Building the Case for Net Zero:

A case study for low carbon residential developments

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Foreword

With the UK's ambition to deliver 300,000 new homes a year and cut emissions by 78% by 2035, we are left with a very serious challenge. How does our industry continue to plan and deliver new communities at scale whilst minimising impact on the environment? Little has been done to better understand how the design choices we make when masterplanning new residential communities will impact our net zero ambitions.

This report gives insight into some of the key considerations that developers, housebuilders, local authorities and consultants should think about when planning new large-scale residential communities. To help facilitate this work, we put forward one of our development sites, Trumpington Meadows on the southern fringe of Cambridge, to use as a real-world example of what could be possible.

The findings of this study show us that there are real improvements to be made if we embrace the low carbon design challenge, which can in fact lead to delivering a far more attractive and healthier environment in which to live. Some examples of co-benefits can be found in the shift away from the private car and traditional drainage solutions, creating more space for amenity and allowing biodiversity to flourish.

What has been evidenced is that embodied carbon measurement is the critical first step to uncovering the most significant carbon hotspots. With grey infrastructure – roads and parking – making up the majority of the embodied carbon, it is clear we need a cultural shift away from car ownership and towards the adoption of active travel methods. Whilst there are emerging materials with lower embodied carbon, many are still untested and in their infancy, highlighting the need to encourage people out of their cars. Clearly reducing areas for cars, providing convenient, attractive, safe alternatives must be the start but we need to be more radical and progressive with those Local Authorities willing to flex old standards. We need less asphalt and more green spaces!

In order to meet the net zero challenge we must be bold, drive innovation and be prepared to look at things through a new lens. Most importantly, we must take others on the journey with us.

Andy Sharpe
Director of Project Management,
Strategic Land
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Executive Summary

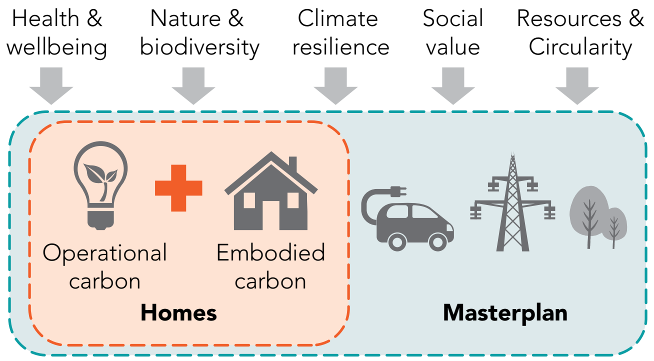
UKGBC's Net Zero Whole Life Carbon Roadmap states that embodied carbon emissions will make up over half of built environment emissions by 2035.[1] For the residential sector, much of the focus on embodied carbon is on homes, leaving the embodied carbon from the masterplan works – including roads, utilities and energy infrastructure – unchecked and ill-considered. Gaining insight into these embodied carbon impacts can also uncover opportunities to improve the masterplan holistically, including climate resilience and resident amenity

UKGBC's Advancing Net Zero programme[2] is helping to drive the transition towards net zero, including through its development of the Net Zero Carbon Buildings Framework[3]. Whilst much of the focus remains on net zero carbon buildings, the carbon impacts outside the property boundary must also be considered. Each tonne of carbon from the built environment, irrespective of sector or project lifecycle stage, must be measured and mitigated in order for the UK's net zero target to remain within reach.

The embodied carbon from masterplan works – which can span many years and consume large amounts of materials – is currently unregulated and is only beginning to be measured by some residential developers. Measurement is the critical first step to understanding the size of the challenge for new developments, before implementing 'quick wins' to cut embodied carbon. An embodied carbon assessment can reveal the greatest sources of emissions – such as from roads, hard surfaces, utilities, and energy infrastructure – and allow testing of different design strategies to mitigate these carbon impacts.

Ultimately, new residential developments must be designed for both people and planet – ensuring they are healthy and habitable for residents, within and beyond their property boundary. Carbon must also be considered alongside a range of other social, environmental, and economic factors, as indicated in Figure 1.

Figure 1: Net zero carbon homes (shown in orange) need to be considered within the broader context of the masterplan (shown in blue) in which they are situated, alongside a range of other factors.



PURPOSE

This report presents the findings from a study examining the design and cost implications of minimising embodied carbon for a real-world, low-rise residential development – Trumpington South in Cambridgeshire. The findings are intended to help 'build the case' for other projects seeking to tackle embodied carbon from masterplan works by providing examples of design strategies which can be practically implemented today.

This guidance aims to help local authorities, investors, housebuilders, developers and the whole value chain better understand the delivery of low carbon residential developments and, in doing so, demonstrate the residential sector's leadership in meeting the UK's net zero challenge.

Later in 2022, UKGBC will be publishing a follow-up report examining the delivery of new net zero carbon homes on the Trumpington South scheme. The report will illustrate design strategies to reduce both embodied carbon and operational carbon by achieving current industry performance targets.

This report is split into two main sections:

1. Design changes

The study is based on a real-world residential scheme for 750 homes in Cambridgeshire, Trumpington South, which is considered representative of a typical urban extension currently going through the planning process. UKGBC convened a task group to undertake a range of masterplan-level design interventions to reduce embodied carbon as much as possible, whilst also considering other aspects such as climate resilience and resident amenity.

The original design was used as a baseline from which two low carbon scenarios were developed, 'intermediate' and 'stretch'. The scope of the study included typical masterplan works – such as roads and hard surfaces, utilities, energy infrastructure – to ensure the findings are widely applicable for other low-rise residential schemes.

2. Cost changes

In parallel, an analysis of the changes to capital costs to practically deliver the design interventions was also undertaken. The findings reveal strong interrelationships between the design of homes and masterplan infrastructure, for example heat infrastructure, and provide a more rounded understanding of where the true costs lie.

The analysis focused on capital costs which can be more accurately estimated based on today's market prices. However, it is widely recognised that these costs are likely to reduce over time as the industry gears up to deliver low carbon projects in the future. Furthermore, other intangible benefits – such as adaption to climate risks, additional green space, and improved resident amenity – have been highlighted as key considerations alongside capital cost.

3. Discussion

In light of this study acting as a pathfinder for other projects seeking to measure and minimise embodied carbon, a third section raises a range of supporting discussion points. These should provide further points of interest and are intended to help stimulate further discussion.

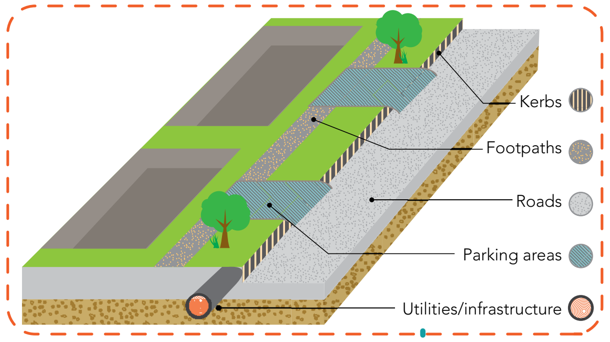
Key discussion points:

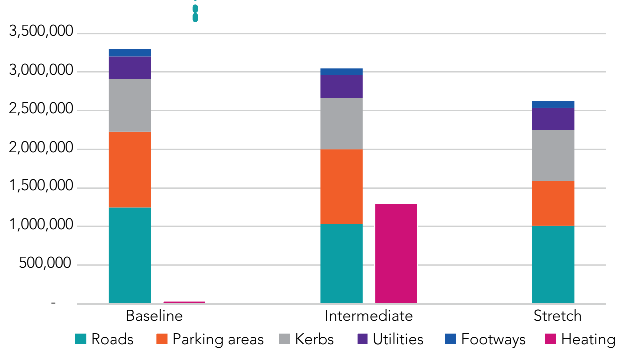
- Embodied carbon measurements and agreed limits
- Contribution to organisational commitments
- Design efficiency and circularity
- Resilience and nature-based solutions
- Wider social benefits

Key findings

The study examines the embodied carbon of a typical residential masterplan, which includes roads, utilities, stormwater, energy systems and other related infrastructure. Embodied carbon related to the construction stage (module A) makes up 85% of the masterplan's total embodied carbon (modules A to C), highlighting the importance of low carbon product and material selection at the design and construction stages.

See page 9 to find out more





The embodied carbon from the baseline masterplan is 3,300,000 kgCO_2e, which is roughly the equivalent of the total embodied carbon from 80 terrace houses. A reduction of 670,000 kgCO_2e (or 20.3% of the baseline total) was achieved in the stretch scenario through a range of 'easy wins' and cost-effective design interventions.

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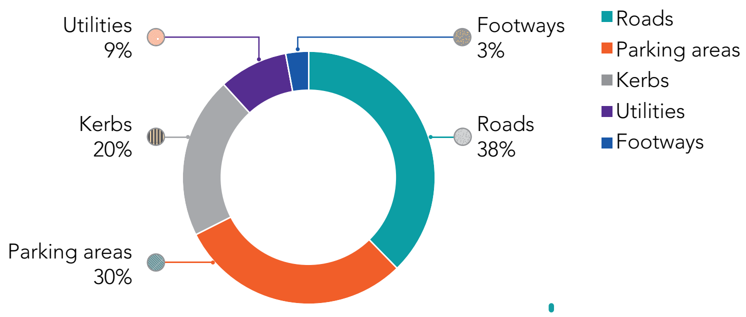
'Grey infrastructure' – comprised of roads, parking and kerbs – makes up 88% of the masterplan's total embodied carbon. The findings demonstrate that this can be reduced by 645,000 kgCO_2e primarily by reducing parking areas and switching from asphalt to permeable paving for tertiary roads

See page 19 to find out more



Extending the swale network to include primary and secondary streets reduces embodied carbon from the stormwater network, whilst also increasing the provision of 'blue/green networks'. This highlights the general principle of reducing materials used, in place of nature-based solutions that help deliver holistic benefits, including climate resilience.

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By anticipating the increased use of vehicle sharing in future, parking provision per home has been reduced which frees up land for more greenery and additional dwellings. The number of homes can be increased by 5.3% (or around 39 homes across the 750-home scheme).

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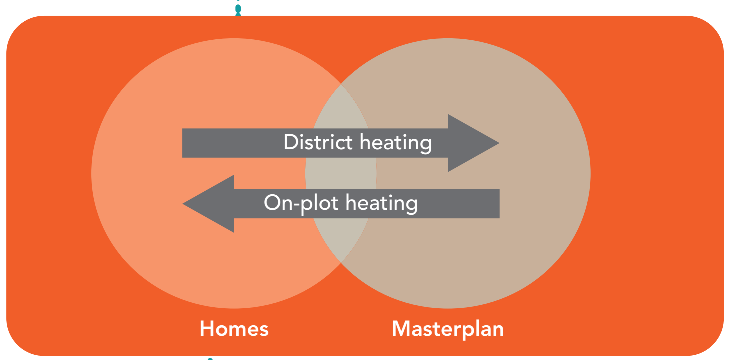

A communal district heat network has been modelled which highlights that embodied carbon can shift from homes to the masterplan, depending on the heating solution selected. This exemplifies the need to take a holistic view during design to consider wider impacts beyond a home's own boundary.

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A range of other value drivers – outside of capital cost – will help improve the feasibility of low carbon residential developments over time. This includes increasing appeal within the planning process and for potential new residents.

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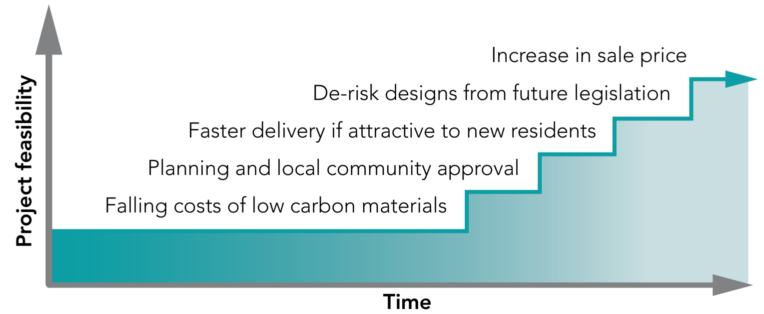
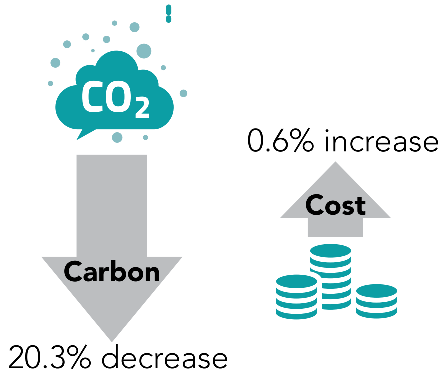




Overall, a 20.3% embodied carbon reduction was achieved between the baseline and stretch scenarios for the masterplan, with a negligible impact on capital costs (0.6% increase). Heating has been modelled and costed separately as it is highly dependent on the design solution used for homes.

See page 33 to find out more

Introduction

UKGBC's Net Zero Whole Life Carbon Roadmap states that embodied carbon emissions will make up over half of built environment emissions by 2035.[1] For the residential sector, much of the focus on embodied carbon is on homes, leaving the embodied carbon from the masterplan works – including roads, utilities and energy infrastructure – out of scope. Gaining insight into these embodied carbon impacts can also uncover opportunities to improve the masterplan holistically, including climate resilience and resident amenity.

Embodied carbon emissions are currently unregulated, and measurement and mitigation within construction is typically voluntary. Some residential developers are beginning to assess the embodied carbon from new homes, yet the embodied carbon from the masterplan works – which can span many years and consume large amounts of materials – is typically an oversight. Each tonne of carbon from the built environment, irrespective of sector or project lifecycle stage, must be measured and mitigated for the UK to credibly meet its climate targets.

This study examines a proposed residential scheme, Trumpington South, as a real-world case study to reveal the embodied carbon impacts from typical masterplan works. The embodied carbon of the scheme was measured, and a task group was charged with iterating the design to mitigate the greatest sources of emissions. The capital costs for these enhancements were estimated to help inform other projects aiming to deliver low carbon residential developments. The analysis was undertaken in parallel with the design for new net zero carbon homes on the scheme, to understand the interrelationships between both masterplan and homes.

In addition to focusing on embodied carbon, the study takes a forward look to anticipate future changes to residential developments. This included, for example, deploying climate resilience measures through nature-based solutions, modelling the shift towards electric vehicle sharing, and considering the impacts of fully electric heating systems.

This guidance aims to help local authorities, investors, housebuilders, developers and the whole value chain better understand the delivery of low carbon residential developments and, in doing so, demonstrate the residential sector's leadership in meeting the UK's net zero challenge.

LOW CARBON MASTERPLANS AND HOMES

This study has taken a complete approach to large-scale residential developments by assessing carbon impacts from both the masterplan and homes. The focus for the analysis on homes was to achieve net zero carbon, given the availability of performance targets that could be used to develop net zero design scenarios. For the masterplan, however, given there are no currently available performance targets, the focus was to reduce embodied carbon from construction works, whilst considering other key urban design factors.

UKGBC published the Net Zero Carbon Buildings Framework Definition[3] in 2019 to build industry consensus on what constitutes a net zero carbon building. For new homes, the framework sets out principles for achieving 'net zero carbon – construction' (at practical completion) and 'net zero carbon – operational energy' (when in-use), with the noted intention to develop a whole life carbon definition in time.

In the context of masterplan works for a new residential development, 'net zero carbon – construction' can broadly be interpreted as minimising embodied carbon from the construction stage to the greatest extent possible before applying offsets to achieve a zero carbon balance. This report focuses on the reduction of embodied carbon (across all lifecycle stages) to reduce the reliance on offsetting.

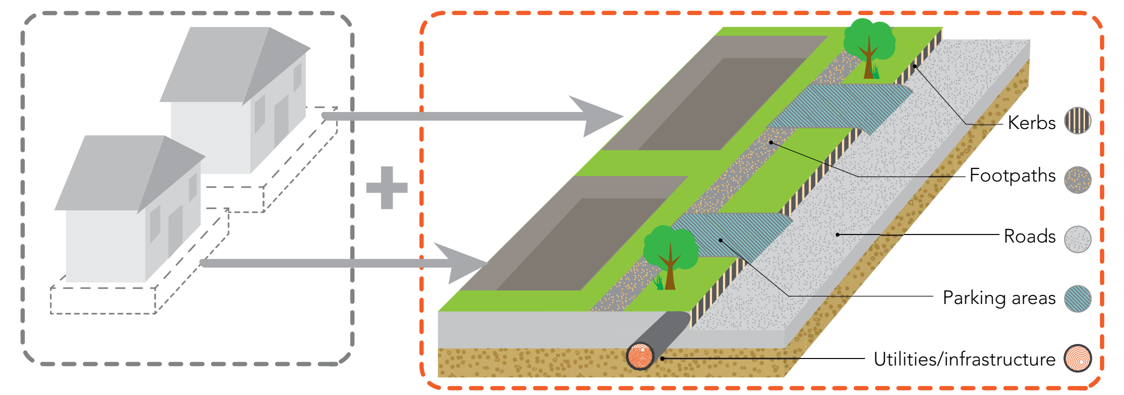
Neither low carbon homes nor masterplans should be viewed in isolation as, typically, trade-offs will arise based on design decisions made for each. An example of this is a district heat network, which increases the masterplan's embodied carbon whilst also impacting the operational carbon intensity of homes.

A follow up report is due to be released later in 2022 which will examine the design and cost implications for delivering new net zero carbon homes at the scheme. Both reports will build an evidence base for the practical considerations in delivering new net zero carbon homes within a low carbon development. A high-level comparison of the scope from both reports is provided in Table 1.

Table 1: High-level comparison of the scope of both studies

Masterplan	Homes
Embodied carbon • Roads • Hard surfaces • Utilities • Infrastructure • Heat network **Urban design** • Nature and biodiversity • Sustainable urban drainage systems • Transportation • Housing density	**Embodied carbon** • Structure and façade • Material selection • Building services **Operational energy** • Building fabric • Building services • Heating system • Renewables

Figure 2: This report focuses on the masterplan (outlined in red) and both reports combined will provide a complete picture of the carbon impacts from a large-scale residential development



SCOPE AND METHODOLOGY

The findings from this study are intended to be applicable across the industry. They should help inform project teams on potential design changes to achieve low carbon residential developments and provide an understanding of the effects this has on capital cost. They should not, however, take the place of proper planning and due diligence undertaken by clients and project teams. Further consideration of the findings will always be required based on project-specific parameters including, for example, location, size, site conditions, constraints, local planning rules and developer specification.

This study is based on a comparative analysis of different design scenarios for a typical new large-scale residential scheme. The proposed Trumpington South development, located in Cambridgeshire and described later in this report, was used as the starting point from which a series of design assumptions have been made. Each design scenario is examined in terms of the carbon and capital cost impacts for both the homes and masterplanning components of the scheme.

UKGBC convened individuals with experience working on the Trumpington South project to form a task group. The task group met regularly over a four-month period to develop the design scenarios, complete the carbon and cost modelling, and prepare findings for this report. We would like to offer a special thanks to all task group members, listed in Acknowledgements, for dedicating their time and expertise to this study.

UKGBC also sought to feed-in views from a wider set of stakeholders – including other designers, developers, housebuilders and financiers – as part of a review group to help enhance the findings of the study. The review group, also listed in Acknowledgements, provided input at two key points during the development of the study, as well as reviewing the findings and final report.

The findings are intended to improve the collective understanding for the residential sector and help 'build the case' for new net zero carbon residential developments. It follows on from a previous UKGBC study which illustrated how two new high-rise buildings – an office tower and residential block – could be designed to reach net zero performance targets and the effect this had on capital cost.[4]

Design scenarios

The scope of the study covered all typical masterplan works required for a large-scale residential development. The 750-home design for Trumpington South was used as a 'baseline' scenario from which two increasingly ambitious low carbon scenarios were developed – the 'intermediate' and 'stretch' scenarios, as per Figure 3.

An embodied carbon assessment of the baseline design was undertaken to understand the total carbon impact, broken down by masterplan elements. This enabled the task group to identify and minimise the most dominant sources of carbon. The operational carbon for the masterplan (e.g. street lighting, vehicle emissions, etc) was excluded from the analysis, as this would require a separate set of modelling, and all embodied carbon related to the homes was assessed separately – to be published in a dedicated report on homes.

The task group were charged with reducing the overall embodied carbon by progressively enhancing the baseline specification. This involved a consensus-led process to determine the most practical and feasible design changes that would be considered acceptable for today's residential market and local design codes. Some of the key factors that drove the group's decision-making process included: capital cost, industry acceptance, risk, and the end customers' perceptions.

The embodied carbon findings are intended to be generally applicable for other large-scale, low density residential developments, and so masterplan works that were considered project-specific were kept out of scope. Additionally, masterplan elements that were considered relatively low impact have also been kept out of scope, however could be considered for other developments. A breakdown of inclusions and exclusions for this study's embodied carbon assessment is provided in Table 2 along with justification for why certain elements have been excluded.

Figure 3: Three increasingly ambitious design scenarios have been developed which aim to reduce embodied carbon

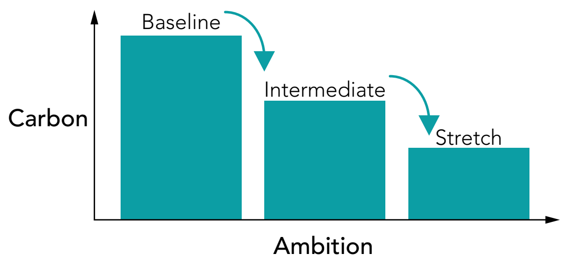


Table 2: Scope of the embodied carbon assessment for the masterplan

Inclusions	
Roads.	
Hard surfaces – parking, squares, footpaths.	
Utilities – electrical, telecoms, potable water.	
Infrastructure – foul water, stormwater, substations.	
Heat network – gas network (baseline), district heat network (intermediate).	
Exclusions	**Rationale**
Utility reinforcement works and costs e.g. electrical network upgrades, etc.	Site-specific
Site preparatory works e.g. soil movements, grading, etc.	Site-specific
Construction emissions (module A5) e.g. emissions from construction machinery, excavation works for utilities, etc.	Site-specific
On-site renewables within masterplan e.g. ground-mounted solar/wind farm, etc.	Site-specific
Transport emissions from future homeowners e.g. vehicle emissions, demand from electric vehicle charging, etc.	Site-specific
External planting, turfing and irrigation systems.	Relatively low impact
Street furniture, equipment and ornamental features.	Relatively low impact
Property boundaries e.g. fencing, etc.	Relatively low impact

Please note, the list of elements excluded from this study's embodied carbon assessment is not exhaustive and there could be other reduction opportunities that should be assessed on a project-by-project basis.

In addition to reducing embodied carbon, the task group took a wider view in seeking to improve the health and habitability of the development. Even under current projections for Cambridge (from 2009 to 2020s), summers are modelled as being 1.5°C warmer, creating a risk of overheating to residents, and winters 7% wetter, with more intense rainfall creating greater risk of flooding.[5] Therefore, developments in planning and design today must consider resilience issues alongside carbon reductions.

Some of the additional interventions modelled include:

- Increasing net biodiversity gain and resident access to nature.
- Improving overall tree coverage and soft landscaping in place of hard surfaces.
- Increasing climate resilience through nature-based solutions and sustainable drainage.
- Improving resident health and wellbeing through access to green space, active travel, improved microclimate, etc.
- Increasing overall yield through the reduction of land for parking and greater density of homes.

UKGBC's Social Value in New Development guide[6] provides a more complete picture of holistic development outcomes that should be targeted, for readers that are interested.

Cost

The scope of the cost analysis has been limited to capital cost based on current day prices to ensure the estimates are as robust as possible. It is widely recognised that the cost to deliver low carbon developments will fall over time, including, for example, improvements in technology and growth in supply chain capacity, as the construction sector shifts to meeting more stringent requirements.

At present, however, the degree of uncertainty is too high for this to be quantified. The reduction in costs due to market forces and increase in value drivers should be considered alongside the findings in this report and other relevant studies.[7]

In addition, other intangible benefits that have not strictly been measured as part of this study would need to be considered when assessing the feasibility of low carbon residential developments. This includes:

- Reduction in physical risks through climate resilience measures.
- Increasing consumer demand for high amenity and low carbon residential developments, which can command a sales premium.
- Future-proofing developments (which can span many years) from changing patterns of living and regulatory changes, etc.

Some of these factors are addressed at a high-level in the Discussion section of this report.

Figure 4: A range of factors should be considered when assessing the feasibility of low carbon residential developments

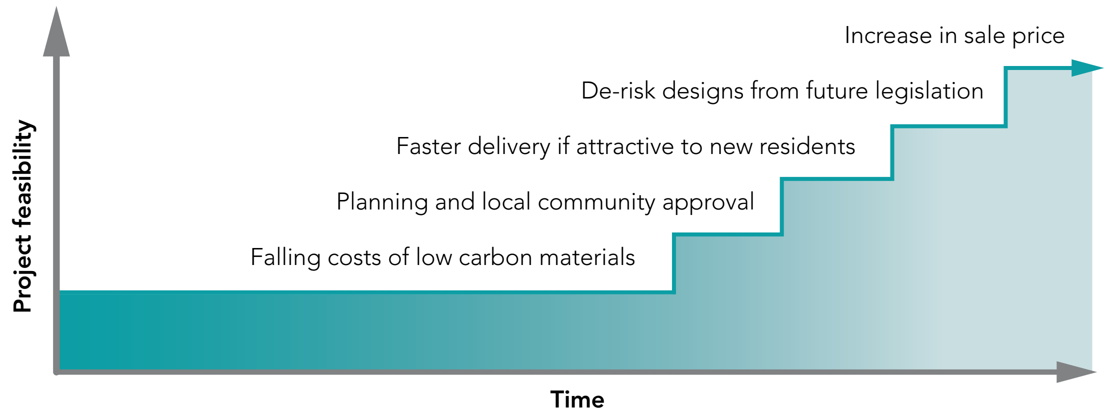


Figure 5: Trumpington South illustrative masterplan

Methodology

Figure 6: Methodology used for this study

1. Select representative masterplan

The original design for Trumpington South was used as representative of a typical residential urban extension development.

2. Undertake baseline assessment

An embodied carbon assessment for the original design revealed embodied carbon hotspots and areas of focus for carbon reductions.

3. Develop design scenarios

The task group focused on ways to enhance the baseline design to reduce embodied carbon.

4. Model carbon and cost

Embodied carbon modelling was undertaken to track carbon reductions, together with cost modelling to estimate the resulting cost uplifts.

5. Discuss

In recognition of this study as a pathfinder for low carbon residential developments and to stimulate further industry discussion, key findings have been presented later in this report.

TRUMPINGTON SOUTH

Trumpington South is a new proposed development in southwest Cambridgeshire, put forward by Grosvenor for the purposes of this study. The scheme was selected as it is considered representative of a typical urban extension, residential-led scheme going through the planning process. Subject to local plan allocation and planning approval, the site could be delivering new homes by 2025. Trumpington South forms part of a wider promotion of land, additional to the consented Trumpington Meadows urban extension, sections of which are completed.

Trumpington South has a strong sustainability strategy, with a vision to help Cambridge Council achieve their ambition of zero carbon by 2050. The development proposal consists of 750+ new homes, a new primary school, a village centre and other mixed-use buildings. Connectivity and active transport were central to the outline planning and design proposals for the development, which wraps around the new guided busway and the Trumpington Park and Ride site, and links into the well-established cycleway network to the city centre. The scheme is also aiming to achieve a significant net biodiversity gain on the land which, as of 2023 (subject to secondary legislation), will need to reach 10% for new developments to be granted planning permission under the recently adopted Environment Act 2021.[8]

The study focuses on the carbon impacts of the homes and masterplan. As such, non-residential buildings have been excluded from the analysis and other holistic sustainability considerations have not been specifically measured, such as sequestration from increased nature provision, transport emissions in-use, and social value impacts.

Figure 7: Photos from the completed Trumpington Meadows development (Photo credit: Terence O'Rourke)

GUIDE TO THIS REPORT

1. **Design**
   Description of the design changes between the design scenarios, and the associated reductions in embodied carbon.
2. **Cost**
   Description of the cost changes between the design scenarios, with discussion on key cost drivers.
3. **Discussion**
   Summary of the market implications and policy recommendations to help guide the delivery of low carbon residential developments.

A series of complementary 'explainer' and 'discussion' boxes are provided throughout the report to provide readers with a better understanding of wider considerations for low carbon residential developments.

Section 1: Design

This section provides an analysis of the changes made to the baseline masterplan to reduce embodied carbon across the intermediate and stretch scenarios. All design scenarios are assumed to build upon and retain the previous design unless otherwise stated. The analysis is split into the following sections:

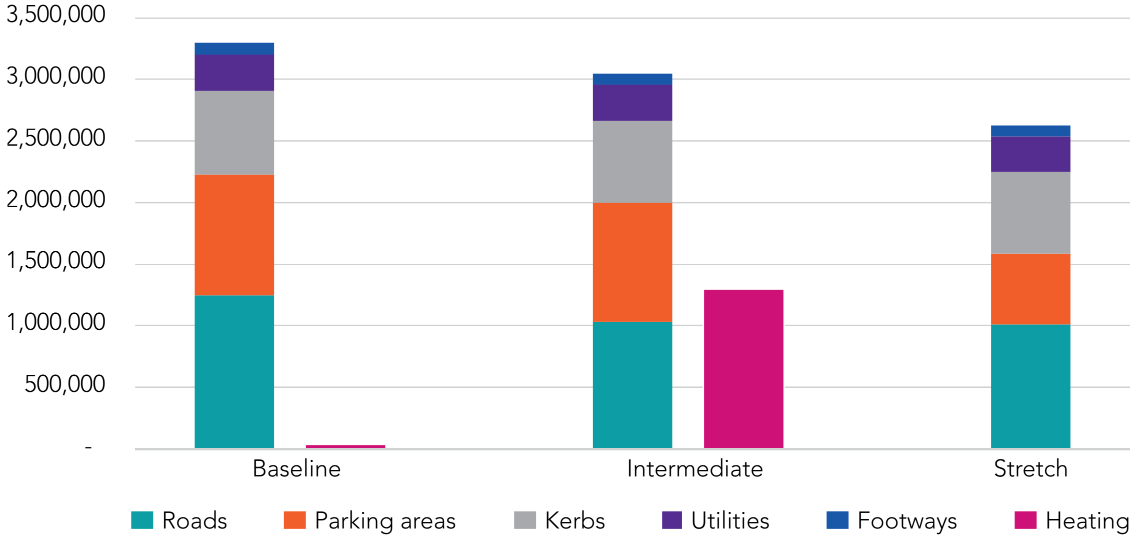
- Results overview
- Roads and hard surfaces
- Parking and landscaping
- Heating

RESULTS OVERVIEW

KEY MESSAGES

- Embodied carbon from the baseline masterplan is 3,300,000 $kgCO_2e$, which is roughly the equivalent of the total embodied carbon from 80 terrace houses.
- 'Grey infrastructure' – comprised of roads, parking areas and kerbs – makes up 88% of the baseline's embodied carbon. This is reduced by 660,000 $kgCO_2e$ (or 20% of the total) in the stretch scenario, primarily by reducing parking area and switching from asphalt to permeable paving on tertiary roads.
- 'Upfront carbon' (module A), which consists of all construction-related emissions up until practical completion, makes up 85% of total embodied carbon (modules A to C), highlighting the importance of selecting low carbon products and materials during design and construction.

Figure 8: Total embodied carbon results ($kgCO_2e$; heating has been separated)



Please note, a gas network has been modelled for the baseline scenario and a district heat network option for the intermediate scenario. This is the heat infrastructure associated with the masterplan and is discussed in detail under the Heating section. All heating systems within the curtilage of homes is covered in the homes' analysis, including the on-plot air source heat pumps in the stretch scenario.

Table 3: Results for total embodied carbon (modules A1-A4, B4-5 and C2-4; $kgCO_2e$)

	Baseline	Intermediate	Stretch
Roads	1,245,000	1,035,000	1,010,000
Parking areas	985,000	965,000	575,000
Kerbs	680,000	665,000	665,000
Utilities (excl. heating)	290,000	290,000	290,000
Footways	95,000	95,000	90,000
Total (excl. heating)	**3,300,000**	**3,055,000**	**2,630,000**
Reduction from baseline	**-**	**-7.4%**	**-20.3%**

Explainer: What is embodied carbon?

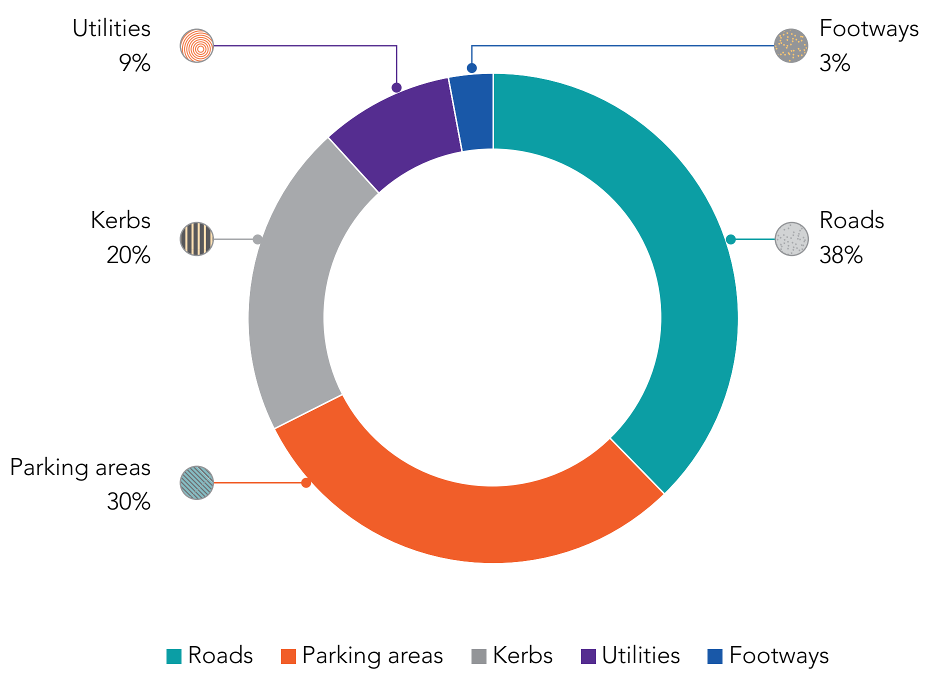
Embodied carbon is defined as the total greenhouse gas emissions and removals related to materials and construction processes throughout the whole lifecycle of a building or infrastructure works, including construction, use, maintenance, repair, replacement, refurbishment, and end-of-life (modules A to C, excluding B5 & B6).[9]

In this study, an embodied carbon assessment was used to calculate the embodied carbon of all infrastructure works over a 60-year lifespan using the internationally recognised standard PAS 2080.[10] An updated assessment was undertaken for each of the three design scenarios, based on different modelling inputs. The One Click LCA software package[11] was used to undertake these assessments.

Environmental Product Declarations (EPDs) were used to model specific products and materials, and where these were not available, generic values were used from the One Click LCA library. It should also be noted that results may differ when using other software packages (e.g. eTool), given different sets of EPD libraries and assumptions may be used.

Default values have been used for some modelling inputs (e.g. module A4, transportation of materials to site) and some modules have not been modelled as these are project-specific (e.g. module A5, construction emissions). Accordingly, the results presented are conservative and assessments on other projects would need to include these project-specific details. The embodied carbon results presented in the following section cover modules A1-A4, B4-5 and C2-4, with module D reported separately – please see Appendix A for detailed results.

Figure 9: Breakdown of embodied carbon for the baseline scenario



ROADS AND HARD SURFACES

KEY DESIGN CHANGES

	Baseline	Intermediate	Stretch
Primary streets	Asphalt	Asphalt	Low temperature asphalt
Secondary streets	Asphalt	Asphalt	Low temperature asphalt
Tertiary streets	Asphalt	Permeable paving	Permeable paving
Parking courts	Asphalt	Permeable paving	Ecogrid E40
Footpath/ cycleway	Concrete edging	Soft path edging	Soft path edging
Swales	Primary streets only	Primary and secondary streets	Primary and secondary streets

The **BASELINE** design is an extension to the existing Trumpington Meadows scheme (shown at north-east in Figure 10). The scheme consists of an active travel network with a 3-metre wide footpath/cycleway incorporated into the primary and secondary streets. A bus loop is provided along the primary street, and a park-and-ride facility is within short access of the site providing efficient access to the centre of Cambridge.

As per Figure 8, roads and hard surfaces make up 91% of the masterplan's total embodied carbon, with utilities making up the remaining 9%. Roads and hard surfaces were investigated to understand key opportunities to reduce embodied carbon, mainly through dematerialisation and material switching. All roads and parking court surfaces are asphalt in the baseline (standard sub-base, base, binder and capping are also modelled). The embodied carbon from roads and parking courts combined equals 68% of embodied carbon, and largely influence the provision of concrete kerbs which contribute an additional 20%.

To reduce the amount of materials used in roads, the task group did consider an option to reduce road widths and potentially only provide footpaths on a single side of roads (effectively halving the amount of concrete required), however these design options were not pursued in an effort to ensure the design would remain adoptable by the local Council. Instead, the amount of parking area was significantly reduced, and this is discussed under the next Parking and landscaping section of this report.

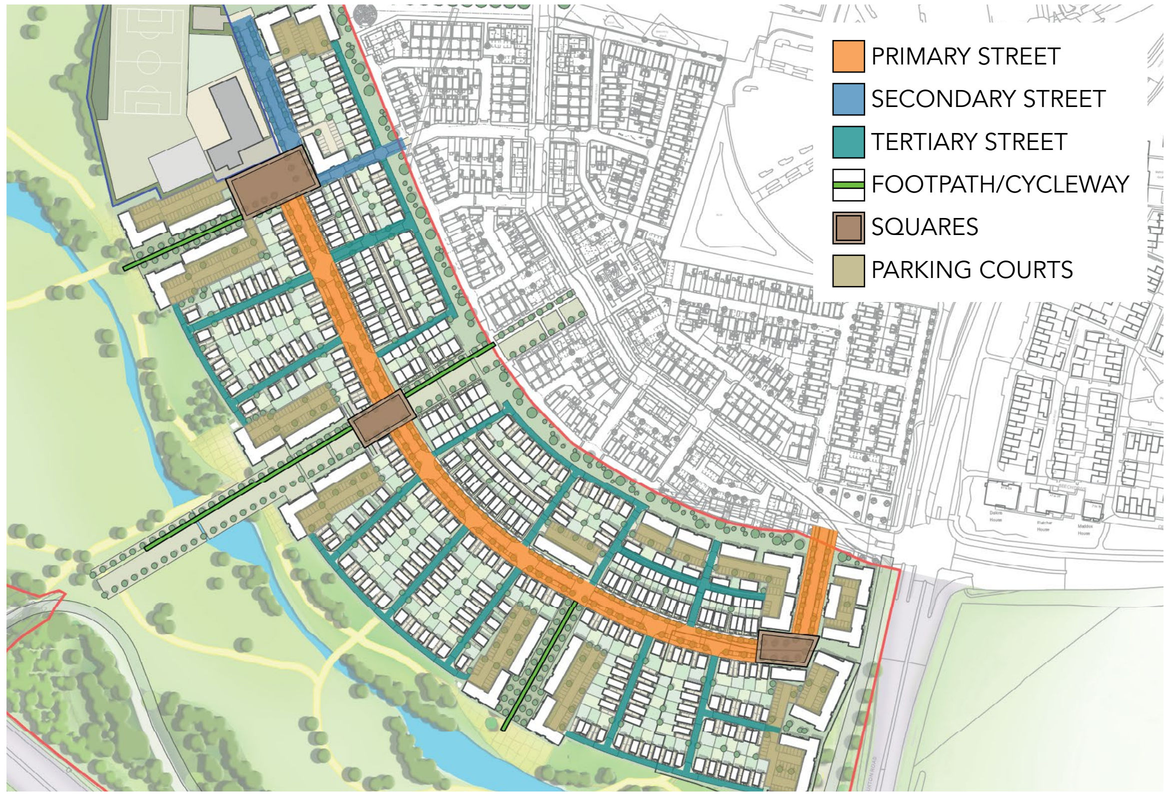
The **INTERMEDIATE** design sees a relatively straightforward switch from asphalt to permeable paving (porous blocks, subject to ground conditions) for the tertiary roads (only) and parking courts. This directly reduces embodied carbon by 210,000 $kgCO_2e$ or 17% for the roads (from 1,245,000 to 1,035,000 $kgCO_2e$). The amount of concrete required is reduced by simply removing kerbs to the footpath/cycleway and using soft edges instead, however the benefit is minimal with a 2% saving (from 680,000 to 665,000 $kgCO_2e$).

Stormwater drainage is modelled for the highways in the baseline scenario, and swales are extended to include primary and secondary streets in the intermediate scenario. This reduces the amount of stormwater drainage required, including PVC piping and excavation of trenches, with potential further savings in reducing the offsite drainage works requirements, depending on discharge locations. In addition to the embodied carbon savings, the sustainable urban drainage systems (SuDS) consisting of permeable paving and increasing the provision of swales have wider environmental benefits. This includes improving natural water cycles by replenishing the ground water table, reducing peak demand on surrounding stormwater infrastructure from flood events, improving neighbourhood amenity through provision of a 'blue/green' network, improving overall water quality at the discharge point, etc.

The **STRETCH** design sought to further optimise the design by switching from the carbon-intensive asphalt to a low carbon alternative. Low temperature asphalt was used in place of regular asphalt, however the saving is relatively small at 25,000 $kgCO_2e$ or 2% for the roads (from 1,035,000 to 1,010,000 $kgCO_2e$). The use of recycled materials in roads could be an opportunity for further carbon savings (or, separately, plastic footpaths/cycleways).

The permeable paving (porous blocks) used in the parking courts are replaced with a proprietary system made of recycled plastic, Ecogrid E40.[12] This, in combination with a reduction in parking area, drastically reduces embodied carbon by 390,000 $kgCO_2e$ or 60% for the parking areas (from 965,000 to 575,000 $kgCO_2e$). This type of system was not extended to the tertiary roads as the roads would experience much higher traffic volumes and, currently, this product is unlikely to be adoptable.

Figure 10: Masterplan with street hierarchy



PARKING AND LANDSCAPING

KEY DESIGN CHANGES

	Baseline	Intermediate	Stretch
Parking (overall spaces per home)	1.3	0.7	0.55
Electric vehicle charging	No provision	50% charging spaces	75% charging spaces
Squares	100% hard landscaped – block paving	75% hard landscape – block paving 25% soft landscape – semi-mature trees and shrubs	50% hard landscape – loose gravel surfacing 50% soft landscape – semi-mature trees and shrubs
Trees per 100 homes (indicative)	35	47	69

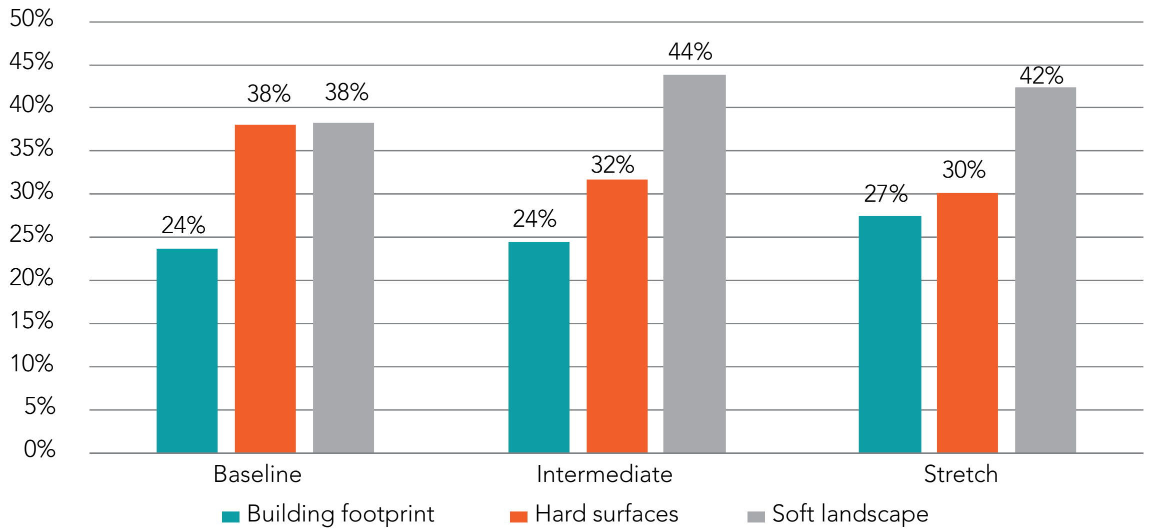
A smaller parcel of the overall masterplan, shown in Figure 10, was used to model changes to the urban design rather than carrying this out across the entire scheme. This parcel of roughly 100 homes was considered representative of the scheme's overall density and housing mix, therefore allowing the findings to be extrapolated. The results provided in this section are in percentage figures, for ease of understanding across the entire scheme.

The **BASELINE** design includes a relatively generous provision of parking for private vehicles (1.3 spaces per home), through a mixture of private parking spaces and parking courts. To reflect expected behavioural changes and the move to 'mobility as a service' rather than relying on private car ownership, the parking ratios in the intermediate and stretch scenarios were reduced, freeing up parking areas for other uses. However, currently, it should be noted that most homeowners are still looking for dedicated parking, and this approach could have risks around market acceptability, for example, sales rates and values. The ratio of parking spaces modelled per home is provided in Table 4.

Table 4: Parking ratio across the three scenarios

	Baseline	Intermediate	Stretch
Overall spaces per home	1.3	0.7	0.55
Spaces per house	2	1.5	0.75
Spaces per apartment	1	0.75	0.5

Figure 11: Ratio between building footprint, hard surfaces and landscaping



The site is predominately covered by three area uses: homes (24%); hard surfaces, including roads and parking (38%); and soft landscaping (38%), as per Figure 11. The footprint from homes largely remains fixed between the three scenarios as the size and number of homes were not decreased. As above, the area dedicated to parking was freed up to explore opportunities to both reduce embodied carbon and improve biodiversity net gain.

The provision of parking spaces in the **INTERMEDIATE** design is almost halved (from 1.3 to 0.7 overall spaces per home). The reduction in private vehicle parking and driveways enables previously detached houses to form a block of semi-detached or terraced houses, as per Figure 12. This more efficient use of spaces allows an additional three homes (for the 100 home scheme) to be added to the scheme. The space made available from reduced parking court areas enables additional soft landscaping to be included, with the provision of trees increasing from 35 to 47, or by 34%.

Subject to planning consent, this modification to the area usage has multiple benefits, including:

- Increasing development yield to help improve the business case for low carbon, nature rich developments.
- Increasing density to help improve provision of shared or public transport.
- Improving residents' access to nature.
- Delivering increased biodiversity net gain.
- Reducing hard surface areas (overall) and the urban heat island effect and surface water flooding risk.

Aside from parking areas, the approach to increasing soft landscaping was extended to the feature squares along the primary and secondary streets. The 100% block paving in squares for the baseline design gives way to 25% soft landscaping in the intermediate design, increasing the overall provision of semi-mature trees and shrubs.

Table 5: Increase in density of homes through reduction in parking areas

	Baseline	Intermediate	Stretch
Detached	24	19	23
Semi-detached	6	8	0
Terrace	0	6	12
Apartment (mid floor)	64	64	64
Total	94	97	99
Increase from baseline	**-**	**3 homes (3.2%)**	**5 homes (5.3%)**

The **STRETCH** design extends the same approaches from the intermediate design, with parking further reduced by 21% (from 0.7 to 0.55 overall spaces per home). Most houses no longer have private parking or driveways, however this gives way to both communal gardens and bike storage areas. The scheme can be densified further, with a group of semi-detached houses combining to form a block of terraced houses. This has the added benefit of lower energy homes, given terraced houses perform best compared to semi-detached or detached houses. The number of homes overall increases again resulting in five additional homes (for the 100 home scheme) compared to the baseline.

Further area from parking courts and squares are converted to soft landscaping, with the number of trees almost doubling from the baseline (from 35 to 69, indicatively). Carbon sequestration, increased biodiversity and resident access to nature are just some of the indirect benefits the additional trees would bring, however these were not attempted to be measured by the task group. Block paving used in the squares is replaced with gravel to both reduce embodied carbon and improved ground water permeability.

Given the planned phase out of petrol and diesel vehicles, the stretch design anticipates 75% of car spaces requiring electric vehicle charging (from nil and 50% in the baseline and intermediate scenarios, respectively). However, upcoming changes to Part S will require at least this level of provision, and potentially more, for new homes from 2022.[13] The costs for the additional electric vehicle infrastructure are included in the costing analysis, however the associated embodied carbon was not modelled given this was considered relatively immaterial. Additionally, the associated uplift in capacity procurement and grid reinforcement would need to be considered.

Figure 12: Schematic illustrating the ability to increase housing density

Discussion: reducing private vehicle usage

The provision of parking between the baseline and stretch designs reduces by around 58% (from 1.3 to 0.55 overall spaces per home). This was considered reasonable given a range of factors, including:

- Increase in shared car ownership (and decrease in private vehicle ownership);
- Active travel provision (footpath/cycleway);
- Access to park-and-ride facility nearby (please note, this is site-specific); and
- Benefit in improving natural biodiversity and/or increasing density of homes.

Whilst the emissions generated from transport were outside the scope of this study, reducing dependence on private vehicle use will be key to delivering low carbon residential developments in the future. This raises interesting discussion points about residents' access to transport options and the design scenarios laid out in this study offer a possibility of what this might look like.

HEATING

KEY DESIGN CHANGES

	Baseline	Intermediate – option A	Intermediate – option B	Stretch
Heating system	Gas boiler (on-plot)	Air source heat pump (on-plot)	District heat network (communal)	Air source heat pump (on-plot)

The embodied carbon from utilities (excluding heating systems) makes up 9% of the baseline's total embodied carbon (290,000 of 3,300,000 $kgCO_2e$). This is comprised of electrical cabling, potable water, foul water, stormwater, and communications – modelling assumptions are included in Appendix B. Given the relatively immaterial impact from these utilities when compared to the overall masterplan emissions, they were not altered across the three scenarios, whereas the heating system was.

The **BASELINE** design assumes a conventional gas network for illustrative purposes, however, this comes with strong caveats. Gas boilers are unlikely to meet the performance requirements under the Future Homes Standard, could be banned within Local Plans ahead of the Future Homes Standard's introduction in 2025, and would not meet UKGBC's definition for a net zero carbon building.[14] Accordingly, any gas boilers installed today will need to undergo likely expensive retrofit[15] to low carbon alternatives before 2050.

The gas network assumes high density polyethylene (HDPE) piping to dwellings, which results in 40,000 $kgCO_2e$ embodied carbon, or 1.2% of the masterplan's entire embodied carbon impact (40,000 of 3,300,000 $kgCO_2e$).

The **INTERMEDIATE** design explores two distinct options to heating – air source heat pumps provided to individual homes and a communal heat network serving the entire scheme. These two options were modelled as a basis for readers to consider the pros and cons for each as a heating solution, alongside the embodied carbon and costs.

The embodied carbon from the district heat network is 904,000 $kgCO_2e$, as per the breakdown in Table 6. This is significant when compared to the masterplan, as it makes up 29.6% of the masterplan works (904,000 of 3,055,000 $kgCO_2e$), however would result in reductions in embodied carbon from homes.

Additionally, the embodied carbon of the infrastructure to provide increased power capacity required to accommodate electric heating would need to be calculated to make a fair comparison across different heating options.

The task group made a decision to model two electrical substations across all three scenarios based on high-level calculations only. This highlights the challenge of low carbon developments interacting with wider infrastructure networks and finding a solution that is efficient both on and off-site i.e. avoiding the risk of all electric schemes requiring large off-site electricity network upgrades.

The embodied carbon from the heat network is challenging to compare with other on-plot solutions, as the impact has effectively shifted from the homes analysis to the masterplan i.e. there will be a commensurate reduction in embodied carbon for homes due to the removal of on-plot heating systems. In this study, the embodied carbon from the heat network was roughly apportioned across the homes, which found that there was a marginal (less than 1%) embodied carbon saving compared to an on-plot air source heat pump. Further detailed analysis would need to be undertaken to confirm these findings.

The energy centre would need to be centrally-located for operational efficiencies which, in this study, is assumed to result in a loss of 1-acre of land, the equivalent of around 12 homes. This would result in a slight reduction in the overall yield of the scheme.

The alternative option for on-plot air source heat pumps results in a reduction in embodied carbon for the masterplan, given the gas network from the baseline design is stripped out. The impact of heating on the masterplan is effectively nil, given the embodied carbon from air source heat pumps will be included within the homes analysis. However, again, the impacts on off-site electricity network upgrades have not attempted to be modelled and would need to be considered. This is maintained for the **STRETCH** scenario also.

Table 6: Breakdown of embodied carbon from district heat network

	Description	Embodied carbon ($kgCO_2e$)
Network pipes	Steel insulated flow/return pipes from energy centre (125mm diameter for network and 25mm diameter to homes).	304,000
Energy centre	Centrally-located building to house the heating systems. 800 kW ASHP capacity, 1,700 kW electric boiler capacity (top up boilers to achieve 2.5 MW total capacity) and 60 m^3 thermal storage.	600,000
Total		**904,000**

Table 7: High-level comparison of embodied carbon from different heating systems

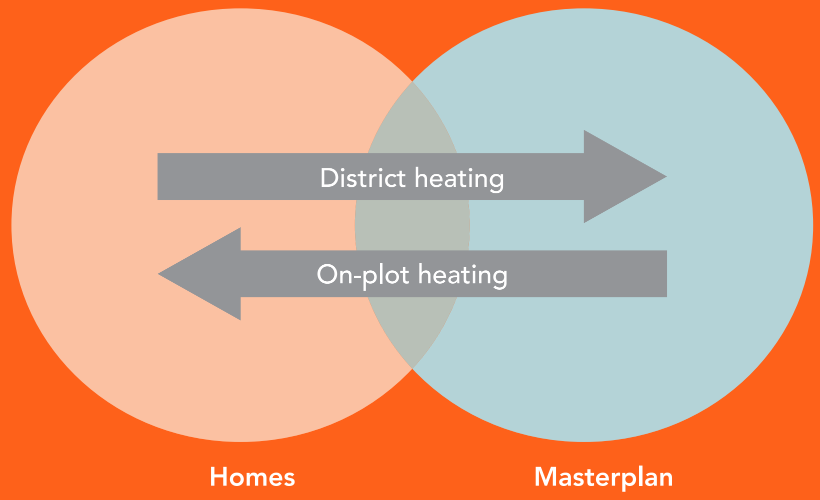
Heating system	Element	Apportioned to	Embodied carbon $kgCO_2e/m^2$
Gas	Gas network	Masterplan	0.07
	Boiler	Homes	19
District heat network	District heat network & energy centre	Masterplan	1.6
	Heat interface unit	Homes	2.7
Air source heat pump	Air source heat pump	Homes	17

Discussion: accounting for the embodied carbon of district energy systems

Embodied carbon assessments for buildings typically only consider construction activities that take place within a site boundary. This can result in other critical systems that a building depends on being treated as an 'externality' and not considered throughout the design process. Examples of this include district heat networks, off-site renewable energy farms, and grid reinforcements.

If undertaking a building-level assessment, the embodied carbon impacts from a new heat network may not be modelled or reported. This study has modelled the embodied carbon impacts from the heat network to provide a complete understanding of its whole life carbon impact. This also raises the question as to whether embodied carbon from communal heat networks should be included within building-level performance targets.

Separately, the cost to install a heat network would also need to be carefully considered. Whether the costs are borne by the developer or housebuilder and the likely feasibility of this remain open questions. In this study, the cost from the district heat network is reported separately to the rest of the masterplan, so that these costs can be assessed independently.



Other

Strategies considered but not modelled for this study:

- **Site preparatory works (difficult to model)**
  Reducing soil movement (e.g. excavation, storage), using existing topography (site specific), reducing underground works (e.g. locating utilities above ground), electrification of construction equipment, etc.
- **On-site renewables (site-specific)**
  Whilst this would be possible for Trumpington South (e.g. a solar farm), this was considered too site-specific and was not modelled in the masterplan. Potential for the scheme to be 'net zero energy' if it were to produce enough energy for all homes on the site.
- **External planting and turfing (and irrigation systems)**
  Carbon sequestration from trees was not modelled as part of this study. This would need to get verification from the UK Woodland Carbon Code and would also not sequester carbon from day one.
- **Street furniture, equipment and ornamental features (immaterial)**
  Material switching or increase recycled content, lighting efficiencies or move to sensor or no lighting.
- **Utility supply networks**
  The use of existing utility networks (e.g. water, electricity, sewage, telecommunications, etc) could reduce the extent of the works required.
- **District heat network**
  The results of this study have focused on a low density development, so the heat network design would be expected to be less if in an urban area (e.g. significantly reduced network length, less connections to individual houses, and more connections to blocks of homes).

Section 2: Cost

As the previous section has shown, the masterplan can be enhanced to significantly reduce embodied carbon. However, a better understanding of the effects on capital cost is necessary to appreciate the changes required to investment and financing decisions. The analysis is split into the following sections:

- Methodology
- Results overview
- Key cost drivers:
  - On-site highways and parking
  - Surface water drainage
  - Heating

METHODOLOGY

This section outlines the estimated changes in cost to achieve the intermediate and stretch design scenarios for the masterplan. For all scenarios, costs are modelled on outline scope changes without detailed design information, using assumed specification based on typical masterplan and Local Authority requirements, and as such represent an order of magnitude estimate.

Costs are based on contractor data and are informed by the Arcadis benchmark database. Where possible, the supply chain has been engaged to provide cost data. In some instances, accurate cost data has been difficult to obtain from the supply chain, which is representative of emerging low carbon materials and a restricted supply chain. As such, assumptions have been made to model the cost change.

Costs are based on current day prices and traditional methods of construction, and it is recognised that as the market matures, costs may decrease as efficiencies are realised. Furthermore, the introduction of government incentives may provide further cost reductions over time.

The market is currently experiencing volatile material and labour prices for key materials and building components. The costs presented within this report do not make any adjustment, nor risk allowance, for material and labour price fluctuations.

This report includes costs associated with the district heat network, not the on-plot heating systems, which is included in the supporting report on homes due to be published later in 2022. For the intermediate scenario with the heat network, costs are disproportionally higher, reflecting the movement of the heat source from within the dwelling into the masterplan.

Facilitating works, external works, overheads and profit, design fees, risk and out of the ordinary project specific costs (i.e. abnormals, such as ground remediation, site specific constraints, pumping, ecology remediation) have been excluded.

RESULTS OVERVIEW

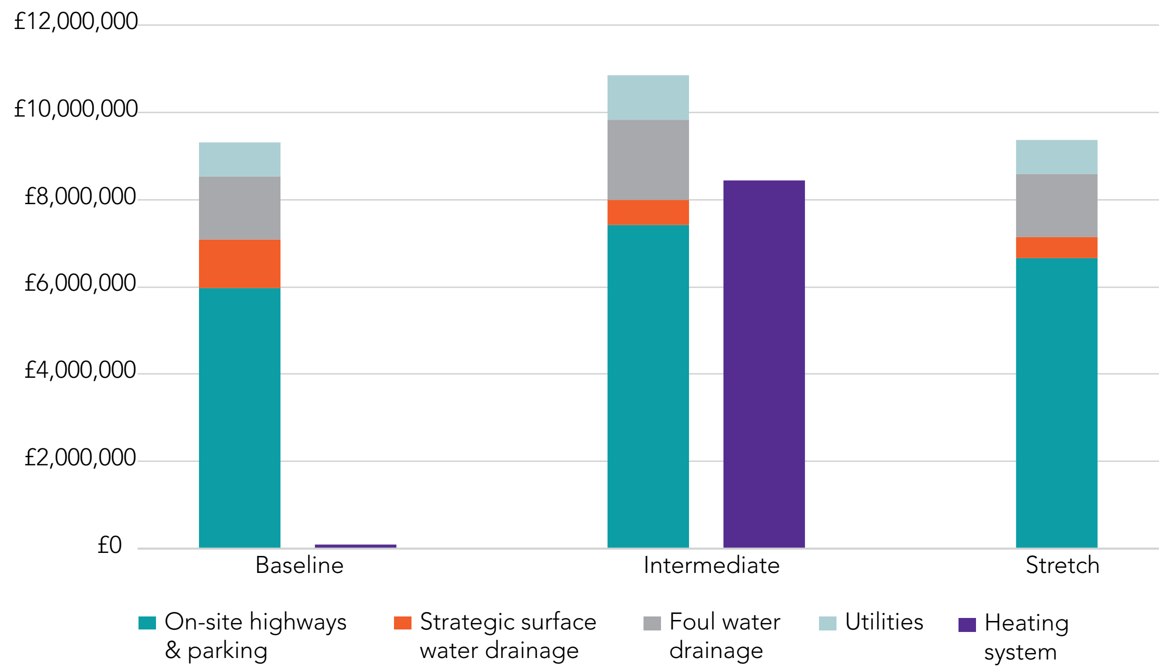
KEY MESSAGES

- Costs increase by 0.6% between the baseline and stretch scenarios, alongside a 20% reduction in embodied carbon.
- The district heat network (modelled in the intermediate scenario) shifts the heat source from within homes to the masterplan, making these costs anomalous to other scenarios.
- The majority of cost changes are associated with the tertiary streets, on-plot drives, squares and surface water drainage.

Overall, as can be seen in the total values in Figure 13, there is a minimal cost uplift of implementing the proposed embodied carbon reduction interventions, or 0.6% uplift between the baseline and stretch scenarios. This is attributable to both a reduction in the cost of surface water drainage, owing to the extension of the swale network, and reduction in the area of parking courts and squares. It is important to note that, whilst the baseline and stretch costs are comparable, the stretch scenario has significantly improved amenity and urban design features, in addition to a 20.3% reduction in embodied carbon.

However, when looking at the intermediate scenario, the results vary depending on whether an on-plot solution (individual air source heat pumps) is modelled versus a communal district heat network. With on-plot heating, the cost increase from the baseline is 15%, compared to 105% with the district heat network.

Figure 13: Total masterplan costs by scenario



Please note, a gas network has been modelled for the baseline scenario (£95,000) and a district heat network option for the intermediate scenario (£8.5mil), separate to the masterplan costs. This is the heat infrastructure associated with the masterplan. All heating systems within the curtilage of homes is covered in the homes' analysis, including the on-plot air source heat pumps in the stretch scenario.

Table 8: Detailed cost breakdown (rounded to nearest £5k)

Scope	Scenario		
On-site highways & parking	**Baseline**	**Intermediate**	**Stretch**
Primary street	£1,655,000	£1,670,000	£1,670,000
Secondary street	£395,000	£395,000	£395,000
Shared drives	£0	£0	£0
Tertiary street	£2,030,000	£2,705,000	£2,705,000
Parking courts	£1,020,000	£1,700,000	£1,085,000
On-Plot Private Drives	£270,000	£345,000	£380,000
Squares	£465,000	£465,000	£290,000
Footpath/cycleway	£145,000	£145,000	£145,000
SUB-TOTAL	£5,980,000	£7,425,000	£6,670,000
Strategic surface water drainage	**Baseline**	**Intermediate**	**Stretch**
Strategic Surface Water Drainage	£1,005,000	£425,000	£320,000
Attenuation and SUDs	£100,000	£145,000	£145,000
SUB-TOTAL	£1,105,000	£570,000	£465,000
Foul water drainage	**Baseline**	**Intermediate**	**Stretch**
Strategic Foul Water Drainage	£880,000	£1,255,000	£885,000
Strategic Foul Water Pumping Station	£580,000	£580,000	£580,000
SUB-TOTAL	£1,460,000	£1,835,000	£1,465,000
Utilities	**Baseline**	**Intermediate**	**Stretch**
Utilities (Builders Work in Connection)	£575,000	£825,000	£575,000
Utilities (Builders Work in Connection - Sub Station)	£200,000	£200,000	£200,000
Diversions	£0	£0	£0
Reinforcements	£0	£0	£0
Point of Connection	£0	£0	£0
SUB-TOTAL	**£775,000**	**£1,025,000**	**£775,000**
GRAND TOTAL (Excl heating)	**£9,320,000**	**£10,855,000**	**£9,375,000**
Heating	**Baseline**	**Intermediate**	**Stretch**
Energy Pipework	£95,000	£5,030,000	£0
Energy Centre	£0	£3,420,000	£0
SUB-TOTAL	£95,000	£8,450,000	£0
GRAND TOTAL (Incl heating)	**£9,415,000**	**£19,305,000**	**£9,375,000**

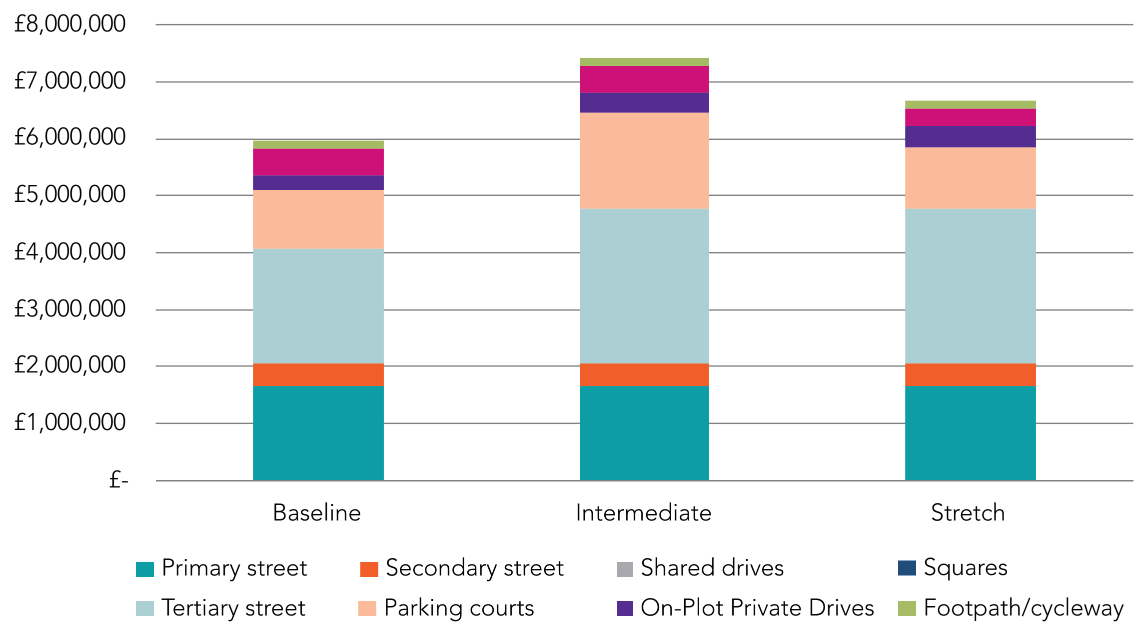
ON-SITE HIGHWAYS AND PARKING

The majority of costs in the baseline scenario for highways and parking are attributed to streets (68% or £4.08m of £5.98m). The costs correlate with total area coverage and the streets from most to least expensive are: tertiary, primary and secondary. A 24% cost uplift occurs between the baseline and intermediate scenario which is primarily due to the introduction of permeable paving to tertiary streets and parking courts, and electric vehicle charging spaces to parking courts.

The cost for streets remains stable between the intermediate and stretch scenarios, even with the switch from standard to low temperature asphalt for primary and secondary streets. The parking court costs are reduced by switching from permeable paving to the proprietary Ecogrid E40 system. Additionally, the costs for squares also reduce due to an increase in soft vs. hard landscaping (i.e. from 25:75 to 50:50).

Overall, the cost uplift between the baseline and stretch scenarios for highways and parking is moderate at 12% (from £6m to £6.7m).

Figure 14: On-site highways and parking



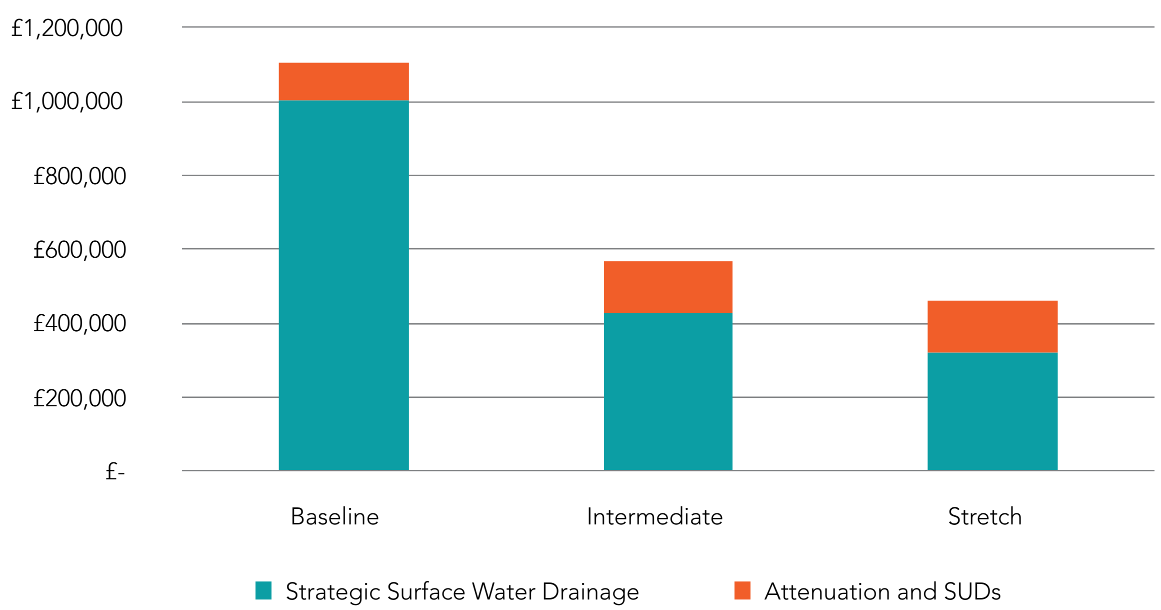
SURFACE WATER DRAINAGE

The costs for surface water drainage are almost halved between the baseline and intermediate scenarios (by £535,000 or 48%) from a reduced requirement for stormwater drainage. This is due to extending the swale network from primary streets only in the baseline, to include primary and secondary streets in the intermediate; overall increase in permeable surfaces; and decrease in parking provision (less hard surface area).

Costs are further reduced between the intermediate and stretch scenarios by 18% due to a reduction in the depth of the pipework, which is assumed to be 3.5m deep in the intermediate scenario, and 2.5m in the stretch scenario (as in the baseline).

For the foul water drainage, costs are higher in the intermediate scenario owing to the need to increase the depths to avoid clashes with the district heat network. Otherwise, the foul water drainage costs remain broadly constant across all scenarios (£1,460,000 for baseline).

Figure 15: Strategic surface water drainage



HEATING

The introduction of a district heat network for the intermediate scenario increases costs as the heating source is shifted from homes to the masterplan. The total cost for the district heat network is estimated at £8.5m, comprising of the pipework (£5m) and energy centre (£3.5m). The costs of the distribution pipework are high given the low-density of the scheme and long network lengths - a network within an urban-setting (i.e. high-rise buildings) would be expected to be significantly less. Again, to make a fair comparison with an on-plot solution, the cost for heating across all 750 individual homes would need to be totalled – these findings will be included in the supporting report on homes.

For all other utilities (e.g. water, electric, telecoms) the costs remain broadly constant across all three scenarios (£775,000 for baseline).

Section 3: Discussion

This report demonstrates that significant embodied carbon savings can be made within the masterplan, with little to no cost uplift. However, with no current or immediately planned regulation to measure and mitigate embodied carbon, the responsibility rests on developers and project teams. This section explores wider considerations relating to embodied carbon and improvement of the overall amenity of the masterplan.

DISCUSSION

As set out in the Introduction, embodied carbon emissions are projected to make up over half of the UK's total built environment emissions by 2035. Whilst this shift can be attributed primarily to reduction in operational carbon due to decarbonisation of the gird, it is critical that the source of embodied carbon emissions are assessed in order for them to be mitigated.

This report has demonstrated that significant embodied carbon savings can be made easily and quickly, with little to no implications on cost – see Table 9. However, developers might reasonably ask why they should invest the time and resources into making these changes now, when there is currently no regulatory driver. This theme is explored below, with competitive advantage and improved brand reputation cited as two key potential drivers.

Whilst this report examines key drivers and enablers for developers and built environment stakeholders, the success of delivering low carbon developments (and of the wider net zero transition) is also dependent on Government support. This may include, for example, funding mechanisms for innovation in low carbon materials, or variable stamp duty rates for in line with the energy performance new homes. Please see the Net Zero Whole Life Carbon Roadmap for detailed policy recommendations for both national and local Government.

Table 9: Headline findings on carbon and cost

	Baseline	Intermediate	Intermediate (incl. DHN)	Stretch
Embodied carbon (change from baseline)	3,300,000 $kgCO_2e$	3,055,000 $kgCO_2e$ (7.4% reduction)	4,350,000 $kgCO_2e$ (not a like-for-like comparison)	2,630,000 $kgCO_2e$ (20.3% reduction)
Cost (change from baseline)	£9,320,000	£10,855,000 (16.5% increase)	£19,305,000 (not a like-for-like comparison)	£9,375,000 (0.6% increase)

Embodied carbon measurements and agreed limits

Embodied carbon from the construction, use and demolition stages represent 20% of total UK built environment emissions today,[1] yet these emissions remain unregulated. Additionally, embodied carbon from masterplan works is rarely measured, let alone mitigated, largely due to the fact that these works can be carried out over many years and are not strictly considered as part of a building's design. The embodied carbon from masterplan works are considered a 'blind spot' within the industry.

As outlined in the Whole Life Carbon Roadmap's action plan, developers should first measure (to assess emissions hotspots) and then implement design strategies to mitigate embodied carbon, for all types of development works. As demonstrated in this study, significant embodied carbon savings can be made relatively easily where measurement is used to inform decision-making. The measurement tools and expertise already exist within the industry to make this action widespread, provided it is prioritised within the design brief. Further, developers aiming to make marketing claims about the sustainability of homes should also address masterplan elements, rather than this being overlooked. In turn, this can help improve overall marketing claims and contribute to enhanced brand reputation.

Contribution to organisational commitments

With the majority of large developers either setting, or having set, net zero commitments as well as commitments to report on their scope 1 to 3 emissions, the embodied carbon that would have previously 'slipped through the cracks' (i.e. from inter-plot and masterplan infrastructure) is now commonly being assessed. This embodied carbon will begin to be offset in order to achieve organisational net zero commitments, providing a strong incentive to reduce the embodied carbon of masterplan works. For example, based on HM Treasury's current recommended carbon price (£70/tCO_2, which is set to increase rapidly in the coming years), the embodied carbon reductions from this study (670,000 $kgCO_2e$) would result in savings of at least £47,000. Whilst upcoming regulation is likely to focus on buildings, organisational commitments may be the key driver for the shift towards embodied carbon reduction at the masterplan level.

Design efficiency and circularity

There is currently limited research around applying circular economy principles to masterplan elements, however using a circular approach to land use and urban planning can result in significant emissions reductions. This can be achieved through prioritising the reuse of existing infrastructure and, for example, ensuring that new developments are located in areas with sufficient transport links to reduce the amount of additional transport infrastructure needed. Additionally, product manufacturers have a role to play in decarbonising their own materials which can encourage the use of conventional materials that have lower embodied carbon (e.g. steel and concrete), alongside innovations that bring to market new material choices.

Resilience and nature-based solutions

The increased tree coverage between the baseline and stretch scenarios will provide real-world benefits, including flood risk mitigation and reducing the risk of overheating during summer months, thereby improving thermal comfort and occupant wellbeing. With the number of extremely hot days in the UK (exceeding 25°C) potentially doubling with a 2°C global temperature increase,[16] homes that are adapted to a changing climate (i.e. that will not require costly retrofit to improve insulation or air conditioning) will be more attractive to prospective homebuyers. This is demonstrated in the stretch design for homes, where all homes have mechanical ventilation with heat recovery (MVHR), which are able to provide summer bypass cooling.

Climate resilience can be further enhanced through the use of sustainable urban drainage systems (SuDS). SuDS help alleviate the risk of flooding, which cost the UK economy an estimated £1.6 billion in 2015-16,[17] in addition to providing water quality management, and storing and sequestering carbon through associated green infrastructure.[18] The carbon sequestration potential of the SuDS was not quantified in this study, however this could potentially be included as a carbon mitigation measure in other new developments.

Wider social benefits

With an increase in the proportion of soft landscaping vs. hard landscaping, and an almost two-fold increase in surrounding trees, the stretch scenario provides residents with far greater access to nature. This comes with a whole host of health and wellbeing benefits; from improved air quality and physical health, to improved mental wellbeing through biophilia.[19]

In order to achieve the UK's net zero target, new residential developments will increasingly need to provide alternatives to fossil fuel based private vehicle ownership, a large part of which is encouraging active lifestyles.[20] The provision of low carbon modes of transport in this study – including active travel options, a park-and-ride facility, and electric vehicle charging spaces – further contributes to improving air quality. This is particularly important for developments on the urban fringe, such as Trumpington South, where connectivity is a critical factor to ensuring easy access to a nearby city centre.

The communal gardens resulting from reduced private car parking and driveways will encourage social interaction, thereby enabling local residents and other occupiers to develop strong social networks. In this way, new developments can play a vital role in improving residents' sense of community and social ties.

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TASK GROUP

UKGBC convened individuals with experience working on the Trumpington South project to form the task group. We would like to offer a special thanks to all task group members for dedicating their time and expertise to meet regularly over a four-month period to undertake the study's analysis. This included developing the design scenarios; completing the design, carbon, and cost modelling; and preparing findings for this report. UKGBC is grateful for their in-kind contribution to undertake this piece of work.

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Organisation	Role	Representatives
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Barratt Developments	Housebuilder	Oliver Novakovic, Danielle Michalska, Daniel Shea
Buro Happold	Sustainability	Mark Dowson, Josephine Benthall, Martha Dillon
Grosvenor Property UK	Developer	Andy Sharpe, Rupert Biggin
One Click LCA Ltd	Sustainability	Marios Tsikos
Terence O'Rourke	Architects and Masterplanner	Terry Williams, Dan Fairley, Richard Burton

REVIEW GROUP

UKGBC sought to feed-in views from a wider set of stakeholders – including other designers, developers, housebuilders and financiers – to help enhance the findings of the study. The review group provided input at two key points during the development of the study.

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Appendices

APPENDIX A: DETAILED EMBODIED CARBON RESULTS (figures rounded; $kgCO_2e$)

Category	Product stage (A1-A3)	Full transport (A4)	Replacement and refurbishment (B4-B5)	Replacement transportation (B4-B5)	Replacement waste (B4-B5)	Waste transportation (C2)	Waste processing (C3)	Waste disposal (C4)	Overall GWP impact
Baseline									
Utilities	188,300	1,400	99,400	120	40	1,800	160	50	291,200
Roads and Hard Surfaces	2,433,300	194,100	291,100	17,100	10,600	54,500	5,800	-	3,006,400
Total	**2,621,600**	**195,500**	**390,500**	**17,220**	**10,640**	**56,300**	**5,960**	**50**	**3,297,600**
Intermediate									
Utilities	188,300	1,400	99,400	120	40	1,800	160	50	291,200
Roads and Hard Surfaces	2,433,400	201,300	77,500	4,600	2,800	39,500	4,400	-	2,763,500
Total	**2,621,700**	**202,700**	**176,900**	**4,720**	**2,840**	**41,300**	**4,560**	**50**	**3,054,700**
Stretch									
Utilities	188,300	1,400	99,400	120	40	1,800	160	50	291,200
Roads and Hard Surfaces	2,042,100	184,600	68,500	4,700	2,900	33,900	3,700	10	2,340,500
Total	**2,230,400**	**186,000**	**167,900**	**4,820**	**2,940**	**35,700**	**3,860**	**60**	**2,631,700**

Breakdown by lifecycle stage

	Upfront carbon (modules A1-4; $kgCO_2e$)	Total embodied carbon (modules A1-4, B4-5, C2-4; $kgCO_2e$)
Baseline	2,817,100 (85.4% of total embodied carbon)	3,297,600
Intermediate	2,824,400 (92.5% of total embodied carbon)	3,054,700 (7.4% reduction from baseline)
Stretch	2,416,400 (91.8% of total embodied carbon)	2,631,700 (20.3% reduction from baseline)

APPENDIX B: MATERIALS AND QUANTITIES USED IN MODELLING UTILITIES AND HEATING SYSTEMS

	Feed from mains connection		Network design		Piping to dwelling		
Utility	**Length (m)**	**Pipe/duct diameter (mm)**	**Length (m)**	**Pipe/duct diameter (mm)**	**Length (m)**	**Pipe/duct diameter (mm)**	**Material**
UKPN	310	200	3,550	150ducts	2,950	Arm. cable	UPVC recycled
Cambridge water	n/a (as diverted already)		3,550	100	2,950	63	HDPE pipe
Anglian water (foul)	32	225	3,550	150	2,950	100	UPVC
Stormwater	32	900	4,000	150	2,950	100	UPVC
BT Openreach	71	90	3,550	90	2,950	Arm. cable	UPVC
GeneSYS comms	366	90	3,550	90	2,950	Arm. cable	UPVC
Heating*							
Gas	74	180	3,550	100	2,950	63	HDPE pipe
DHN flow	-	-	3,550	125	2,950	25	Steel ins.
DHN return	-	-	3,550	125	2,950	25	Steel ins.

* Please note, gas pipes have been modelled for the baseline scenario and DHN flow/return pipes for option B of the intermediate scenario, separate to utilities. This is the heat infrastructure associated with the masterplan, and all heating systems within the curtilage of homes has been included within the homes' analysis.

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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**

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