid with compliance with all Part L 2021 criteria

£/m² of construction		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	~~-£33~~	~~-£73~~	~~-£4~~	~~£14~~
	Good practice	£0	-£40	£28	£46
	Ultra-low energy	£60	£20	£88	£107

Table 9.2 – Relative costs (£/m²) of each case compared to the '0' baseline, overlaid with compliance with all Part L 2021 criteria

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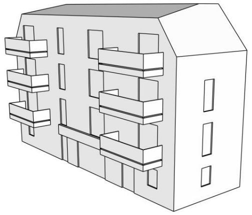
Low-rise apartment building | Capital costs



Cost analysis shows that the Good practice standard with gas is similar in cost to a BAU fabric with a heat pump.

The ultra-low energy fabric is c.2.4% more expensive than the Good Practice specification largely as a result of the costs of the higher specification walls, floor and windows.

The introduction of a heat pump or better heat pump (GSHP) adds around 2-5% to the capital cost the higher costs being for a system with a relatively expensive ground array.

Direct electric heating and hot water systems are c.2% less expensive than gas boiler option.

Low-rise apartment (~ £2,500/m² baseline construction cost)

% uplift in cost per m² of construction		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	~~-2.4%~~	~~-4.6%~~	~~-0.3%~~	~~2.3%~~
	Good practice	0.0%	-2.3%	2.1%	4.7%
	Ultra-low energy	2.4%	0.2%	4.5%	7.1%

Table 9.3 – Relative costs (%) of each case compared to the '0' baseline, overlaid with compliance with all Part L 2021 criteria

£/m² of construction		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	~~-£59~~	~~-£116~~	~~-£9~~	~~-£57~~
	Good practice	£0	-£57	£51	£117
	Ultra-low energy	£61	£4	£112	£178

Table 9.4 – Relative costs (£/m²) of each case compared to the '0' baseline, overlaid with compliance with all Part L 2021 criteria

✗ Would not pass all 3 building regulations Part L 2021 metrics

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Mid-rise apartment building | Capital costs

Cost analysis shows that the Good practice standard with gas is similar in cost to a BAU fabric with a heat pump.

The ultra-low energy fabric is c.1.6% more expensive than the Good Practice specification largely a result of the costs of the higher specification walls, floor and windows. The additional cost of the more energy efficient fabric is a smaller percentage than for the low-rise flats or terrace houses this is a combination of the relatively lower additional cost due to a better form factor and the higher overall cost of this form of development per m^2.

The introduction of a heat pump or more efficient heat pump (GSHP) adds around 1.5-3% to the capital cost the higher costs being for a system with a relatively expensive ground array. The costs of a shared ground array are lower for the mid-rise flat scenario than for the low-rise flats. This reflects the greater economies of scale achieved in the larger mid-rise archetype.

Direct electric heating and hot water systems are c.2-3% less expensive than gas boiler option.

✗ Would not pass all 3 building regulations Part L 2021 metrics

Mid-rise apartment (~ £3,200/m^2 baseline construction cost)

% uplift in cost per m^2 of construction		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	✗ -2.0%	✗ -4.8%	✗ -0.4%	✗ 1.2%
	Good practice	0.0%	-2.8%	1.6%	3.2%
	Ultra-low energy	1.6%	-1.2%	3.2%	4.7%

Table 9.5 – Relative costs (%) of each case compared to the '0' baseline, overlaid with compliance with all Part L 2021 criteria

£/m^2 of construction		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	✗ -£50	✗ -£120	✗ -£9	✗ £29
	Good practice	£0	£-71	£41	£79
	Ultra-low energy	£40	-£31	£81	£118

Table 9.6 – Relative costs (£/m^2) of each case compared to the '0' baseline, overlaid with compliance with all Part L 2021 criteria

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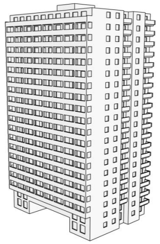
High-rise apartment building I Capital costs



Cost analysis shows that the Good practice standard with gas is similar in cost to a BAU fabric with a heat pump.

The ultra-low energy fabric is less than 1% more expensive than the Good Practice specification largely a result of the costs of the higher specification walls, floor and windows. The additional cost of the more energy efficient fabric is a smaller percentage than for either the other flats or house archetypes. This is due to a combination of the relatively lower additional cost due to a better form factor and the higher overall cost of this form of development per m^2.

The introduction of a heat pump or a more efficient heat pump (GSHP) adds around 1.5-3% to the capital cost the higher costs being for a system with a relatively expensive ground array. The costs of a shared ground array are lower for the high-rise flat scenario than for the low-rise flats. This reflects the greater economies of scale achieved in the larger high-rise archetype.

Direct electric heating and hot water systems are c.2% less expensive than gas boiler option.

The total additional cost of applying ultra-low fabric standards and a highly efficient low carbon heating system is estimated at less than 3% of the baseline cost of construction.

✗ Would not pass all 3 building regulations Part L 2021 metrics

High-rise apartment (~ £3,400/m^2 baseline construction cost)

	% uplift in cost per m^2 of construction	With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	✗ ~~-1.0%~~	✗ ~~-2.9%~~	✗ ~~-0.1%~~	✗ ~~1.1%~~
	Good practice	0.0%	-1.9%	1.1%	2.1%
	Ultra-low energy	0.8%	-1.2%	1.9%	2.9%

Table 9.7 – Relative costs (%) of each case compared to the '0' baseline, overlaid with compliance with all Part L 2021 criteria

	£/m^2 of construction	With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	✗ ~~-£35~~	✗ ~~-£103~~	✗ ~~£3~~	✗ ~~£38~~
	Good practice	£0	-£68	£38	£73
	Ultra-low energy	£29	-£40	£66	£101

Table 9.8 – Relative costs (£/m^2) of each case compared to the '0' baseline, overlaid with compliance with all Part L 2021 criteria

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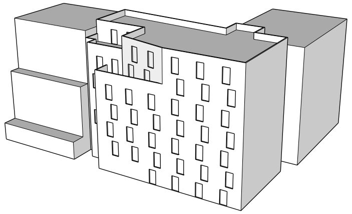
Office building | Capital costs



Cost analysis shows that the Good practice standard with gas is similar in cost to a BAU fabric with a heat pump.

The ultra-low energy fabric is less than 2% more expensive than the Good Practice specification largely a result of the costs of the higher specification walls, windows, ventilation and lighting systems.

The introduction of an air source heat pump adds less than 1% to the capital cost of the building with a more expensive ground source heat pump solution (GSHP) increasing costs by 2-4% depending on fabric standard.

The more energy efficient fabric standards enable reductions in the size of the building's heating system meaning that the additional cost of a specification with both a GSHP and an ultra-low energy specification is only 0.7% more expensive than a GSHP and BAU fabric combination.

Office building (~ £4,050/m^2 baseline construction cost)

% uplift in cost per m^2 of construction		With PV			
		Gas boiler	VRF	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	~~-0.9%~~	-2.9%	-0.2%	3.0%
	Good practice	0.0%	-1.6%	0.4%	2.7%
	Ultra-low energy	1.8%	0.6%	2.0%	3.7%

Table 9.19– Relative costs (%) of each case compared to the '0' baseline, overlaid with compliance with all Part L 2021 criteria

£/m^2 of construction		With PV			
		Gas boiler	VRF	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	~~-£35~~	-£116	-£9	£120
	Good practice	£0	-£64	£15	£110
	Ultra-low energy	£74	£23	£82	£150

Table 9.10 – Relative costs (£/m^2) of each case compared to the '0' baseline, overlaid with compliance with all Part L 2021 criteria

✗ Would not pass both building regulations Part L 2021 metrics

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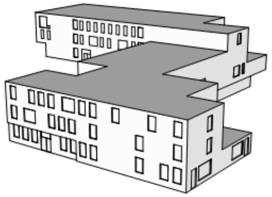
Primary school | Capital costs



The additional costs associated with the most energy efficient specification and better heat pump are less than 4% higher than the Part L compliant solution of a BAU specification with heat pump.

For the more energy efficient specifications, the low level of space heating demand means that the costs of adopting low carbon heating is relatively low, with an air source heat pump adding virtually no additional cost in comparison to a gas boiler.

The additional costs of the more energy efficient standards are driven by enhanced ventilation, lighting, windows and insulation specifications.

Primary school (~ £3,400/m^2 baseline construction cost)

% uplift in cost per m^2 of construction		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	-1.1%	-3.1%	0.0%	3.3%
	Good practice	0.6%	-1.0%	1.1%	2.9%
	Ultra-low energy	2.9%	-1.4%	2.9%	3.6%

Table 9.11 – Relative costs (%) of each case compared to the '0' baseline, overlaid with compliance with all Part L 2021 criteria

£/m^2 of construction		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	-£37	-£104	£0	£112
	Good practice	£22	-£35	£39	£100
	Ultra-low energy	£97	£47	£95	£121

Table 9.12 – Relative costs (£/m^2) of each case compared to the '0' baseline, overlaid with compliance with all Part L 2021 criteria

✗ Would not pass both building regulations Part L 2021 metrics

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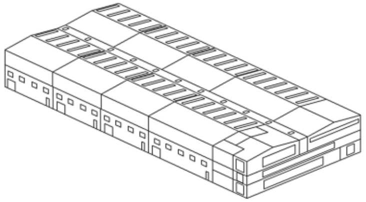
Industrial building I Capital costs



The additional costs of the electrically heated solutions modelled are dominated by the need for additional radiant panels to provide space heating to the warehouse space. This is because of the lower flow temperatures achieved by these systems and the resulting need for more panels.

More energy efficient warehouse specifications reduce the need for more radiant panels for the electrically heated solutions, so the additional cost of these options is lower than for the less efficient options.

The lowest cost Part L compliant solution is the ultra-low energy standard with a gas boiler. In cost terms the saving from a reduced need for radiant panels offsets the additional costs of the higher fabric standard.

Industrial building (~ £1,300/m^2 baseline construction cost)

% uplift in cost per m^2 of construction		With PV			
		Gas boiler	VRF	Four pipe chiller	Heat pump more efficient
Fabric & ventilation	Business as usual	~~-6.5%~~	3.8%	5.2%	7.1%
	Good practice	~~-2.2%~~	3.8%	4.7%	5.8%
	Ultra-low energy	0.0%	5.5%	6.2%	7.3%

Table 9.13 – Relative costs (%) of each case compared to the '0' baseline, overlaid with compliance with all Part L 2021 criteria

£/m^2 of construction		With PV			
		Gas boiler	VRF	Four pipe chiller	Heat pump more efficient
Fabric & ventilation	Business as usual	~~£0~~	£50	£50	£92
	Good practice	~~-£29~~	£49	£61	£76
	Ultra-low energy	£0	£71	£81	£95

overlaid with compliance with all Part L 2021 criteria

✗ Would not pass both building regulations Part L 2021 metrics

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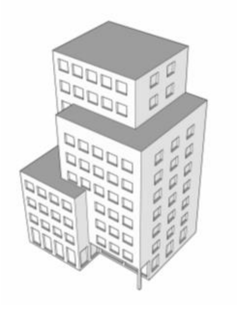
Hotel | Capital costs



In comparison to the building regulations compliant option (Good practice with Gas boiler) the cost of lower carbon solutions range from a small cost saving for the least energy efficient option to a cost increase of around 2.3% for the most energy efficient option with a Better heat pump.

The additional cost of an air source heat pump is negligible in comparison to the gas boiler alternative.

Hotel (~ £4,250/m^2 baseline construction cost)

	% uplift in cost per m^2 of construction	With PV			
		Gas boiler	Heat pump (220)	Heat pump (400/300)	Heat pump (450/300)
Fabric & ventilation	Business as usual	~~-0.8%~~	~~-2.2%~~	-0.3%	0.8%
	Good practice	0.0%	~~-1.3%~~	0.5%	1.6%
	Ultra-low energy	1.4%	~~-0.8%~~	1.9%	2.8%

Table 9.15 – Relative costs (%) of each case compared to the '0' baseline, overlaid with compliance with all Part L 2021 criteria

	£/m^2 of construction	With PV			
		Gas boiler	Heat pump (220)	Heat pump (400/300)	Heat pump (450/300)
Fabric & ventilation	Business as usual	~~-£36~~	~~-£74~~	-£12	£35
	Good practice	£0	~~-£35~~	£23	£67
	Ultra-low energy	£59	~~£32~~	£80	£118

Table 9.16 – Relative costs (£/m^2) of each case compared to the '0' baseline, overlaid with compliance with all Part L 2021 criteria

✗ Would not pass both building regulations Part L 2021 metrics

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Summary costs per m^2 of construction | Domestic

The tables below show the summary results for the domestic archetypes in comparison to the 'zero additional cost' Part L 2021 compliant option.

Terrace house (~ £2,020/m^2 baseline construction cost)

% uplift in cost per m^2 of construction		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	~~-1.5%~~	~~-3.5%~~	~~-0.2%~~	~~0.7%~~
	Good practice	0.0%	-2.0%	1.4%	2.3%
	Ultra-low energy	3.0%	1.0%	4.4%	5.3%

Mid-rise apartment (~ £3,200/m^2 baseline construction cost)

% uplift in cost per m^2 of construction		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	~~-2.0%~~	~~-4.8%~~	~~-0.4%~~	~~1.2%~~
	Good practice	0.0%	-2.8%	1.6%	3.2%
	Ultra-low energy	1.6%	-1.3%	3.2%	4.7%

Low-rise apartment (~ £2,500/m^2 baseline construction cost)

% uplift in cost per m^2 of construction		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	~~-2.4%~~	~~-4.5%~~	~~-0.3%~~	~~2.3%~~
	Good practice	0.0%	-2.3%	2.1%	4.7%
	Ultra-low energy	2.4%	0.2%	4.5%	7.1%

High-rise apartment (~ £3,400/m^2 baseline construction cost)

% uplift in cost per m^2 of construction		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	~~-1.0%~~	~~-2.9%~~	~~-0.1%~~	~~1.1%~~
	Good practice	0.0%	-1.9%	1.1%	2.1%
	Ultra-low energy	0.8%	-1.2%	1.9%	2.9%

Table 9.17 – Summary of all domestic relative costs (£/m^2) compared to the '0' baseline, overlaid with compliance with all Part L 2021 criteria

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Summary costs per m^2 of construction I Non-domestic

The tables below show the summary results for the non-domestic archetypes in comparison to the ‘zero additional cost’ Part L 2021 compliant option.

Office building (~ £4,050/m^2 baseline construction cost)

% uplift in cost per m^2 of construction		With PV			
		Gas boiler	VRF	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	~~-0.9%~~	-2.9%	-0.2%	3.0%
	Good practice	0.0%	-1.6%	0.4%	2.7%
	Ultra-low energy	1.8%	0.6%	2.0%	3.7%

Industrial building (~ £1,300/m^2 baseline construction cost)

% uplift in cost per m^2 of construction		With PV			
		Gas boiler	VRF	Four pipe chiller	Heat pump more efficient
Fabric & ventilation	Business as usual	~~-6.5%~~	3.8%	5.2%	7.1%
	Good practice	~~-2.2%~~	3.8%	4.7%	5.8%
	Ultra-low energy	0.0%	5.5%	6.2%	7.3%

Primary school (~ £3,400/m^2 baseline construction cost)

% uplift in cost per m^2 of construction		With PV			
		Gas boiler	Direct electric	Heat pump less efficient	Heat pump more efficient
Fabric & ventilation	Business as usual	-1.1%	-3.1%	0.0%	3.3%
	Good practice	0.6%	-1.0%	1.1%	2.9%
	Ultra-low energy	2.9%	-1.4%	2.9%	3.6%

Hotel (~ £4,250/m^2 baseline construction cost)

% uplift in cost per m^2 of construction		With PV			
		Gas boiler	Heat pump (220)	Heat pump (400/300)	Heat pump (450/300)
Fabric & ventilation	Business as usual	~~-0.8%~~	~~-2.2%~~	-0.3%	0.8%
	Good practice	0.0%	~~-1.3%~~	0.5%	1.6%
	Ultra-low energy	1.4%	~~-0.8%~~	1.9%	2.8%

Table 9.18 – Summary of all non-domestic relative costs (£/m^2) compared to the ‘0’ baseline, overlaid with compliance with all Part L 2021 criteria

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Summary | Capital costs by policy option

The base compliant option for each specification is based on the cost of the most typical modelled scenario compliant with Building Regulations Part L2021. This base option is set at zero cost and all other options are shown net of this cost. For most archetypes, the zero-cost base option is combination A2, for the School combination C1 is lower cost than A2 whereas for the Industrial building combination A3 is the lowest cost compliant option.

In general, there are more compliant options for Policy option 1 than Policy option 2, however for the industrial building option 2 has more compliant solutions thanks option 1. Reflecting on the reduced number of compliant options, the cost range for policy option 2 is wider than that for policy option 1.

At the lower end of the scale the uplift cost for Policy option 2 ranges from 1% to 4% of construction costs whereas for Policy option 1 the range is -2% to 1%. The higher percentage costs for Policy option 2 tend to be linked to the additional costs with meeting the minimum space heating demand standards, particularly for residential developments.

Note: capital cost commentary on heat networks

Cost benchmarks have not been created for heat network scenarios. This is because of the very wide range of variables that can affect costs as both the network and building level.

Variables include whether the network is existing or new, the heat density in the area, the distance from the generation source, whether additional capacity is required to enable a connection, ground conditions, etc. Further the business model applied can affect the portion of a connection cost recovered via different means. For example, that between capital connection cost (and whether this extends to the HIU within a building or just to a plate heat exchanger) the unit rate for heat supply and the availability charge.

Typically, connection to a heat network will enable some avoided costs and space take at the building level, however there will still be a need for heat circulation infrastructure, pumps and controls and for heat exchangers meaning, therefore the level of cost saving relative to a 'standard' gas boiler-based connection could be quite modest.

Archetype	Base compliant option	Compliant options		Uplift range (£m^{2})		Uplift range (%)	
		Policy option 1	Policy option 2	Policy option 1	Policy option 2	Policy option 1	Policy option 2
Terrace	A2	tbc	C3, D3	tbc	£88 - £107	tbc	4% - 5%
Low rise	A2	B3, D1, C2, D2, C3, D3	C3, D3	£-57 - £178	£112 - £178	-2% - 7%	4% - 7%
Mid rise	A2	C3, D1, D2, D3	C3, D3	£29 - £118	£81 - £118	1% - 5%	3% - 5%
High rise	A2	tbc	B3, C3, D3	tbc	£-40 - £101	tbc	-1% - 3%
School	C1	A3, B3, C1, C2, C3, D1, D2, D3	A3, B3, C2, C3, D2, D3	£0 - £121	£39 - £121	1% - 4%	1% - 4%
Hotel	A2	B2, B3, D2, D3	B3, C3, D3	£-54 - £99	£13 - £99	-1% - 3%	1% - 3%
Office	A2	B2, B3, C2, D2, C3, D3	B3, C3, D3	£-64 - £150	£23 - £150	-2% - 4%	1% - 4%
Industrial	A3	B3, C3, D1, D2, D3	B2, B3, C2, C3, D2, D3	£71 - £95	£49 - £95	5% - 7%	4% - 7%

Table 9.19 – Summary of cost uplift associated with cases compliant with policy options 1 and 2

The codes above correspond to the combination of heating system and fabric and ventilation specifications used throughout the report.

They differ for each typology but an example is provided for the domestic buildings on the right.

Heating system	Fabric and Ventilation
A. Gas boiler	**1.** Business as usual*
B. Direct electric	**2.** Good practice
C. Less efficient heat pump	**3.** Ultra-low energy
D. More efficient heat pump	

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9.2

Domestic energy costs

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Energy cost analysis

- Projections based on latest (Jan 2023) projections from BEIS
- Projections for year one cost (assumed to be 2025)
- Projections show central scenario with a sensitivity analysis for the highest combined cost scenario
- Gas scenarios include an additional standing charge of £102 pa
- No assessment of PV generation (same for all options) and levels of self consumption / export (different for all options)
- More energy efficient options will be better able to utilise time of use tariffs / demand response when the market for such products is re-established.

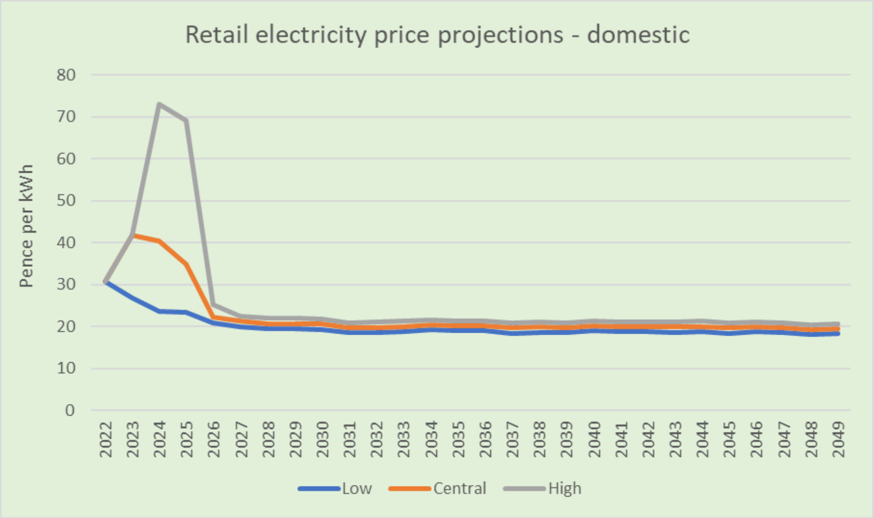

Figure 9.2 – Retail electricity price projections (Domestic)

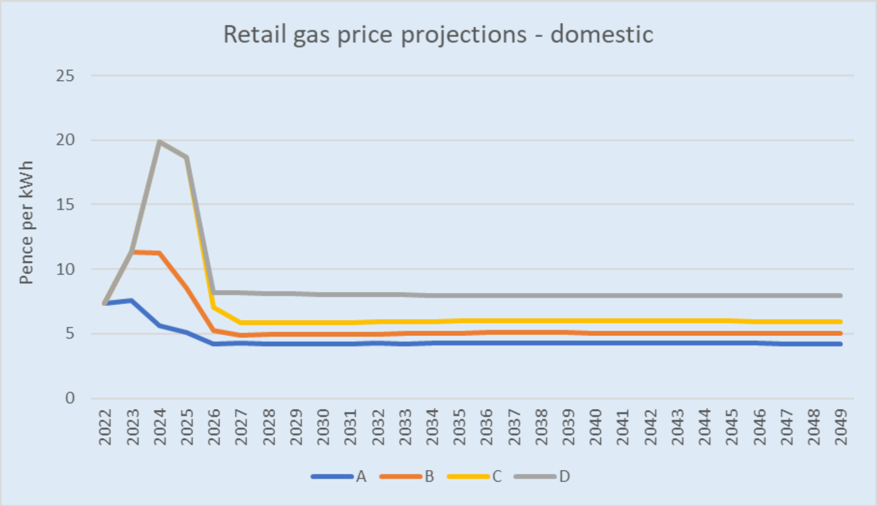

Figure 9.3 – Retail gas price projections (Domestic)

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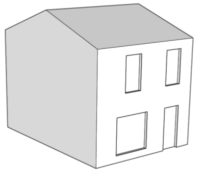
Terrace house | Energy costs



- Compared to the reference scenario only 2d, 3a, c and d are lower cost.
- Scenarios 1d and 2c are also comparable in cost terms
- Direct electric solutions are significantly more expensive than the reference specification with 2b being around £850 higher per year.

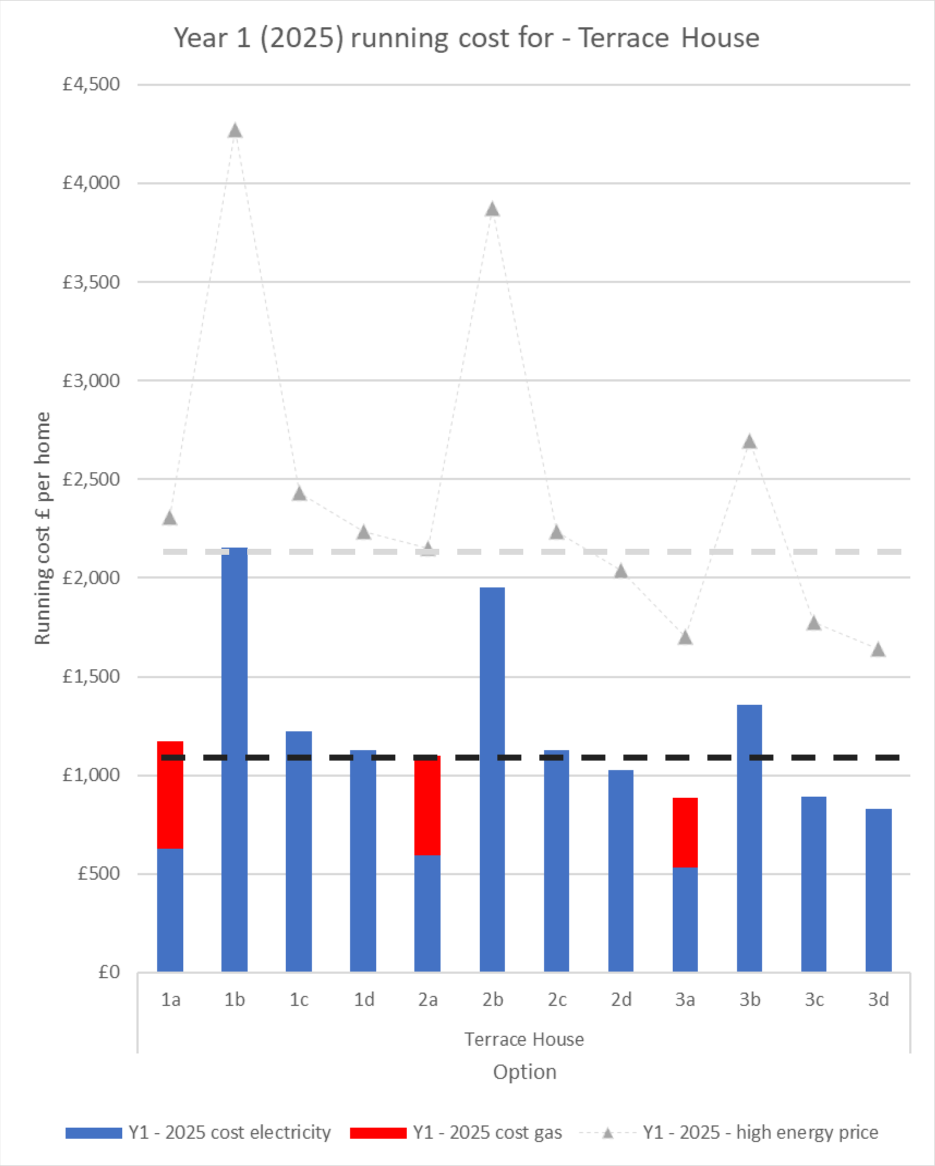


Figure 9.4 – Estimated year 1 energy costs for each case

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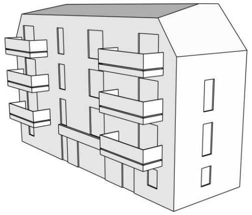
Low-rise apartment building | Energy costs



- Compared to the reference scenario only 2d, 3a and d are lower cost.
- Direct electric significantly more expensive even with ultrahigh efficiency levels
- 1d and 3c are broadly similar cost to reference scenario

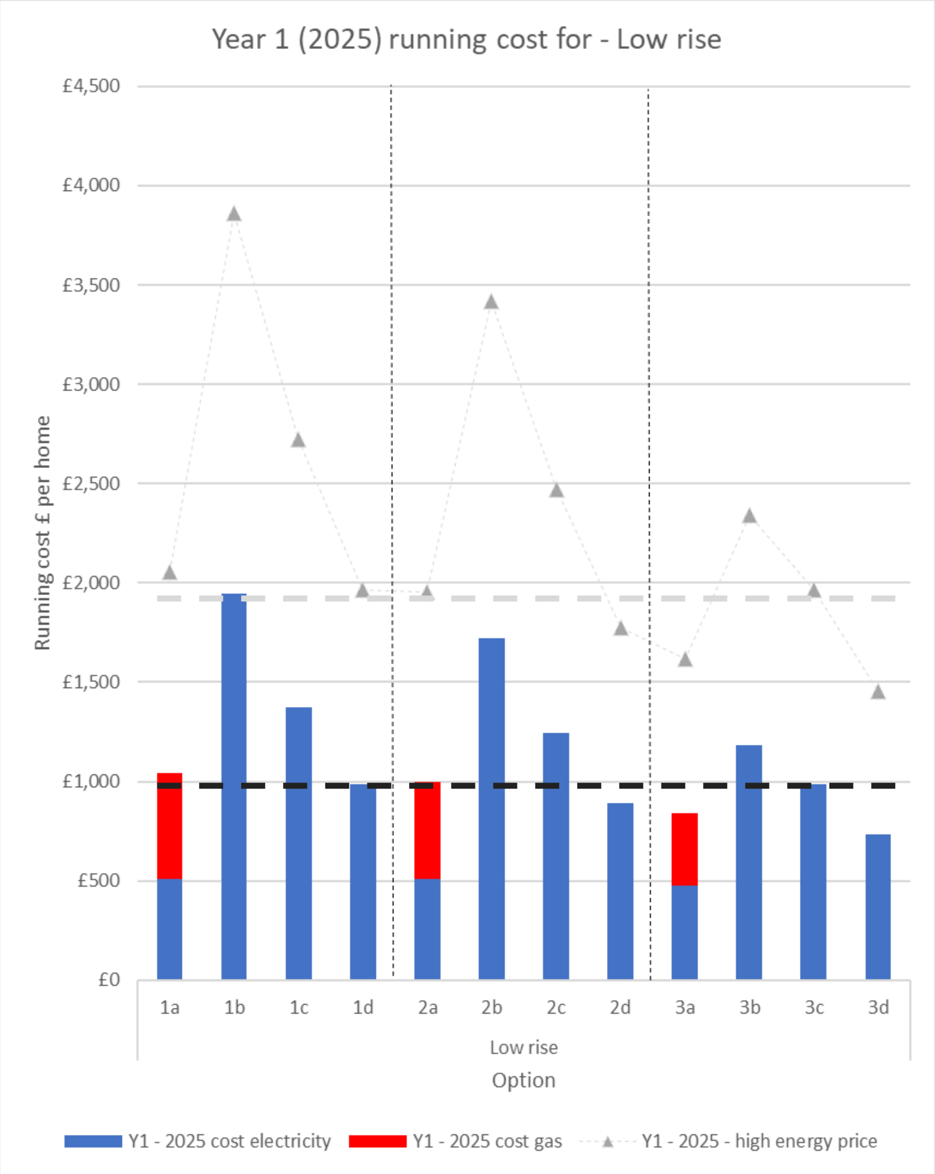


Figure 9.5 – Estimated year 1 energy costs for each case

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Mid-rise apartment building | Energy costs

- Compared to the reference scenario only 3a and d are lower cost.
- Direct electric significantly more expensive even with ultrahigh efficiency levels
- 1d, 2d and 3c are broadly similar cost to reference scenario

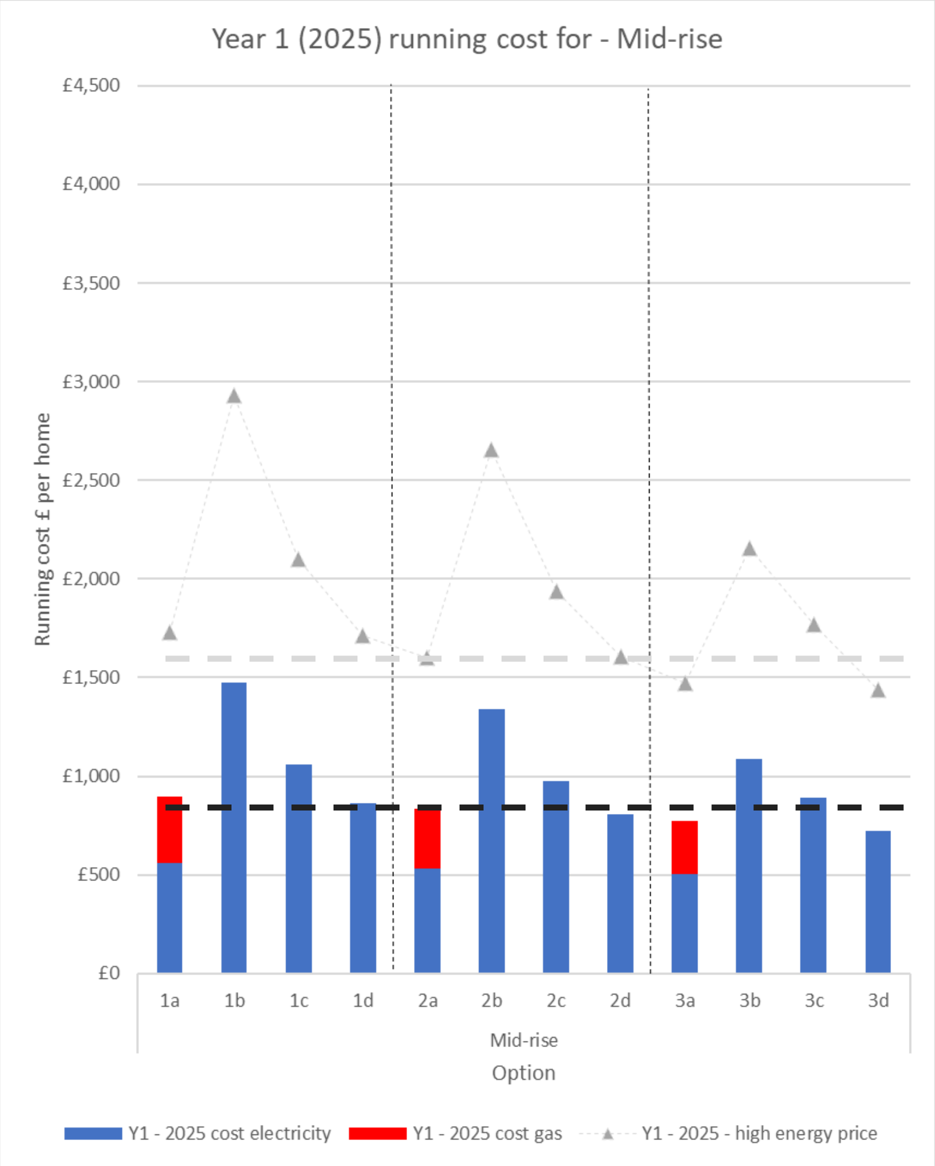

Figure 9.6 – Estimated year 1 energy costs for each case

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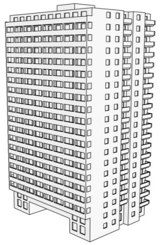
High-rise apartment building | Energy costs



- Compared to the reference scenario only 2d, 3a and d are lower cost.
- Direct electric significantly more expensive even with ultrahigh efficiency levels
- 1d, 2d and 3c are broadly similar cost to reference scenario

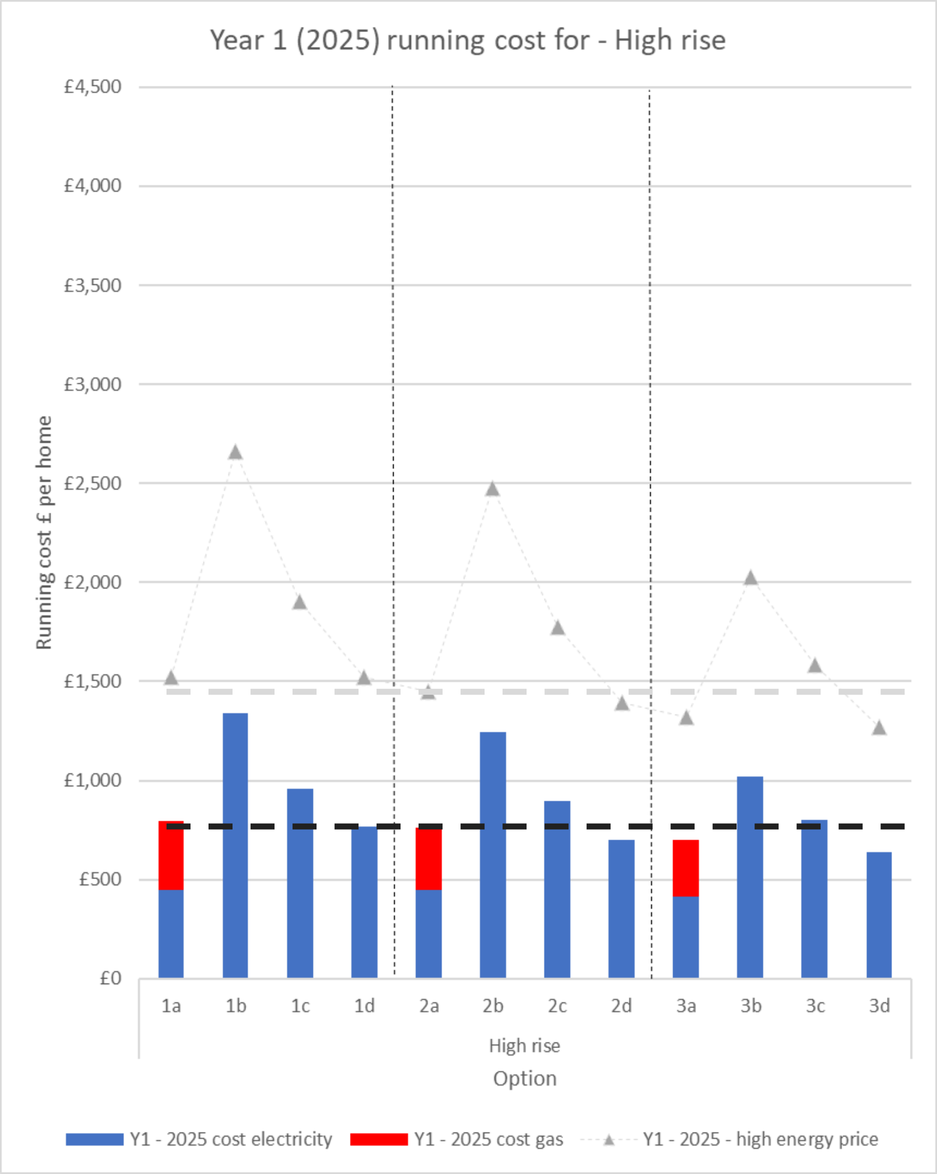


Figure 9.7 – Estimated year 1 energy costs for each case

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Impact on other household costs

No material variation in non-energy household costs are anticipated from the options considered in this study

- Most of the cost variation associated with the different options is linked to either passive measures (eg insulation, window specification, etc) or to the heating system, which lead to lower energy costs.
- Replacement of a heat pump is likely to be slightly more expensive than replacing a gas boiler. However, it is high likely that the first replacement of a gas boiler installed after 2023 (i.e. in 2038 or beyond) will be with a heat pump. In this scenario replacement of a gas boiler with a heat pump will be more expensive thana like for like heat pump replacement.
- Maintenance of heat pumps is unlikely to materially more expensive than gas boilers in the medium term. Heat pumps do not pose the same gas safety risks as boilers and so maintenance checks are likely to be lighter touch in many instances. The ground source heat pump options are likely to have lower maintenance costs than a boiler equivalent given to the sealed nature of these systems.
- Those options with direct electric heating will have lower maintenance and replacement costs than gas based systems.

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10.0

Offsetting

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The issues with carbon offsetting identified in 2019 remain

Policy option 1 still gives a significant role to offsetting

As it has been described previously in the report, a 35% on-site improvement over Part L 2021 may be relatively easy to comply with for some buildings. In those cases, if it is cheaper to offset than to seek further carbon reductions on site, applicants will generally find it tempting to limit their commitments in terms of on-site performance to the 35% minimum, and offset the residual regulated emissions (representing the majority of them). This is an issue as carbon emissions during the lifetime of this building and its equipment will be higher than they should be, and there may be other implications too (e.g. energy bills for residents higher than what they could have been).

Unregulated emissions are not even offset

Apart from the London borough of Islington, current planning policy still focuses on regulated carbon emissions only and requires only the residual regulated emissions to be offset. This means that unregulated emissions are not offset.

The challenge of delivering carbon savings elsewhere for boroughs

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, and it is virtually impossible to save 1 tonne of carbon at the current GLA carbon price (£60-95). And if carbon is not saved at the rate assumed by the carbon offset payment, can we really refer to the new buildings which used this mechanism as 'Zero Carbon'?

This goes against the recommendations of the Climate Change Committee

The Climate Change Committee is clear that carbon offsetting should be reserved to the hard-to-treat sectors, and not new buildings.

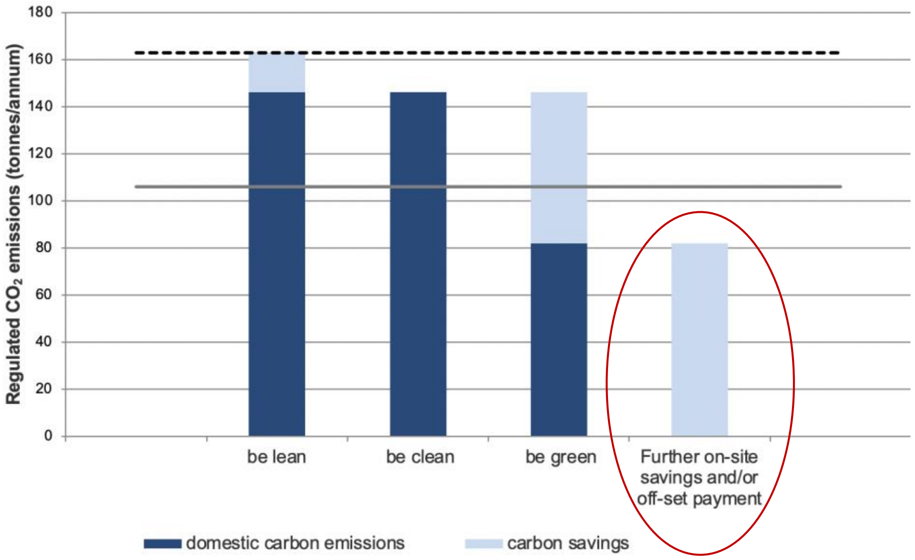

Figure 10.1 - Regulated carbon emissions for a policy compliant energy strategy for the high rise typology

It illustrates that carbon offset payments play too large a role in current 'net zero' planning policy. In the above chart supposedly 50% of the reduction in regulated carbon emissions associated with the development will come from the offset payment. This ability to offset, and the relatively low cost of doing so, does not incentivise sufficient carbon reductions on site, and it ignores unregulated emissions.

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Offsetting and Policy option 1 | How carbon offsetting would work

Addressing the current issues with carbon offsetting

The status quo with the current carbon offsetting system is not an option. If Policy option 1 is selected, it should seek to address the issues summarised on the previous page:

1. Reducing carbon emissions on site should be the priority, minimising the role of offsetting. A set of ambitious (but deliverable) on-site % regulated carbon reduction targets over Part L 2021 should be set for each typology.
2. Carbon offsetting should not only cover regulated emissions: unregulated emissions should be covered too.
3. Carbon offsetting should not be the cheapest option: its price should be at least as high as the cost of installing PVs on the building. That would encourage applicants to do this instead of doing less and pay into the offset fund.
4. The carbon offset price should be set at a level which enables each London borough to save carbon elsewhere on a 1:1 basis, administer the carbon offset fund, and ensure that all other good practice principles on carbon offsetting are complied with (e.g. additionality).

High level comparison between flat rate vs tiered rates

The Towards Net Zero Carbon study in 2019 recommended a tiered approach with a high carbon price (i.e. £1,000 tCO_2) when applicants would fail to achieve the levels of on-site performance recommended. This approach may still be used but as the carbon offset price is increasing anyway, it may not be necessary or would have to be increased too. It also recommended, for domestic buildings only, a cheaper carbon offset price to reward applicants achieving a level of on-site performance much greater than the minimum. This is no longer considered necessary.

In conclusion, a flat rate is now recommended. Its price should ideally be £880/tCO_2 over 30 years (see following page for more details).

1 Set the minimum on-site Part L improvement at the right level to minimise residual (regulated) carbon emissions

Minimum levels for each typology could be considered*. For example:

- 65% better than Part L 2021 for domestic buildings
- 25% better than Part L 2021 for offices
- 35% better than Part L 2021 for schools
- 45% better than Part L 2021 for industrial buildings
- 10% better than Part L 2021 for hotels

2 Include unregulated carbon in the zero carbon definition to encourage reductions

In the absence of a quantified target on unregulated carbon, the carbon offset mechanism could be used to incentivise its reduction.

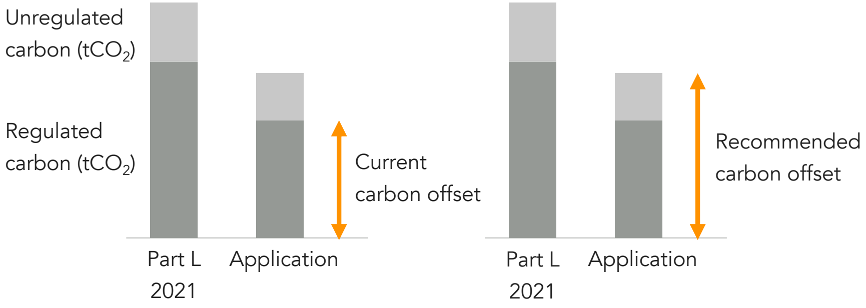

Figure 10.2 – Carbon offsetting should not only cover all regulated CO_2 emissions

3 Set the carbon offset price at a level sufficient to incentivise greater carbon savings on site rather than offsetting

The following page suggests that this level at £330-880/tCO_2 for 30 years to make sure it is less economical than to install additional PVs

4 Set the carbon offset price at a level sufficient to be able to save the same amount of carbon elsewhere

The following page suggests that this level is either at £330-880/tCO_2 for 30 years for PVs or £480/tCO_2 for 30 years for retrofit.

**Councils may also wish to consider an approach that uses a mid-point percentage uplift for all non-residential typologies.*

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Offsetting and Policy option 1 | Recommendations for the carbon offset price

The non-traded cost of carbon

This approach underpins the figure of £95/tCO_2 currently recommended by the GLA. The Zero Carbon Hub used this approach and assumed a 'central scenario' in 2012 and it was also used by the GLA/AECOM when they considered carbon offsetting and allowable solutions. The GLA have opted for the 'high scenario' in 2017.

Our recommendation is to stop using the non-traded cost of carbon and to focus instead of a carbon offset price representing what it would cost to the applicant to save more carbon on-site and/or what it would cost a London Borough to fund an equivalent carbon saving elsewhere.

Funding additional PVs on-site

If the applicant is to be incentivised to save more carbon on-site rather than pay into a carbon offset fund, the cost of additional PVs is a good proxy. Using a reasonable cost rate for a high output PV system with micro-inverters (£1,016/kWp*) and applying a 10% additional rate for administering and managing the PV funding process would give a carbon offset price of £330-880/tCO_2 depending on which carbon factor is used for electricity (respectively 136gCO_2/kWh and 50gCO_2/kWh).

Funding PVs off-site or social housing/public building retrofit

The cost of retrofit is notoriously variable and its 'low carbon component' difficult to isolate. Based on an indicative cost of £20,000/retrofit, and an indicative carbon saving of £2tCO_2/yr, the carbon offsetting cost should be £370/tCO_2/yr, including a 10% additional rate for administration and management.

If the offset contribution is used to fund PV systems in the borough, a carbon offset price of of £330-880/tCO_2 is recommended.

It should be noted that it is up to boroughs to decide what most appropriate offset mechanism is though. They can develop separate SPDs to determine locally appropriate use of offset funds.

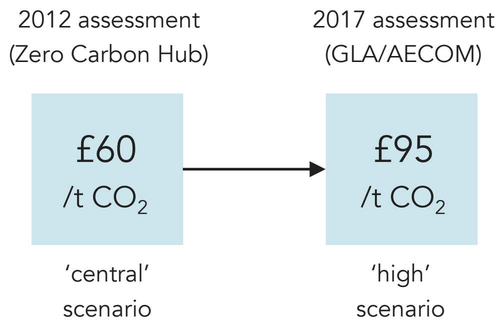

Figure 10.3 - Carbon offset price using the the non-traded cost of carbon approach. The GLA recommended price dates back from 2017 and is considered insufficient to save carbon on a 1:1 basis

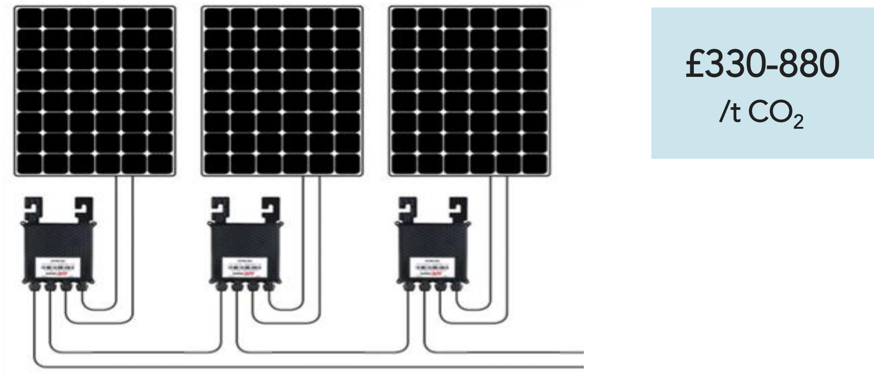

Figure 10.4 - If the carbon offset price is to incentive more PVs on-site, it should be set at more than ***£330/tCO_2*** *assuming the same electricity carbon factor as SAP 10.2 of 136 gCO_2/kWh (Part L 2021).*

However, should a London borough wish to use an electricity carbon factor representative of the average electricity carbon content over the lifetime of the PV system (e.g. 50gCO_2/kWh), this number would increase to ***£880/tCO_2****.*

Both carbon offset prices include a 10% administration and management fee.

** Median cost of 10-50kWp PV installations for 2021/22 from MCS (Source: DESNZ)*

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Offsetting and Policy option 2 | How energy offsetting could work

Moving towards energy offsetting

Policy option 2 is based on energy metrics, most importantly the buildings' predicted energy use (Energy Use Intensity - EUI) but also the balance between annual energy use and annual renewable energy generation on-site.

In order for the role of energy offsetting to be clearly defined, we would recommend the following:

1. Option A - Policy option 2 should seek to minimise the building' predicted energy and maximise PV generation on site.
2. Option A - Once officers are satisfied that the building complies with these policy requirements, energy offsetting could be used to deal with the residual difference between energy use and renewable energy generation.

Case study: *if we take the example of a residential development of 5,000m^2 GIA with an Energy Use Intensity of 27 kWh/m$^2_{\text{GIA}}$/yr and a PV generation of 15 kWh/m$^2_{\text{GIA}}$/yr. There is a shortfall between annual energy use and renewable energy generation of 12 kWh/m$^2_{\text{GIA}}$/yr, which equates to 60,000 kWh/yr. The applicant should pay into the Council's offset fund a sum of £79,200 (i.e £1.32/kWh x 60,000 kWh) to enable the Council to install a renewable energy system elsewhere which would generate 60,000 kWh/yr.*

Another option is possible (Option B) in case the London borough decides to set a specific renewable energy generation target. In this case, the energy offset will not seek to address the gap between the predicted EUI and renewable energy generation on-site, but the gap between the policy requirement for PV generation (e.g. 100 kWh/m$^2_{\text{footprint}}$) and renewable energy generation on-site. The targets provided on this page are only indicative. If a London borough wishes to proceed with Option B, it is recommended to undertake a technical evidence base to establish which targets would be technically feasible based on a variety of typologies and buildings.

1

Option A

Set the EUI requirement at the right level to minimise energy use and require PVs to match the EUI

These levels could be specific to each typology, e.g:

- 35 kWh/m$^2_{\text{GIA}}$ for domestic
- 70 kWh/m$^2_{\text{GIA}}$ for offices
- 70 kWh/m$^2_{\text{GIA}}$ for schools
- 35 kWh/m$^2_{\text{GIA}}$ for industrial buildings
- 160 kWh/m$^2_{\text{GIA}}$ for hotels

Option B

Set a renewable energy generation requirement at the right level to maximise renewable energy generation

These levels could be specific to each typology, e.g:

- 100 kWh/m$^2_{\text{fp}}$ for domestic
- 50 kWh/m$^2_{\text{fp}}$ for offices
- 80 kWh/m$^2_{\text{fp}}$ for schools
- 150 kWh/m$^2_{\text{fp}}$ for industrial buildings
- 50 kWh/m$^2_{\text{fp}}$ for hotels

2

Work out the difference between the energy used by the development and how much renewable energy it will generate

Any shortfall of renewable energy generation will lead to an energy offset payment

Work out the difference between the target and the actual renewable energy generation

Any shortfall of renewable energy generation will lead to an energy offset payment

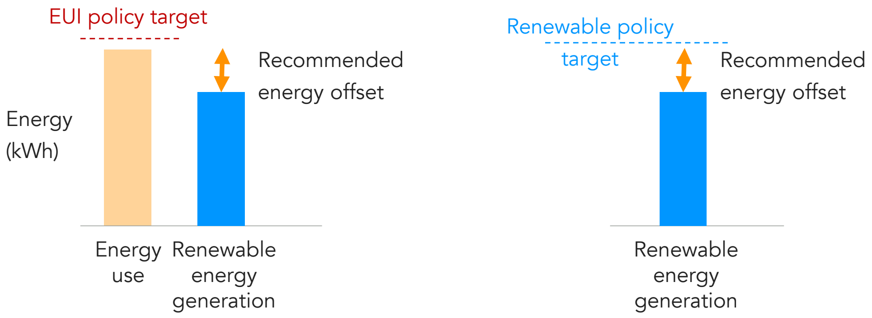

Figure 10.5 – Two alternative options for the energy offset

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Offsetting and Policy option 2 | Recommendations for the energy offset price

A fair energy offset price for applicants

As the source of the energy offset is the gap between energy use and renewable energy generation (or the gap between the required and actual renewable energy generation on site), its price should be set on the basis of the cost of PVs.

Using a reasonable cost rate for a high output PV system with micro-inverters (i.e. £1,016/kWp*) and applying a 10% additional rate for administering and managing the PV funding process, would give an energy offset price of £1.32/kWh/yr**.

Funding PVs, retrofit and other climate mitigation projects

It is up to boroughs to decide what most appropriate offset mechanism is. They can develop separate SPDs to determine locally appropriate use of offset funds.

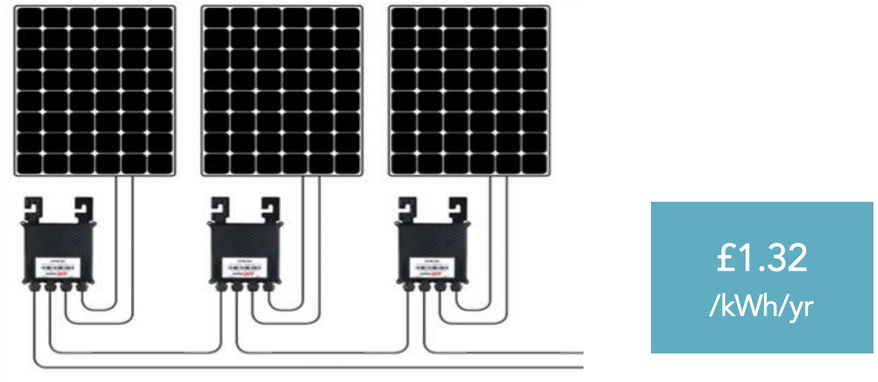

Figure 10.6 - If the energy offset price is to incentive more PVs on-site, it should be set at **more than £1.32/kWh**.

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* *Median cost of 10-50kWp PV installations for 2021/22 from MCS (Source: DESNZ)*

*** This is assuming a conservative electricity generation rate for the PV system of 850 kWh/kWp.*

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Assessing the impact of offsetting on costs

Although the main objective of policy options 1 and 2 is to maximise performance on-site, offsetting may still be required. The move away from fossil fuels and the decarbonisation of the grid are generally reducing offset costs for developers, but any future increase in scope for offsetting or carbon offset price may counter-balance this effect. Assessing its impact on capital costs depends on a number of parameters:

1. **Which policy option will be used?**

   With policy option 1, carbon emissions assessed with Part L energy modelling will need to be offset. With policy option 2 it is the shortfall of renewable energy generation which needs to be 'offset'.

2. **Which targets will be used?**

   The report provides some indicative targets for each policy option but London boroughs may decide to use different ones.

3. **What will be offset?**

   For policy option 1, London boroughs should decide whether to follow this report's recommendation and offset unregulated emissions as well, or just regulated emissions.

   For policy option 2, London boroughs should decide whether to offset the shortfall between the EUI and the on-site renewable energy generation (option A) or to offset the shortfall between the target and the actual renewable energy generation on-site (option B). They may also decide not to use offsetting.

4. **Which price will be used?**

   Finally, London boroughs should confirm which carbon offset price they will want to use.

Figure 10.7 - The above process is recommended to estimate the additional cost of offsetting.

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11.0

Policy recommendations:

indicative targets, policy wording and key considerations for implementation

11.0 Policy recommendations: indicative targets, policy wording and key considerations for implementation

This section provides recommendations on how indicative policies could be written and which targets they could refer to. It also highlights considerations for implementation.

Although the consultant team recommends Policy option 2, these are provided for both policy options.

It is very important to note that this study is an evidence base, not a policy document. Its purpose is to inform and support Local Authorities in developing future planning policy targets that will deliver Net Zero Carbon development, through providing robust and up-to-date evidence regarding carbon emission reductions and energy efficiency in buildings.

Although indicative minimum targets and policy wording are provided, Local Authorities may decide to set higher targets appropriate to their borough.

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11.1

Policy option 1 recommendations: indicative targets and policy wording

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Policy option 1 I Summary of indicative targets and wording

Carrying on with the current framework

Some London boroughs may want to carry on using the Part L framework to go beyond the requirements of Part L 2021 and drive the design and construction of better buildings in their boroughs. This system has the advantage of being broadly consistent with the current approach in the GLA energy assessment guidance (2022) but it also has a number of weaknesses evidenced in this report (e.g. the single metric approach does not incentivise energy efficiency or renewable energy generation significantly, Part L energy modelling is not a prediction of energy use, etc.).

Different targets for domestic and non-domestic

Part L 2021 works very differently between domestic and non-domestic buildings, driven mainly by the different Part L energy modelling calculation methodologies: SAP for domestic buildings and NCM/SBEM for non-domestic buildings. Based on this analysis we would recommend requiring different levels of on-site carbon performance for domestic and non-domestic buildings.

Policy targets for non-domestic buildings

National and regional planning policy has previously set one emissions reduction target for all non-domestic buildings, due to a lack of evidence available to justify setting specific targets for different building types. This study sets out detailed evidence for a range of non-domestic buildings and, based on this new evidence, recommends distinct policy targets for each building type thereby maximising potential carbon savings.

Councils may also wish to consider an approach that uses a mid-point percentage uplift for all non-residential typologies

No more 'be lean' requirement

The 'be lean' requirement is challenging to achieve for non-domestic buildings and and, for domestic buildings, has little added value compared with the FEE requirement in Part L 2021.

Indicative policy wording for Policy option 1

Overarching policy

All developments must achieve Net Zero Carbon according to the Building Regulations framework, i.e. a 100% improvement over Part L 2021 and offset their residual emissions.

On-site carbon reduction

All developments must reduce carbon emissions on-site as much as possible.

In terms of regulated emissions, the minimum level of on-site performance required is:

- *Domestic buildings: 65% better than Part L 2021*
- *Office buildings: 25% better than Part L 2021*
- *School buildings: 35% better than Part L 2021*
- *Industrial buildings: 45% better than Part L 2021*
- *Hotel: 10% better than Part L 2021*
- *Other non-domestic buildings: 35% better than Part L 2021 (tbc)*

Buildings must also comply with the other requirements of the Building Regulations Part L 2021, e.g. Fabric Energy Efficiency criterion for domestic buildings and Primary Energy criterion for all buildings and demonstrate compliance at planning stage.

Applicants must undertake Part L 2021 modelling to demonstrate compliance.

Unregulated emissions must also be reduced as much as possible.

Carbon offsetting

On-site carbon reductions should be maximised as far as possible before any remaining emissions are offset. If the Council is satisfied that the development has maximised on-site reductions but the development is still short of achieving Net Zero Carbon, the developer is expected to make a cash-in-lieu contribution to the Council's carbon offsetting fund at a price of £880/tCO$_2$ per year over a period of 30 years.

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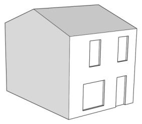
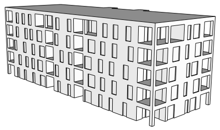
Policy option 1 I Domestic buildings I Summary of which cases would comply

What would be the effect of Policy option 1 with these targets?

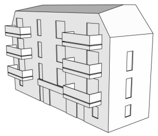
This diagram indicates which domestic building cases scenarios would be able to comply with the indicative wording proposed for Policy option 1 with an on-site minimum compliance threshold of **65% better than Part L 2021.**



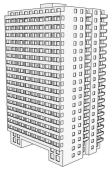
Terrace house



Mid-rise apartment building



Mid-rise apartment building



High-rise apartment building

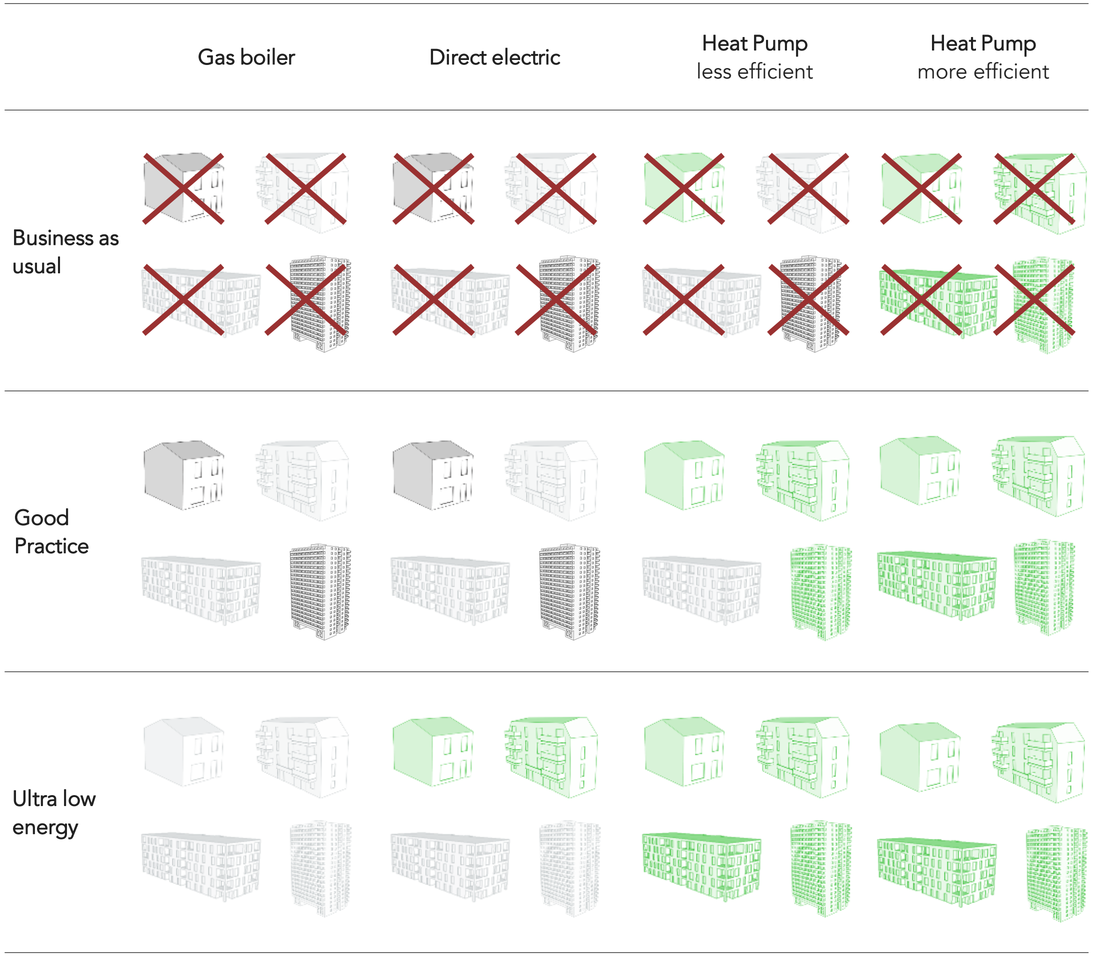


Figure 11.1 - Diagram indicating which domestic building cases would be able to comply with the indicative wording proposed for Policy option 1

⬜ Non-compliant

🟩 *Case compliant with proposed Policy option 1*

✗ Would not pass all 3 building regulations Part L 2021 metrics

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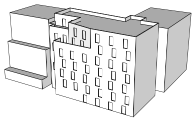
Policy option 1 I Non-domestic buildings I Summary of which cases would comply

What would be the effect of Policy option 1 with these targets?

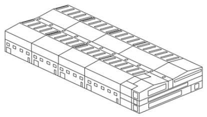
The adjacent diagram shows which non-domestic building cases would comply with Policy option 1 if the on-site compliance threshold was set at:

- Office buildings: 25% better than Part L 2021
- School buildings: 35% better than Part L 2021
- Industrial buildings: 45% better than Part L 2021
- Hotel: 10% better than Part L 2021

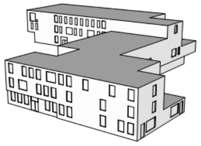
Councils may also wish to consider an approach that uses a mid-point percentage uplift for all non-residential typologies.



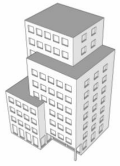
Office



Industrial



School



Hotel

Figure 11.2 - Diagram indicating which non-domestic building cases would be able to comply with the indicative wording proposed for Policy option 1

▨ Non-compliant

🟩 *Case compliant with proposed Policy option 1*

✗ Would not pass both building regulations Part L 2021 metrics

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11.2

Policy option 2 recommendations: indicative targets and policy wording

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Policy option 2 | Summary of indicative targets and policy wording

Using a different policy framework

This section details indicative policy recommendations for London boroughs interested in considering Policy option 2.

A suite of policies are proposed that address a range of considerations.

The following aspects have been considered in detail in this report.

- Space heating demand policy
- Energy Use Intensity (EUI) policy
- Offsetting (as last resort) policy

The following policies have not been considered in detail, but an example of wording is provided.

- Low carbon heat policy
- On-site renewable energy generation policy
- Assured energy performance policy

Finally, embodied carbon policies are strongly recommended but were outside the scope of this study.

Indicative policy wording for Policy Option 2

Overarching policy

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

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

- *Space heating demand policy*
- *Low carbon heat policy*
- *Energy Use Intensity (EUI) policy*
- *On-site renewable energy generation policy*
- *Assured energy performance policy*
- *Offsetting (as last resort) policy*
- *Embodied carbon policies (see separate document)*

Buildings must also comply with the other requirements of the Building Regulations Part L 2021, e.g. Fabric Energy Efficiency criterion for domestic buildings and Primary Energy criterion for all buildings and demonstrate compliance at planning stage.

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Policy option 2 | Summary of indicative targets and policy wording | Space heating demand (SHD)

Space heating demand policy

The space heating demand is the amount of heat energy needed to heat a building over a year and is expressed in kWh/m²/yr. It is a measure of the thermal efficiency of the building elements.

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

The Climate Change Committee recommends a space heating demand of less than 15-20 kWh/m²/yr for new homes. This recommendation is also in line with the recommendations of the Royal Institute of British Architects (RIBA), the Low Energy Transformation Initiative (LETI) and the UK Green Building Council.

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

Indicative policy wording for Policy Option 2

Space heating demand policy

- *All dwellings should achieve a space heating demand of less than 15 kWh/m^2_{GIA}/yr.*
- *All non-domestic buildings should achieve a space heating demand of less than 15 kWh/m^2_{GIA}/yr.*

Applicants must undertake predictive energy modelling to demonstrate compliance.

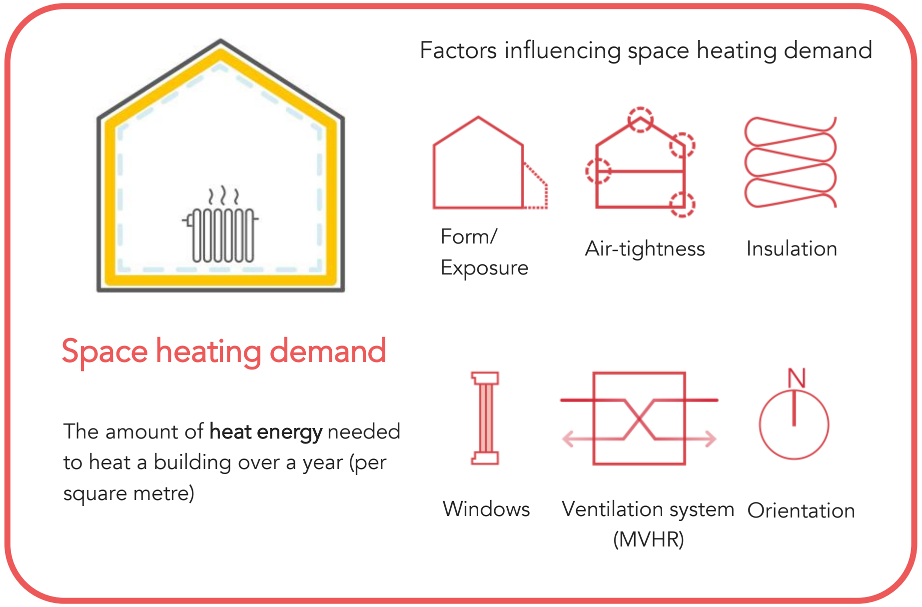
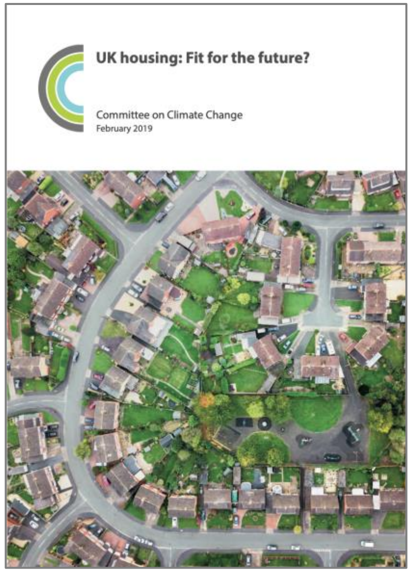


Figure 11.3 – The space heating demand metric



UK housing: Fit for the future?

Committee on Climate Change
February 2019

Figure 11.4 – UK housing: Fit for the future? (CCC, 2019)

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

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

For reference, Passivhaus requires 15 kWh/m²/yr, and most new domestic buildings have a heating demand of 40-120 kWh/m²/yr.

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Policy option 2 | Summary of indicative targets and policy wording | Energy Use Intensity (EUI)

Energy Use Intensity (EUI) policy

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

Energy Use Intensity (EUI) is the total energy needed to run a home over a year (per square metre). It is a measure of the total energy consumption of the building (kWh/m^2/yr). The EUI of a building covers all energy uses: space heating, domestic hot water, ventilation, lighting, cooking and appliances.

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

Indicative policy wording for Policy Option 2

Energy Use Intensity (EUI) policy

Domestic buildings *- All dwellings should achieve an Energy Use Intensity (EUI) of no more than 35 kWh/m^2GIA/yr.*

Non-domestic buildings *- Non-domestic buildings should achieve an Energy Use Intensity (EUI) of no more than the following (where technically feasible) by building type or nearest equivalent:*

- *Student/keyworker accommodation, care homes – 35 kWh/m^2_{GIA}/yr*
- *Warehouses and light industrial units – 35 kWh/m^2_{GIA}/yr*
- *Schools – 65 kWh/m^2_{GIA}/yr*
- *Offices, Retail, HE Teaching facilities, GP surgeries – 70 kWh/m^2_{GIA}/yr*
- *Hotels – 160 kWh/m^2_{GIA}/yr*

Applicants must undertake predictive energy modelling to demonstrate compliance.

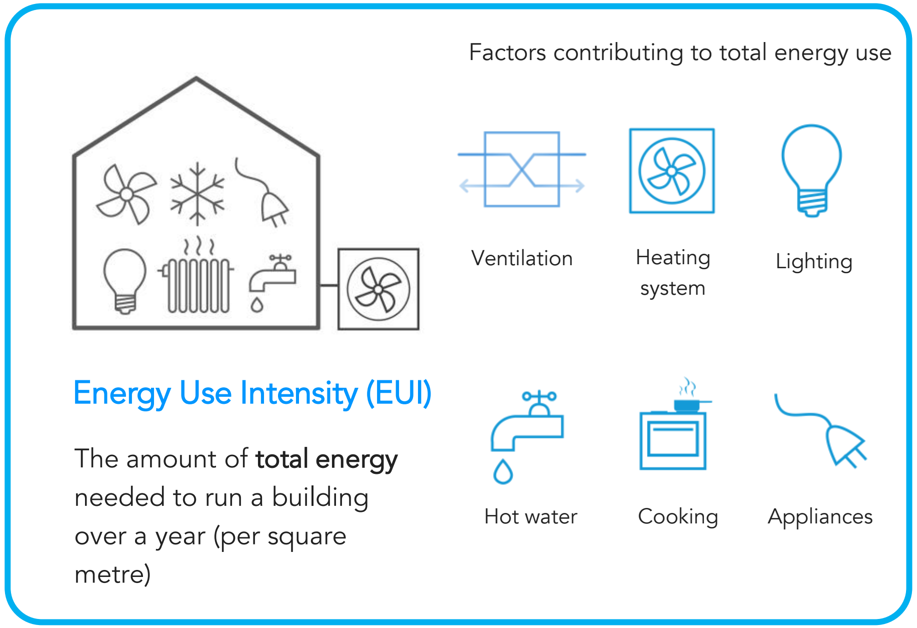

Figure 11.5 – The Energy Use Intensity (EUI) metric

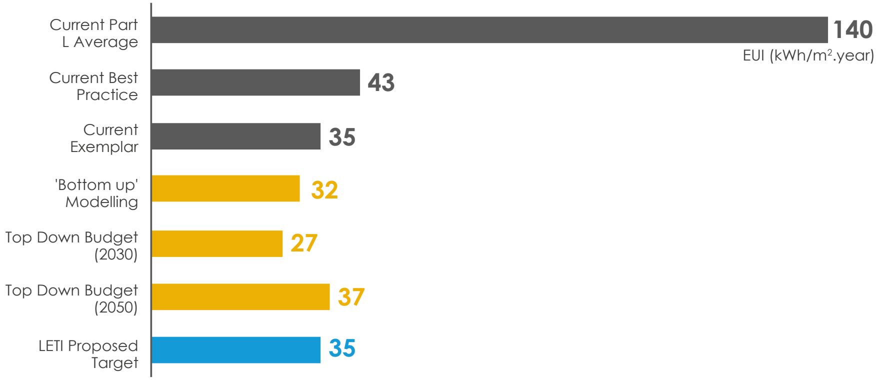

Figure 11.6 - LETI domestic top-down analysis taken from LETI Climate Emergency Design Guide

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

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Policy option 2 | Summary of indicative targets and policy wording | Energy offsetting (as last resort)

Offsetting (as last resort) policy

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

Our recommendation is to limit the role and scope of the offset mechanism to a 'renewable energy offset' with the offset price could be expressed in £/kWh instead of £/tCO$_2$*. This would make it independent from carbon factor changes.*

Indicative policy wording for Policy Option 2

Offsetting (as last resort) policy

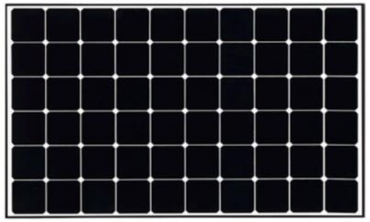
Offsetting will only be accepted as a means to achieving planning policy compliance a last resort if the building is compliant with all other Net Zero carbon buildings policies and in particular if the following conditions have been met:

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

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

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

Figure 11.7 - List of requirements an application would have to meet before being allowed to use offsetting as a planning compliance mechanism. It is proposed to restrict the offset mechanism to fund 'missing' PVs



£1.32 /kWh

Potential offset price (based on the energy balance shortfall)

Figure 11.8 - Based on the current average price and performance of a PV system, and with the addition of a 10% project management fee, an offset price of ***£1.32/kWh*** *is recommended.*

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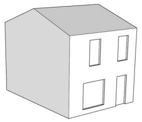
Policy option 2 I Domestic buildings I Summary of which cases would comply

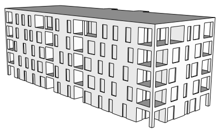
What would be the effect of Policy option 2 with these targets?

The adjacent diagram shows which domestic building cases would comply with Policy option 2 if the compliance thresholds were set at:

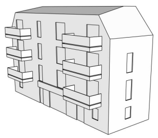
- Space heating demand < 15 kWh/m^2_{GIA}.yr
- EUI < 35 kWh/m^2_{GIA}.yr



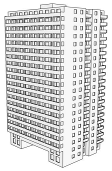
Terrace house



Mid-rise apartment building



Mid-rise apartment building



High-rise apartment building

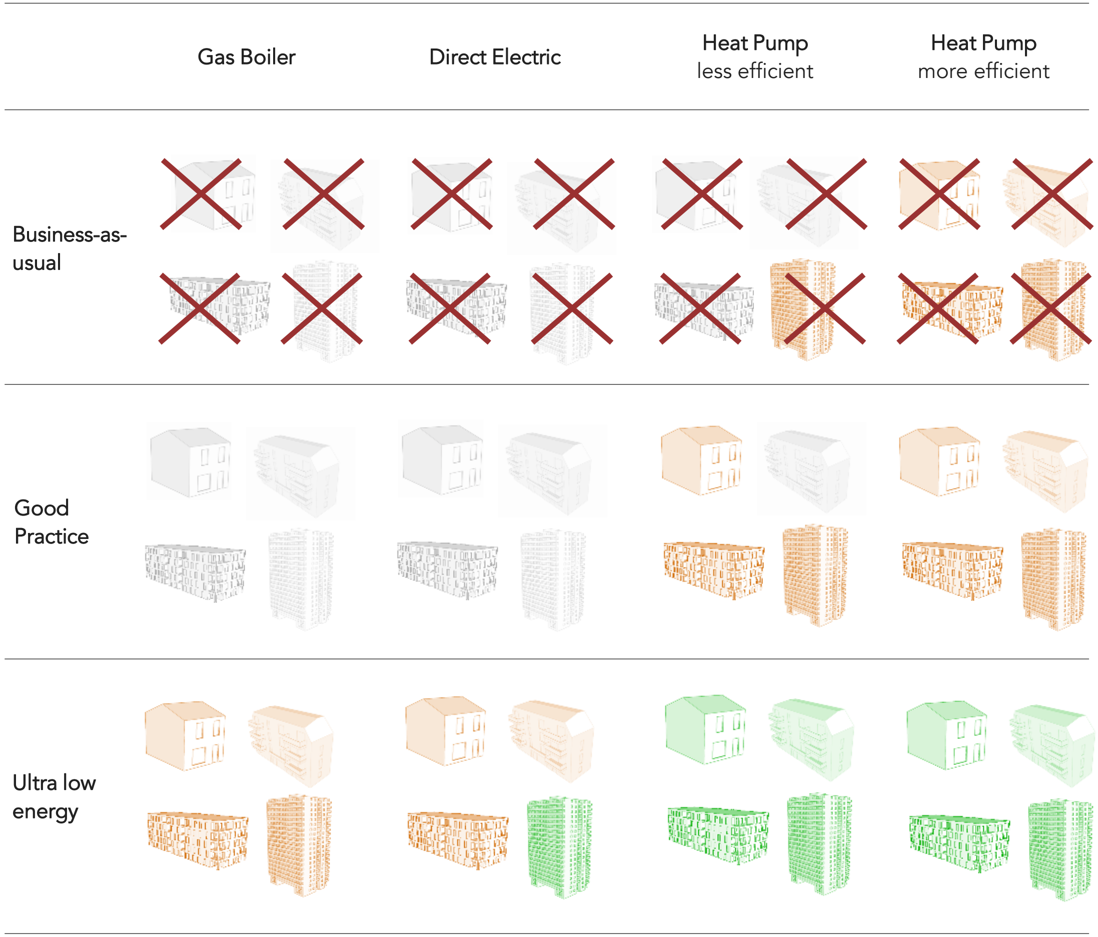


Figure 11.9 - Diagram illustrating which cases in which each domestic typology is able to comply with Policy Option 2 metrics

- ⬜ Non-compliant with either space heating demand or EUI
- 🟧 Meets space heating demand or EUI requirements
- ✗ Would not pass all 3 building regulations Part L 2021 metrics
- 🟩 Meets both space heating demand and EUI requirements

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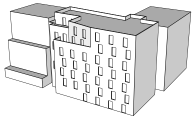
Policy option 2 | Non-domestic buildings | Summary of indicative targets and policy wording

What would be the effect of Policy option 2 with these targets?

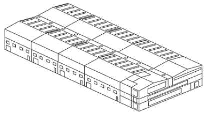
The adjacent diagram shows which non-domestic building cases would comply with Policy option 2 if the compliance thresholds were set at:

- Space heating demand < 15 $kWh/m^2_{GIA}.yr$

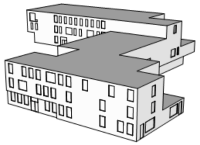
- Industrial buildings: EUI < 35 $kWh/m^2_{GIA}.yr$
- Schools: EUI < 65 $kWh/m^2_{GIA}.yr$
- Office buildings: EUI < 70 $kWh/m^2_{GIA}.yr$
- Hotels: EUI < 160 $kWh/m^2_{GIA}.yr$



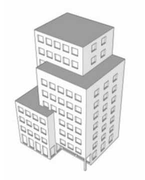
Office



Industrial



School



Hotel

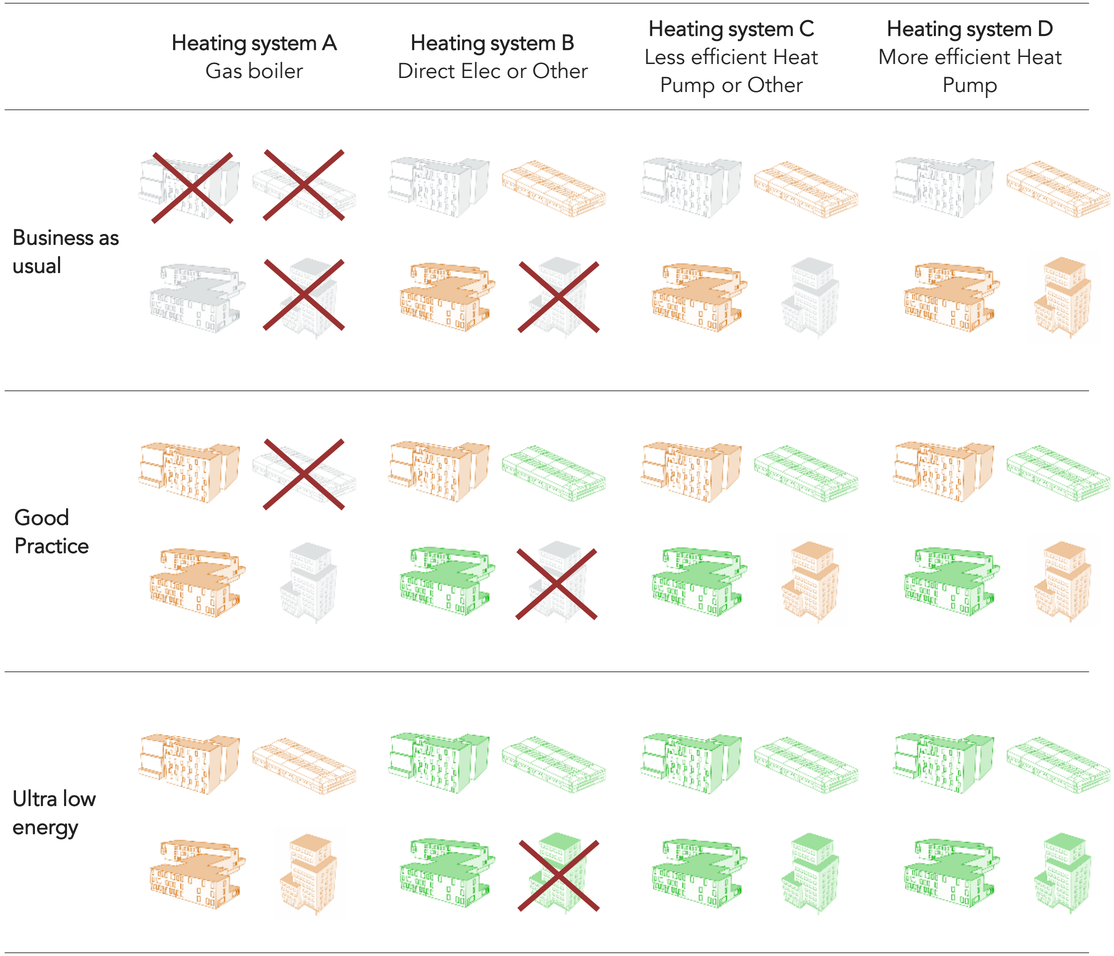


Figure 11.10 – Diagram illustrating which cases in which each non-domestic typology is able to comply with Policy Option 2 metrics

⬜	Non-compliant	🟧	Compliant with Space heating demand or EUI requirements
✗	Would not pass both building regulations Part L 2021 metrics	🟩	Compliant with Space heating demand and EUI requirements

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Policy option 2 | Summary of indicative targets and policy wording | Low carbon heat

Low carbon heat policy

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

Low carbon alternatives that are currently available may primarily focus on electric provision of heat, or on nearby waste heat sources. Sustainable green hydrogen is not currently a viable option.

Electricity can be provided through on-site renewables and through grid electricity which is being decarbonised. However, it is important that developments strongly limit energy use to reduce the burden on the national grid in the wider context of electricification of transport and buildings. The use of electricity for heating would also benefit air quality as there would be no local emissions.

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

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

Indicative policy wording for Policy Option 2

Low carbon heat policy

- *No new developments shall be connected to the gas grid.*
- *Heat shall be provided through low carbon fuels*

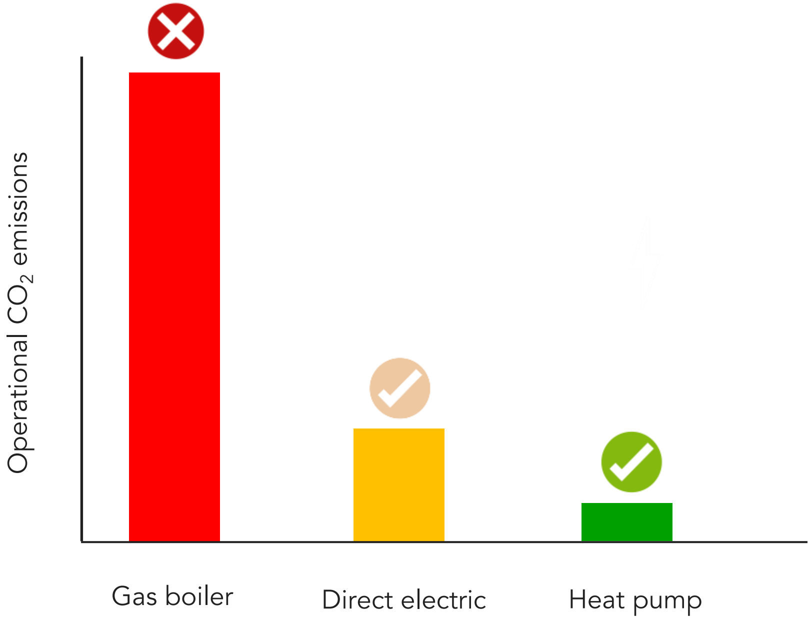

Figure 11.11 - The choice of heating system will affect operational CO_2 emissions over a long time. Electric forms of heating (direct electric and heat pumps) will emit a fraction of a gas boiler carbon emissions (see above the average over 2022-2050)

Important note: Other heat sources may include waste heat from infrastructure (such as sewage, energy from waste, underground or data centres), which could help provide heat to a wider network. Heat networks are another way of providing heat to developments.

This study does not include recommendations regarding heat networks, however the study demonstrates that policy recommendations could also be applied to heat network scenarios. Boroughs should undertake further local evidence studies to progress their heat network strategies.

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On-site renewable energy generation policy

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

The most robust way to deliver the overall objective of a balance between total energy use and renewable energy generation for new buildings at a system level is to seek to achieve this balance at the site level.

This would also have the advantage of generating 'free' electricity close to its point of use, helping to deliver significant energy cost savings for residents and building users.

This is expected to be mainly from solar PVs in London.

Indicative policy wording for Policy Option 2

Renewable energy generation policy

Renewable energy should be generated on-site for all new developments.

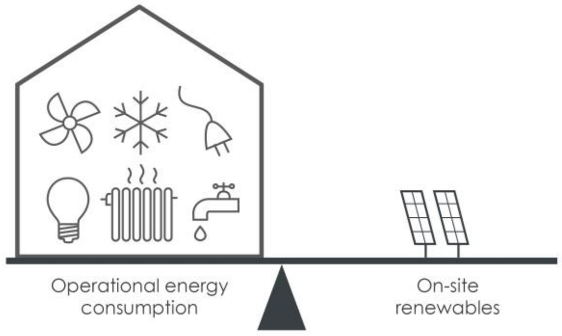
As a minimum, the amount of energy generated in a year must be:

- *at least 80 kWh/$m^2_{building\ footprint}$ per annum* for all building types*
- *at least 120 kWh/$m^2_{building\ footprint}$ per annum* for industrial buildings*

(measured in per square meter of building footprint)

The amount of energy generated in a year should match or exceed the predicted annual energy demand of the building, i.e. Renewable energy generation (kWh/m^2/yr) = or > EUI (kWh/m^2/yr).

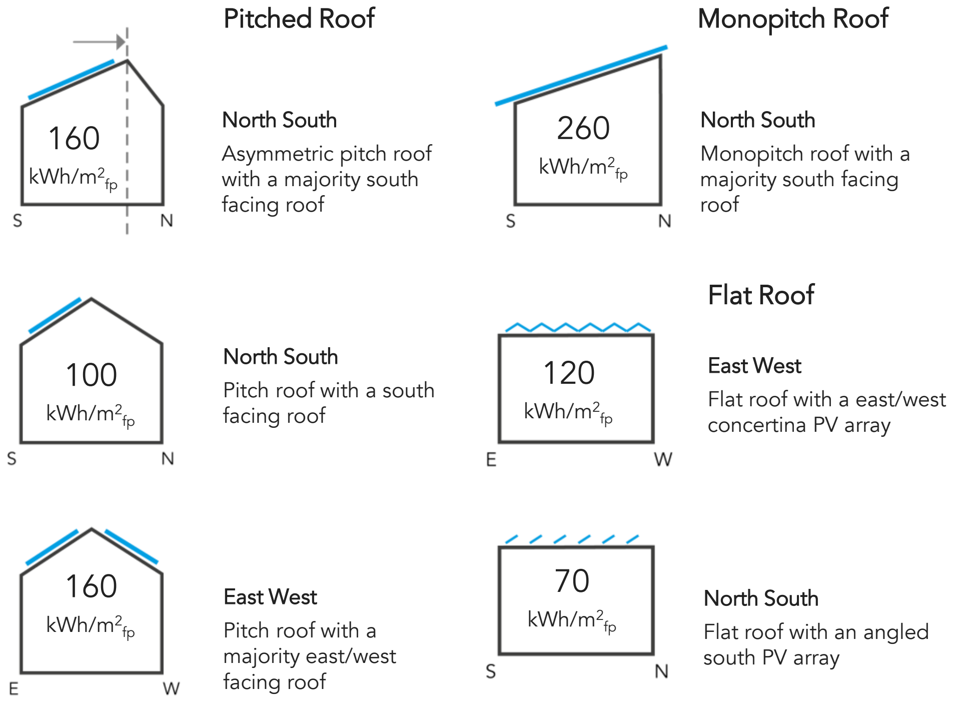
When this is not technically possible and suitably justified, the applicant should pay into the Council's offset fund a sum of money equivalent to this shortfall.



Energy balance

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

Figure 11.12 - A key component of a net zero carbon building is achieving an energy balance – the amount of renewable energy generated in a year matches the energy used by the building in a year.



Pitched Roof

North South
Asymmetric pitch roof with a majority south facing roof

North South
Pitch roof with a south facing roof

East West
Pitch roof with a majority east/west facing roof

Monopitch Roof

North South
Monopitch roof with a majority south facing roof

Flat Roof

East West
Flat roof with a east/west concertina PV array

North South
Flat roof with an angled south PV array

Figure 11.13 - Roof design can be optimised to maximise energy output from photovoltaics. A useful indicator of this is expressed in kWh generated per m^2 of building footprint (kWh/m^2_{fp})

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Assured energy performance policy

In order for the Net Zero Carbon buildings policy to be effective, it is important that new buildings deliver their intended performance. Unfortunately, the actual energy performance of buildings often fails to meet the design standard. This difference is commonly referred to as 'the Performance Gap'. The Zero Carbon Hub concluded in their Evidence Review Report in 2014 that a compliance process focused on design rather than as built performance is a key contributor to the performance gap.

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

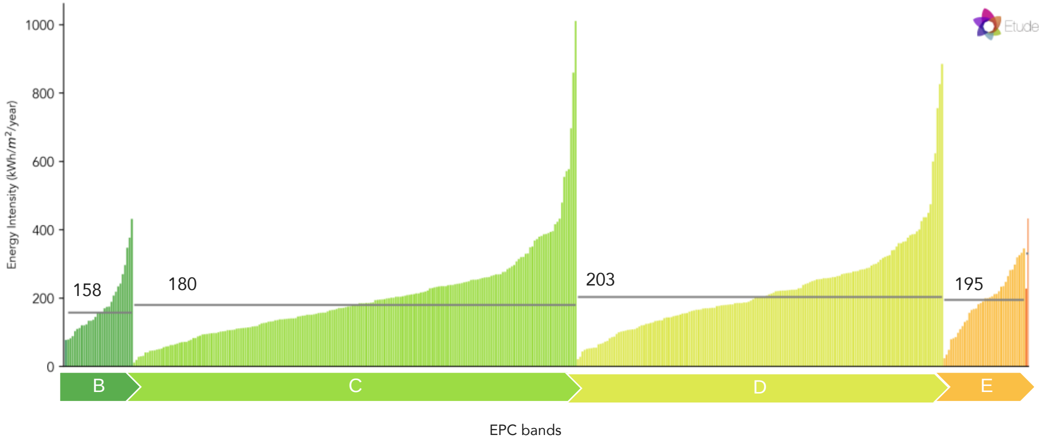

Figure 11.14 - EPC data compared with measured energy consumption of 420 homes. There is little correlation and only marginal improvement on average energy consumption per EPC rating which demonstrates the existence of a performance gap between intended and actual energy performance.

Indicative policy wording for Policy Option 2

Assured energy performance policy

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

Figure 11.15 - Good examples of insulation installed on site, showing methods to eliminate gaps (wedging and overfilling). Left: Goldsmith street © Etude, Right: © Green building store.

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11.3

Key considerations for implementation

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Important recommendations for implementation

Considerations for implementation of policy options 1 and 2

Planning policy targets, including those set out in this study, must always assume a "fixed set of conditions" which can never fully capture the nuances and reality of buildings in use and their particular site conditions and constraints.

It is also widely accepted that there is currently a performance gap between predicted and actual energy performance when designing buildings. Taking a policy option 2 approach based on predictive energy modelling will help to reduce this performance gap. However, quality standards set at planning stage are often not carried forward into the actual built design as specifications may be 'downgraded' at a later stage through the 'value-engineering' process. Poor construction quality is another reason that energy performance may not perform as expected in 'as-built' development*.

** A good way for Local Plans to avoid these problems and support successful policy implementation would be to require proposals to meet an independently certified quality assurance standard (e.g. Passivhaus certification). Local Authorities could also consider supporting minor applications through providing a bespoke, simplified energy statement template for minor schemes to reduce the burden on applicants.*

Policy option 2: benefits

- ✓ Different policies for space heating demand, energy use and renewable energy generation deliver on these three objectives and none of them is diluted or traded off against another.
- ✓ A more rigorous methodology is used to estimate and predict energy performance.
- ✓ All energy uses matter and are taken into account, and designers need to evaluate this energy use.
- ✓ A fixed absolute target incentivises actual performance.
- ✓ Performance in-use can be validated using metered energy data.
- ✓ A more energy efficient building form is incentivised which aids in reducing heating and cooling demand.

Considerations for implementation	**Recommended next steps**
Consistency between applications Predicted energy modelling can be used to reliably estimate energy use and to drive suitable design and construction decisions. For domestic buildings, the PHPP tool has been shown to predict energy use much more accurately than the current version of SAP. For non-domestic buildings, IESVE, TAS and PHPP are three energy modelling packages that can be used to carry out TM54 assessments.	Prepare predictive energy modelling guidelines for all boroughs
Benchmark data As detailed modelling at pre-planning (i.e. before detailed design) may not always be possible, applicants my rely on benchmarks which are generally out of date (e.g. CIBSE benchmark data for catering). Learning from monitoring should also be a priority, with a view updating benchmarks and targets at regular intervals, via a SPD or equivalent.	Gather and share benchmarks over the next few years.
Sample of buildings modelled This study has only looked at one non-domestic building for each typology. A greater sample number of buildings and a wider range of typologies would help inform the development of more robust EUI-targets, especially for non-domestic buildings. *This applies to other building types and policy option 1 as well but to a less extent.*	Wider group of consultants to create 'wider' evidence base
Skills in predictive energy modelling and high performance building Industry awareness has grown significantly in recent years, however predictive energy modelling and analysis and delivery of quality standards such as Passivhaus on site are not yet common practice.	Upskilling is necessary and will be beneficial. Policy requirements will help the industry to upskill

Figure 11.16 – Summary of potential implementation risks as well as their proposed mitigation strategy

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12.0 Appendices

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Energy and cost modelling assumptions for **mid-rise apartment building**

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Energy and cost modelling assumptions for **high-rise apartment building**

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Energy and cost modelling assumptions for **office building**

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Energy and cost modelling assumptions for **primary school**

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Energy and cost modelling assumptions for **hotel**

Heat networks

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Heat networks: further information on distribution losses

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Heat networks: interim systems

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Heat networks: Energy from Waste and carbon emissions

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Net Zero Carbon in operation: definition

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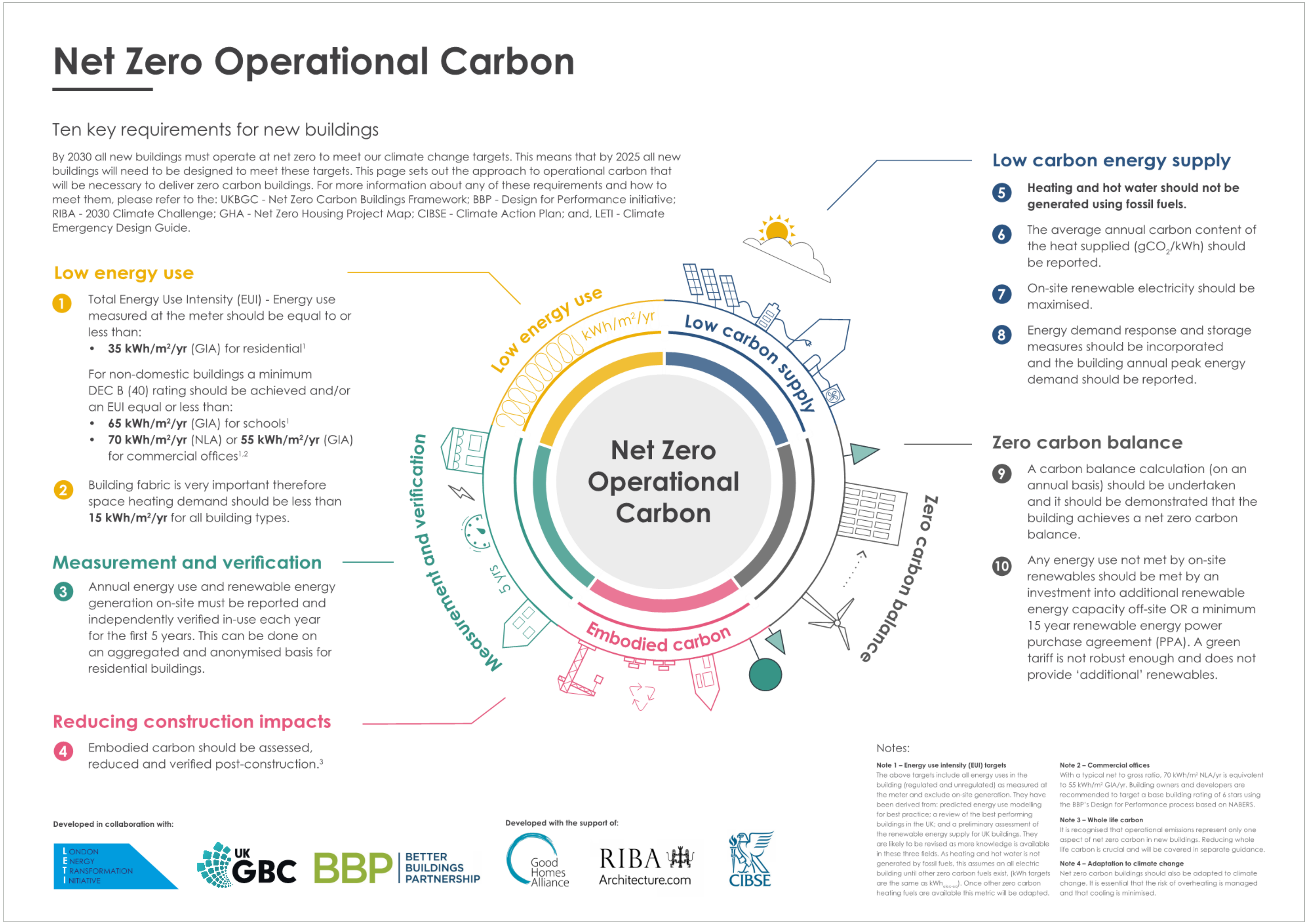
Net Zero Operational Carbon: definition

Ten key requirements for a Net Zero Operation Carbon

Developed by UKGBC, LETI and BBP, and supported by the Good Homes Alliance, RIBA and CIBSE



Net Zero Operational Carbon

Ten key requirements for new buildings

By 2030 all new buildings must operate at net zero to meet our climate change targets. This means that by 2025 all new buildings will need to be designed to meet these targets. This page sets out the approach to operational carbon that will be necessary to deliver zero carbon buildings. For more information about any of these requirements and how to meet them, please refer to the: UKGBC - Net Zero Carbon Buildings Framework; BBP - Design for Performance initiative; RIBA - 2030 Climate Challenge; GHA - Net Zero Housing Project Map; CIBSE - Climate Action Plan; and, LETI - Climate Emergency Design Guide.

Low energy use

① Total Energy Use Intensity (EUI) - Energy use measured at the meter should be equal to or less than:

- **35 kWh/m²/yr** (GIA) for residential[1]

For non-domestic buildings a minimum DEC B (40) rating should be achieved and/or an EUI equal or less than:

- **65 kWh/m²/yr** (GIA) for schools[1]
- **70 kWh/m²/yr** (NLA) or **55 kWh/m²/yr** (GIA) for commercial offices[1,2]

② Building fabric is very important therefore space heating demand should be less than **15 kWh/m²/yr** for all building types.

Measurement and verification

③ Annual energy use and renewable energy generation on-site must be reported and independently verified in-use each year for the first 5 years. This can be done on an aggregated and anonymised basis for residential buildings.

Reducing construction impacts

④ Embodied carbon should be assessed, reduced and verified post-construction.[3]

Low carbon energy supply

⑤ **Heating and hot water should not be generated using fossil fuels.**

⑥ The average annual carbon content of the heat supplied (gCO_2/kWh) should be reported.

⑦ On-site renewable electricity should be maximised.

⑧ Energy demand response and storage measures should be incorporated and the building annual peak energy demand should be reported.

Zero carbon balance

⑨ A carbon balance calculation (on an annual basis) should be undertaken and it should be demonstrated that the building achieves a net zero carbon balance.

⑩ Any energy use not met by on-site renewables should be met by an investment into additional renewable energy capacity off-site OR a minimum 15 year renewable energy power purchase agreement (PPA). A green tariff is not robust enough and does not provide 'additional' renewables.

Notes:

Note 1 – Energy use intensity (EUI) targets
The above targets include all energy uses in the building (regulated and unregulated) as measured at the meter and exclude on-site generation. They have been derived from: predicted energy use modelling for best practice; a review of the best performing buildings in the UK; and a preliminary assessment of the renewable energy supply for UK buildings. They are likely to be revised as more knowledge is available in these three fields. As heating and hot water is not generated by fossil fuels, this assumes an all electric building until other zero carbon fuels exist. (kWh targets are the same as $kWh_{elec-eq}$). Once other zero carbon heating fuels are available this metric will be adapted.

Note 2 – Commercial offices
With a typical net to gross ratio, 70 kWh/m² NLA/yr is equivalent to 55 kWh/m² GIA/yr. Building owners and developers are recommended to target a base building rating of 6 stars using the BBP's Design for Performance process based on NABERS.

Note 3 – Whole life carbon
It is recognised that operational emissions represent only one aspect of net zero carbon in new buildings. Reducing whole life carbon is crucial and will be covered in separate guidance.

Note 4 – Adaptation to climate change
Net zero carbon buildings should also be adapted to climate change. It is essential that the risk of overheating is managed and that cooling is minimised.

Developed in collaboration with:
LONDON ENERGY TRANSFORMATION INITIATIVE
UK GBC
BBP BETTER BUILDINGS PARTNERSHIP

Developed with the support of:
Good Homes Alliance
RIBA Architecture.com
CIBSE

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Glossary

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Glossary

Be clean	Is the second step of the London Plan Energy Hierarchy that looks at the heating infrastructure provided to new developments and requires that the heat and energy provided is as efficient as possible.
Be green	Is the third step of The London Plan Energy Hierarchy seeking to incentivise energy generation through renewable technologies.
Be lean	Is the first step of The London Plan Energy Hierarchy aiming to encourage developers to reduce the energy demand through passive and active design measures.
Be seen	Is the fourth step of The London Plan Energy Hierarchy requiring monitoring and reporting of the actual operational energy performance of major developments for at least five years.
Building Emission Rate (BER)	The actual building emission rate (BER) for the proposed building (other than dwellings) is calculated following the National Calculation Methodology (NCM) and is based on its actual specification. the BER is expressed in terms of its annual CO_2 emissions of the proposed building expressed in kg/m^2.
Capacity	The capacity of the system is the maximum power output. It depends on the installation's size and technical capability. The capacity may be in terms of electrical or thermal output.
Carbon budget	A carbon budget is the cumulative amount of carbon dioxide (CO_2) emissions permitted over a period of time to keep within a certain temperature threshold.
Carbon offsetting	Carbon offsetting consists of financing projects to reduce carbon dioxide emissions by purchasing carbon credits.
CIBSE	The Chartered Institution of Building Services Engineers (CIBSE) is an international professional engineering association based in London, England that represents building services engineers.
CIBSE TM54	The TM54 is a Technical Memorandum published by CIBSE that sets a methodology to calculate predicted in-operation energy use.
Combined heat and power (CHP)	A system which generates electricity whilst also capturing usable heat generated in the process. Typically, when referring to CHP it is inferred that this is gas-fired though this does not necessarily need to be the case.
Dwelling Emission Rate (DER)	The dwelling emissions rate is used within SAP 'Standards Assessment Procedure' and is the annual CO2 emissions from all new dwellings and is expressed in kilograms per square meter of floor area (kg/m^2). The quantity is calculated in accordance with the applicable regulatory document and expressed in kilograms per unit floor area to two decimal places In another sense, the DER is equal to the annual CO_2 emission per unit of floor area for, space heating, water heating, ventilation, and lighting less the emission that could be saved from renewable technology.
EDSL Tas	Is a building modelling and simulation tool capable of performing hourly dynamic thermal simulation for buildings of any size.

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Embodied carbon	Embodied carbon refers to the greenhouse gas emissions associated with the manufacture, transport, construction, repair, maintenance, replacement and deconstruction of all building elements. Upfront embodied carbon refer to the initial amount of embodied carbon associated with the building.
EUI	Energy Use Intensity expresses a building's energy use as a function of its size, typically expressed as energy consumption in kWh/m^{2}yr. The measurement of floor area can be expressed in terms of Net Lettable Area (NLA) or Gross Internal Area (GIA).
Fabric Energy Efficiency (FEE)	It is a measure of the efficiency of the building fabric that would reduce the amount of energy required to heat a home. Under the current Part L 2013, the Fabric Energy Efficiency Standard (FEES) metric sets the benchmark for a building through its 'notional building' and minimum u-values for fabric standards.
Future Home Standard (FHS)	The Future Homes Standard is a criteria linked to energy efficiency that comes into play in the UK in 2025. The key purpose of the standard is to significantly reduce carbon emissions, with properties being built with 75% less carbon compared with existing regulations.
Global warming potential (GWP)	The Global Warming Potential of a refrigerant is often expressed in carbon dioxide equivalents (CO_2e). The timescale the value refers to may be in the order of 50 or 100 years.
Heat Pump	A heat pump is a device that transfers thermal energy from a heat source to a heat sink (e.g. the ground to a house). There are many varieties of heat pump e.g. air, ground and water source heat pumps. The first word in the title refers to the heat source from which the pump draws heat. The pumps run on electricity, however less energy is required for their operation than they generate in heat, hence their status as a renewable technology.
IES-VE	The IES Virtual Environment (VE) is a suite of building performance analysis applications. It can be used by designers to test different options, identify passive solutions, compare low-carbon & renewable technologies, and draw conclusions on energy use, CO_2 emissions and occupant comfort.
kW	Stands for kilowatt. A kilowatt is a unit of power equivalent to a thousand watts.
kWh	Stands for a kilowatt hour and is a unit of energy. It is equal to the amount of energy a system will generate in an hour whilst running at a kilowatt power output.
London Energy Transformation Initiative (LETI)	LETI is a voluntary network of individuals across the built environment. Responsible for releasing thought documents including Climate Emergency Design Guide.
MW	Stands for megawatt. A megawatt is a unit of power equivalent to a million watts.

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MWh	Stands for a megawatt hour and is a unit of energy. It is equal to the amount of energy a system will generate in an hour whilst running at 1 megawatt power output.
NABERS	Is a sustainability rating for the built environment through the provision of a rating from one to six stars for buildings efficiency across energy, water, waste and indoor environment.
National Calculation Methodology (NCM)	It is the procedure for demonstrating compliance with the Building Regulations for buildings other than dwellings is by calculating the annual energy use for a proposed building and comparing it with the energy use of a comparable 'Notional' building.
Net Zero Carbon (NZC)	A ‘**Net Zero’ (whole life) Carbon’** Asset is one where the sum total of all asset related GHG emissions, both operational and embodied, over an asset’s life cycle (Modules A0-A5, B1-B8, C1-C4) are minimised, which meets local carbon, energy and water targets or limits, and with residual ‘offsets’, equals zero. A **‘Net Zero Operational Carbon – Energy’** asset is one where no fossil fuels are used, all energy use (Module B6) has been minimised, meets the local energy use target or limit (e.g. kWh/m^{2}yr) and all energy use is generated on- or of- site using renewables that demonstrate additionality. Direct emissions from renewables and any upstream emissions are ‘offset’. The definition of ‘Zero Carbon’ used by the London Plan focuses in operational emissions, excluding ‘unregulated’ energy use and relying on carbon offsetting.
Notional building (Part L)	A hypothetical building of the same size, shape, orientation and shading as the actual building, with the same activities, zoning and system types and exposed to the same weather data, but with pre-defined specified properties for the building fabric, fittings and services. The notional building is concurrent with the national building regulations for Wales 2014, Northern Ireland 2012 and England 2013. For Scotland 2013, the ‘notional’ building is generated based upon a building designed to meet the 2002 standards and a percentage improvement is applied to define the compliant building target carbon dioxide emission rate (TER).’ BRE Group
Operational carbon	The term used to describe the emissions of carbon dioxide and other greenhouse gases during the in-use operation of a building, most materially from energy use and refrigerants.
Part L	Part L is a building regulation that concerns construction projects that are new, or result in the change of use of a dwelling or all other buildings in England. It sets the standards for the energy performance and carbon emissions of new and existing buildings.
Photovoltaics (PV)	A technology which is used to generate renewable electricity using energy from the sun; typically installed on rooftop or across large fields.
Primary energy	Energy from fossil fuel and renewable sources that has not undergone any conversion or transformation process. Primary energy is transformed by the means of energy generation used and its transmission to the building.

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Regulated energy	Regulated energy is building energy consumption resulting from the specification of controlled, fixed building services and fittings, including space heating and cooling, hot water, ventilation, fans, pumps and lighting. Such energy uses are inherent in the design of a building
Renewable energy	Renewable energy is derived from sources which are naturally replenished or are practically inexhaustible. They are often described as 'clean', 'green' or 'sustainable' forms of energy because of their minimal environmental impact compared to fossil fuels.
Retrofit	Is the process of making changes to existing buildings so that energy consumption and emissions are reduced. These changes should also provide the benefit of a more comfortable and healthier home with lower fuel bills.
RIBA	The Royal Institute of British Architects is a professional body for architects primarily in the United Kingdom, but also internationally, founded for the advancement of architecture.
Simplified Building Energy Model (SBEM)	Is a calculation which measures the energy performance of a non-residential building. It is currently used to work out if a new building ill comply with Building Regulations, and also to generate Energy Performance Certificates (EPC).
Sleeving	If a new building connects to a high carbon heat network and leads to the addition of a new low carbon heat source, sleeving allows the use of the low carbon content of heat by the building for its planning energy calculations.
Space heating demand (SHD)	The amount of heat energy needed to heat a building over a year (per square metre)
Standard Assessment Procedure (SAP)	Is the methodology used by the UK government to assess and compare the energy and environmental performance of dwellings. Its purpose is to provide accurate and reliable assessments of dwellings that are needed to underpin energy and environmental policy initiatives.
Target Emission Rate (TER)	Is a pre-set building specification that sets a minimum allowable standard for the energy performance of a building and is defined by the annual CO_2 emissions of a notional building of the same size and shape to the proposed one. It is expressed in annual kg of CO_2 per m^2 (kgCO2/m2).
UKGBC	The UK Green Building Council (UKGBC) is a United Kingdom membership organisation, formed in 2007, which aims to 'radically transform' the way that the built environment in the UK is planned, designed, constructed, maintained and operated.
Unregulated energy	Unregulated energy is building energy consumption resulting from a system or process that is not 'controlled', ie energy consumption from systems in the building on which the Building Regulations do not impose a requirement. For example, this may include energy consumption from systems integral to the building and its operation, e.g. IT equipment, lifts, escalators, refrigeration systems, external lighting, ducted-fume cupboards, servers, printers, photocopiers, laptops, cooking, audio-visual equipment and other appliances.
Waste water heat recovery	Is a system designed to retrieve thermal energy from hot water used in a shower before it disappears down the drain.

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12.3

Energy and cost modelling assumptions for all typologies

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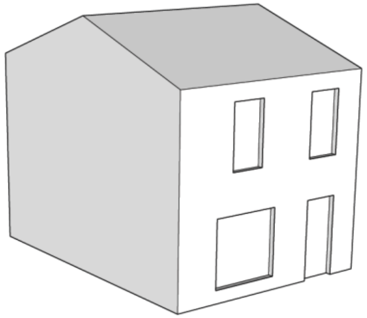
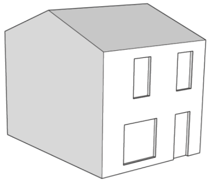
12.3.1

Energy and cost modelling assumptions for terrace house





Terrace House | Fabric & Ventilation

This table summarises the different energy efficiency assumptions modelled based on the three different fabric and ventilation scenarios.

NEW New input for SAP 10.2

	1 **Business as Usual***	2 **Good Practice**	3 **Ultra Low Energy**
Description	This scenario represents the type of energy efficiency performance most applicants are used to deliver.	This scenario represents an intermediate level of performance: better than business as usual but not as good as ultra low energy.	This scenario represents a feasible best practice level of performance, approximately equivalent to Passivhaus.
Floor U-Value (W/m^{2}K)	0.11	0.10	0.08
External wall U-Value (W/m^{2}K)	0.18	0.15	0.11
Roof U-Value (W/m^{2}K)	0.13	0.12	0.10
Soffit U-Value (W/m^{2}K)	N/A	N/A	N/A
Windows U-value (W/m^{2}K) Windows g-value	 1.40 0.6	 1.20 0.6	 0.80 0.6
External doors (W/m^{2}K)	1.6	1.4	1.2
Thermal bridging (W/m^{2}K)	Good practice (e.g. y-value ≃ 0.08 W/m^{2}K)	Better practice (e.g. y-value ≃ 0.05 W/m^{2}K)	Best practice (e.g. y-value ≃ 0.04 W/m^{2}K)
Air Permeability (m^3/m^2/hr)	3	2	<1
Ventilation system and design	Good quality MVHR Long ducts to outside	Good quality MVHR Long ducts to outside	High quality MVHR Short ducts to outside
MVHR heat recovery efficiency	85%	85%	90%
MVHR specific fan power	0.8 W/l/s (SAP) 1.75 W/l/s (PHPP)	0.7 W/l/s (SAP) 1.25 W/l/s (PHPP)	0.6 W/l/s (SAP) 0.85 W/l/s (PHPP)

- *The term 'Business as Usual' scenarios is meant to represent the type of fabric and ventilation specifications that most applicants in London would consider 'standard' for a mid-rise apartment building. For consistency it has not been changed compared with the initial 2019 study. We think that this approach is acceptable as 'Business as usual' has not changed significantly in terms of fabric and ventilation specifications*

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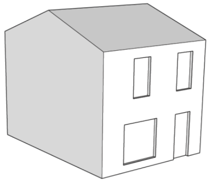

Terrace House | Building services

This table summarises the different heating system assumptions modelled based on the four different scenarios.

NEW New input for SAP 10.2

	A Gas boiler	B Direct electric	C Less efficient Heat Pump System *Individual heat pump*	D More Efficient Heat Pump System *Individual heat pump*
Description	Individual condensing gas boiler and hot water cylinder	Direct electric and individual hot water cylinder	Individual air source heat pump serving each domestic unit	Individual air source heat pump serving each domestic unit
Communal heating distribution and Distribution Loss Factor (DLF)	N/A	N/A	N/A	N/A
Heating emitters	LTHW radiators fed by gas boiler	Direct electric panel radiators	LTHW radiators fed by individual heat pump or warm air	LTHW radiators fed by individual heat pump or warm air
Hot water system	A 180L hot water store in each unit	A 180L hot water store in each unit	A 180L hot water store in each unit	A 180L hot water store in each unit
Heating and hot water seasonal efficiency	89.5%	100%	270% space heating 210% water heating *Blended efficiencies for SAP models 1/2/3: 253% /245% / 235%* *Flow temperature 45°C*	330% space heating 280% water heating *Blended efficiencies for SAP models 1/2/3: 317% / 311% /303%* *Flow temperature 35°C*
Showers NEW	2 showers – 8 l/min each	2 showers – 8 l/min each	2 showers – 8 l/min each	2 showers – 8 l/min each
Waste Water Heat Recovery	No WWHR assumed	No WWHR assumed	No WWHR assumed	No WWHR assumed
Internal lighting	10 light bulbs @ 5W and 95lW	10 light bulbs @ 5W and 95lW	10 light bulbs @ 5W and 95lW	10 light bulbs @ 5W and 95lW

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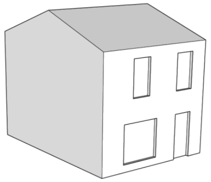

Terrace House | Photovoltaics (PVs)

This table summarises the different sizes of PV system assumed.

NEW New input for SAP 10.2

	Max PV
Description	This assumes a clear effort to design the roof in order to maximise the area of PVs.
Photovoltaic Panels (kWp)	5.1 for the end terrace houses 3.8 for the mid terrace houses
Assumed area (Panel area)	152m^2 for the whole terrace
Tilt	45° (South)
Shading	Average/unknown
Battery capacity (kWh) NEW	N/A

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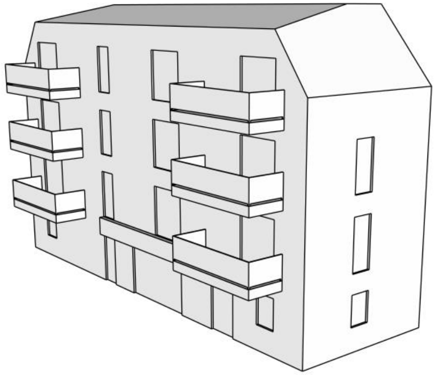
Energy and cost modelling assumptions for low-rise apartment building



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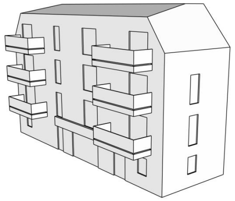

Low rise apartment building | Fabric & Ventilation

This table summarises the different energy efficiency assumptions modelled based on the three different fabric and ventilation scenarios. The SAP Calculations assume a 5 story building.

NEW New input for SAP 10.2

	1 **Business as Usual***	2 **Good Practice**	3 **Ultra Low Energy**
Description	This scenario represents the type of energy efficiency performance most applicants are used to deliver.	This scenario represents an intermediate level of performance: better than business as usual but not as good as ultra low energy.	This scenario represents a feasible best practice level of performance, approximately equivalent to Passivhaus.
Floor U-Value (W/m^{2}K)	0.13	0.10	0.08
External wall U-Value (W/m^{2}K)	0.18	0.15	0.13
Roof U-Value (W/m^{2}K)	0.15	0.12	0.10
Soffit U-Value (W/m^{2}K)	N/A	N/A	N/A
Windows U-value (W/m^{2}K) Windows g-value	 1.40 0.4	 1.20 0.5	 0.80 0.5
External doors (W/m^{2}K)	N/A	N/A	N/A
Thermal bridging (W/m^{2}K)	Good practice (e.g. y-value ≃ 0.1 W/m^{2}K)	Better practice (e.g. y-value ≃ 0.07 W/m^{2}K)	Best practice (e.g. y-value ≃ 0.04 W/m^{2}K)
Air Permeability (m^3/m^2/hr)	<3	<3	<1
Ventilation system and design	Good quality MVHR Long ducts to outside	High quality MVHR Long ducts to outside	High quality MVHR Short ducts to outside
MVHR heat recovery efficiency	85%	90%	90%
MVHR specific fan power	0.8 W/l/s (SAP) 1.75 W/l/s (PHPP)	0.7 W/l/s (SAP) 1.25 W/l/s (PHPP)	0.6 W/l/s (SAP) 0.85 W/l/s (PHPP)

** The term 'Business as Usual' scenarios is meant to represent the type of fabric and ventilation specifications that most applicants in London would consider 'standard' for a mid-rise apartment building. For consistency it has not been changed compared with the initial 2019 study. We think that this approach is acceptable as 'Business as usual' has not changed significantly in terms of fabric and ventilation specifications*

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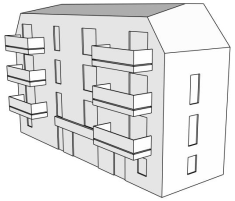
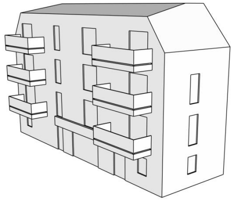


Low rise apartment building | Building services

This table summarises the different heating system assumptions modelled based on the four different scenarios.

NEW New input for SAP 10.2

	A Gas boiler	B Direct electric	C Less efficient Heat Pump System *Communal heat pump*	D More Efficient Heat Pump System *Ambient loop heat pump/ Individual heat pump*
Description	Communal gas boiler supplying heat interface units in all flats	Direct electric and individual hot water cylinder	Communal air source heat pump supplying heat interface units in all flats	Small individual heat pump systems with hot water cylinder (could translate to ambient loop with GSHP
Communal heating distribution and Distribution Loss Factor (DLF)	Flow and return temperature 70°C/50°C . Assumed DLF = 1.05	N/A	Flow and return temperature 65°C/50°C . Assumed DLF = 1.5	Ambient loop or N/A Assumed DLF = 1.5
Heating emitters	LTHW radiators fed by HIU	Direct electric panel radiators	LTHW radiators fed by HIU	LTHW radiators fed by individual heat pump
Hot water system	HIU provides instantaneous hot water	180L hot water store with an immersion heater in each domestic unit	HIU provides instantaneous hot water	A 180L hot water store in each unit
Heating and hot water seasonal efficiency	93%	100%	190% space heating 210% water heating *Blended efficiencies for SAP models 1/2/3: 200% /201% / 204%*	330% space heating 280% water heating *Blended efficiencies for SAP models 1/2/3: 304% / 300% /293%*
Showers NEW	2 showers – 8 l/min each	2 showers – 8 l/min each	2 showers – 8 l/min each	2 showers – 8 l/min each
Waste Water Heat Recovery	No WWHR assumed	No WWHR assumed	No WWHR assumed	No WWHR assumed
Internal lighting	10 light bulbs @ 5W and 95lW	10 light bulbs @ 5W and 95lW	10 light bulbs @ 5W and 95lW	10 light bulbs @ 5W and 95lW



Low rise apartment building | Photovoltaics (PVs)

This table summarises the different sizes of PV system assumed.

NEW New input for SAP 10.2

	Max PV
Description	This assumes a clear effort to design the roof in order to maximise the area of PVs.
Photovoltaic Panels (kWp)	23.4
Assumed area (Panel area)	107m^2
Tilt	10° (Horizontal)
Shading	Average/unknown
Battery capacity (kWh) NEW	N/A

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12.3.3

Energy and cost modelling assumptions for mid-rise apartment building

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Mid rise apartment building | Fabric & Ventilation

This table summarises the different energy efficiency assumptions modelled based on the three different fabric and ventilation scenarios. The SAP Calculations assume a 5 story building.

NEW New input for SAP 10.2

	1 Business as Usual*	2 Good Practice	3 Ultra Low Energy
Description	This scenario represents the type of energy efficiency performance most applicants are used to deliver.	This scenario represents an intermediate level of performance: better than business as usual but not as good as ultra low energy.	This scenario represents a feasible best practice level of performance, approximately equivalent to Passivhaus.
Floor U-Value (W/m^{2}K)	0.13	0.10	0.08
External wall U-Value (W/m^{2}K)	0.18	0.15	0.13
Roof U-Value (W/m^{2}K)	0.15	0.12	0.10
Soffit U-Value (W/m^{2}K)	N/A	N/A	N/A
Windows U-value (W/m^{2}K) Windows g-value	 1.40 0.4	 1.20 0.5	 0.80 0.5
External doors (W/m^{2}K)	N/A	N/A	N/A
Thermal bridging (W/m^{2}K)	Good practice (e.g. y-value ≃ 0.1 W/m^{2}K)	Better practice (e.g. y-value ≃ 0.07 W/m^{2}K)	Best practice (e.g. y-value ≃ 0.04 W/m^{2}K)
Air Permeability (m^3/m^2/hr)	<3	<3	<1
Ventilation system and design	Good quality MVHR Long ducts to outside	High quality MVHR Long ducts to outside	High quality MVHR Short ducts to outside
MVHR heat recovery efficiency	85%	90%	90%
MVHR specific fan power	0.8 W/l/s (SAP) 1.75 W/l/s (PHPP)	0.7 W/l/s (SAP) 1.25 W/l/s (PHPP)	0.6 W/l/s (SAP) 0.85 W/l/s (PHPP)

** The term 'Business as Usual' scenarios is meant to represent the type of fabric and ventilation specifications that most applicants in London would consider 'standard' for a mid-rise apartment building. For consistency it has not been changed compared with the initial 2019 study. We think that this approach is acceptable as 'Business as usual' has not changed significantly in terms of fabric and ventilation specifications*

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Mid rise apartment building | Building services

This table summarises the different heating system assumptions modelled based on the four different scenarios.

NEW New input for SAP 10.2

	A Gas boiler	B Direct electric	C Less efficient Heat Pump System *Communal heat pump*	D More Efficient Heat Pump System *Communal heat pump*
Description	Communal gas boiler supplying heat interface units in all flats	Direct electric and individual hot water cylinder	Communal air source heat pump supplying heat interface units in all flats	Communal air source heat pump supplying heat interface units in all flats
Communal heating distribution and Distribution Loss Factor (DLF)	Flow and return temperature 70°C/50°C . Assumed DLF = 1.05	N/A	Flow and return temperature 65°C/50°C . Assumed DLF = 1.5	Flow and return temperature 65°C/50°C . Assumed DLF = 1.5
Heating emitters	LTHW radiators fed by HIU	Direct electric panel radiators	LTHW radiators fed by HIU	LTHW radiators fed by individual heat pump
Hot water system	HIU provides instantaneous hot water	180L hot water store with an immersion heater in each domestic unit	HIU provides instantaneous hot water	A 180L hot water store in each unit
Heating and hot water seasonal efficiency	93%	100%	190% space heating 210% water heating *Blended efficiencies for SAP models 1/2/3: 200% /201% / 204%*	330% space heating 280% water heating *Blended efficiencies for SAP models 1/2/3: 304% / 300% /293%*
Showers NEW	2 showers – 8 l/min each	2 showers – 8 l/min each	2 showers – 8 l/min each	2 showers – 8 l/min each
Waste Water Heat Recovery	No WWHR assumed	No WWHR assumed	No WWHR assumed	No WWHR assumed
Internal lighting	10 light bulbs @ 5W and 95lW	10 light bulbs @ 5W and 95lW	10 light bulbs @ 5W and 95lW	10 light bulbs @ 5W and 95lW

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Mid rise apartment building | Photovoltaics (PVs)

This table summarises the different sizes of PV system assumed.

NEW New input for SAP 10.2

	Max PV
Description	This assumes a clear effort to design the roof in order to maximise the area of PVs.
Photovoltaic Panels (kWp)	55
Assumed area (Panel area)	250m^2
Tilt	10° (Horizontal)
Shading	Average/unknown
Battery capacity (kWh) NEW	N/A

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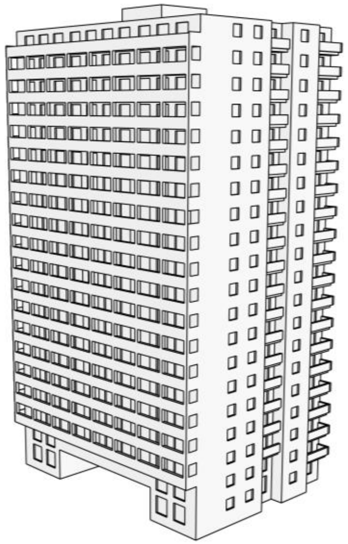
12.3.4

Energy and cost modelling assumptions for high-rise apartment building



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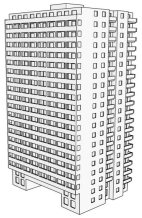

High rise apartment building | Fabric & Ventilation

This table summarises the different energy efficiency assumptions modelled based on the three different fabric and ventilation scenarios.
The SAP Calculations assume a 5 story building.

NEW New input for SAP 10.2

	1 Business as Usual*	2 Good Practice	3 Ultra Low Energy
Description	This scenario represents the type of energy efficiency performance most applicants are used to deliver.	This scenario represents an intermediate level of performance: better than business as usual but not as good as ultra low energy.	This scenario represents a feasible best practice level of performance, approximately equivalent to Passivhaus.
Floor U-Value (W/m^{2}K)	0.13	0.10	0.08
External wall U-Value (W/m^{2}K)	0.18	0.18	0.15
Roof U-Value (W/m^{2}K)	0.15	0.12	0.10
Soffit U-Value (W/m^{2}K)	N/A	N/A	N/A
Windows U-value (W/m^{2}K) Windows g-value	 1.40 0.4	 1.20 0.5	 0.90 0.5
External doors (W/m^{2}K)	N/A	N/A	N/A
Thermal bridging (W/m^{2}K)	Good practice (e.g. y-value ≃ 0.15 W/m^{2}K)	Better practice (e.g. y-value ≃ 0.08 W/m^{2}K)	Best practice (e.g. y-value ≃ 0.06 W/m^{2}K)
Air Permeability (m^3/m^2/hr)	<3	2	<1
Ventilation system and design	Good quality MVHR Long ducts to outside	High quality MVHR Long ducts to outside	High quality MVHR Short ducts to outside
MVHR heat recovery efficiency	85%	90%	90%
MVHR specific fan power	0.8 W/l/s (SAP) 1.75 W/l/s (PHPP)	0.7 W/l/s (SAP) 1.25 W/l/s (PHPP)	0.6 W/l/s (SAP) 0.85 W/l/s (PHPP)

** The term 'Business as Usual' scenarios is meant to represent the type of fabric and ventilation specifications that most applicants in London would consider 'standard' for a mid-rise apartment building. For consistency it has not been changed compared with the initial 2019 study. We think that this approach is acceptable as 'Business as usual' has not changed significantly in terms of fabric and ventilation specifications*

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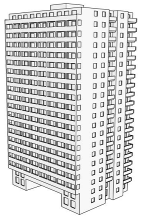

High rise apartment building | Building services

This table summarises the different heating system assumptions modelled based on the four different scenarios.

NEW New input for SAP 10.2

	A Gas boiler	B Direct electric	C Less efficient Heat Pump System *Communal heat pump*	D More Efficient Heat Pump System *Communal heat pump*
Description	Communal gas boiler supplying heat interface units in all flats	Direct electric and individual hot water cylinder	Communal air source heat pump supplying heat interface units in all flats	Communal air source heat pump supplying heat interface units in all flats
Communal heating distribution and Distribution Loss Factor (DLF)	Flow and return temperature 70°C/50°C . Assumed DLF = 1.05	N/A	Flow and return temperature 65°C/50°C . Assumed DLF = 1.5	Flow and return temperature 65°C/50°C . Assumed DLF = 1.5
Heating emitters	LTHW radiators fed by HIU	Direct electric panel radiators	LTHW radiators fed by HIU	LTHW radiators fed by individual heat pump
Hot water system	HIU provides instantaneous hot water	180L hot water store with an immersion heater in each domestic unit	HIU provides instantaneous hot water	A 180L hot water store in each unit
Heating and hot water seasonal efficiency	93%	100%	190% space heating 210% water heating *Blended efficiencies for SAP models 1/2/3: 200% /201% / 204%*	330% space heating 280% water heating *Blended efficiencies for SAP models 1/2/3: 304% / 300% /293%*
Showers NEW	2 showers – 8 l/min each	2 showers – 8 l/min each	2 showers – 8 l/min each	2 showers – 8 l/min each
Waste Water Heat Recovery	No WWHR assumed	No WWHR assumed	No WWHR assumed	No WWHR assumed
Internal lighting	10 light bulbs @ 5W and 95lW	10 light bulbs @ 5W and 95lW	10 light bulbs @ 5W and 95lW	10 light bulbs @ 5W and 95lW

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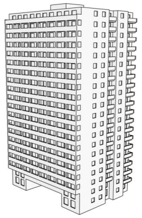


High rise apartment building | Photovoltaics (PVs)

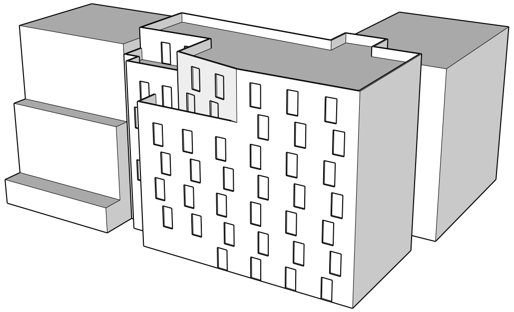
This table summarises the different sizes of PV system assumed.

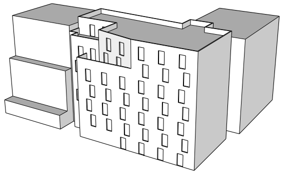
NEW New input for SAP 10.2

	Max PV
Description	This assumes a clear effort to design the roof in order to maximise the area of PVs.
Photovoltaic Panels (kWp)	37.95
Assumed area (Panel area)	170m^2
Tilt	10° (Horizontal)
Shading	Average/unknown
Battery capacity (kWh) NEW	N/A

12.3.5

Energy and cost modelling assumptions for office building





Office building | Fabric & Ventilation

This table summarises the different energy efficiency assumptions modelled based on the three different fabric and ventilation scenarios. Modelling was carried out for a 7-storey office of 4000m² GIA.

NEW New input for Part L 2021

	1 Business as Usual	2 Good Practice	3 Ultra Low Energy
Description	This scenario represents the type of energy efficiency performance most applicants are used to deliver.	This scenario represents an intermediate level of performance: better than business as usual but not as good as ultra low energy.	This scenario represents a feasible best practice level of performance, approximately equivalent to Passivhaus.
Floor U-Value (W/m^{2}K)	0.15	0.12	0.09
External wall U-Value (W/m^{2}K)	0.25	0.18	0.13
Roof U-Value (W/m^{2}K)	0.15	0.13	0.10
Windows U-value (W/m^{2}K)* Windows g-value	 1.60 0.40	 1.40 0.40	 0.80 0.40
External doors (W/m^{2}K)	2.0	1.5	1.5
Thermal bridging (W/m^{2}K)	Good practice (5% of losses)	Better practice (3% of losses)	Best practice (1% of losses)
Air Permeability (m^3/m^2/hr)	5	3	1
Ventilation system and design	Standard quality AHU	Good quality AHU	Best practice AHU
AHU heat recovery efficiency	75%	80%	90%
AHU specific fan power	1.8 W/l/s 0.3 W/l/s (FCU terminal units)	1.6 W/l/s 0.3 W/l/s (FCU terminal units)	1.2 W/l/s 0.3 W/l/s (FCU terminal units)
Demand Control Ventilation NEW	No	Yes - CO2 sensors with speed control	Yes - CO2 sensors with speed control
Internal Lighting (lm/W) NEW	95	105	115
Lighting Control	PIR Presence Detection + Daylight Dimming in Offices only	PIR Presence Detection + Daylight Dimming in Offices only	PIR Presence Detection + Daylight Dimming in Offices only

The term 'Business as Usual' Business as usual' scenarios is meant to represent the type of fabric and ventilation specifications that most applicants in London would consider 'standard' for a mid-rise apartment building. For consistency it has not been changed compared with the initial 2019 study. We think that this approach is acceptable as 'Business as usual' has not changed significantly in terms of fabric and ventilation specifications

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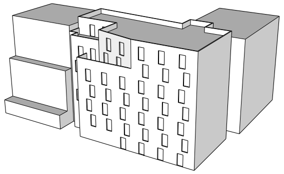

Office building | Building services

This table summarises the different heating system assumptions modelled based on the four different scenarios.

	A Gas boiler	B VRF	C Less efficient Heat Pump System *Communal heat pump*	D More Efficient Heat Pump System *Communal heat pump*
Description	Gas boiler serving a heating system with flow and return temperature 70°C/50°C	VRF unit	Heat pumps serving a heating system with flow and return temperature 65°C/50°C	Heat pumps serving a heating system with low flow and return temperatures 45°C/40°C fed from ambient loop.
Heating emitters	LTHW Fan Coil Unit fed by Gas Boiler	Fan Coil Unit fed by VRF	LTHW Fan Coil Unit fed by Heat Pump	LTHW Fan Coil Unit fed by Heat Pump
Hot water system	Direct electric hot water to toilets A 400L hot water store for the showers fed by gas boiler	Direct electric hot water to toilets A 400L hot water store for the showers fed by heat pump	Direct electric hot water to toilets A 400L hot water store for the showers fed by heat pump	Direct electric hot water to toilets A 400L hot water store for the showers fed by heat pump
Heating and hot water seasonal efficiency	95% for heating and hot water	350% for heating 300% for hot water	220% for heating and hot water	400% for heating 300% for hot water
Waste Water Heat Recovery (WWHR)	No WWHR assumed	No WWHR assumed	No WWHR assumed	No WWHR assumed
Cooling seasonal efficiency	3.5 EER 5.0 SEER	3.5 EER 5.0 SEER	3.5 EER 5.0 SEER	3.5 EER 5.0 SEER

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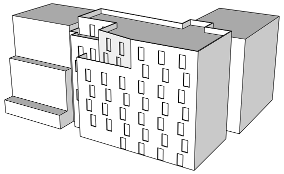

Office building | Photovoltaics (PVs)

This table summarises the different sizes of PV system assumed.

NEW New input for Part L 2021

	No PV	PV	Max PV
Description	This assumed no PVs at all on the roof or any of the elevation	This assumes a standard practice for PVs. No particular effort has been made to design the roof in order to accommodate PVs.	This assumes a clear effort to design the roof in order to maximise the area of PVs.
Photovoltaic Panels (kWp)	0	N/A	N/A
Module Efficiency (%)	N/A	20%	20%
Assumed area (Panel area)	N/A	308.8 (50% of building footprint area)	432.3 (70% of building footprint area)
Tilt	N/A	30°	30°
Shading	N/A	Average/unknown	Average/unknown
Battery capacity (kWh) NEW	N/A	N/A	N/A

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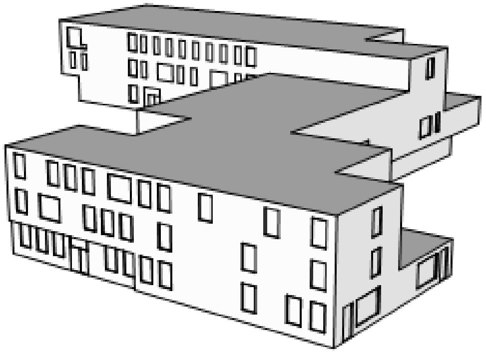
12.3.6

Energy and cost modelling assumptions for primary school



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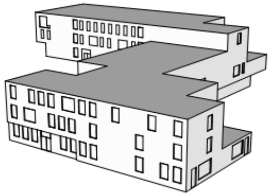

Primary school building | Fabric & Ventilation

This table summarises the different energy efficiency assumptions modelled based on the three different fabric and ventilation scenarios. Modelling was carried out for a 3/4-storey primary school of 6000m² GIA.

NEW New input for Part L 2021

	1 Business as Usual	2 Good Practice	3 Ultra Low Energy
Description	This scenario represents the type of energy efficiency performance most applicants are used to deliver.	This scenario represents an intermediate level of performance: better than business as usual but not as good as ultra low energy.	This scenario represents a feasible best practice level of performance, approximately equivalent to Passivhaus.
Floor U-Value (W/m^{2}K)	0.15	0.12	0.09
External wall U-Value (W/m^{2}K)	0.20	0.18	0.13
Roof U-Value (W/m^{2}K)	0.15	0.13	0.11
Thermal bridge performance*	25% added to the U-values	25% added to the U-values	25% added to the U-values
Windows			
U-value (W/m^{2}K)*	1.40	1.20	0.80
Windows g-value	0.50	0.50	0.50
External doors (W/m^{2}K)	1.6	1.6	1.6
Air Permeability (m^3/m^2/hr)	5	3	1
Ventilation system and design	Fan assisted ventilation	Good quality MVHR	Best practice MVHR
AHU heat recovery efficiency	0%	70%	80%
AHU specific fan power	0.5 W/l/s	1.6 W/l/s	1.2 W/l/s
Demand Control Ventilation NEW	No	No	Yes - CO_2 sensors with speed control
Internal Lighting (lm/W) NEW	95	105	115
Lighting Control	PIR Absence Detection + Daylight Dimming in Teaching and Offices only PIR Presence Detection in Circulation, Toilets, Stores, Kitchen, Dining, Server and Changing	PIR Absence Detection + Daylight Dimming in Teaching and Offices only PIR Presence Detection in Circulation, Toilets, Stores, Kitchen, Dining, Server and Changing	PIR Absence Detection + Daylight Dimming in Teaching and Offices only PIR Presence Detection in Circulation, Toilets, Stores, Kitchen, Dining, Server and Changing

The term 'Business as Usual' is meant to represent the type of fabric and ventilation specifications that most applicants in London would consider 'standard' for a school.

For consistency it has not been changed compared with the initial 2019 study. We think that this approach is acceptable as 'Business as usual' has not changed significantly in terms of fabric and ventilation specifications

**Variations in thermal bridging have not been modelled as the software doesn't support modelling psi values so adds a default 25% uplift to all U-values in actual building in accordance with NCM.*

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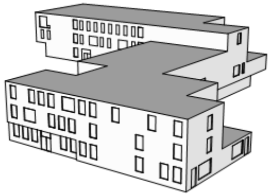

Primary school building | Building services

This table summarises the different heating system assumptions modelled based on the four different scenarios.

	A Gas boiler	B Direct electric	C Less efficient Heat Pump System *Communal heat pump*	D More Efficient Heat Pump System *Communal heat pump*
Description	Gas boiler serving a heating system with flow and return temperature 70°C/50°C	Direct electric panel radiators providing heating	Heat pumps serving a heating system with flow temperature 65°C	Heat pumps serving a heating system with low flow temperature 45°C fed from ambient loop
Heating emitters	LTHW radiators fed by gas boiler	Direct electric panel radiators	LTHW radiators fed by heat pump	LTHW radiators fed by heat pump
Hot water system	A 2500L hot water store	Direct electric point-of-use hot water to bathrooms	Direct electric point-of-use hot water to bathrooms	Direct electric point-of-use hot water to bathrooms
Heating and hot water seasonal efficiency	95% for heating and hot water	100% for heating and hot water	400% for heating* 100% for hot water	450% for heating* 100% for hot water
Waste Water Heat Recovery (WWHR)	No WWHR assumed	No WWHR assumed	No WWHR assumed	No WWHR assumed
Cooling seasonal efficiency	No cooling assumed	No cooling assumed	No cooling assumed	No cooling assumed
Distribution efficiency (heating, cooling and DHW)	95%	95%	95%	95%

*Heat pumps in Systems C and D have been improved from the initial 2019 study to more closely align with the other typologies and take account of the minimum permissible performance levels set by Part L.

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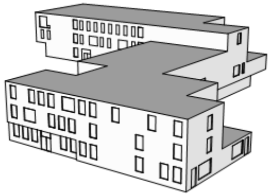

Primary school building | Photovoltaics (PVs)

This table summarises the different sizes of PV system assumed.

NEW New input for Part L 2021

	No PV	PV
Description	This assumed no PVs at all on the roof or any of the elevation	This assumes a standard practice for PVs. No particular effort has been made to design the roof in order to accommodate PVs.
Photovoltaic Panels (kWp)	0	135.5
Module Efficiency (%)	N/A	TBC%
Assumed area (Panel area)	N/A	607.8m^2 (25% of footprint)
Tilt	N/A	10° (Horizontal)
Shading	N/A	Average/unknown
Battery capacity (kWh) NEW	N/A	N/A
Predicted Annual Yield	N/A	114,657 kWh

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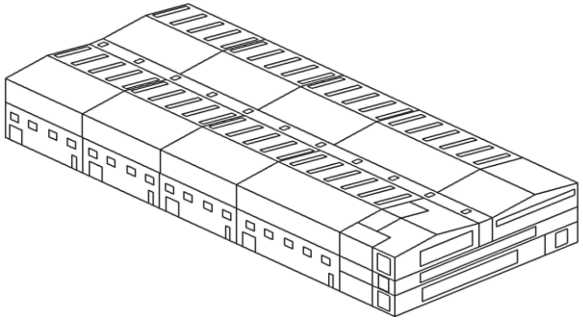
12.3.7

Energy and cost modelling assumptions for industrial building



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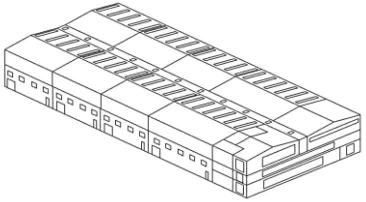

Industrial building | Fabric & Ventilation

This table summarises the different energy efficiency assumptions modelled based on the three different fabric and ventilation scenarios. Modelling was carried out for a 2-storey industrial building of 9000m² GIA.

NEW New input for Part L 2021

	1 Business as Usual	2 Good Practice	3 Ultra Low Energy
Description	This scenario represents the type of energy efficiency performance most applicants are used to deliver.	This scenario represents an intermediate level of performance: better than business as usual but not as good as ultra low energy.	This scenario represents a feasible best practice level of performance, approximately equivalent to Passivhaus.
Floor U-Value (W/m^{2}K)	0.18	0.15	0.13
External wall U-Value (W/m^{2}K)	0.26	0.18	0.14
Roof U-Value (W/m^{2}K)	0.16	0.13	0.11
Windows/Rooflights U-value (W/m^{2}K)* Windows g-value	 1.60 / 2.00 0.40 / 0.50	 1.40 / 1.60 0.40 / 0.50	 1.20 / 1.40 0.40 / 0.50
External doors – Pedestrian / Vehicle (W/m^{2}K)	2.0 / 1.3	1.5 / 1.3	1.5 / 1.3
Thermal bridging (W/m²K)	Good practice (5% of losses)	Better practice (3% of losses)	Best practice (1% of losses)
Air Permeability (m³/m²/hr)	5	3	2
Ventilation system and design	Industrial offices: AHU with HR Industrial warehouses: Exhaust only	Industrial offices: AHU with HR Industrial warehouses: AHU with HR	Industrial offices: AHU with HR Industrial warehouses: AHU with HR
AHU heat recovery efficiency	Industrial offices: 75% Industrial warehouses: NA	Industrial offices: 80% Industrial warehouses: 80%	Industrial offices: 80% Industrial warehouses: 80%
AHU specific fan power	Industrial offices: 1.6 (0.2 for terminal units) Industrial warehouses: 0.5	Industrial offices: 1.4 (0.2 for terminal units) Industrial warehouses: 1.4	Industrial offices: 1.2 (0.15 terminal units) Industrial warehouses: 1.2
Demand Control Ventilation NEW	No	No	Yes - CO_2 sensors with speed control only in offices
Internal Lighting (lm/W) NEW	100	110	115
Lighting Control	PIR Presence Detection + Daylight Dimming in offices only	PIR Presence Detection + Daylight Dimming in offices only	PIR Presence Detection + Daylight Dimming in offices only

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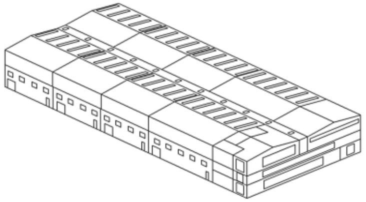

Industrial building | Building services

This table summarises the different heating system assumptions modelled based on the four different scenarios.

	A Gas boiler	B VRF	C Less efficient Heat Pump System *Four pipe chiller*	D More Efficient Heat Pump System *Central heat pump*
Description	Gas boiler serving a heating system with flow and return temperature 70°C/50°C	ASHP serving the warehouse spaces and VRF system for the office spaces.	Four pipe chiller which does simultaneous heating and cooling	Heat pumps serving a heating system with low flow and return temperatures 45°C/40°C fed from ambient loop.
Heating emitters (Workshop)	Radiant panels	Radiant panels	Radiant panels	Radiant panels
Heating seasonal efficiency (Workshop)	95%	300%	300%	350%
Heating emitters (Office)	FCU	FCU	FCU	FCU
Heating seasonal efficiency (Office)	95%	450%	300%	350%
Hot water system	Direct electric	Direct electric	Direct electric	Heat pump
Hot water seasonal efficiency	100%	100%	100%	300%
Cooling seasonal efficiency (Office spaces)	3.5 EER 5.0 SEER	3.5 EER 5.0 SEER	3.0 EER 4.0 SEER	3.5 EER 5.0 SEER

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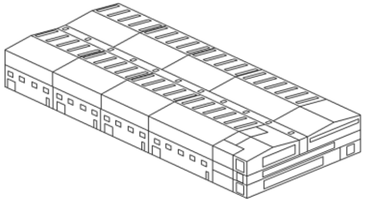

Industrial building | Photovoltaics (PVs)

This table summarises the different sizes of PV system assumed.

NEW New input for Part L 2021

	No PV	PV
Description	This assumed no PVs at all on the roof or any of the elevation	This assumes a standard practice for PVs. No particular effort has been made to design the roof in order to accommodate PVs.
Photovoltaic Panels (kWh/year)	0	122,160
Module Efficiency (%)	N/A	20%
Assumed area (Panel area)	N/A	666 m^2 (20% of building footprint area)
Tilt	N/A	30° (Horizontal)
Shading	N/A	Average/unknown
Battery capacity (kWh) NEW	N/A	N/A

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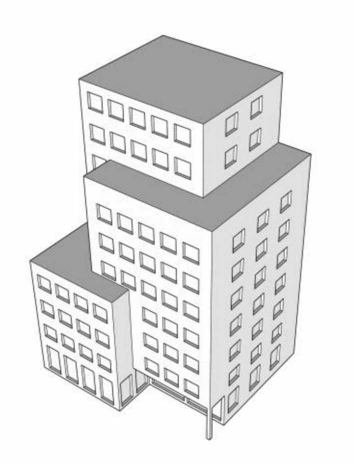
12.3.8

Energy and cost modelling assumptions for hotel



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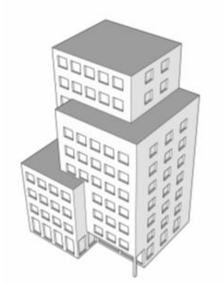

Hotel building | Fabric & Ventilation

This table summarises the different energy efficiency assumptions modelled based on the three different fabric and ventilation scenarios. Modelling was carried out for a 11 storey hotel with 100 bedrooms, ground floor restaurant and 3900m^2 GIA.

NEW New input for Part L 2021

	1 Business as Usual	2 Good Practice	3 Ultra Low Energy
Description	This scenario represents the type of energy efficiency performance most applicants are used to deliver.	This scenario represents an intermediate level of performance: better than business as usual but not as good as ultra low energy.	This scenario represents a feasible best practice level of performance, approximately equivalent to Passivhaus.
Floor U-Value (W/m^2K)	0.15	0.12	0.09
External wall U-Value (W/m^2K)	0.25	0.18	0.13
Roof U-Value (W/m^2K)	0.15	0.13	0.10
Thermal bridge performance*	25% added to the U-values	25% added to the U-values	25% added to the U-values
Windows U-value (W/m^2K) Windows g-value	 1.40 0.4	 1.20 0.4	 0.80 0.4
Air Permeability ($m^3/m^2/hr$)	5	3	1
Ventilation system and design	AHU	AHU	AHU
AHU heat recovery efficiency	75%	80%	80%
AHU specific fan power	1.6 W/l/s	1.4 W/l/s	1.2 W/l/s
Demand Control Ventilation NEW	No	No	Yes - CO_2 sensors with speed control
Internal Lighting (lm/W) NEW	95	105	115
Lighting Control	Manual on/off and daylight controls are assumed for all bedrooms. PIR presence detection + daylight dimming in restaurant and reception, PIR to circulation and all back of house spaces	Manual on/off and daylight controls are assumed for all bedrooms. PIR presence detection + daylight dimming in restaurant and reception, PIR to circulation and all back of house spaces	Manual on/off and daylight controls are assumed for all bedrooms. PIR presence detection + daylight dimming in restaurant and reception, PIR to circulation and all back of house spaces

The term ‘Business as Usual’ Business as usual’ scenarios is meant to represent the type of fabric and ventilation specifications that most applicants in London would consider ‘standard’ for a hotel.
For consistency it has not been changed compared with the initial 2019 study. We think that this approach is acceptable as ‘Business as usual’ has not changed significantly in terms of fabric and ventilation specifications
**Variations in thermal bridging have not been modelled as the software doesn’t support modelling psi values so adds a default 25% uplift to all U-values in actual building in accordance with NCM.*

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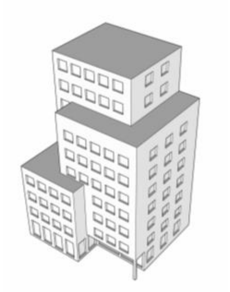

This table summarises the different heating system assumptions modelled based on the four different scenarios.

	A Gas boiler	B Less efficient Heat Pump System *Central heat pump*	B VRF	D More Efficient Heat Pump System *Central heat pump*
Description	Gas boiler serving a heating system with flow and return temperature 70°C/50°C	Heat pumps serving a heating system with flow temperature 65°C	VRF units	Heat pumps serving a heating system with low flow temperatures 45°C fed from ground source array
Heating emitters	LTHW Fan Coil Unit fed by gas boiler	LTHW Fan Coil Unit fed by reversible chiller/heat pump	LTHW Fan Coil Unit fed by VRF	LTHW Fan Coil Unit fed by heat pump
Hot water system	A 3500L hot water store	A 3500L hot water store	A 3500L hot water store	A 3500L hot water store
Heating and hot water seasonal efficiency	95% for heating and hot water	220% for heating and hot water*	400% for heating 300% for hot water	450% for heating 300% for hot water
Waste Water Heat Recovery (WWHR)	No WWHR assumed	No WWHR assumed	No WWHR assumed	No WWHR assumed
Cooling seasonal efficiency	5.0	5.0	5.0	5.0
Distribution efficiency (heating, cooling and DHW)	95%	95%	95%	95%

**The system C heat pump efficiency of 220% was used to be consistent with the CoC1 study. The minimum efficiency allowed under Part L is 250%.*

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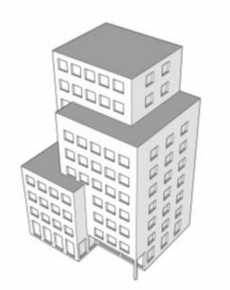

Hotel building | Photovoltaics (PVs)

This table summarises the different sizes of PV system assumed.

NEW New input for Part L 2021

	No PV	PV
Description	This assumed no PVs at all on the roof or any of the elevation	This assumes a standard practice for PVs. No particular effort has been made to design the roof in order to accommodate PVs.
Photovoltaic Panels (kWp)	0	45.02
Module Efficiency (%)	N/A	TBC%
Assumed area (Panel area)	N/A	202m² (50% of footprint)
Tilt	N/A	30° (Horizontal)
Shading	N/A	Average/unknown
Battery capacity (kWh) NEW	N/A	N/A
Predicted Annual Yield	N/A	38,120 kWh

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12.4

Heat networks

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12.4.1

Heat networks: Distribution losses

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Distribution losses | What they are

Heat losses occur at different points in a heat network. Primary losses must be included in the calculation of carbon intensity of the heat supplied by the network. Secondary losses are only counted, wholly or partially, if the counterfactual system doesn't have the same losses. Both primary and secondary losses are included in the Part L assessment.

Primary Losses

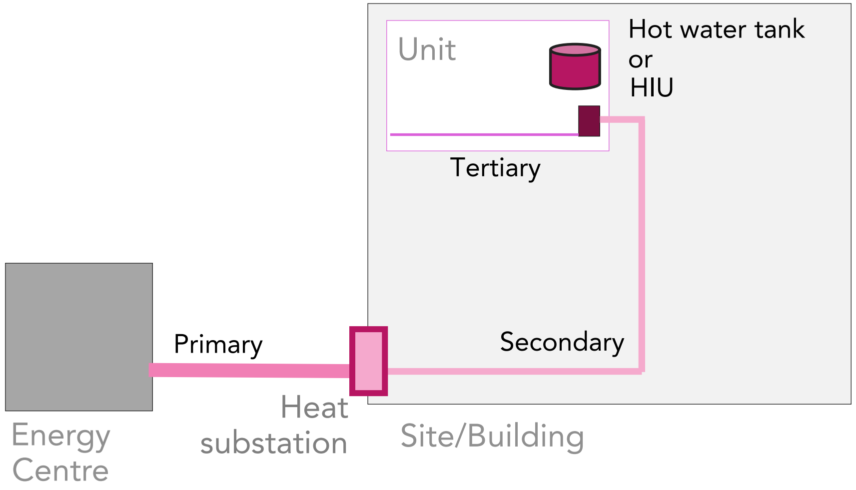
- Within the Energy Centre.
- From primary pipework between the heat generation equipment and the site, generally within the ground. Pre-insulated pipework is generally used. The larger the pipe diameter (larger networks and greater number of homes connected), the higher the heat loss per metre of pipework. Phased systems, which use larger pipework than immediately needed to allow for future expansion of the network, carry a distribution heat loss penalty in the early phases as a result.

Secondary Losses

- From heat substations at the entry point to each building or core. Most large heat networks incorporate heat exchangers at the point of entry to individual sites, buildings or cores. The losses from the heat substations may be counted as primary or secondary or split, depending where in the system the main DHN meter is located.
- From secondary pipework between the site boundary, or the heat substation and each domestic unit. Some parts of the secondary pipework may be in the ground on the site, and some will be in communal risers and corridors within apartment buildings.

Tertiary Losses

- Heat Interface Units (HIU) or hot water storage and pipework, especially hot water for domestic use, lose heat within each dwelling. These losses are not included in assessments of distribution losses but in summer, these heat losses from the network still occur and contribute to overheating risks in the homes.



Categories of distribution and standing losses on a heat network

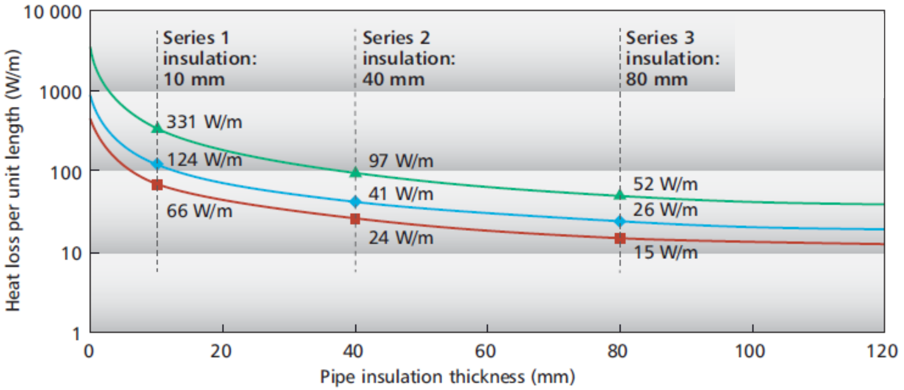


Figure 30 Indicative heat losses from insulated pipes and relative performance of Series 1–3 insulation (for a pair of flow and return pipes at fixed ambient and fluid temperatures) (source: GLA, 2014)

Typical pipework losses (extract from CIBSE CP1) for pre-insulated heat network pipes of different diameters.

The losses from networks are heavily driven by the length of the pipework – this can be several km for some systems. It is important that these are evaluated for the specific systems and not estimated simply as a factor, assuming best practice can always be delivered.

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Distribution losses | The risk of focusing on % instead of absolute losses

It is a fundamental characteristic of heat networks that buildings using the heat are linked to the energy centre by a system of pipework carrying hot water. The temperature of the water varies between different system types. Older networks generally have water at or above 80^{O}C, more modern networks generally are being designed to work at lower temperatures, more suited to heat pumps.

The losses from networks are heavily driven by the length of the pipework – this can be several km for some systems. It is important that these are evaluated for specific heat networks and not estimated simply as a factor, assuming best practice can always be delivered.

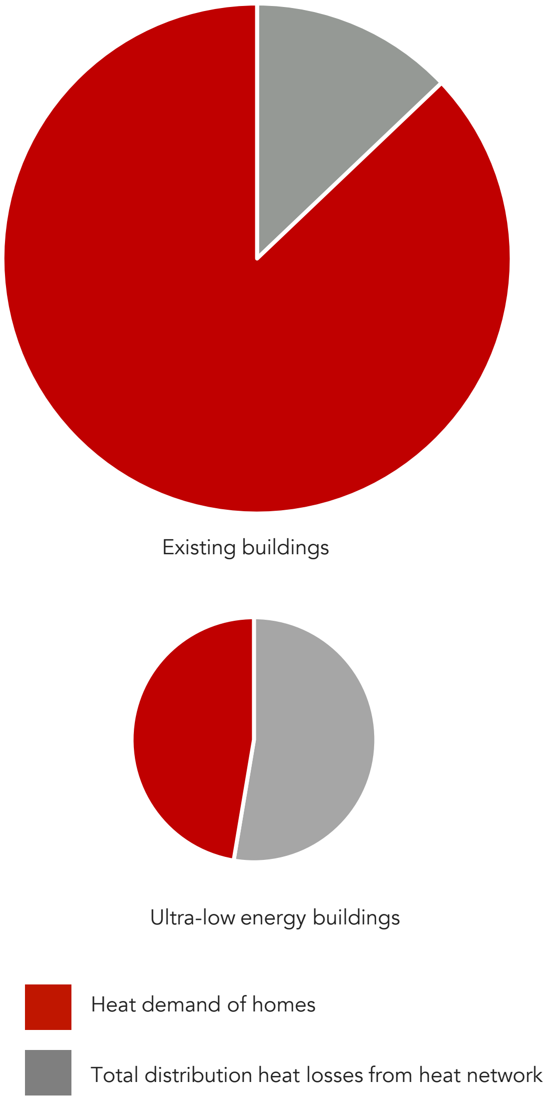
Distribution Loss Factor (DLF)

In a Part L assessment, distribution losses from heat networks are the combination of primary distribution losses (off-site) and secondary losses (on-site).

According to the latest SAP guidance, a default value of 2.0 should be used (i.e. the amount of heat lost is equal to the amount of heat delivered to homes), unless the network is designed to CP1, in which case it can be reduced to 1.5 (i.e. the amount of heat lost is half the amount of heat delivered to homes). Alternatively, a loss factor specific to the network can be used.

Assessing distribution losses only as a proportion of heat demand is not accurate though. The same absolute losses would represent a much higher proportion of heat demand for ultra-low energy buildings compared to 'business as usual' or existing buildings.

We recommend that heat losses are calculated in absolute terms and a network specific loss factor calculated from the **actual predicted system losses** and the **actual predicted heat demand of the homes** connected to the network.



Distribution losses of a heat network do not vary with heat demand: the smaller the heat demand, the higher proportion distribution losses will be

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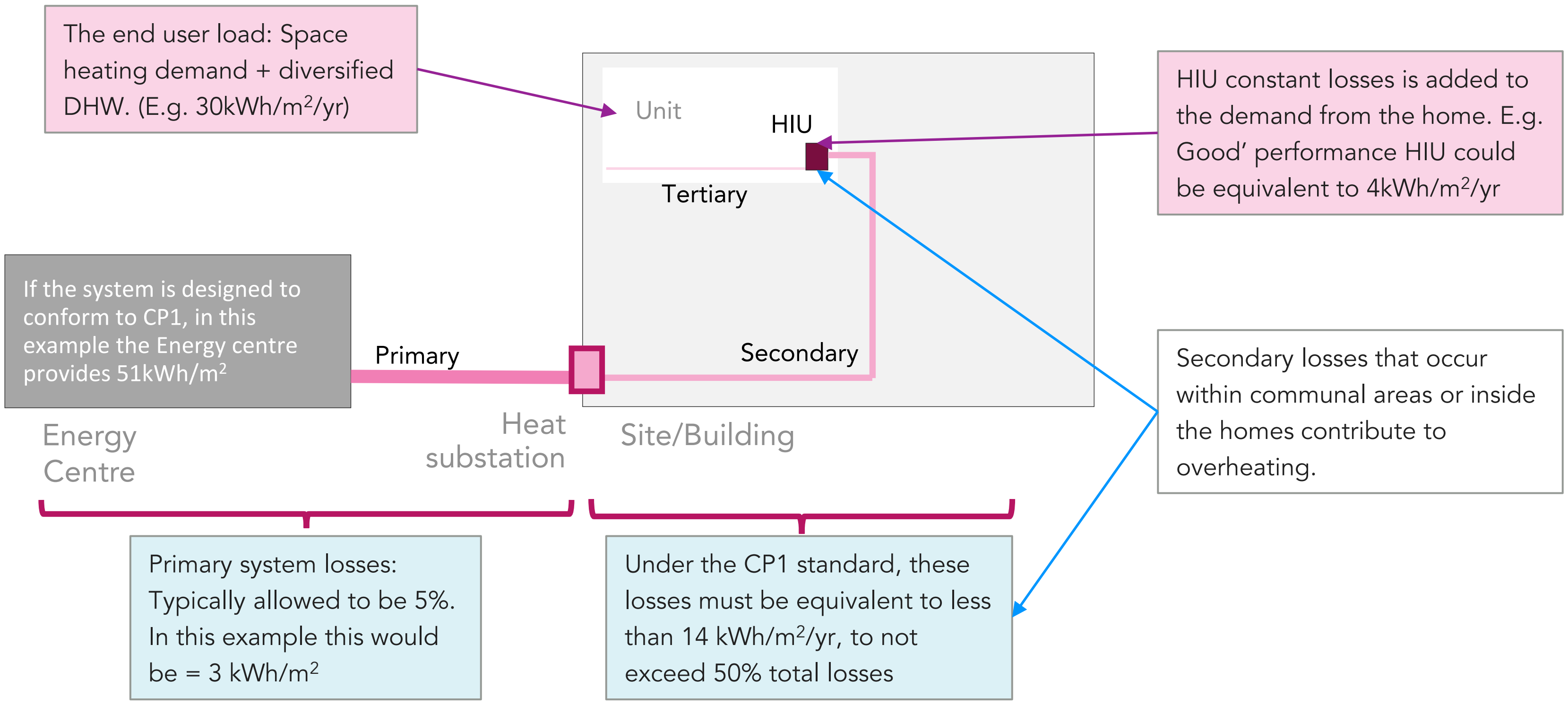
Distribution losses | A better understanding of absolute losses and what applicants need to provide



The end user load: Space heating demand + diversified DHW. (E.g. 30kWh/m^2/yr)

HIU constant losses is added to the demand from the home. E.g. Good' performance HIU could be equivalent to 4kWh/m^2/yr

If the system is designed to conform to CP1, in this example the Energy centre provides 51kWh/m^2

Secondary losses that occur within communal areas or inside the homes contribute to overheating.

Primary system losses: Typically allowed to be 5%. In this example this would be = 3 kWh/m^2

Under the CP1 standard, these losses must be equivalent to less than 14 kWh/m^2/yr, to not exceed 50% total losses

Figure 10.2 - Example of distribution losses on a heat network

The applicant's proposal should state the assumed, calculated or predicted energy demand for each home connected to the network. This should be the space heat demand and a diversified domestic hot water demand. The losses from the Heat Interface Units (HIU) are included in the heat demand of the home, along with losses from pipework inside the home.

The proposal should state the primary losses. This is usually given as a % of the heat generated in the energy centre (as opposed to of the heat delivered to the end user which is used for the other loss calculations) and is calculated by the DH network provider.

The heat lost from equipment and pipework that is on the building side of the heat substation, (or main building heat meter if there is no heat substation) are secondary losses, up to but not including the heat interface units in each home. The heat substation is usually on the secondary side of the meter but this should be stated and shown on the schematic and the losses from it accounted for.

For a system designed to conform to CIBSE best practice guide 'CP1', the absolute total of the primary and secondary losses should be less than half the total heating and hot water demand of the homes served.

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Distribution losses | How they are represented in Part L calculations

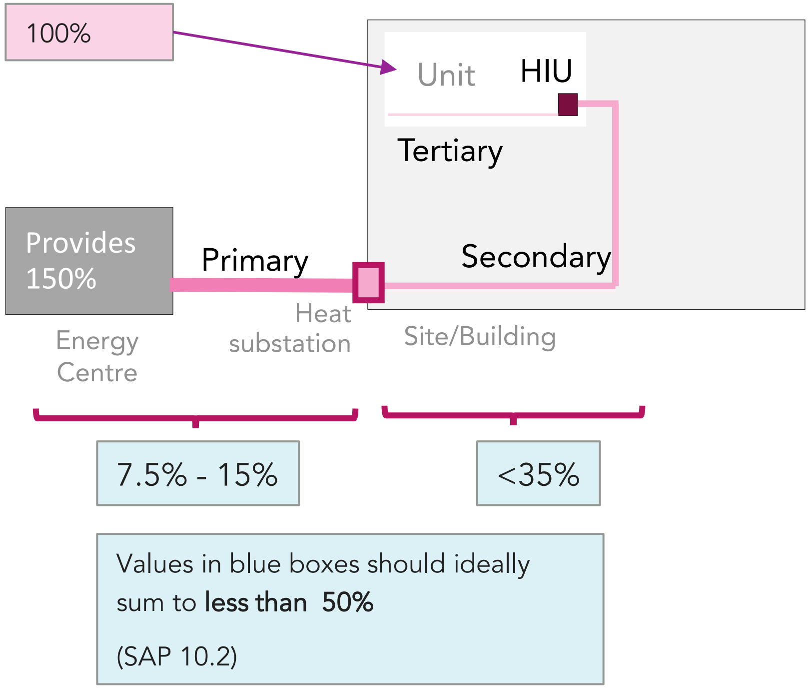
The difference between the energy entering the distribution network and that delivered to an end user is referred as 'distribution losses'. The energy performance of the buildings served – the heat they need –affects the absolute efficiency that the network is required to achieve.

These losses relate directly to carbon emissions and although some can be unavoidable, they can be reduced by suitable techniques and equipment efficiency.

In a Part L assessment, distribution losses from heat networks are the combination of primary distribution losses (off-site) and secondary losses (on-site).

Relevant points of the guidance include:

- For domestic use, assessments carried out using SAP would represent these losses with the **Distribution Loss Factor** (DLF), applicable to domestic and non-domestic buildings.
- For an Ultra low energy home of around $70m^2$ NIA, if the total demand for the home is 100%, then all the losses within the system have to sum to less than 50% to comply with SAP 10.2.
- According to the latest SAP guidance, a default value of 2.0 should be used for new buildings supplied by heat networks if those are not designed and commissioned in accordance with CIBSE's code of practice (CP1).
- CIBSE design guidance sets a limit for heat losses from pipework within the building equivalent to 35% of the CCC compliant home. The guidance also recommends limiting primary pipework losses to 10% of the heat generated, i.e 15% of heat delivered.
- If the network is designed to CP1, the DLF can be reduced to 1.5. Evidence must be available from both the network design and commissioning engineers to validate the design.
- Alternatively, a loss factor specific to the network can be used.



Breakdown of distribution losses to comply with the CIBSE CP1 design requirements.

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12.4.2

Heat networks: interim systems

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Interim systems when the network is not ready

Heat networks are large scale installations which generally need a reasonably significant heat demand in place to function effectively. Where the network is serving principally new developments, it is often necessary to have an interim arrangement in place in the early stages until sufficient accommodation has been built to provide a large enough load for the final plant. This will often be the case for networks based around CHP plant.

Conversely, for networks based around Energy from Waste (EfW) plant, it is often the case that new housing or other developments are built some years before a planned Energy from Waste plant is built and operational, due to the long lead times and complex permissions needed for the EfW plant.

In both instances, an interim system is needed to provide the heat source to the homes that are built and occupied before the heat network is fully up and running. Most often, this interim solution will be gas fired boiler plant because the capital costs are low.

Although the GLA energy assessment guidance states that interim solutions have to be time limited, the risk is that the interim solution is in place for many years, or even becomes effectively permanent if the full system plan is never delivered. This allows the installation of many gas boilers which do not meet policy requirements for carbon emissions reductions.

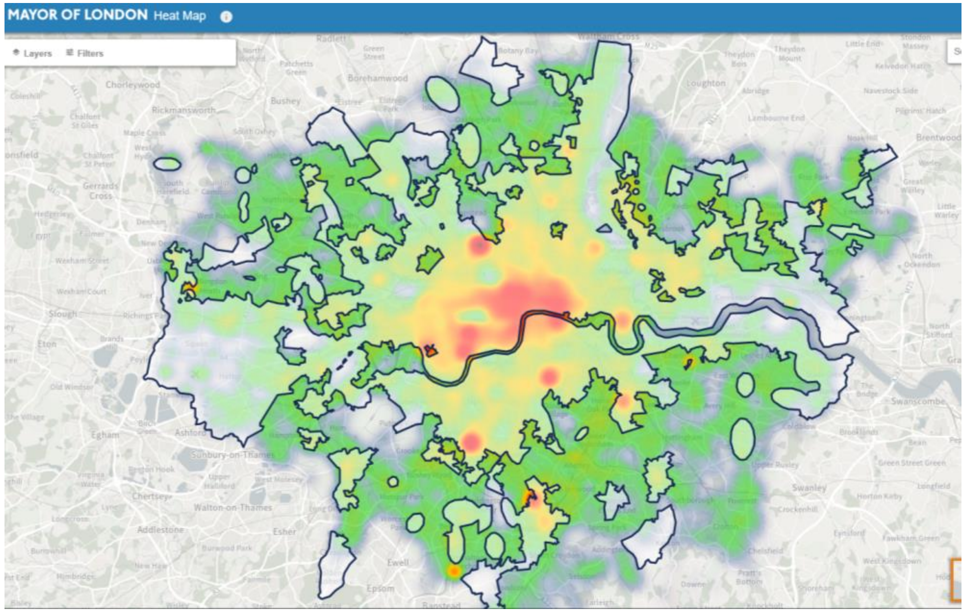

Figure 9.3 - Heat Network Priority Areas cover a substantial proportion of Greater London

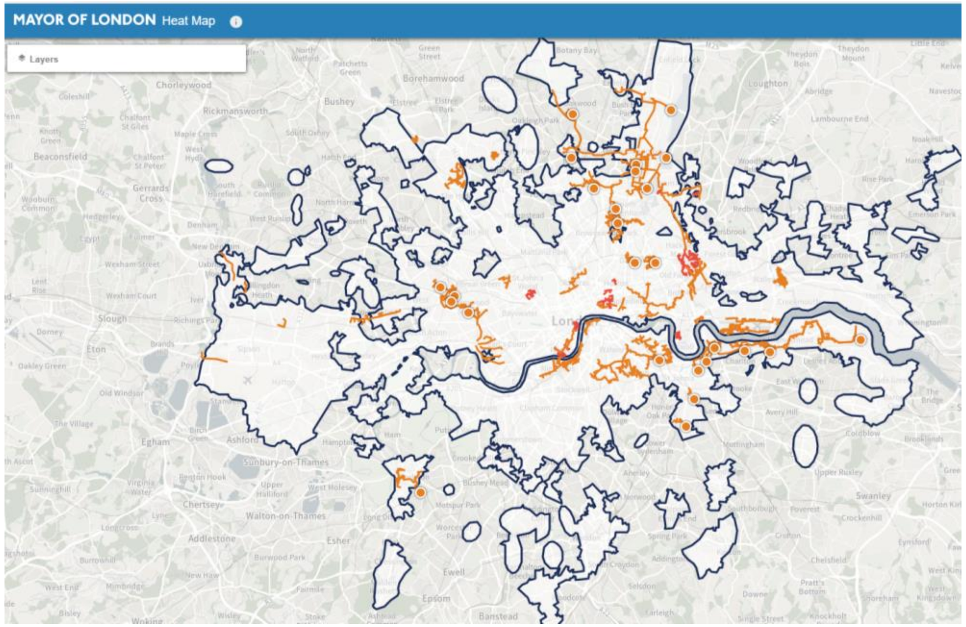

Figure 9.4 - The extent of the existing operational heat networks is very limited, although there are more networks proposed

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12.4.3

Heat networks: Energy from Waste and carbon emissions

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Energy from Waste | Carbon factors

Carbon Dioxide emissions

Energy from waste (EfW) plants, where municipal waste is burned to generate electricity and, as a by-product, heat, are generally considered to be low carbon heat sources for heat networks. However, it should be recognised that for each tonne of waste burned, between 700 and 1,700 kg of CO_2 is produced (Environment Agency).

These emissions are attributed to the electricity generated and not to the heat, so in the inventory of emissions, the heat appears to have very low carbon emissions. For electricity generation, the CCC have advised that the EfW generation emissions need to reduce in UK net zero, so the EfW plant will come under pressure to decarbonise before 2050. There are two ways to reduce the emissions; reduce the amount of waste that is burned or adopt a Carbon Capture and Storage (CCS) technology. Currently, CCS is not available at scale. If it is developed, it is likely that its operation will be dependent on having specific geology at the emissions sites where it is used. If CCS is either not viable, or not possible in the specific location, then either the amount of waste burned will have to reduce, or the plant will have to be relocated. Either way, the source of low carbon heat relied upon by the heat network could significantly reduce or could disappear entirely, so for any EfW based system, a back up low carbon heat source should be identified and considered in the planning.

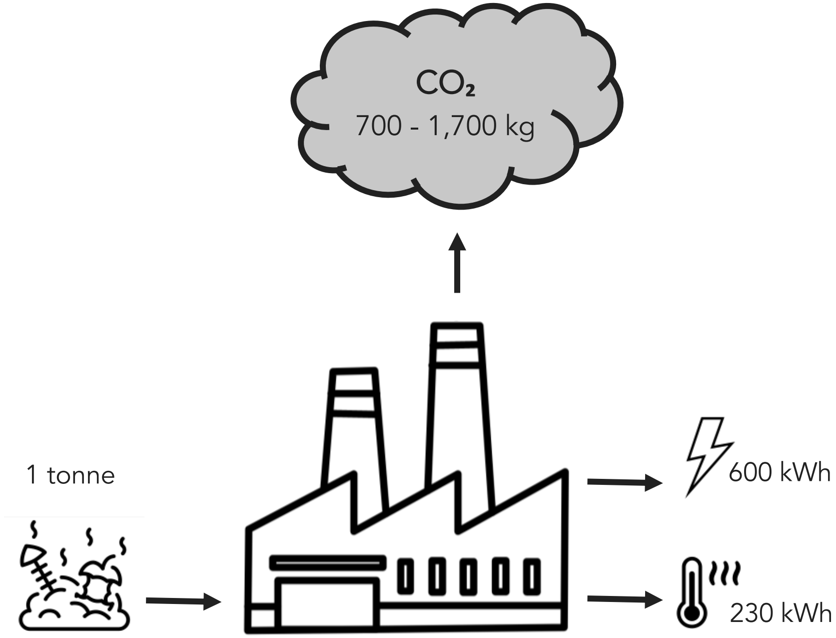

Diagram showing electricity, heat, and carbon dioxide produced through the combustion of 1 tonne of municipal solid waste in a typical waste to energy plant.

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