Building the Case for Net Zero:
Closing the gap towards net zero carbon new-build homes

Summary Report

OCTOBER 2022

Acknowledgements

UKGBC would like to offer a special thanks to all task group members who contributed to this study:


Andy Matthews
Arcadis


Andy Sharpe
Grosvenor


Dan Fairley
Terence O'Rourke


Daniel Shea
Barratt


Danielle Michalska


Elliot Taylor
Arcadis


Josephine Benthall
Buro Happold


Marios Tsikos
One Click LCA


Mark Dowson
Buro Happold


Martha Dillon
Buro Happold


Oliver Novakovic
Barratt


Richard Burton
Terence O'Rourke


Richard Proctor
Arcadis


Rupert Biggin
Grosvenor


Terry Williams
Terence O'Rourke


David Day
Arcadis

With thanks to the task group organisations:

ARCADIS, BARRATT DEVELOPMENTS PLC, BURO HAPPOLD, GROSVENOR, One Click LCA, TERENCE O'ROURKE

With thanks to UKGBC's Advancing Net Zero Programme Partners:

Lead Partner:

Laudes Foundation

Corporate Partners:

ARUP, bam, Berkeley Group, British Land, BURO HAPPOLD, CBRE, ENGIE Impact, GROSVENOR, HOARE LEA, Hydrock, ISG, JLL, lendlease, LLOYDS BANKING GROUP, Low Carbon Alliance, ROCKWOOL, Turner & Townsend

Contents

EXECUTIVE SUMMARY	**4**
Best practice targets	4
Key findings	5
INTRODUCTION	**6**
Purpose	6
Context	7
Methodology	7
FIRST PRINCIPLES FOR A DEFINITION OF NET ZERO CARBON NEW-BUILD HOMES	**8**
KEY FINDINGS	**10**
Operational energy	12
Embodied carbon	14
Cost changes	17
Top 4 cost variables	18
GLOSSARY OF TERMS	**20**
REFERENCES	**21**

This document is produced for general guidance only. How you choose to use it is up to you. While the guidance has been produced in good faith, it does not constitute advice and UKGBC and the authors of this guidance do not represent or warrant that the content is suitable for your purposes, accurate, complete or up to date. UKGBC and the authors exclude all liability whether arising in contract, tort (including negligence) or otherwise, and will not be liable to you for any direct, indirect or consequential loss or damage, arising in connection with your use of, or reliance on, the guidance.

Executive Summary

This feasibility case study, produced by UKGBC alongside a diverse industry task group, examines a typical, low-rise residential development with four home typologies to test the technical and financial viability of such a scheme achieving current best practice design targets.

It is clear that new homes being built today are a long way from achieving the performance thresholds likely to be required for credible net zero carbon claims[1]. Indeed, substantially reducing whole life carbon emissions from new-build homes is critically urgent in order to enable true 'net zero carbon' homes as soon as possible.

It is currently unclear whether current best practice design targets will be ambitious enough trajectories, yet they provide a helpful proxy for the step change in performance likely to be required from new-build homes to bring them closer to a credible net zero carbon definition (as illustrated in Table 1).

The purpose of this work is two-fold: firstly, we will provide the key principles for a definition of net zero carbon new-build homes; secondly, we will provide real-world evidence of how practical it might be (in technical design and economic terms) to achieve substantial improvements in the operational and embodied carbon performance of new-build homes by 2025 (or soon thereafter). Both areas of focus have been selected with the aim of enabling genuine net zero carbon new-build homes to be delivered as soon as possible.

It should be noted that the findings of this research relate to one particular residential scheme, with a pre-determined set of home typologies. While it cannot be deemed a conclusive set of results for all new-build homes in all UK locations, it provides indicative insights into the relative challenges and opportunities for closing the gap between current new home delivery and net zero carbon standards.

BEST PRACTICE TARGETS

Given that science-based decarbonisation levels have not yet been defined in absolute terms, it was decided that the appropriate targets to utilise for this particular feasibility study should be both currently in use by industry leaders, and a substantial improvement on standard levels of performance typically achieved by new-build homes in today's market.

As a result, the project team defined two separate decarbonisation steps – one categorised as 'intermediate' and another as 'stretch' across both operational and embodied carbon for new-build homes. These can both be legitimately positioned as closing the gap between performance achieved by new-build homes today and genuinely credible net zero carbon new-build homes in the future. They are summarised in Table 1 below.

The performance targets required to warrant credible claims of net zero carbon new-build homes will need to be science-based and derived from the carbon budget remaining for the whole of the UK. They will then need to be apportioned in relative terms to the UK's residential sector, thereby ensuring only a fair share of the carbon budget is used.

These targets are due to be developed under the UK Net Zero Carbon Buildings Standard[2] initiative that is currently underway, drawing upon analysis from UKGBC's Net Zero Whole Life Carbon Roadmap published in November 2021.[3] In the interim, the stretch targets in Table 1 provide a useful 'net zero carbon' scenario for the purpose of this feasibility study, the modeling for which was undertaken in 2021. Together, they provide a useful stretch scenario for the purpose of this feasibility case study, the modelling for which was undertaken in 2021.

Table 1: Energy and embodied carbon performance targets for new-build homes

			Analysed in this feasibility case study		
		Business as usual	Intermediate targets	Stretch targets	Net zero carbon targets
		From RIBA 2030 Climate Challenge and LETI Climate Emergency Design Guide			TBC
Operational energy	Regulated	31% carbon reduction (Part L, 2021)	75-80% carbon reduction (Future Homes Standard, 2025)	100% carbon reduction (speculative target)	Currently under development via the UK Net Zero Carbon Buildings Standard initiative
	Regulated and unregulated[6]	120 kWh/m^2/year	60 kWh/m^2/year	35 kWh/m^2/year	
Embodied carbon	Upfront carbon emissions (construction only, module A)[7]	800 $kgCO_2e/m^2$	500 $kgCO_2e/m^2$	300 $kgCO_2e/m^2$	
	Embodied carbon emissions (whole life, modules A-C, excl B5 & B6)[8]	1200 $kgCO_2e/m^2$	800 $kgCO_2e/m^2$	625 $kgCO_2e/m^2$	

KEY FINDINGS

The most encouraging finding of this feasibility case study was that both intermediate and stretch targets for both operational and embodied carbon can be achieved on new-build residential schemes today. In other words, the substantial decarbonisation of this type of new-build home is very much within reach using technical design solutions available in today's marketplace.

Regarding the **operational carbon** efficiency, the case study research found that:

- Achieving near Passivhaus standards for the building fabric will significantly help to achieve the stretch levels of energy performance for new-build homes (35-40 kWh/m^2/per year).
- Delivering such high standards for the building fabric will require improvements in construction standards and processes to reduce the 'performance gap', and general upskilling of all trades will be required to deliver this at scale.
- Homes powered by fossil fuels (e.g., gas boilers) are not compliant with a net zero carbon future as they produce substantial greenhouse gas emissions so would need retrofitting in the 2030s to achieve our national carbon targets. Any new-build home which seeks to close the gap with net zero carbon will need to switch to highly efficient zero carbon heat sources.

Regarding the **embodied carbon** efficiency, the case study research found that:

- Low-carbon products verified using Environmental Product Declarations can be substituted into the original design. However, some products may not be reasonably switched out at this point as these may be too expensive or limited in supply, highlighting additional maturity required from the supply chain.
- In this case study, the superstructure makes up over half of the total upfront carbon, primarily due to the use of carbon-intensive construction materials (e.g., structural steel beams, concrete block, brick and stone façade). Significant carbon reduction emissions can therefore be found by redesigning structural frames to use lean designs, and by focussing on reducing manufacturing-related emissions for beams, blocks and bricks and developing reused material supply chains.
- Achieving ultra-low levels of energy performance can result in additional embodied carbon. For example, adding low carbon insulation to walls can increase wall thickness, highlighting the importance of undertaking whole life carbon assessments to drive decision-making.
- Best practice targets were reached, but the study was not able to reduce the embodied carbon to zero using traditional design practices. To achieve this today, targeting reused materials, adaptive reuse of existing spaces and using sustainably sourced timbers would be required.

In terms of the financial viability of making such changes to the design of the original scheme, the case study research found that the intermediate targets could be achieved today with a capital cost uplift estimated to be around 8%. However, perhaps unsurprisingly, the case study research also found that achieving the stretch targets in today's market conditions would be challenging – with an estimated 19% capital cost uplift to doing so on this particular scheme. The most significant contributing design factors were the significant upgrades to building fabric and additional building services to deliver ultra-low levels of energy performance, which are considered relatively expensive in today's market.

When considering any such capital cost increases, it is worth reflecting on historic trends. In the period between 2009 and 2015, the additional capital costs of delivering new homes that met the Code for Sustainable Homes level 4 had almost halved[4] – principally due to clarity and consistency on medium-term policy[5] direction, allowing the supply chain to confidently invest in the changes required to meet such standards and thereby dramatically reduce the capital cost of doing so over time. The fact that the technical solutions exist already today suggests that, with some additional policy incentives, the overall cost of delivering these should reduce as mass scale up of adoption is achieved.

The overarching conclusion has to be that any aspiration to deliver credible net zero carbon new-build homes at scale is reliant upon specific and targeted policy interventions to help stimulate the market for low carbon technologies, products, materials and construction practices. For example, setting thermal energy demand limits will drive improvements in building fabric, leading to increased demand and lowering of costs for high-performing insulation.

The Future Homes Standard that is being introduced in 2025 presents a unique opportunity to embed some of the targets used in this case study into Building Regulations – indeed, unless it does so, the future delivery of net zero carbon new-build homes is very much at risk.

Introduction

This report aims to bring greater clarity to the ongoing debate surrounding net zero carbon new-build homes in the UK. In close collaboration with the partners of our Advancing Net Zero programme in 2021/22, UKGBC set out to investigate both the technical feasibility and cost implications of achieving different levels of operational energy and embodied carbon performance for four representative types of new-build homes.

This was undertaken with a view to identifying how quickly we might be able to achieve much higher levels of performance than those being achieved today – indeed, levels of performance that more closely resemble what is likely to be required for new-build homes to credibly claim to be net zero carbon. It follows on from a previous UKGBC study[9] which illustrated how two new high-rise buildings – an office tower and residential block – could be designed to reach best practice performance targets and the effect this had on capital cost.

This study is based on an assumption that build rates of new homes will continue to increase to meet the governmental target of building 300,000 new-build homes a year by the mid-2020s,[10] which validates the need to urgently close the gap between the performance of new-build homes today and the achievement of genuinely net zero carbon new-build homes. However, from a whole life carbon perspective, the first priority should always be to refurbish and retrofit existing homes where appropriate and repurpose suitable existing buildings into residential ones so as to drive down the need for new-build homes. This reduces upfront construction and embodied carbon of new-build development.

This is an important consideration for sectoral modelling to determine the contribution that both new-build homes and existing homes can make to the overall carbon budget for the UK built environment sector. It should be noted that UKGBC has an extensive separate workstream on home retrofit for Government and industry to become involved in.[11]

This Summary Report includes the headline findings and takeaways from the study and was launched alongside the Technical Report which includes the detailed modelling and further technical information. The Summary Report should, ideally, be read before the Technical Report to provide adequate context and framing.

PURPOSE

The purpose of this feasibility case study is to:

1. **Propose first principles for a definition of new-build net zero carbon homes** which, following the inclusion of science-based performance targets to be agreed in future, can be utilised consistently as a credible medium-term goal.
2. **Investigate both the technical and financial feasibility** of achieving best practice design targets today that more closely resemble the level of ambition required for science-based net zero carbon performance targets.

The findings are intended to help improve the collective understanding of both Government and industry, outlining the path for the delivery of new-build net zero carbon homes at scale. For those looking to future-proof homes currently in design, the findings are intended to raise awareness and stimulate forward planning to address the key challenges.

CONTEXT

- The latest IPCC report unequivocally states that the global economy must halve emissions by 2030 to avoid the worst effects of climate change by limiting global temperature increase to 1.5C.[12]
- In the UK, the government has committed to reducing emissions by 78% by 2035 and reaching net zero emissions by 2050,[13] whilst continuing to meet the needs of the economy and build 300,000 new-build homes a year by the mid-2020s.[14]
- The 2022 Report to Parliament by the Committee on Climate Change[15], however, categorically highlights buildings, and specifically policies to decarbonise new-build homes, as being a key risk to the delivery of the required emissions reductions for the Government's pathway and the Sixth Carbon Budget.
- The World Green Building Council states that all new buildings (including homes) should be net zero for operational carbon and have at least 40% less embodied carbon by 2030.[16]

UKGBC's Net Zero Whole Life Carbon Roadmap states that new-build homes '*must be equipped to deliver the energy performance levels required for net zero… [to] avoid the need for future retrofitting and remove the risk of future occupant disruption, cost and embodied carbon emissions.*' [17]

New-build homes designed in the UK today to meet Part L 2021 are still not achieving sufficiently ambitious levels of fabric performance and operational thermal efficiency to qualify as net zero carbon. In fact, they are not yet required to reduce embodied or upfront carbon at all. Delivering new-build homes that are genuinely net zero carbon requires a step change from current business-as-usual practices.

METHODOLOGY

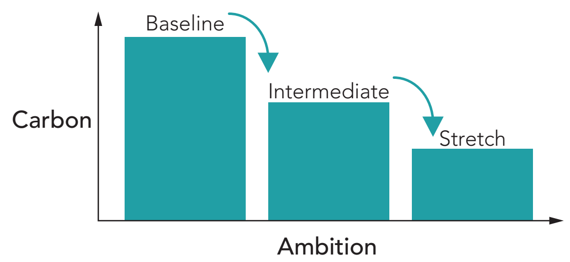
This feasibility case study was based on a comparative analysis of different design scenarios for a real-world, large-scale residential scheme. The Trumpington South development, located in Cambridgeshire, is a 750-home low-rise residential scheme being proposed by Grosvenor. This scheme was selected as a case study as it was considered representative of current new low-rise residential developments. This report – on homes – has been published following an initial report[18] on the masterplan. Both reports should be read in conjunction to paint a complete picture of low carbon residential development delivery.

The **baseline** scenario assumes that homes currently in design will perform roughly in alignment with Part L 2021 updates (introduced in June 2022). Best practice design targets have then been used covering both operational (regulated and unregulated energy) and embodied carbon emissions. Targets used have already been adopted by other industry bodies and represent both **intermediate** and **stretch** scenarios, as described in the next section and outlined in Table 1.

All three scenarios were then modelled for carbon, energy, and cost by iterating design and construction choices for the following home typologies:

Type	No. of bedrooms	Size
Detached house	4	145m²
Semi-detached house	3	113m²
Terrace house	3	103m²
Apartment block	1&2	3-4 storey

Figure 1: Four types of homes were modelled across three design scenarios representing increasingly ambitious reductions in carbon



First principles for a definition of net zero carbon new-build homes

UKGBC published the Net Zero Carbon Buildings Framework Definition[19] in 2019 – widely recognised as the industry consensus for how to achieve a net zero carbon building. Prior to this publication, historical 'zero carbon' policies focused mainly on operational energy. Our framework expands the scope of the definition to encompass the whole life carbon impacts, which can be broken down into two main components:

- **Operational carbon** – covering emissions related to regulated and unregulated energy use.
- **Embodied carbon** – covering emissions related to materials and construction processes throughout the construction, operation and end-of-life of a building (estimated over a 60-year lifespan).

For new-build homes, the framework sets out how 'net zero carbon – construction' can be achieved (at practical completion) whilst enabling them to achieve 'net zero carbon – operational energy' (when in-use). See Figure 2.

In terms of how to achieve net zero carbon, there is broad consensus that the following guiding principles would need to be met for new-build net zero carbon homes:

- High fabric standards
- Low embodied carbon materials (including reuse, disassembly, etc.)
- Low energy demand (including energy demand management and flexibility)
- No fossil fuel use
- On-site renewable generation
- Performance monitoring (in-use), and intelligent energy control mechanisms

However, it is crucial to note that while UKGBC's Framework specifies clearly which scopes of carbon should be included in net zero carbon building claims, it does not yet provide scientifically derived targets for those scopes that are in line with sector-level 1.5°C compatible pathways by 2050. Doing this requires a sectoral approach to setting both operational energy and embodied carbon targets for different asset types to define the acceptable levels of 'residual emissions' for new construction and existing buildings that would ultimately need to be removed or neutralised. Just as the SBTi Corporate Net Zero Standard[20] specifies that a company is only considered to have reached net zero when it has achieved its long-term science-based target and used carbon removals to neutralize any limited emissions that cannot be eliminated, so should buildings that are claiming to be net zero carbon also have to achieve scientifically pre-determined reductions in both operational and embodied carbon that are then neutralised.

This is the main reason why leading industry organisations (BBP, BRE, The Carbon Trust, CIBSE, IStructE, LETI, RIBA, RICS, and UKGBC) have joined forces to develop a Net Zero Carbon Buildings Standard.[21] This standard will include the metrics by which net zero carbon is evaluated, as well as the performance targets, or limits, that need to be met across different scopes. New-build homes will be a priority asset type for this Standard, with the underpinning metrics and targets set to be published in 2023.

In the meantime, best practice targets have emerged from a range of industry organisations including UKGBC itself, as well as the London Energy Transformation Initiative (LETI) and Royal Institute of British Architects (RIBA). Whilst these targets may not ultimately match the science-based performance targets required for new-build homes, they are on the correct trajectory and can be used as proxies for what will need to be achieved on the pathway to true net zero carbon. Given the significant gap between business-as-usual performance based on today's Building Regulations, and the carbon reduction targets that will be required for credible net zero carbon claims, they represent useful interim targets for both an intermediate and a stretch scenario.

The table below sets out the best-practice design targets selected for the purpose of this feasibility case study. Please note, in addition to meeting performance targets, residual emissions must also be neutralised or removed to make any credible net zero carbon building claim – as set out in UKGBC's Framework for guidance on offsets and renewable energy procurement.

Figure 2: UKGBC's framework sets out two definitions for net zero carbon that can be achieved today

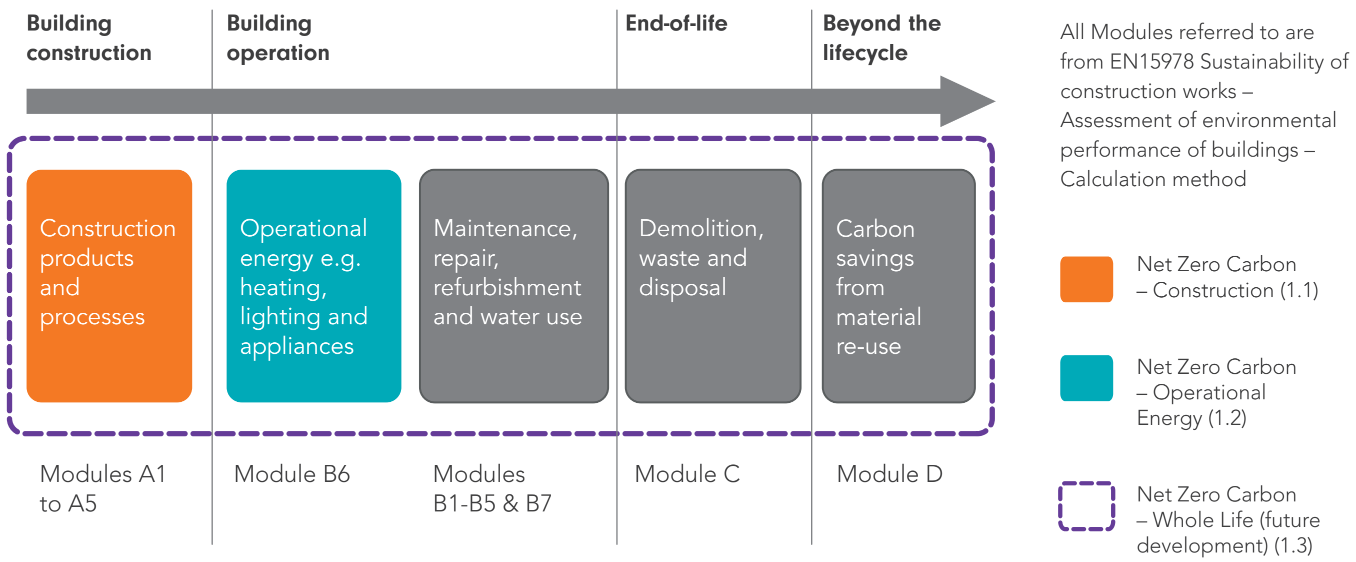


Table 2: Energy and embodied carbon performance targets for new-build homes

			Analysed in this feasibility case study		
		Business as usual	Intermediate targets	Stretch targets	Net zero carbon targets
		From RIBA 2030 Climate Challenge and LETI Climate Emergency Design Guide			TBC
Operational energy	Regulated	31% carbon reduction (Part L, 2021)	75-80% carbon reduction (Future Homes Standard, 2025)	100% carbon reduction (speculative target)	Currently under development via the UK Net Zero Carbon Buildings Standard initiative
	Regulated and unregulated[33]	120 $kWh/m^2/year$	60 $kWh/m^2/year$	35 $kWh/m^2/year$	
Embodied carbon	Upfront carbon emissions (construction only, module A)[34]	800 $kgCO_2e/m^2$	500 $kgCO_2e/m^2$	300 $kgCO_2e/m^2$	
	Embodied carbon emissions (whole life, modules A-C, excl B5 & B6)[35]	1200 $kgCO_2e/m^2$	800 $kgCO_2e/m^2$	625 $kgCO_2e/m^2$	

Key findings

This section presents the key findings of the feasibility case study. The findings provide a set of design options* to reach the operational energy and embodied carbon targets respectively, for both the intermediate and stretch scenarios. This is followed by the associated capital cost of delivering these design options in today's market conditions.

Table 3: Summary of technical design options to meet increasingly ambitious performance targets

		Baseline	Intermediate	Stretch
BUILDING FABRIC				
Windows	Type	Double	Double	Triple
	U-value	1.4	1.1	0.7
	G-value	0.44	0.6	0.6
External walls (U-value)		0.21	0.17	0.13
Roof (U-value)		0.19	0.12	0.1
Ground floor (U-value)		0.2	0.14	0.1
Thermal bridging		Default thermal bridges	Approved construction details	Passivhaus construction details
Air tightness (m³/(hm²) @ 50 Pa)		5	3	1

	Baseline	Intermediate	Stretch
BUILDING SERVICES			
Ventilation	Natural ventilation (for houses) Mechanical extract ventilation (for apartments)	Mechanical extract ventilation (for all)	Mechanical ventilation with heat recovery (for all)
Heating	Gas boiler (on-plot)	Option 1 - Air source heat pump (on-plot); and Option 2 - Air source heat pumps (via a district heat network)	Air source heat pump (on-plot)
Renewables*	2.2 kWp	3.2 kWp	4.4 kWp
STRUCTURE & FAÇADE			
Substructure	Concrete foundations Beam and block floor	As for baseline, but concrete foundations increase in size by 10% for point loads	Low carbon cement and concrete
Superstructure	Traditional masonry frame with structural steel beams Timber flooring and stairs (houses); concrete flooring and stairs (apartments)	Timber beams and frame Timber flooring and stairs (houses and apartments)	Timber beams and frame Timber flooring and stairs (houses and apartments) Low carbon products for PVC membranes, finishes, sanitaryware
Insulation	Expanded polystyrene insulation	Expanded polystyrene insulation	Glass wool insulation
Façade	Brick and natural stone cladding Steel entrance canopy	Brick cladding only Steel entrance canopy removed	1/3 brick cladding, 2/3 timber cladding

Please see the Technical Report for a full breakdown and further description of design changes.

* It should be noted that the design options are relevant to this case study of Trumpington South low rise residential scheme based on four specific home typologies (see methodology) and may not be appropriate solutions for all new build homes.

OPERATIONAL ENERGY

Energy use from existing homes makes up 48% of UK built environment emissions,[22] and so driving the highest standards of energy efficiency in operation and ensuring that all energy used is generated through renewables is essential in achieving 'net zero carbon' new-build homes.

The design of new-build homes will need to shift to achieve more ambitious levels of energy performance. Three significant design changes modelled for this feasibility case study are outlined below.

Building fabric

Reducing energy demand is the most important measure to ensure new-build homes only use their "fair share" of the available renewable energy supply. Improving building fabric, including tightening wall U-values and air tightness levels, reduces thermal demand and, combined with heat recovery systems, total energy use. This study demonstrates that achieving near Passivhaus standards for building fabric can help to achieve the stretch levels of energy performance needed for new-build homes (35-40 kWh/m^2/per year).

High-quality construction

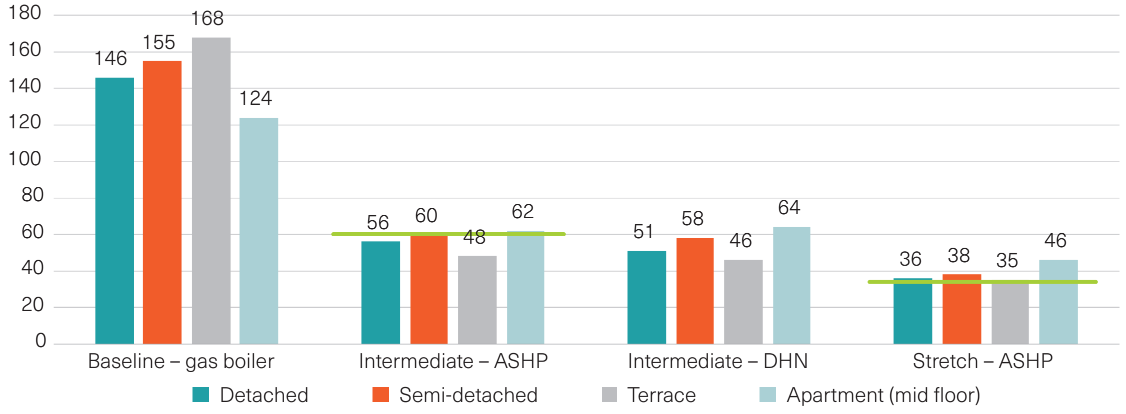
Delivering higher building fabric standards will require improvements in construction standards and processes to reduce the performance gap. For example, achieving ambitious airtightness rates requires careful consideration of construction detail, quality assurance checks during construction, and testing post-construction. This study demonstrates that these higher standards are achievable, however would have an effect on a project's preliminaries in today's market and will undoubtedly require further upskilling of the construction trades.

Zero carbon heating

Homes powered by fossil fuels (e.g., gas boilers) are not compliant with a net zero future as they produce substantial greenhouse gas emissions, so would need retrofitting with zero carbon heat sources in the 2030/2040s to bring them into line. New-build homes seeking to close the gap with 'net zero carbon' must be designed using low carbon heating systems such as air source heat pumps. This study demonstrates that air source heat pumps can help to deliver both the intermediate and stretch targets, with a heat network also modelled for comparison.

Figure 3 illustrates the impact of these different design approaches on each of the four separate home typologies planned for Trumpington South.

Figure 3: Regulated and unregulated energy results – total energy use intensity before renewables (kWh/m^2/year)



Key Green line indicates the target: Intermediate = 60; Stretch = 35 kWh/m^2/year
ASHP = air source heat pump
DHN = district heat network (only modelled for the intermediate scenario)

Conclusions

- ✓ Both the intermediate and stretch energy targets are achievable for this typology of new-build homes in design today, using existing technologies and design approaches
- ✓ The use of an air source heat pump, along with fabric performance improvements, future-proofs these homes making it unlikely they will need to undergo expensive retrofit works in future to become 'net zero carbon' in operation

The results demonstrate that, based on available design practices and technologies, the stretch target is within reach for most typologies. However, this would require a significant shift from the business as usual approach to residential design – reflected in the baseline scenario. Reductions are in the order of 62-75% between the baseline and intermediate and stretch scenarios, respectively (i.e., from 146 to 56 and 36 kWh/m^2/year for the detached house). This represents significant savings in terms of energy and carbon.

The switch from gas boiler to air source heat pump – with the supporting improvements to building fabric performance - means these homes would avoid having to undergo further costly retrofit works in future – which in itself would save substantial embodied carbon savings later in the lifecycle of the homes. Marginal energy efficiency gains are achieved using the district heat network compared to individual air source heat pumps.

The terraced house performs best in the intermediate and stretch scenarios, likely due to the smaller building envelope and benefit of insulation from party walls. Although apartments consume the least energy (kWh) due to their generally smaller size, here they perform worst out of all four typologies due to the results being considered on an energy intensity per square metre basis (kWh/m^2).

This illustrates the complexity of the subject, and suggests both Government and industry should consider bespoke targets for different types of new-build homes (e.g., low-rise versus high-rise).

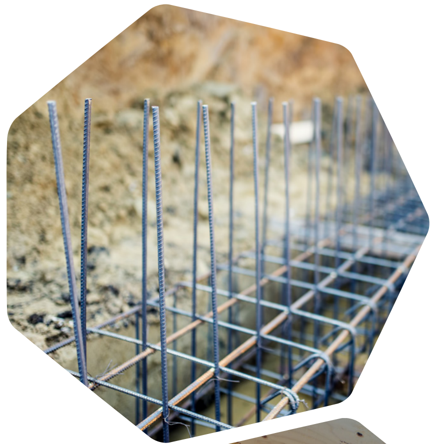
EMBODIED CARBON

Embodied carbon from a typical new-build home makes up over half its whole life carbon impact (over a 60-year lifespan),[23] so any credible net zero carbon building claim must consider embodied carbon. As operational carbon continues to decrease, the relative impact of embodied carbon is set to increase and will make up over half of built environment emissions by 2035.[24]

The design of new-build homes will need to shift to achieve reductions in embodied carbon. Three significant changes modelled for this feasibility case study are outlined below.

Material switching

The original design of the home largely remains the same, however, low carbon products, verified using Environmental Product Declarations, have been substituted in where possible. For example, cement used in the foundation was replaced with 60% ground granulated blast-furnace slag (GGBS*), and PVC membranes in the frame were replaced with low carbon alternatives. However, other products could not be substituted as alternatives were considered too expensive or limited in supply, for example, reused or recycled products. This highlights the need for growth in the supply chain's capacity to deliver more low carbon products to the market, in terms of both cost and availability.



Innovation in product manufacturing

In this case study, the superstructure makes up over half of the total upfront carbon in the baseline scenario (295 of 507 $kgCO_2e/m^2$ for the detached house), primarily due to the use of carbon-intensive construction materials (e.g., structural steel beams, concrete block, brick and stone façade). This highlights the need for innovation from product manufacturers to reduce manufacturing-related emissions and produce lower carbon products (especially given the current market momentum around demand-side drivers such as SteelZero,[25] ConcreteZero[26]). Simultaneously, innovation in design and construction practices can also be pursued. In this case study, the switch to a timber frame helped to reduce embodied carbon by 54% (from 295 to 160 $kgCO_2e/m^2$ between baseline and stretch), which also highlights the potential to grow new material supply markets (to ensure responsible sourcing and supply for timber construction).

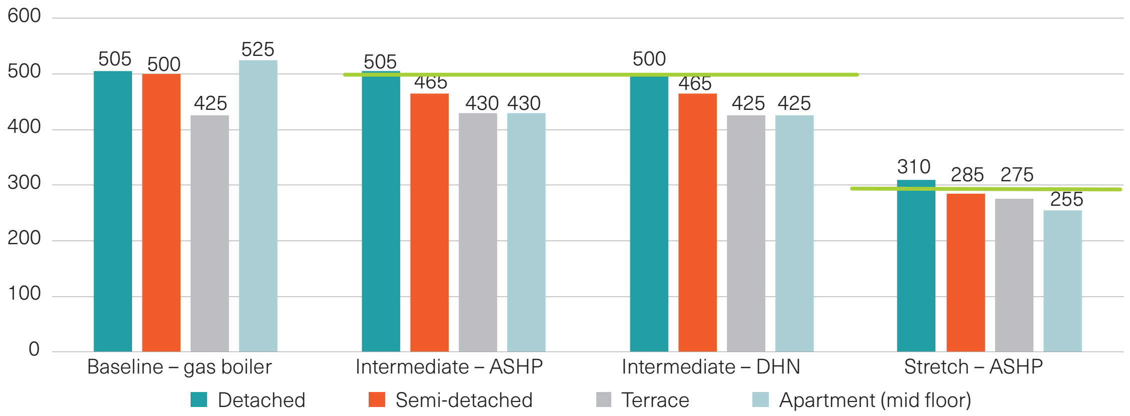
Trade-offs

This study found that achieving ultra-low levels of energy performance can result in additional embodied carbon. For example, cellulose insulation was selected to meet Passivhaus U-values, however, given the technical specifications, additional cavity space was required which thickened the walls and increased overall embodied carbon. The designers had to carefully balance both energy and embodied carbon performance requirements. The final result was a relaxation of the initial wall U-values (from 0.10 to 0.13) and switch from cellulose to glass wool insulation (which required less cavity space). This highlights the need to take a whole life carbon approach to avoid unintended consequences and the importance of undertaking whole life carbon assessments to drive decision-making.

* At the time of writing there are known challenges in sourcing GGBS as the industry moves towards adopting it at scale and the supply doesn't match demand. This demonstrates the need for further R&D and innovation in product manufacturing.

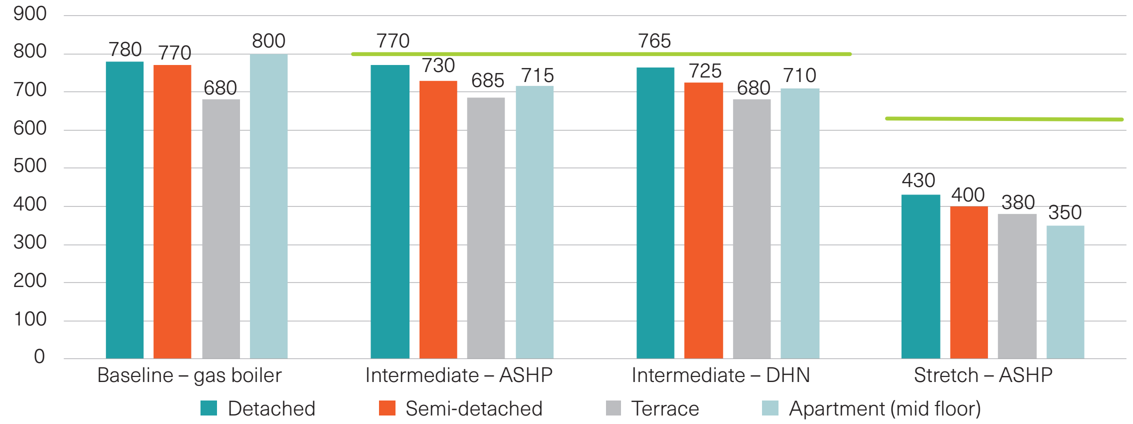
Figures 4 and 5 below illustrate the impact of these different design approaches on each of the four separate home typologies planned for Trumpington South.

Figure 4: Upfront carbon results (module A; $kgCO_2e/m^2$)



Key Green line indicates the target
ASHP = air source heat pump
DHN = district heat network (only modelled for the intermediate scenario)

Figure 5: Embodied carbon results (modules A to C, excluding B6 & B7; $kgCO_2e/m^2$)



Key Green line indicates the target
ASHP = air source heat pump
DHN = district heat network (only modelled for the intermediate scenario)

Conclusions

- ✓ Substantial reductions in embodied carbon can be delivered for new-build homes in design today, using existing products and design practices
- ✓ The difference in embodied carbon between a home served by a local heating system and a community heat network was shown to be negligible (<1%) in the case of this analysis
- ✓ More work is required to develop a consistent set of upfront construction and embodied carbon targets for different building typologies
- ✓ Best practice embodied targets were met in the stretch scenario, but the study found it impossible to reduce the embodied carbon to zero using traditional design practices. To achieve this today, targeting reused materials, adaptive reuse of existing spaces and using sustainably sourced timbers would be required.

All homes evaluated achieved both the intermediate and stretch upfront carbon and embodied carbon sets of targets (with the exception of the detached house for upfront carbon in the stretch scenario).

This clearly demonstrates that substantial embodied carbon savings can be achieved by homes in design today, even without significant reductions in product manufacturing emissions, or robust supplies of reused or recycled materials. This also suggests that the derivation of embodied carbon targets may need to be revisited given, for example, that targets under the stretch scenario are easily achieved, which leaves room for strengthening ambition. Different embodied carbon targets tailored to different types of homes would also be beneficial.

Reducing emissions today presents the greatest benefit in mitigating the effects of climate change, and so reducing construction-related upfront carbon emissions should become a priority. Reductions in upfront carbon are primarily delivered by using alternative low carbon products, whilst maintaining much of the existing design. The terrace and apartment types have the lowest upfront carbon, largely given they share structural frames and foundations with other dwellings, with the apartment's upfront carbon intensity halving between the baseline and stretch scenarios (from 525 to 255 $kgCO_2e/m^2$).

COST CHANGES

As the previous section has shown, homes can be designed and delivered today that achieve ambitious reductions across both operational and embodied carbon scopes – both of which are pre-requisites for any claims of net zero carbon new-build homes. Despite this, a better understanding of the effects of the capital cost of construction are necessary to determine just how feasible it would be to specify the delivery of these homes at scale today. The table below provides modelled costs from the baseline scenario to the intermediate and stretch scenarios.

It is important to note that this modelling was undertaken in August 2021 and does not account for market price fluctuations or developments in technology and supply chain availability since then. The cost modelling demonstrates an estimated order of cost associated with the design changes modelled. The top four key cost drivers (based on percentage uplift from baseline) are highlighted in orange in the table below and discussed further over page.

Table 4: Cost results for a typical blended house (represented per building element on a cost per metre square basis to allow direct comparison between the scenarios)

Blended houses	Baseline	Intermediate			Stretch		
	$£/m^2$	$£/m^2$	Variance $£/m^2$	Change from baseline	$£/m^2$	Variance $£/m^2$	Change from baseline
1 Substructure	£149	£153	£5	3%	£163	£14	10%
2 Superstructure	£644	£682	£38	6%	£765	£121	19%
2.1 Frame	£58	£77	£19	32%	£77	£19	32%
2.2 Upper Floors	£46	£46	£0	0%	£48	£2	4%
2.3 Roof	£54	£62	£8	16%	£62	£8	16%
2.4 Stairs and Ramps	£5	£5	£0	0%	£5	£0	0%
2.5 External Walls	£276	£283	£7	3%	£352	£77	28%
2.6 Windows & External Doors	£67	£67	£0	0%	£77	£11	16%
2.7 Internal Walls & Partitions	£100	£103	£4	4%	£107	£7	7%
2.8 Internal Doors	£39	£39	£0	0%	£39	£0	0%
3 Internal Finishes	£145	£145	£0	0%	£152	£7	5%
4 Fittings, Furnishing & Equipment	£64	£64	£0	0%	£64	£0	0%
5 Services (incl PV)	£257	£313	£56	22%	£340	£83	32%
9 Preliminaries	£113	£122	£9	8%	£149	£35	31%
Total $£/m^2$	**£1,371**	**£1,478**	**£107**	**8%**	**£1,634**	**£263**	**19%**

Please see the Technical Report for a full breakdown of costs, including for the apartment.

TOP 4 COST VARIABLES

1. Services, incl PV (£83 of £263 per m² uplift for stretch scenario)

The increase in costs to building services in the stretch scenario makes up the largest proportion of the total cost increase. This reflects the addition of technologies to complement improved building fabric, including air source heat pumps, mechanical ventilation with heat recovery, and additional photovoltaics (to achieve 100% carbon reduction for regulated energy). Government regulation and incentives are needed to help drive and support a market for these low carbon technologies – alongside the banning of any new gas boiler installations as soon as possible – which will help drive economies of scale and allow costs to fall.

2. External walls (£77 of £263 per m² uplift for stretch scenario)

The increase in costs to external walls are attributable to the improved building fabric, including increased insulation (glass wool), increased external wall build up, as well as high-quality construction details (e.g, Passivhaus), and tighter air permeability rate (1.0).

Setting stricter limits on thermal demand and energy use intensity will challenge the industry to design for improved building fabric, bringing this closer to standard practice. Naturally, the industry will adapt to deliver against these requirements, finding efficiencies and, again, allowing costs to fall.

3. Preliminaries (£35 of £263 per m² uplift for stretch scenario)

The preliminaries increase by just £9/m² (8%) between the baseline and intermediate scenario, however a £35/m² (31%) increase is observed from the baseline to stretch. This is largely to account for additional costs associated with achieving the required airtightness values, including quality assurance checks during construction and testing post-construction. As the industry increases its capacity and capability to close the gap with credible net zero carbon design strategies, a commensurate and rapid fall in preliminary costs can be expected.

4. Frame (£19 of £263 per m² uplift for stretch scenario)

The increase in costs to the frame are largely attributable to the switch from a traditional concrete block and steel frame construction (high embodied carbon) in the baseline scenario to a timber frame solution (low embodied carbon). A requirement to measure embodied carbon in Building Regulations will challenge designers to seek out low carbon products and materials and could help grow a market for responsibly-sourced timber in the UK. Outstanding challenges will also need to be addressed, including perceived fire risk and insurance.

Conclusions

- ✓ **New-build homes of the typologies modelled in this case study can achieve significant improvements in both operational and embodied carbon (intermediate targets) for a circa 8% capital cost uplift.**
- ✓ **For those same homes to achieve the stretch operational and embodied targets in today's market conditions would be challenging – with an estimated 19% capital cost uplift to doing so on this particular scheme.**
- ✓ **However, history suggests that a clear and consistent medium and long-term policy direction would give sufficient confidence to the market for the supply chain to invest in necessary solutions and the costs to drop substantially over the course of the decade ahead.**

The case study research found that the intermediate targets could be achieved today with a capital cost uplift estimated to be around 8% (£107/m² averaged across all the house types modelled). Given the savings that this would potentially present to the occupier in terms of reduced energy bills (this would need to undergo modelling to be verified) and reduced obsolescence on the market value of the homes in future, this may be recoverable through either an improved yield or market rent and/or improved eligibility for green financial products such as home improvement loans or mortgages.

Furthermore, for any developer retaining the ultimate freehold of the new homes built, it would make sense to incur the additional short-term cost by way of avoiding higher costs further down the line to retrofit the properties to a higher standard of energy and carbon efficiency.

However, perhaps unsurprisingly, the case study research also found that achieving the stretch targets in today's market conditions would be challenging – with an estimated 19% capital cost uplift (£262/m² for blended houses) to do so on this particular scheme.

When considering any such capital cost increases, it is worth reflecting on historic trends. In the period between 2009 and 2015, the additional capital costs of delivering new homes that met the Code for Sustainable Homes level 4 had almost halved[4] – principally due to clarity and consistency on medium-term policy[5] direction, allowing the supply chain to confidently invest in the changes required to meet such standards and thereby dramatically reduce the capital cost of doing so over time. The fact that the technical solutions exist already today suggests that, with some additional policy incentives, the overall cost of delivering these should reduce as mass scale up of adoption is achieved.

The overarching conclusion has to be that any aspiration to deliver credible net zero carbon new-build homes at scale is reliant upon specific and targeted policy interventions to help grow the market for low carbon technologies, products, materials and construction practices. As an example, setting thermal energy demand limits will drive improvements in building fabric, leading to increased demand and the lowering of costs for high-performing insulation.

The Future Homes Standard that is being introduced in 2025 presents a unique opportunity to embed some of the intermediate targets used in this case study into Building Regulations – indeed, unless it does so, the future delivery of net zero carbon new-build homes is very much at risk.

Glossary of terms

Embodied carbon – total greenhouse gas emissions and removals related to materials and construction processes throughout the whole lifecycle of a building, including construction, use, maintenance, repair, replacement, refurbishment, and end-of-life (modules A to C, excluding B5 & B6 from BS EN 15978).[27]

Net zero carbon – construction – when the amount of carbon emissions associated with a building's product and construction stages up to practical completion is zero or negative, through the use of offsets.[28]

Net zero carbon – operational energy – when the amount of carbon emissions associated with the building's operational energy on an annual basis is zero or negative. A net zero carbon building is highly energy efficient and powered from on-site and/or off-site renewable energy sources, with any remaining carbon balance offset.[29]

Regulated energy – energy consumption resulting from the specification of controlled, fixed building services and fittings, including space heating and cooling, hot water, ventilation and lighting.[30]

Unregulated energy – energy consumption of the home that is not 'controlled', i.e. energy consumption from aspects of the home on which Building Regulations do not impose a requirement e.g. appliance energy use.[31]

Upfront carbon – total greenhouse gas emissions related to materials and construction processes up to practical completion (module A from BS EN 15978).[32]

References

1 The ultimate performance thresholds required to warrant a credible net zero carbon claim for new-build homes have yet to be defined as part of ongoing work to develop a UK Net Zero Carbon Buildings Standard. https://www.nzcbuildings.co.uk/

2 Cross-industry group (2022), UK Net Zero Carbon Buildings Standard: https://www.nzcbuildings.co.uk/

3 UKGBC (2021), Net Zero Whole Life Carbon Roadmap: A Pathway for the UK Built Environment: https://www.ukgbc.org/ukgbc-work/net-zero-whole-life-roadmap-for-the-built-environment/

4 Lessons from AIMC4 for cost-effective fabric-first low-energy housing June 2014 www.aimc4.com

5 In 2006, the Labour Government introduced the target that from 2016 all new homes built should be 'zero carbon'. A commitment to delivering zero carbon homes from 2016 was included in the Budget 2013 and Clause 32 of the Infrastructure Bill provided an amendment to the Building Act 1984 extending matters that could be covered by Building Regulations. The intent was for homes to be built to at least level 4 of the Code for Sustainable Homes by 2016 – but this was subsequently scrapped by the Conservative Government in May 2015

6 Royal Institute of British Architects (2021), 2030 Climate Challenge: https://www.architecture.com/about/policy/climate-action/2030-climate-challenge/sign-up, BAU = compliance approach; Intermediate = 2025 target; Stretch = 2030 target

7 London Energy Transformation Initiative (2020), Climate Emergency Design Guide: https://www.leti.london/cedg, BAU = Baseline; Intermediate = Best practice 2020; Stretch = Best practice 2030

8 Royal Institute of British Architects (2021), 2030 Climate Challenge: https://www.architecture.com/about/policy/climate-action/2030-climate-challenge/sign-up, BAU = compliance approach; Intermediate = 2025 target; Stretch = 2030 target

9 UKGBC (2020), Building the Case for Net Zero: https://www.ukgbc.org/ukgbc-work/building-the-case-for-net-zero/

10 Ministry of Housing, Communities & Local Government (2018), Government announces new housing measures: https://www.gov.uk/government/news/government-announces-new-housing-measures

11 UKGBC (2020), Accelerator Cities: https://www.ukgbc.org/ukgbc-work/accelerator-cities/

12 IPCC (2021), Climate Change 2021: The Physical Science Basis: https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/

13 UK Parliament (2021), Climate change targets: the road to net zero?: https://lordslibrary.parliament.uk/climate-change-targets-the-road-to-net-zero/

14 Ministry of Housing, Communities & Local Government (2018), Government announces new housing measures: https://www.gov.uk/government/news/government-announces-new-housing-measures

15 Climate Change Committee (2022), 2022 Progress Report to Parliament: https://www.theccc.org.uk/publication/2022-progress-report-to-parliament/

16 WorldGBC (2022), The Net Zero Carbon Buildings Commitment: https://www.worldgbc.org/thecommitment

17 UKGBC (2021), Net Zero Whole Life Carbon Roadmap: A Pathway for the UK Built Environment: https://www.ukgbc.org/ukgbc-work/net-zero-whole-life-roadmap-for-the-built-environment/

18 UK Green Building Council (2022), Building the Case for Net Zero: A case study for low rise residential developments, https://www.ukgbc.org/ukgbc-work/building-the-case-for-net-zero-low-rise-developments/

19 UKGBC (2019), Net Zero Carbon Buildings: A Framework Definition: https://www.ukgbc.org/ukgbc-work/net-zero-carbon-buildings-a-framework-definition/

20 Science Based Targets (2021), The Net-Zero Standard: https://sciencebasedtargets.org/net-zero

21 Cross-industry group (2022), UK Net Zero Carbon Buildings Standard: https://www.nzcbuildings.co.uk/

22 UKGBC (2021), Net Zero Whole Life Carbon Roadmap: A Pathway for the UK Built Environment: https://www.ukgbc.org/ukgbc-work/net-zero-whole-life-roadmap-for-the-built-environment/

23 Royal Institution of Chartered Surveyors (RICS) (2017), Whole life carbon assessment for the built environment RICS professional statement https://www.rics.org/uk/upholdingprofessional-standards/sector-standards/buildingsurveying/whole-life-carbon-assessment-for-the-builtenvironment/

24 UKGBC (2021), Net Zero Whole Life Carbon Roadmap: A Pathway for the UK Built Environment: https://www.ukgbc.org/ukgbc-work/net-zero-whole-life-roadmap-for-the-built-environment/

25 The Climate Group (2022), SteelZero: https://www.theclimategroup.org/steelzero

26 The Climate Group (2022), ConcreteZero: https://www.theclimategroup.org/concretezero

27 Whole Life Carbon Network (2021), Carbon Definitions for the Built Environment, Buildings and Infrastructure: https://www.leti.london/carbonalignment

28 UKGBC (2019), Net Zero Carbon Buildings: A Framework Definition: https://www.ukgbc.org/ukgbc-work/net-zero-carbon-buildings-a-framework-definition/

29 UKGBC (2019), Net Zero Carbon Buildings: A Framework Definition: https://www.ukgbc.org/ukgbc-work/net-zero-carbon-buildings-a-framework-definition/

30 Building Research Establishment (2018), Home Quality Mark ONE Technical Manual England: https://www.homequalitymark.com/professionals/standard/

31 Building Research Establishment (2018), Home Quality Mark ONE Technical Manual England: https://www.homequalitymark.com/professionals/standard/

32 Whole Life Carbon Network (2021), Carbon Definitions for the Built Environment, Buildings and Infrastructure: https://www.leti.london/carbonalignment

33 Royal Institute of British Architects (2021), 2030 Climate Challenge: https://www.architecture.com/about/policy/climate-action/2030-climate-challenge/sign-up, BAU = compliance approach; Intermediate = 2025 target; Stretch = 2030 target

34 London Energy Transformation Initiative (2020), Climate Emergency Design Guide: https://www.leti.london/cedg, BAU = Baseline; Intermediate = Best practice 2020; Stretch = Best practice 2030

35 Royal Institute of British Architects (2021), 2030 Climate Challenge: https://www.architecture.com/about/policy/climate-action/2030-climate-challenge/sign-up, BAU = compliance approach; Intermediate = 2025 target; Stretch = 2030 target

This study explores the design and cost implications of delivering low carbon residential developments. We welcome input from any interested stakeholders on the content and potential future areas of study.

If you have any questions on this report or would like to provide feedback, please email **ANZ@ukgbc.org**

UK Green Building Council

The Building Centre
26 Store Street
London WC1E 7BT

T 020 7580 0623
E info@ukgbc.org
W ukgbc.org

Together for a better built environment