Greater Cambridge Local Plan - Strategic spatial options appraisal: implications for carbon emissions.

Bioregional, on behalf of Greater Cambridge Shared Planning Authority

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Glossary and acronyms

BAU	Business as usual. Refers to today's current practices in design, construction and transport
BEIS	UK national government department for Business, Energy, Innovation and Skills
Building envelope	The external elements of a building (external wall, roof, windows)
Carbon intensity	Amount of carbon emitted during the production of a unit of energy
CO_2	Carbon dioxide
CSRM	Cambridge Sub-Regional Model (a transport modelling tool used by the local authority that is bespoke to the area's transport patterns)
Energy performance gap	The difference between the predicted energy use of a building when it is designed compared to actual use. Usually occurs due to a combination of faults or changes in the construction process, modelling inaccuracies, and unanticipated user behaviours
Embodied carbon	Carbon emissions that already happened during the production, transport and assembly of goods before they are used or operated (such as building materials and construction)
EV	Electric vehicle
GB	Greenbelt
GCSP	Greater Cambridge Shared Planning
GHGs	Greenhouse gases
kWh	Kilowatt-hours (a unit of energy)
Operational carbon	Carbon emitted during the operation of a building or vehicle
PV	Photovoltaics (solar panels generating electricity)
tCO_2/y	Tonnes of carbon dioxide per year
ZC	Zero carbon

Contents

Executive summary

We are commissioned by Greater Cambridge Shared Planning service to assess the scope for the new local plan to respond to climate emergency by supporting a transition to net zero carbon, including robust evidence-based carbon targets.

National government policy obliges the local plan to provide for growth of homes and associated facilities to meet the needs of a growing population and economic activity, as well as for existing residents and businesses that are currently constrained by unsuitable premises. It has to consider spatial options that could realistically bring that new growth forward (considering the conditions that exist in each type of location, and how this could constrain or enable new development).

Because new growth comes with demand for materials, heat, electricity and transport, it is typically associated with growth in carbon emissions. The amount of emissions depends on where it is built, provisions for sustainable travel, the quality of buildings, and how much renewable energy is deployed alongside new growth.

To inform decisions as to how to minimise the climate impact of the required new growth, this report models and compares the carbon emissions of the growth and spatial options being considered for the new Greater Cambridge Local Plan. We also identify a suite of policies to address the carbon emissions of new growth, and model how this affects the overall carbon outcome for each spatial option.

At this stage of plan making, the Councils have asked consultants preparing a range of evidence to compare the different choices available. The planning service provided figures showing three scenarios for growth that reflect the range of possibilities for economic and populational change within the plan period (see Table 1), beyond the existing commitments of 36,407 new homes not yet built.

Table 1: Growth Scenarios (number of new homes beyond existing commitments)

Minimum	Medium	Maximum
3,900	9,800	26,300

The provided growth figures also define eight spatial options for where these homes might be delivered. The spatial options are titled:

1. Densification of existing urban areas
2. Edge of Cambridge - outside the Green Belt
3. Edge of Cambridge – including some of the Green Belt
4. Dispersal - new settlements
5. Dispersal - villages
6. Public transport corridors
7. Supporting a high-tech corridor by integrating homes and jobs
8. Expanding a growth area around transport nodes

The title of each option refers to the type of location where ***most*** of its growth will occur. However, most options blend some growth in other types of location too (for example, see table for the medium growth scenario). In all eight options, the maximum growth spatial scenarios being tested include bringing forward committed growth planned at three new settlements with a total of 8,600 homes (90% of which are on public transport links). These sites are already allocated in the current local plans, but those 8,600 homes are anticipated to be built out beyond the end of the plan period except in the maximum growth scenario, where faster build out rates are assumed.

This report sits within our wider net zero carbon study for the local plan, which also includes defining what 'net zero' means, exploring planning powers, setting targets, exploring the feasibility and cost implications of building to net zero carbon standards, the role of offsetting, and shaping policies to reflect the above.

We have created a bespoke model to assess the carbon implications of the spatial options, covering the following sources of emissions due to new development:

1) Building construction materials and processes (embodied upfront carbon).
2) Building heating and electricity usage (operational carbon).
3) Occupant and visitor transport (transport carbon).

This model is based on localised data on development densities and required supporting social infrastructure, energy use of local new builds, local transport carbon, and national projections for reductions in electricity grid carbon intensity. Data vary from figures released by national government, to local data on recent planning approvals and transport. From this we generated six different spatial categories that reflect the kinds of growth (size, density, required additional infrastructure, transport patterns) that happens in Greater Cambridge: urban; edge of city (greenbelt or non); public transport corridor; new settlement; village.

By entering the amount of new housing growth in each location category, the model then adds a corresponding amount of additional supporting infrastructure (schools, healthcare, libraries, offices and community facilities). As mentioned, most spatial options have growth in more than one location category.

The model also offers a range of policies to reduce carbon emissions. To develop these, we used our own and other experts' knowledge about the extent to which it is possible to optimise transport and buildings' energy performance, and renewable energy generation.

The following two policy regimes have been modelled:

1) Business As Usual (BAU) – based on current typical practice.
2) Zero Carbon Policy: making significant improvements to new buildings' energy efficiency, embodied carbon, renewable energy generation, sustainable transport and usage of electric vehicles .

On the following pages we present outputs from our work to give three insights:

- A scalar comparison of the emissions from growth options, versus Greater Cambridge's existing emissions (and the approximately estimated emissions associated with allocated but as-yet unbuilt developments)
- The difference between carbon emissions from new growth in the plan period depending on spatial option, level of growth, and policies applied
- A comparison of the per-home annual emissions of each option in the medium growth scenario in the mid-plan year, after zero carbon policies have been applied.

Please note that the figure for 'existing growth commitments' is a much looser estimation than the 'new growth' options and the 'existing emissions' figures[1]. This figure is provided just to show the order of magnitude of existing commitments that are not yet built and anticipated in the housing trajectory to be completed by 2041 (36,407 new homes), compared to additional new growth being considered for the local plan (a maximum of 26,300 further new homes). We intend to develop a more accurate estimation of the emissions from the committed-but-unbuilt 36,407 new homes by exploring in greater detail where those homes are being built and to what energy performance standard, so that they could be entered into our tool in a more accurate way.

The scenarios being tested would represent an uplift of between 0.4% - 15% to Greater Cambridge's existing annual $CO_{2,}$[2]. Zero carbon policies result in major reductions to total plan period carbon emissions for all scenarios (Figure 2).

In terms of spatial choices, Option 1 (Densification) has the lowest emissions, with Option 6 (Public Transport Corridors) a close second. Option 5 (Villages) has by far the highest carbon emissions, with or without the carbon reduction policies. Figure 3 shows that this is largely due to transport.

Please note that this carbon modelling approach is innovative. We have not identified any 'standard practice' as there is for other planning evidence pieces such as transport, water or objective housing needs assessment. We have endeavoured to use the best available data on how emissions are generated from buildings and transport to produce a credible broad-brush picture of the carbon emissions differences between each spatial option, with or without special plan policies to reduce that carbon. Our methodology is available in the appendix.

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[1] The existing planning commitments represent 36,407 new homes and associated infrastructure. Because we do not have full information on their location and energy performance, we model them as an average of our six location categories.

[2] To compare with the BEIS data (which is for 2018), we modelled the new growth as if it were already operational in 2020. This is to give a sense of scale. We also removed embodied carbon from the new growth figures in this comparison, because BEIS data does not include this. The BEIS 'full dataset' sectors are: land use; commercial / industrial; domestic. The subset for local authorities is smaller because it excludes large industrial sites, railways, motorways and land use.

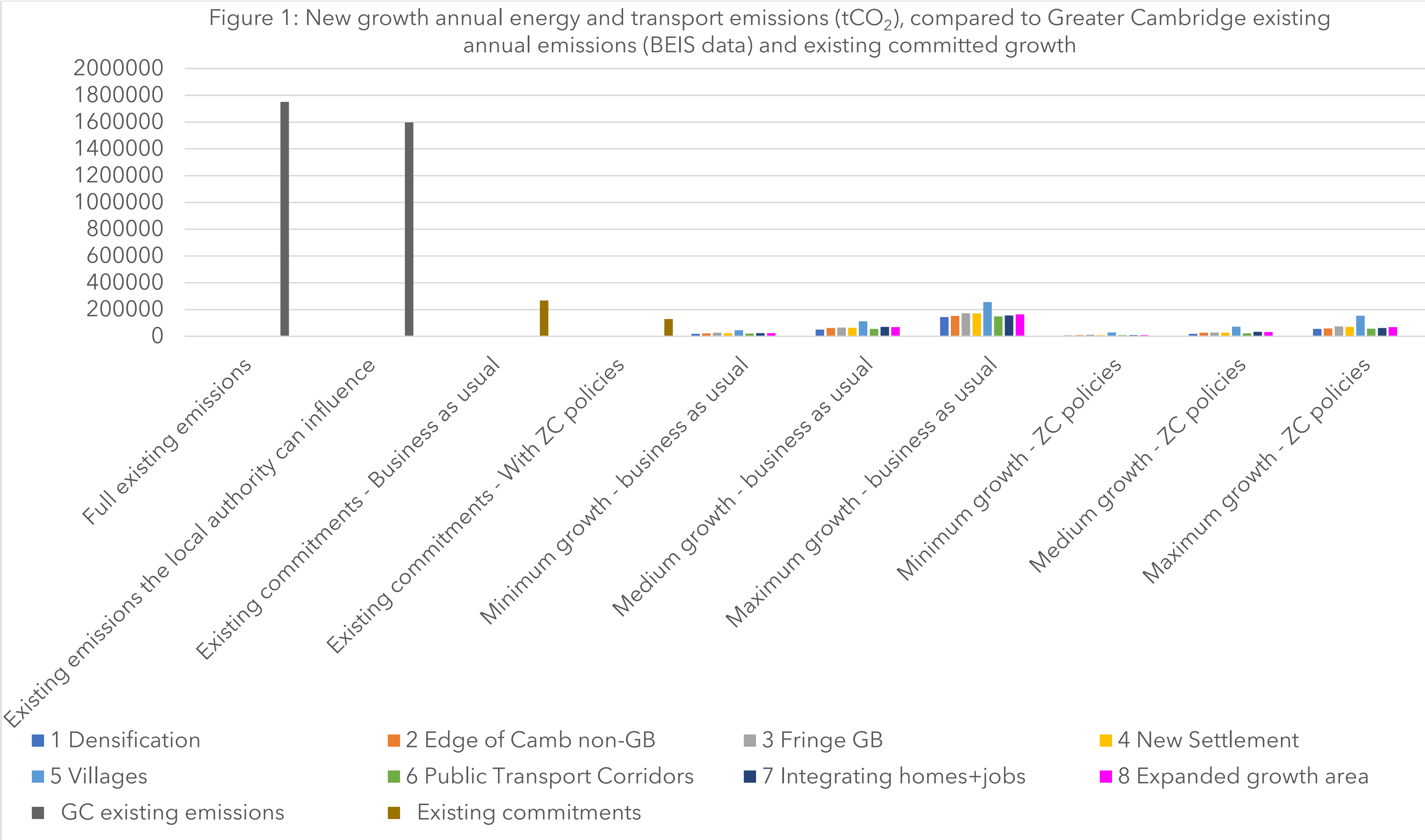
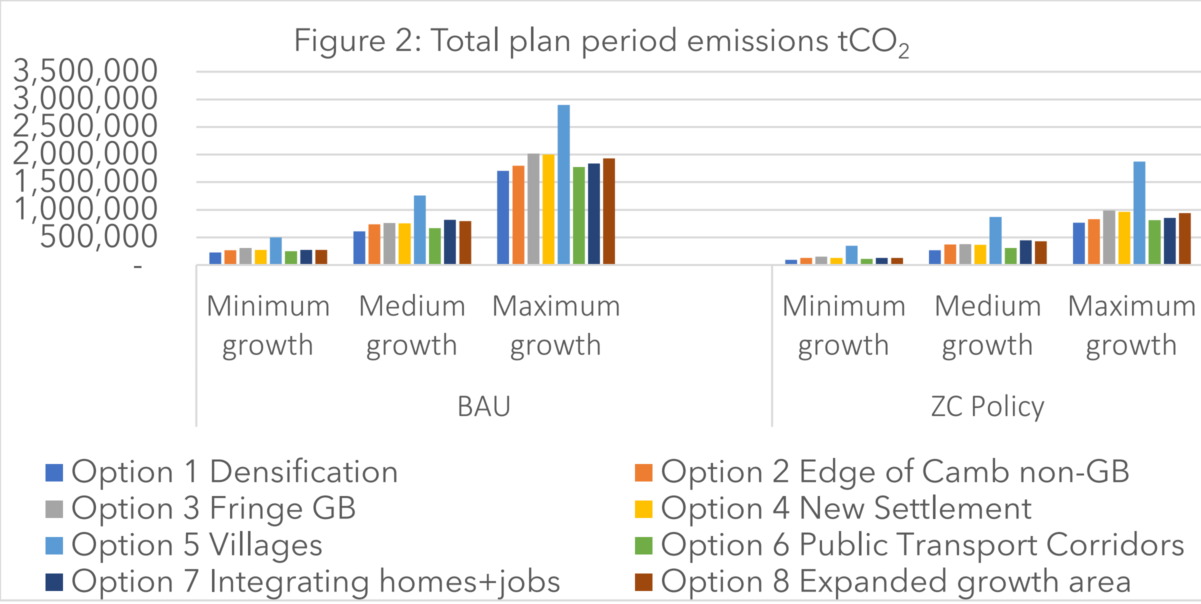
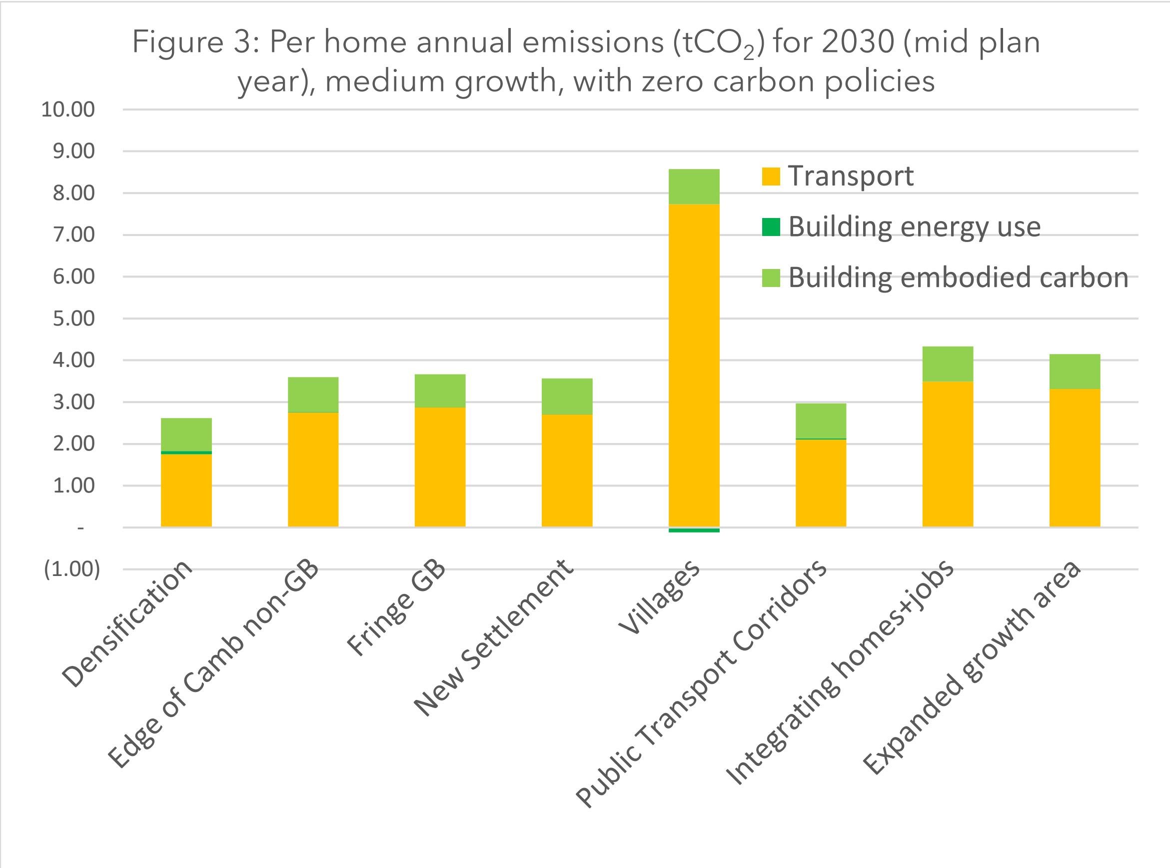


Figure 1: New growth annual energy and transport emissions (tCO_2), compared to Greater Cambridge existing annual emissions (BEIS data) and existing committed growth
2000000
1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
Full existing emissions
Existing emissions the local authority can influence
Existing commitments - Business as usual
Existing commitments - With ZC policies
Minimum growth - business as usual
Medium growth - business as usual
Maximum growth - business as usual
Minimum growth - ZC policies
Medium growth - ZC policies
Maximum growth - ZC policies
1 Densification
2 Edge of Camb non-GB
3 Fringe GB
4 New Settlement
5 Villages
6 Public Transport Corridors
7 Integrating homes+jobs
8 Expanded growth area
GC existing emissions
Existing commitments



To understand the drivers of difference between each scenario, the following chart shows a breakdown of annual emissions per home in the mid-plan year, with a medium level of growth, after zero carbon policies have been applied. The mid-plan year represents the median annual emissions throughout the plan period.



We see that the **main difference is due to transport** – with cars as the only realistic mode for most trips by most village dwellers. This is also true in 'business as usual', but the zero carbon policies bring transport into even sharper focus because the policies are able to eliminate carbon from buildings' energy use.

To a lesser extent, there are differences due to the lower density of typical village developments compared to compact urban homes. In 'business-as-usual', larger and lower-rise homes have worse emissions from space heating and embodied carbon, due to more floor space and building envelope. New rural homes also need more new infrastructure, which in urban settings is often already present. However, if zero carbon policies are applied as in Figure 3, then the low-rise village homes gain a small carbon benefit because they can fit more rooftop solar panels per dwelling, hence they achieve negative emissions for building energy. Still, this does not cancel out the major carbon disadvantage of car use in rural areas. There are mitigation measures that can help reduce the carbon impact of transport, but while planning can help deliver the infrastructure (for public transport, active travel and electric vehicles), the uptake of these not guaranteed.

Beyond the urban/rural split, differences between other options also largely relate to the public transport links of the anticipated sites identified in the GCSP growth figures. For example, North-East Cambridge is a major site in Option 2 (Edge, non-Green Belt). This is next to a major train station and would most likely be quite high-density, therefore has been modelled as 'urban'. In contrast, the 'fringe Green Belt' growth was not specified to be as well-connected to public transport and is likely not to be as high density for landscape impact reasons, therefore has been modelled as a suburb.

The transport impacts modelled have been calibrated with reference to the parallel transport study which has been undertaken using the Cambridge Sub-Regional Model (CSRM). Whilst this has informed the results significantly, the two studies are not completely comparable due to differences in scope, metrics, and methodology. The details of this are discussed in Appendix 1.

The difference in transport carbon between options is not expected to reduce rapidly. A switch to electric vehicles is coming, but they remain a very small proportion of overall vehicles. Existing fossil fuel cars will stay on the road a long time[3] after the 2030 national ban[4] on sales of new ones. To address transport CO_2, the most effective action is to choose spatial options that reduce car dependence.

This work is set within the wider context of transitioning society to net zero carbon by 2050, as required by the Climate Change Act. All sectors of society and the economy have a role to play to getting to net zero carbon. The local plan will focus on the role that new development and major refurbishment must play in reducing

[3] Cars stay on the road an average of 14 years from their first sale to scrapping. https://www.smmt.co.uk/industry-topics/sustainability/average-vehicle-age/

[4] As of 17th November 2020, the 2035 ban has been moved forward to 2030. https://www.newscientist.com/article/2260042-uk-10-point-climate-plan-bans-new-petrol-and-diesel-car-sales-by-2030/

emissions. Wider action will also be required beyond the remit of the local plan in order for Greater Cambridge's total emissions to reach net zero. The new growth emissions modelled in this report represent a small addition to the area's overall total[5] for most growth levels and options, as per Figure 1.

The local plan could also take further action to reduce the 'existing emissions' shown in Figure 1, by facilitating a large and rapid roll-out of additional new renewable energy infrastructure that could help decarbonise the grid electricity used by existing activities. It could also explore how to encourage the retrofitting of existing buildings, such as considering how new planning permissions could raise offset funds that could help existing buildings switch from gas heating to renewable energy or deploy green infrastructure that captures carbon from the air (trees or peatland). We are developing policy recommendations on these other topics as part of our wider net zero carbon study.

[5] To make the two options comparable, we took out the embodied carbon figures from new growth, because embodied carbon is not included in the BEIS data.

Introduction

Our wider study, and how this report fits in

The Greater Cambridge Shared Planning Service (GCSP) are in the process of preparing a joint Local Plan for the Greater Cambridge area. A key issue for consideration in the Local Plan is the role of plan making in responding to the climate emergency, delivering net zero carbon development while still accommodating growth. We have been commissioned to assess the scope for the new local plan to respond to the climate emergency by supporting a transition to net zero carbon. As well as setting robust evidence-based carbon reduction targets, this also includes policy advice to ensure that new development plays its role in contributing to the transition to net zero carbon in Greater Cambridge. Net zero carbon means that carbon emissions are equal to carbon removals. Bioregional are conducting this study with our partners Etude (zero carbon buildings engineers) and third-party consultants Mode (transport), Currie & Brown (costs), and Perkins & Will (sustainable masterplanning).

Our wider study on net zero carbon for GCSP has six tasks. This report relates to **Task B: spatial analysis**. The full list of is as follows:

- Task A: Defining what net zero means for the local plan area (which gases and sources to include), and exploring planning powers to achieve that
- **Task B: Spatial analysis**, creating a tool that can model the different carbon emissions that will occur depending on where and how we build
- Task C: Defining carbon reduction targets and policies for the local plan
- Task D: Modelling whether it is possible to create buildings that we need in order to be 'net zero carbon', including several different kinds of building
- Task E: Exploring the difference in costs for net zero carbon buildings
- Task F: Exploring the potential role of offsetting.

Our work also covers consultation with a range of external stakeholders holding expertise in topics such as embodied carbon, planning law, and other local authorities tackling the same topic. Later, we will also provide feedback on specific policy options as they are developed.

Our work to date on the other tasks has identified several key points, including:

- The plan should take action on 7 different greenhouse gases, but carbon dioxide (CO_2) is the most important due to its large scale and long life in our atmosphere. CO_2 mostly comes from our use of fossil fuel energy. In the local plan region, damaged peatlands are also a source of CO_2.
- As well as having an end goal of 'net zero', it is vital to limit the total amount of CO_2 that we emit between now and 2050 – because it is the cumulative emissions that determine our climate impact. This is called a carbon

budget. To get onto a safe climate pathway, we cannot afford for new growth to add significantly to the baseline carbon burden. Policies will therefore need act strongly on the emissions associated with new development.

- New buildings' energy use, and their occupants' transport, are the main areas where the local plan can drive carbon savings. Peatlands should also be considered when choosing locations (using advice from the green infrastructure studies being conducted by another consultancy).
- It is already technically feasible to create net zero carbon new buildings based on typical local architypes, with a modest cost uplift that will reduce over time as the construction industry gets used to new techniques, regulatory standards increase, and the cost of renewable technology falls.
- Measures to reduce carbon emissions in other sectors in Greater Cambridge, such as agriculture and existing settlements, are outside of the scope of this report but are still vital for the area's wider 'net zero' goal.

Assessment of strategic (non-site specific) spatial options

Cambridge City Council and South Cambridgeshire District Council completed public consultation on the Greater Cambridge Local Plan First Conversation (Issues and Options) in early 2020. Building on the initial options set out in the First Conversation, the Councils have identified three growth levels (low, medium and high) for homes and jobs, and eight strategy spatial options (non-site specific) for testing. Detail of the options and how they were developed is set out in the Greater Cambridge Local Plan: strategic spatial options for testing – methodology document.

The Councils have asked consultants producing Local Plan evidence studies, including the Sustainability Appraisal, to assess the strategic options with regard to their initial evidence findings. This report forms one element of that assessment.

The initial evidence findings will be reported to the Joint Local Plan Advisory Group in autumn 2020 and help to inform further engagement with stakeholders.

Process of Local Plan preparation

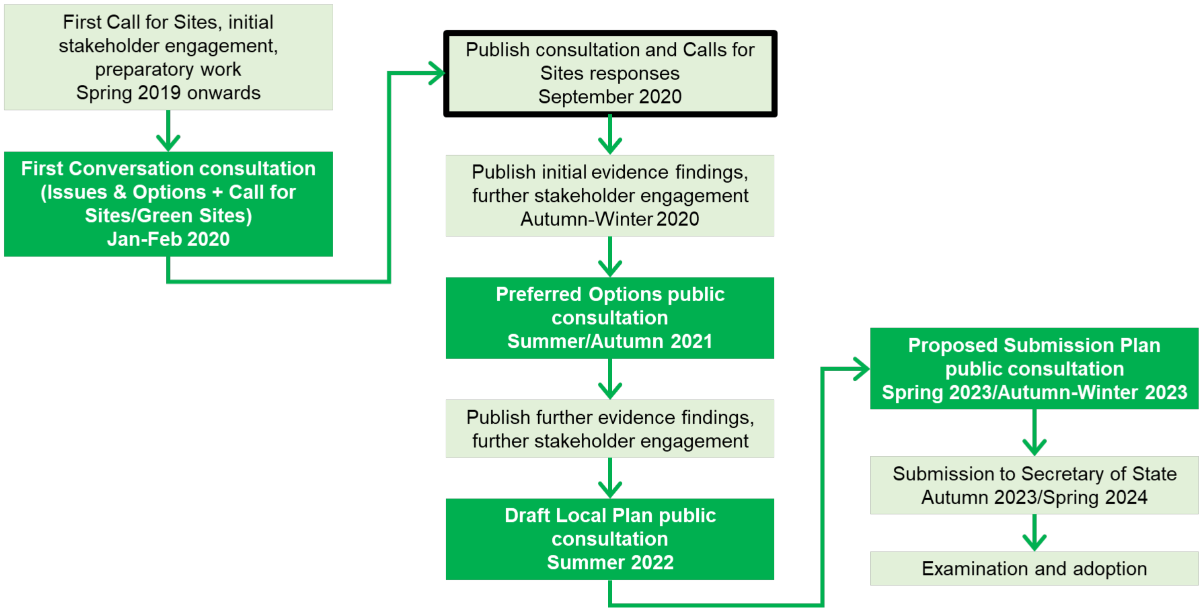


Figure 4: Process of local plan preparation. Provided by GCSP, September 2020.

Preferred Options public consultation is planned for Summer/Autumn 2021, including a preferred strategy and draft allocations. The process of Local Plan preparation is set out below in Figure 1.

The strategic options

The three growth level options tested in this report (as per GCSP figures) are:

- Minimum – Standard Method homes-led (3,900 new homes)
- Medium – central scenario employment-led (9,800 new homes)
- Maximum – higher employment-led (26,300 new homes)

This is **additional** new growth that the local plan seeks to accommodate, on top of growth to which the planning service has already committed but is not yet built.

The spatial scenarios tested through this report are:

1. Densification of existing urban areas
2. Edge of Cambridge – outside the Green Belt
3. Edge of Cambridge – Green Belt
4. Dispersal – new settlements
5. Dispersal – villages
6. Public transport corridors
7. Supporting a high-tech corridor by integrating homes and jobs
8. Expanding a growth area around transport nodes

The title of each option refers to the type of location where **most** of the growth will occur. However, **most of these options have some growth in other types of location too** (for example, see our table for the medium growth scenario). Additionally, in the maximum growth scenario, all eight options receive an additional 8,600 homes split across three new settlements (90% are assumed on public transport links (based on an estimate of when they will be built out relative to transport improvements). These sites are already allocated in the current local plans, but are expected to come forward after the end of the plan period except in the maximum growth scenario, where faster build out rates are assumed.

Our methodology

This analysis set out to compare the carbon emissions implications of the spatial options to be tested through the Greater Cambridge local planning process.

A bespoke carbon model has been created that covers the following sources of carbon emissions:

1) Building construction materials and processes (embodied upfront carbon).
2) Building heating and electricity usage (operational carbon).
3) Occupant and visitor transport (transport carbon).

The tool produces an annual carbon emissions figure for a given amount of growth. Total plan period emissions are then provided, based on an assumption that growth with be built out at an equal rate each year of the plan period.

Please note that this carbon modelling approach is new and innovative. There is therefore no 'standard practice' as there would be for certain other planning evidence pieces such as transport modelling, water modelling or objective housing needs assessment. However, we have endeavoured to take an approach that uses the best available data on how emissions are generated from buildings and transport to produce a credible broad-brush picture of the carbon emissions differences between each spatial option, with or without special planning policies to reduce that carbon. Our full methodology is available as an appendix.

Buildings data sources

The modelling is residential-led, in that the required number of additional new homes (over and above those already committed to) are used as an input, and then proportionate allocations are made for the quantity of supporting non-residential buildings typically required to support the housing. Hence the model covers the following types of new development:

- Residential
- Nurseries and primary schools
- Secondary Schools
- Libraries
- Community centres
- NHS
- Commercial space

The model is built using real data including, but not limited to:

- Bespoke energy modelling of a selection of recent local planning applications using Passivhaus Planning Package (total energy use including appliances)
- Densities and infrastructure requirements of recent local developments representative of each spatial location, using recent planning applications
- Existing local plan guidance and data (e.g. space standards; affordability; school place requirements)
- Occupancy and population projections from Cambridge Insight[6]
- BEIS/DEFRA national data on electricity grid carbon intensity, including future projections to the end of the plan period and beyond
- Benchmark embodied carbon of contemporary buildings
- Carbon reductions (operational and embodied) that are typically achieved via changes to building design (fabric, heating system and solar panels) recommended by green building industry expert groups

Transport data and assumptions

Transport carbon emissions have been estimated using local BEIS and Census per capita carbon emissions data. This is then calibrated on a scale from 0 -10 representing the potential for each mode of travel in each location type, undertaken by an experienced transport consultant using insight on travel distances and modal share from the Cambridge Sub-Regional Transport Model (produced for the purposes of other Local Plan studies).

The tool starts with each local authority areas' per capita transport CO_2 emissions released annually by BEIS. Because there is in fact variation within local authority areas, our transport consultant then calibrated these emissions on a sliding scale of ten equal intervals from 'best' to 'worst' using data on commuting modal share and trip length in different local neighbourhoods. The consultant then made professional judgements on the potential improvements to carbon emissions if sustainable travel initiatives were enacted for each travel mode in each category of location. Please see appendix on transport methodology for more detail.

Location categories represented in the model

Using the real local data described in 'buildings' and 'transport' methodology as above, the model offers six types of location category within which the emissions of each home would be expected to be roughly similar (including associated infrastructure). Those six categories are:

- Urban
- Edge of city greenbelt
- Edge of city non-greenbelt
- New settlement
- Village
- Public transport corridor.

[6] https://cambridgeshireinsight.org.uk/

The characteristics that differ between these different categories (and affect their carbon emissions) include:

- Typical density (affecting home size, heating demand, amount of materials, number of storeys, and amount of roof space available for solar panels)
- Amount of additional infrastructure needed per new home (because new settlements need new schools, offices and so on, while new urban development can sometimes share existing infrastructure)
- Transport patterns of the new residents.

The tool allows us to enter any number of homes in each location category, to reflect how growth is distributed within each spatial option as per the strategic options and growth scenarios figures provided to us by Greater Cambridge Shared Planning service.

Effects of zero carbon policy

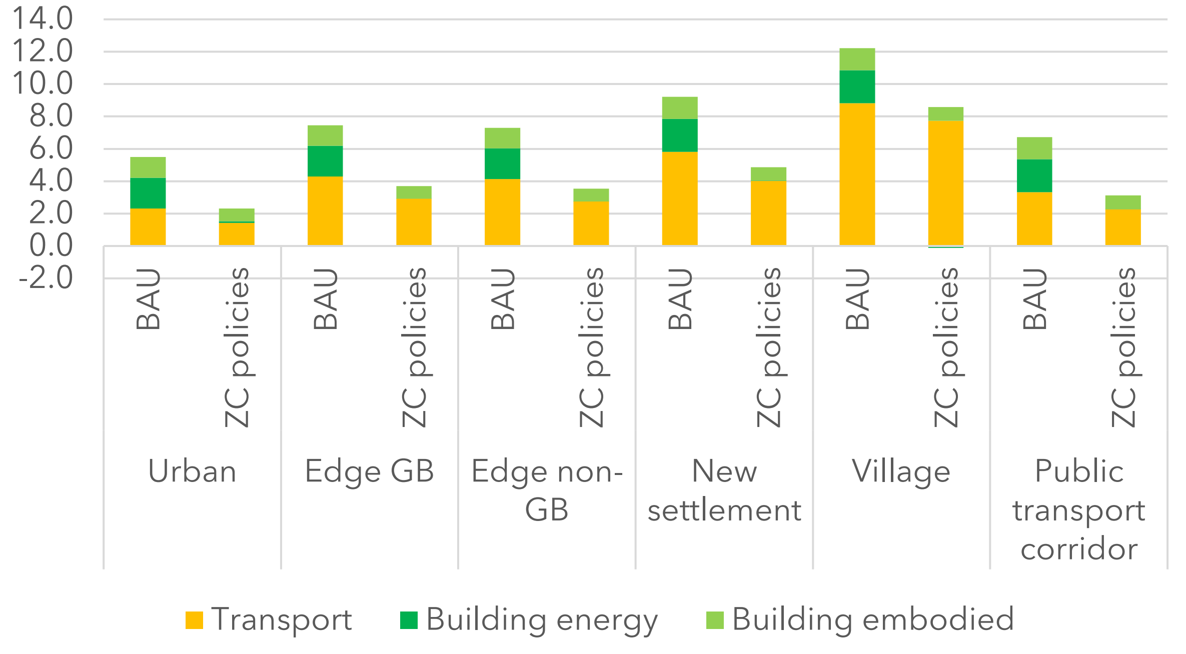
The model offers a range of options to apply policies to reduce carbon emissions in energy use, buildings' embodied carbon, and transport. For this report, the following two policy regimes have been modelled:

1) Business As Usual (BAU) – based on current typical practice and transport.
2) Zero Carbon Policy (ZC Policies):
    a. Apply best in class space heating standards (15 kwh/sqm) in both homes and other buildings
    b. All new homes to use heat pumps, no domestic gas boilers
    c. All new non- domestic buildings to use heat pumps, no gas boilers
    d. On site renewable energy generation at new buildings - PV
    e. Embodied carbon of new buildings – 40% reduction over baseline
    f. Energy Performance gap – medium level of mitigation in new builds (+25% on modelled energy)
    g. Transport: Potential – increased sustainable travel initiatives
    h. 10% of private vehicles are electric (average across plan period[7]). This links to the electricity grid carbon intensity for the selected year.

The following chart (Figure 5) shows the annual carbon emissions for 1 home depending on the location category, in the mid-plan year of 2030.

[7] A transition to electric vehicles is underway, but is slow. EVs represent less than 1% of the fleet today. Scrappage data show that vehicles remain on the road for an average of 14 years from first sale, so there will be many second-hand petrol and diesel vehicles in use long after all new car sales are electric (which is halfway through the plan period, 2030). For the purpose of planning for net zero carbon, it is important not to be over-optimistic on this.

Figure 5: Annual carbon emissions (tCO_2/y) for 1 home in each location category, with and without zero carbon policies, 2030



Interpreting GCSP growth figures and calculating total plan period CO_2

The model was run for the following spatial growth options:

1. Densification
2. Edge of city, non-Green Belt
3. Fringe of city, Green Belt
4. New settlement
5. Villages
6. Public transport corridors
7. Integrating homes + jobs
8. Expanded growth area

The minimum growth scenario brings 3,900 new homes, medium growth is 9,800; and maximum growth is 26,300. As previously noted, the 8 **options are titled according to where the majority of growth** happens, but **most options also include some growth in other location types**. In the maximum growth scenario, all options include an additional 8,600 homes in three already planned new settlements, 90% of which are on high quality public transport links (based on an estimate of when they will be built out relative to transport improvements). These three new settlements are already allocated, but are presumed to come forward after the end of the plan period except in the maximum growth scenario where faster build out rates are assumed. Details can be found in the Greater Cambridge Local Plan: strategic spatial options for testing – methodology document.

Each of the 8 options was modelled by inputting the anticipated numbers of new homes into the appropriate location categories that our tool offers: urban, edge of city (Green Belt or non), new settlement, village, or public transport corridor. We used location categories that best represent the appropriate density and transport options, often across multiple categories in our tool. Where the GCSP growth numbers specify a particular site or type of location, we took that into account.

For example, in Option 6 (Public Transport Corridors) in a medium growth scenario, the total of 9,800 homes is distributed as follows:

- Villages with public transport (5,400 homes, entered into our tool under the category 'public transport corridors')
- New settlements with public transport (2,500 homes; entered into our tool under the category 'public transport corridors')
- An emerging Cambridge suburb next to a train station (1,900 homes; entered into our tool under the category 'urban').

The model provides results for any given year, based on the carbon intensity of the electricity grid at that time (using central government projections). To model the total emissions for the plan period (2020 – 2041), we have assumed an even rate of build-out each year from the first year, reaching the total amount of new growth in the year 2041. To simulate this, we modelled what the annual emissions would be if all homes were built and occupied in the mid-plan year of 2030 (representative of the average emissions across the plan period because the decarbonisation of the electricity grid is projected to be fairly steady from now to 2041). We then divided that total by 2 to reflect that it is half-way through the linear build out rate assumed, giving us an annual average emissions rate. We then multiplied that figure by the number of years in the plan period (2020-2041 inclusive) to reflect the total cumulative emissions. In effect, this models a consistent build-out rate year on year.

Results and analysis

Comparative results, mid-plan

In order to better understand the underlying drivers behind the different level emissions from each option, Table 2 and Figure 6 both show the breakdown of emissions per source: transport, building energy and embodied carbon. The table is colour coded for the relative level of emissions by source for each spatial option.

Here we have run the model for the mid-plan period year (2030), for the medium growth scenario, with the zero carbon policies applied. The difference between the spatial options would be similar for any given year or growth scenario.

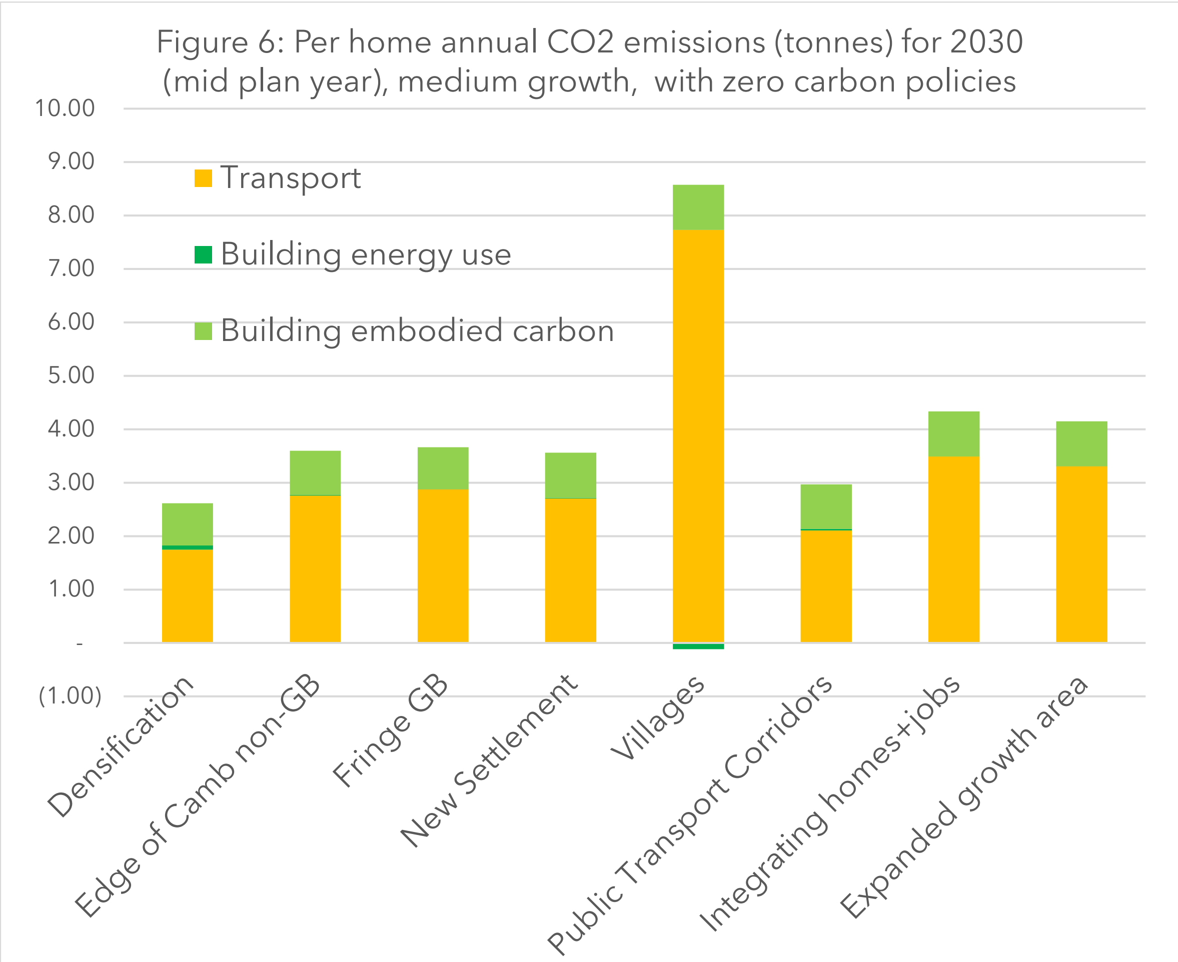


Figure 6 Annual carbon emissions for 2030 under medium growth with ZC policy

As can be seen from Figure 6, transport carbon shows by far the most significant variation across the spatial options (+342% variation between lowest and highest). The primary determinant of how each option compares in terms of its carbon emissions is the quality of access to public, active, and low carbon travel modes, and the need to travel regularly. This is why Option 1 (densification) and Option 2 (public transport corridors) perform so much better than Option 5 (villages).

Carbon emissions from building energy use is less variable (166% variation between lowest and highest). Since we have applied zero carbon policies which include best-practice in energy efficiency, buildings' energy use emissions are then most affected by the ability of each building to provide enough solar PV panels to offset the electricity demand on site. Lower-rise schemes, which would be more typical in villages and new settlements, have a greater ratio of roof space to internal area, and therefore a greater capacity to meet their own electricity demand from an **on-site** renewable (zero carbon) source[8].

Embodied carbon is almost consistent across the scenarios (+7% variation between lowest and highest). The minor change is dependent on the modelled development mix between flats and houses and number of bedrooms. This affects the amount of materials used for construction per dwelling created, as higher rise flats use less material per dwelling than low density detached housing. There is also a difference in the level of required new infrastructure (schools, libraries, health facilities etc) depending on the location of the housing, which in turn has its own embodied carbon associated with its construction.

Please see Table 3 for a more precise numerical breakdown of how each spatial option performs for carbon emissions from each of the three sources (building energy, building embodied carbon, and transport).

[8] Whilst more dense development does have a slightly more efficient thermal envelope (flats have fewer external walls, floors and ceilings than detached housing) this only slightly counters the more dominant effect of the ability to provide sufficient rooftop PV to offset the building energy use carbon. This is particularly the case once zero carbon polices have been applied to improve energy efficiency to the highest levels. The remaining operational carbon emissions from dense schemes' energy use could be helped via contributions to offsite renewables, as explored in a separate task (F) described in the introduction.

Table 2: Annual carbon emission per home (tonnes of CO_2 per year) for 2030, medium growth, with zero carbon policies.

This table is an alternative way to show the same information as in Figure 6.

Please note: the red-amber-green colour coding in the tables is allocated per row (comparing spatial options across each emissions source), not across the whole set of combinations of emissions sources and spatial options.

	1	2	3	4	5	6	7	8
ZC Policy Medium Growth, 2030	Densification	Edge non-GB	Fringe GB	New Settlement	Villages	Public Transport Corridors	Integrating homes+jobs	Expanded growth area
Transport	1.75	2.76	2.88	2.71	7.73	2.11	3.49	3.31
Building energy use	0.08	0.01	0.00	0.01	-0.12	0.03	-0.02	0.00
Building embodied carbon	0.79	0.82	0.78	0.84	0.84	0.83	0.84	0.83
Total annual CO_2 (tCO_2/a) in 2030	2.61	3.59	3.66	3.56	8.46	2.97	4.32	4.15

To compare the individual drivers of the carbon coming from the highest and lowest carbon emitting options, see figures 7 and 8 below. Each shows the respective proportions of emissions by type of development, plus transport, in our mid-plan sample year with medium growth and with zero carbon policies. This demonstrates not only that village development has a higher proportion of its emissions due to transport, but also the different ratios of flats to houses and non-residential spaces in each respective location.

Figure 7: Sources of CO_2 - Option 5 Villages, 2030, with zero carbon policies

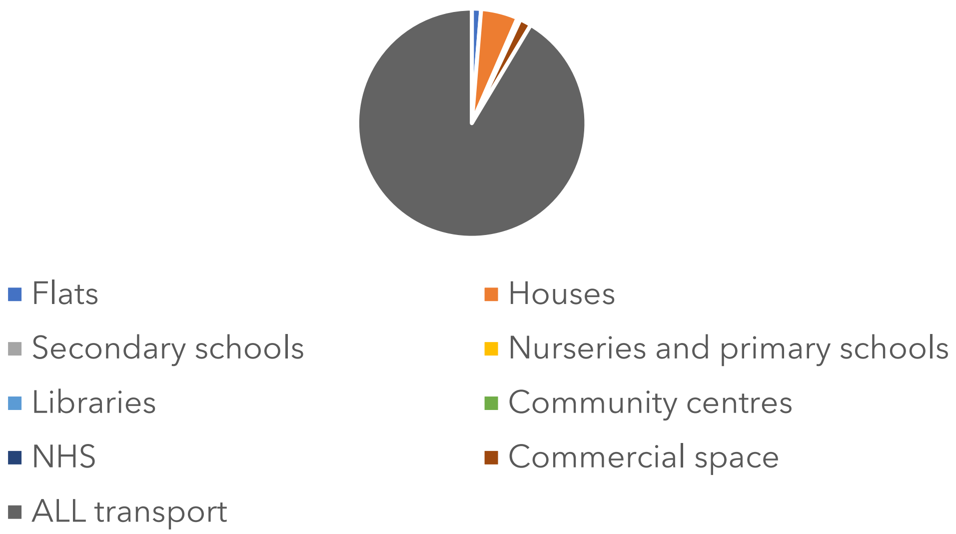
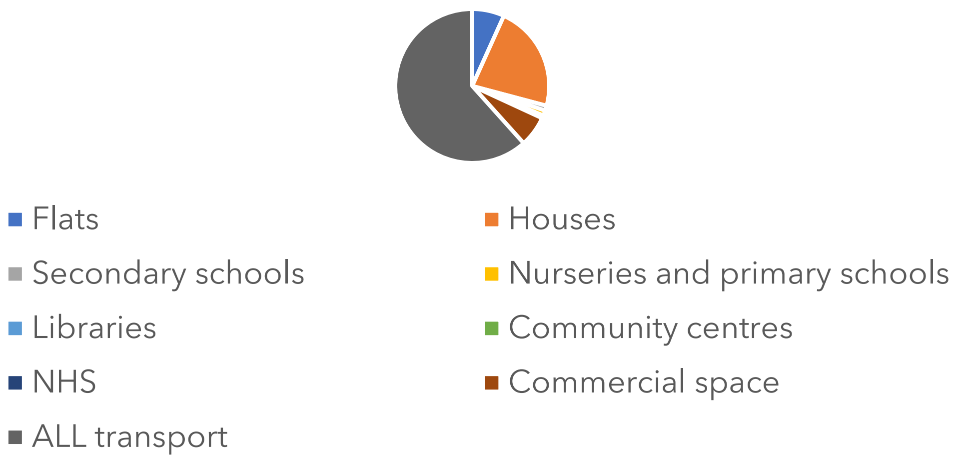


Figure 8: Sources of CO2 - Option 1 Urban densification, with zero carbon policies



See table 3 in the discussion section, for a narrative explanation of the emissions performance of each growth scenario in 2030, medium growth, with zero carbon policies.

Total plan period emissions with and without zero carbon policies

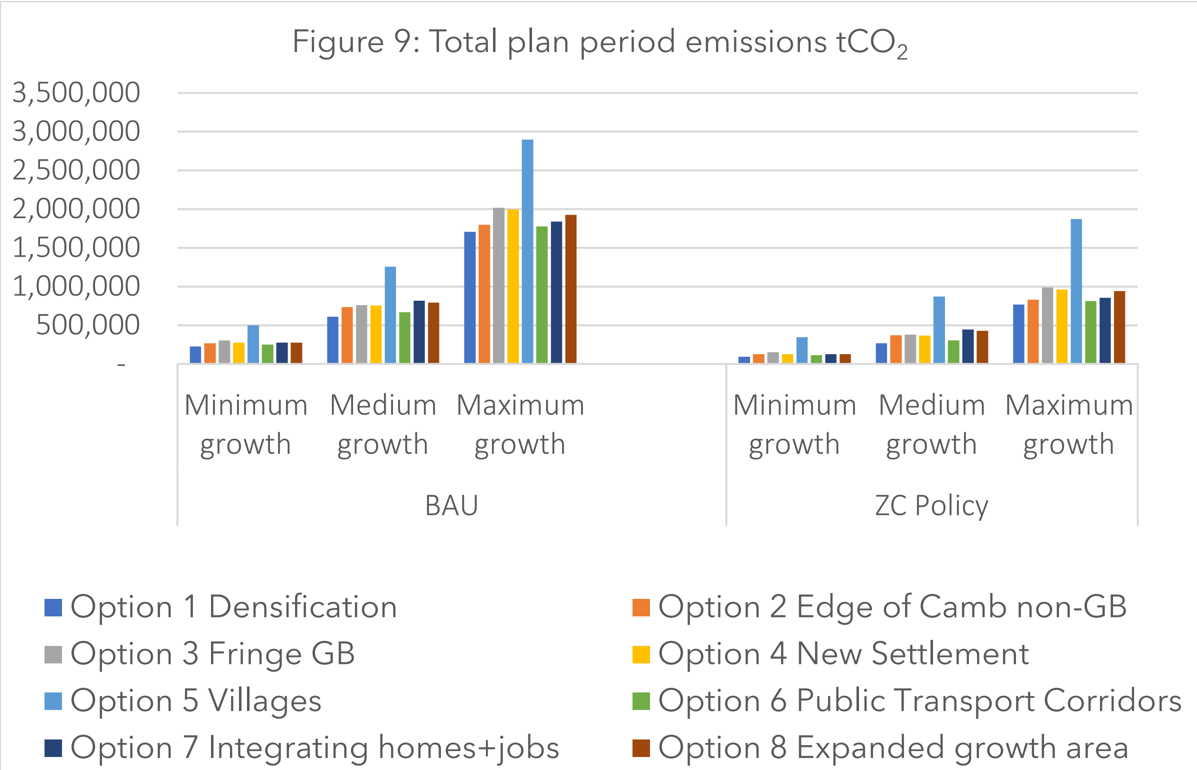


Figure 9 shows the carbon emissions generated by all options for proposed new growth across the plan period (excluding existing commitments). For simplicity, we have assumed an even rate of growth (build out) per year from 2020 to 2041.

Figure 10, overleaf, compares Greater Cambridge's existing annual emissions to new growth emissions, to give an impression of the scale of impact. 2020 is selected because it the most comparable to the 'existing emissions' data, which is from 2018 (because the tool includes reductions in the carbon intensity of grid electricity over time).

As well as the 3,900-26,300 new homes that the new local plan seeks to enable, Figure 10 also includes a very rough estimation of the emissions associated with growth that the planning service has already committed to but is not yet built (36,407 new homes). The actual emissions from these 36,407 committed homes will depend location and the energy performance. We did not have this information at the time of writing, so we have applied an emissions rate matching the average across all our location categories. We intend to refine towards a more accurate figure by working with GCPS to understand the location and likely energy performance of these existing planning commitments in greater detail.

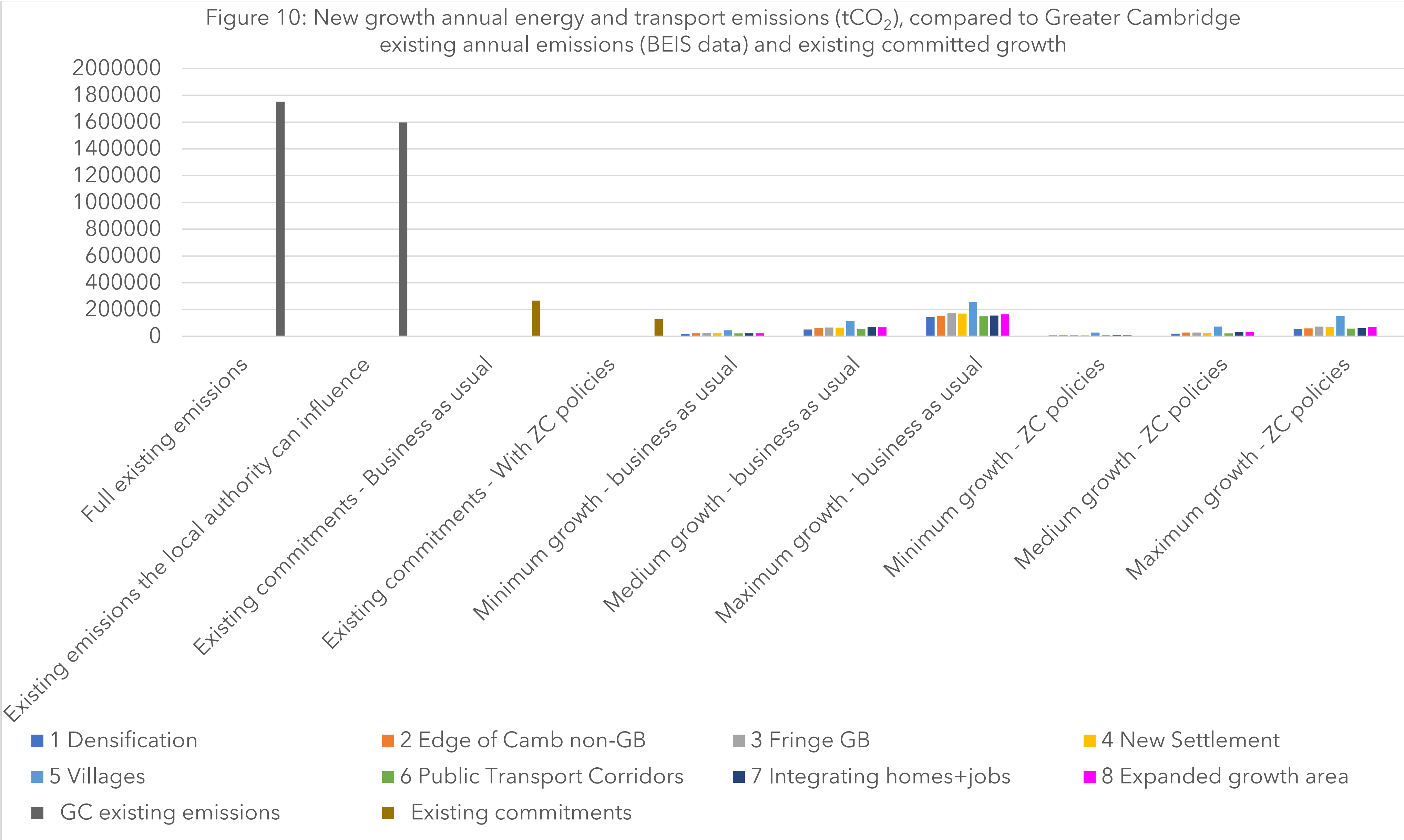


Figure 10: New growth annual energy and transport emissions (tCO_2), compared to Greater Cambridge existing annual emissions (BEIS data) and existing committed growth
2000000
1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
Full existing emissions
Existing emissions the local authority can influence
Existing commitments - Business as usual
Existing commitments - With ZC policies
Minimum growth - business as usual
Medium growth - business as usual
Maximum growth - business as usual
Minimum growth - ZC policies
Medium growth - ZC policies
Maximum growth - ZC policies
1 Densification
2 Edge of Camb non-GB
3 Fringe GB
4 New Settlement
5 Villages
6 Public Transport Corridors
7 Integrating homes+jobs
8 Expanded growth area
GC existing emissions
Existing commitments

Discussion

The results show that **most** options and growth scenarios result in a **very small increase on existing overall annual emissions** from Greater Cambridge. The exception is if **maximum growth** takes place as per the '**villages' option**, and with '**business as usual'** construction and transport. This would represent an **increase equivalent to 15% of Greater Cambridge's existing annual emissions**. If growth is **minimum** and is located as per Option 1 (**urban densification**) with **zero carbon policies** applied, the **increase is only 0.4%**. Medium growth with zero carbon policy in other spatial options would result in an uplift of only 1 to 2% on existing emissions, or 4% if the villages option is chosen.

The results therefore make a strong case for choosing a spatial option with a focus on minimising the need for private cars.

The results also show that applying zero carbon policy achieves dramatic improvement. These policies would allow 'maximum growth' to take place with similar amount of carbon emitted to 'medium growth' with business as usual, except for in Option 5 Villages. We can also see that after zero carbon policies are applied, the difference between the best and worst options becomes more pronounced: when zero carbon policies are applied, the 'villages' option emits about 4 times as much as the 'densification' option, whereas with 'business as usual' policies this is only about 2 times as much. This is because transport is villages' weak spot, and policy has less effect on transport than on buildings.

With the exception of the outlier (Option 5, Villages), there is only about a 13% to 40% difference between the remaining spatial options compared to the lowest-carbon option (Urban Densification). Once outside the most dense and walkable / cyclable urban area, the key to the difference between options is the number of homes that are specified to be on public transport in the GCSP growth figures.

To illustrate this, it is useful to focus on the difference between edge-of-city green belt and edge-of-city non-Green Belt. Our tool itself does not recognise much carbon difference between these two types of development locations (see figure 5 for a comparison of 1 home in each of the spatial locations). However, a difference appears in the modelled scenarios due to the mixture of *locations* in the figures provided by GCSP for each growth scenario. Option 2 (Edge of Cambridge – outside the Green Belt) specifies the North-East Cambridge area as a key growth site. This is next to a train station and is likely to achieve relatively high densities, so homes at that site were modelled as an 'urban' location, in addition to that option's other homes which are in 'new settlements on public transport corridors'. In contrast, in Option 3 (Edge of Cambridge – Green Belt), no specific locations are mentioned. This option has a small number of homes in the urban centre, but the majority in unspecified greenbelt sites. Therefore, we have assumed a suburban density and transport context, for the greenbelt sites. This could improve dramatically if greenbelt sites were on direct regular public transport links.

Even under the best-performing spatial option with the ‘zero carbon’ policies applied, there is still a residual amount of carbon emitted from buildings. This is due to the assumed imperfect effect of the zero carbon policies on buildings: there will still be some energy performance gap (+25% more energy consumption in real life compared to the design). Also, embodied carbon is only partially reduced (by 40%). These are dwarfed by the transport carbon – see next section.

Buildings’ remaining carbon from energy use could be eliminated if additional renewable energy were deployed at pace with new buildings, in addition to the solar panels on the buildings’ own roofs. New large-scale renewable energy will be necessary in any case for Greater Cambridge to make its wider transition to zero carbon as per the UK’s legal commitment in the Climate Change Act, to address the ‘existing emissions’ shown in figure 10.

There are further measures that could be implemented, beyond the zero carbon policies that have been modelled here for spatial comparison purposes. These will be discussed and explored elsewhere as part of our work on Tasks C, D, E and F.

If the local plan requires all new homes and buildings to include the maximum possible amount of solar electricity generation on their roofs (ideally including optimised roof orientation and design), then many buildings up to three storeys could export more energy than they consume. In reality large development sites will have a range of densities within them, so plan policy might require additional rooftop PV to be provided in the lower-density parts of the site, to help offset the lack of PV due to reduced roof area of higher density parts of the site. In a separate part of our work, we are modelling how feasible it would be to implement this kind of requirement, what the cost uplift would be for the new buildings to provide this additional PV, and whether offsetting could fund this.

Further steps towards neutralising the remaining carbon from buildings, over and above the zero carbon policies already applied, are explored in other workstreams, and could include:

- Even greater mitigation of the energy performance gap, through better build quality and monitoring
- Even more mitigation of embodied carbon of buildings, perhaps using design codes that encourage timber and recycled materials and discourage cement, concrete, steel and aluminium.

The role of transport

After zero carbon policies are applied, the vast majority of the remaining carbon comes from road transport, where habits are notoriously difficult to change. Carbon reduction policies have a less direct, less guaranteed effect on actual transport carbon than they do on buildings energy use and materials.

A potential shift to electric vehicles (EVs) is underway. The modelling is designed to be ambitious but not overoptimistic in this regard, with the ‘zero carbon policies’ regime including an average of 10% of vehicles being electric in all years.

This is because EVs are currently less than 1% of the overall vehicle fleet (the transition has been slower than anticipated), and the current Government's national ban on sales of new fossil fuel cars comes near the end of the plan period. Existing fossil fuel cars currently remain on the road for about 14 years from first sale, causing a lag in the rate of change in the overall fleet. Governments ban on the sale of fossil fuel cars also only applies to new vehicles, so the second-hand car market will still see the sale and use of fossil fuelled vehicles. Furthermore, it is not impossible that this future ban will be moved or discarded (as was the national zero carbon homes policy that was meant to come into force from 2016). As such, for the purposes of this report in considering the role of new development, it is important to not overstate the transition to low emissions vehicles.

If a sudden shift to EVs does happen in the plan period – for example as a result of legislation, market changes, or a scrappage scheme – the transport emissions from less connected locations would be reduced. If development in more rural sites is not on a high quality public transport link, policies should be in place to ensure that the development supports all residents to switch to EVs from first occupation, through the provision of EV charging infrastructure and the role of travel plans.

It is important to note that a switch to EVs does involve raw materials and energy use to produce the vehicles, therefore active and public transport should still be considered preferable. This is out of scope for our study, although academics in Cambridgeshire[9] recently found that the whole-life carbon of EVs is still better than that of conventional vehicles, due to avoided fossil fuel use.

Our modelling cannot account for the fact that growth in some settings could result in step changes to transport patterns of *existing* households as well as new homes. For example, if a village develops into a town with more facilities, that could reduce the amount of car trips that existing residents take, or reach a size that would attract better facilities, more public EV charging, or better quality public transport links. However, this is an optimistic scenario, and any step change may not manifest for many years, if at all. Furthermore, growth may also attract people from further away to travel greater distances to visit, offsetting some or all of the benefit. We have not gone into this level of complexity, in order to avoid overestimating nor underestimating these effects, which would be on a very localised scale for each location. It is important not to be over-optimistic about making shifts to established transport habits, and therefore from a carbon point of view it is most effective to focus growth choices on reducing car dependence.

Table 2 provides a breakdown of how homes are distributed across different sites in each spatial option under the medium growth scenario. With zero carbon policies, we explore how the level of carbon emissions are affected accordingly.

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[9] Cambridge University Science Policy Exchange (2019), 'Net Zero Cambridgeshire: What actions must Cambridgeshire County Council take to reach net zero carbon emissions by 2050?' Available here.

Table 3: Description of the driving factors for carbon emissions for each spatial option in a **medium growth** scenario (total 9800 homes), in the year **2030**, with **zero carbon policies,** in order of best to worst climate impact

Option with medium growth and ZC policy	Carbon emissions per home for 2030 (tCO_2/y)	Description
1 Densification	2.61	This option has the majority of homes in urban settings (7,500) and some suburban (2,300). This results in the best public and active transport access of the scenarios and the most efficient materials use for higher rise construction in places with lower requirement for new supporting infrastructure. This is slightly counter balanced by having the least ability of the scenarios to provide enough on-site PV panels for the homes' electricity demand, so net emissions from home energy are actually the highest of the scenarios. Adding offsite renewables matched to their remaining energy demand could alleviate this.
6 Public Transport Corridors	2.97	This option has a mixture of homes in urban settings (1,900) and settlement on public transport corridors (5,400 homes in villages on public transport, and 2,500 in new settlement also with public transport corridors). Hence it has opportunities to reduce car use and therefore second lowest transport carbon. This is slightly countered by a medium efficiency of materials used due to the mix of low and higher rise construction, and a mixed ability to provide enough on-site PV panels for the same reason.
4 New Settlement	3.56	This option is all homes in new settlements on a mixture of public transport corridors (7,350) and on road network (2,450). This creates mid-range transport carbon emissions. It is modelled at mid-density; hence the building energy emissions are in the middle. However, embodied carbon is high due to the need for additional supporting infrastructure and the predominance of larger houses rather than more efficient flats.
2 Edge of Camb non-GB	3.59	This option allocates homes across four different settings - urban densification (1,900), edge non-GB (1,900), new settlements on public transport (5,000) and rural villages (1,000). This produces a very even blend, and hence mid-range emissions across the three sources of carbon emissions.

3 Fringe GB	3.66	This option is based on the majority of homes on the urban fringe within the Green Belt (9,500) with a few in urban densification (300). The urban fringe is assumed to have medium public and active travel accessibility and hence transport emissions. It is of medium density, hence medium ability to provide renewables on-site and therefore medium building energy emissions. It is the second lowest for embodied carbon due to having a reasonably high number of flats and smaller houses, but predominantly due to low assumed new supporting infrastructure due to the accessibility of nearby existing facilities.
8 Expanded growth area	4.15	This option allocates homes across urban (1,900), along public transport corridors (5,740) and dispersed villages (2,160). Hence, this also produces mid-range emissions across the range of emissions sources. The transport is slightly higher than average due to the development in dispersed villages.
7 Integrating homes+jobs	4.32	This option has the majority of homes in new settlements on transport nodes (7,610), with some homes in dispersed villages (2,190). The effect of this is to create the second highest carbon emissions overall, predominantly due to the transport emissions from the dispersed village homes. There is also more embodied carbon due to the lower density housing and significant new supporting infrastructure required for new settlements and villages.
5 Villages	8.46	This option is based on all homes (9,800) in village settings, not specified in the GCSP growth figures to be on any particular transport links. This is therefore the worst transport emissions by a substantial margin and a slightly higher embodied carbon due to low rise detached housing and necessary new supporting infrastructure. In contrast, it has the best net building energy performance (managing to be a net exporter of zero-carbon energy), because the lower density makes it the most able to provide substantial renewable energy on-site through rooftop PVs. Overall, the carbon cost of the transport far outweighs the smaller benefit from the increased PV, making this the most carbon intensive option. If the villages were on public transport (as they were in option 6) this option would not perform quite so badly.

Conclusion

In planning for the growth of Greater Cambridge in response to national targets for house building and employment growth, the GCSP must balance economic growth with a reduction in emissions, in order that new development can play its part in enabling Greater Cambridge to achieve net zero carbon by 2050. Our analysis of the carbon implications of the spatial strategy show us that with the implementation of zero carbon policies, the emissions associated with buildings' energy use can be reduced to near-zero and their embodied carbon can also be significantly reduced.

Transport emissions are the deciding factor in the carbon differences between spatial options. These are harder to deal with purely via policies within the local plan, and are most strongly affected by where development takes place.

Option 1 Densification has the lowest carbon emissions, with Option 6 Public Transport Corridors a close second best. Option 5 Villages is by far the highest-carbon option, with 2 – 4 times as much carbon emissions as Option 1 Densification. This is largely due to the significantly larger modelled use of private cars as the only realistic transport for most trips by most village dwellers[10]. By contrast, Option 6 Public Transport Corridors has some village homes that *are* specified to be on good public transport, and therefore were modelled as such.

There are also small differences in carbon emissions due to the lower density of typical village developments compared to more compact urban homes. With current construction practices (lacking zero carbon policies), larger and lower-rise homes have worse carbon emissions from building energy and embodied carbon, due to more floor space and building envelope and predominantly heated by gas boilers. However, if carbon reduction policies are applied – which include the maximising solar panels, efficient fabric and heat pumps – then the low-rise homes can achieve a carbon reduction benefit because they can fit more solar panels per dwelling on their roofs than they need to fulfil their own energy needs, thus exporting net excess energy to the grid over the course of a year. Nonetheless, in our modelling this does not cancel out the significant carbon disadvantage of increased car use in poorly connected rural locations.

Differences between other spatial options largely relate to the public transport links of the anticipated sites. For example, a key site considered in option 2 'edge, non-Green Belt' is next to a train station and many of this option's other homes follow a relatively dense urban pattern. Homes at that site were modelled as 'urban'. In contrast, 'fringe Green Belt' sites are unspecified and therefore treated as suburban and not quite so well connected to public transport.

[10] The village homes in Option 5 were not specified to be in villages with good public transport or active travel options.

The effect of applying zero carbon policies is dramatic and would, for example, allow maximum growth to take place while limiting carbon emissions to a similar level as would be emitted in medium growth without zero carbon policy, except in the Villages scenario. These policies require that buildings are highly energy efficient, are built to a high quality, use low-carbon building materials, never use fossils on site, and generate most (or all) of their own electricity with renewables. The policies also improve transport by supporting EV use and promoting active and sustainable modes as much as possible for each spatial location.

With a full shift to electric vehicles still a long way off (considering the time lag lifespan of fossil fuel cars from first purchase as previously explained), from a carbon point of view it is best to focus growth choices on minimising car dependence. The choice of spatial option (and public transport provision, if not in a central urban location) is therefore crucial to reduce carbon emissions from transport associated with growth.

Appendix: carbon modelling tool methodology

This section outlines the methodology behind the spatial modelling tool.

It should be noted that this exercise is highly innovative in plan making, and to our knowledge no precedent or commonly accepted approach exists. Hence, we have had to devise a new methodology using the available reliable data, and industry experience and judgement of the expert partners involved.

This is the first iteration of this modelling methodology, which will no doubt evolve over the plan making period.

We are currently exploring options for how we may be able to prepare and share greater detail behind the tool going forwards.

Objective: To develop a tool that can assess and compare the high-level energy and carbon implications of development in different spatial locations.

As explained in the body of this report, the tool models the following three key sources of carbon emissions, which were felt to represent those most relevant to a spatial decision on where to allocate growth:

4) **Embodied upfront carbon** from building construction materials and processes.
5) **Operational carbon** from building heating and electricity usage.
6) **Transport carbon** from occupant transport.

1. Embodied upfront emissions are largely dependent on the volume of development created. This is determined by the development mix – the total square metreage of each different typology of building, which varies according to the location. For example, urban locations tend to have homes with smaller number of rooms, built at higher density and higher rise non-residential buildings.

2. Operational carbon emission are largely dependent on the above development mix factors multiplied by the energy use intensities (that is, energy use by type and use – domestic and non-domestic, regulated and unregulated, and so on).

3. Transport emissions are largely determined by the access to public and active travel modes, and proximity to amenity and employment. See the separate appendix chapter on the transport methodology adopted.

Methodology

Development mix was established as follows:

1. Representative development densities (dwellings per hectare, dph) were established for each spatial location from the local plan development

schedule and policies where available. These were cross checked against recent actual planning applications.

2. The number of types, bedrooms and gross internal area (GIA) was then based on local plan guidance and standards (such as % affordable, and minimum space standards).
3. The house types, bedrooms and the tenures were then converted into new population using local plan multipliers including people per household, adults, children, and so on.
4. These estimated populations were then used to establish approximate infrastructure requirements (non-domestic buildings) referencing relevant planning obligations and S106 contributions[11].
5. We then undertook spot checks for the infrastructure requirements against planning applications data for different locations.
6. The derived housing density and development mixes per spatial location were then peer reviewed by an experienced master planner (Perkins & Will).

Energy use intensities (EUI) were established as follows:

1. Domestic EUI was modelled using Passivehaus Planning Package (PHPP) for indicative housing types (detached, semi-detached, flats) based on actual recently approved planning permissions. The baseline modelling was to current Part L Building Regulations compliant standard (nationally regulated minimum performance). This modelling included assumptions around occupancy and appliances to produce unregulated as well as regulated[12] emissions.
2. Non-domestic EUI was established using the DEC (Display Energy Certificate) database to download Greater Cambridge post code specific samples of recently completed buildings – no older than 5 years and EPC (Energy Performance Certificate) A to C, under the categories of Sports facilities, Community Centres, Offices, NHS, Schools and Nurseries.
3. These EUI are then converted into carbon emissions for a specific year within the plan period using Treasury green book data for greenhouse gas emissions for appraisal[13]. This takes into account what proportion of the energy use is gas, electricity or other, including the gradual decarbonisation of the electricity grid into the future.
4. Associated solar panel electricity generation was calculated for the following scenarios, assuming 350W per monocrystalline panel:

[11] Section 106 is a planning tool negotiated between the planning authority and the developer to make a development acceptable. It often takes the form of a payment by the developer towards an amount of necessary infrastructure.
[12] 'Regulated' emissions are the emissions associated with 'regulated' energy use. Regulated energy use is the part of a building's energy use that is controlled by national building regulations – that is, space heating, hot water, ventilation and permanent lighting. 'Unregulated' energy use is due to plug-in appliances.
[13] Treasury Green Book data is available here.

   a. Houses/non-resi: Duo roof archetype (average orientation: south-east; south-west/30 degrees) assuming use of 50% of roof area.
   b. Flats: Flat roof archetype (average orientation: south-east; south-west/flat) assuming use of 80% of roof area.

Embodied carbon emissions were established as follows:

1. Embodied carbon factors for kilogrammes of CO_2 per square metre of gross internal area were sourced from the London Energy Transformation Initiative Embodied Carbon Primer[14] which provides factors for residential, commercial and schools.
2. Total upfront emissions were then divided by an assumed 60-year lifecycle to allocate a per-year emissions allowance for each building.

[14] Please see Embodied Carbon Primer, available here.

Appendix: transport assumptions

Our transport consultant devised a modelling method for how transport carbon emissions vary between different spatial locations in the plan area. This method is anchored in BEIS nationally reported benchmark data from the Greater Cambridge area, further refined by using a rating scale of modal choices for each spatial location type and finally calibrated against outputs from the Cambridge Sub-Regional Model (CSRM) for transport. Some important distinctions between these methodologies are further discussed at the end of this section.

Our transport tool starts with the most recent annual per capita transport CO_2 emissions for Cambridge City and for South Cambridgeshire respectively, from the subnational emissions figures released annually by BEIS. This is the best currently available data on the average person's transport emissions in these two locations.

However, we also want to further calibrate that data to reflect the variation in transport habits *within* both of those local authority areas, ranging from central urban dwellers who walk, cycle or use public transport for most purposes, and vice versa for rural dwellers without good public transport who do not tend to be able or willing to walk or cycle to their place of work, school, shops and amenities.

To calibrate a range of emissions in each BEIS location, our transport consultant used the latest Census data (2011) about the percentage of journeys to work that are made by car in different locations (available at a much finer grain, down to neighbourhood level).

The consultant then used this percentage of car commutes as an indicator for people's general lifestyle car use and applied it to each of the BEIS per-capita transport emissions. This gave a minimum and maximum per capita transport carbon figure.

The transport consultant then set a scale of emissions from 'lowest' in the urban setting to 'highest' in the most remote village setting. Each location was scored for each transport mode from 0 to 10 based on the transport consultant's expert opinion of the locations. Each location was given an overall 'current' and 'potential' transport score based on the average across all modes. The 'potential' score is an improvement based on our consultant's expert opinion on the extent to which sustainable transport initiatives could improve sustainable modal share for that specific location.

The transport consultant then cross-compared the interim results with data from the CSRM (predicted modal share and trip lengths specific to the Cambridge region) to make sure our modelling approach concurred in terms of profile across the different spatial locations.

The carbon values for transport are effectively a high level estimation based on a top-down allocation of a proportion of the regional average, based on localised travel data. In contrast the carbon emissions for buildings are based on a 'bottom up' modelling per building type. They also are not sensitive to 'tipping points' such as if a village were to grow into a town that can achieve more trip containment. However, because they are still anchored to actual regional data on per capita emissions, trip lengths and car use, we believe they are still within a reasonable range. Most importantly, since the purpose of this modelling exercise is to compare spatial locations, rather than produce accurate absolute emissions factors, we feel this is an appropriate approach.

In the 'zero carbon policies' scenario, we assumed an average 10% of private vehicles are electric across the plan period. We believe this is reasonable given that it is currently less than 1%, and the proposed national ban on sales of new fossil fuel cars comes near the end of the plan period. This ban does not affect the second-hand car market, and existing fossil fuel cars will remain on the road for circa 14 years from first sale, causing a lag in the rate of change in the fleet.

Important distinctions between our modelling and the CSRM

As discussed, our transport impacts methodology has been calibrated with reference to the parallel transport study which has been undertaken using the Cambridge Sub-Regional Model (CSRM).

The specific CSRM outputs referenced are Percentage Mode Share of Trip Growth and Change in travel distance (Total pcu-kms) (Strategic Options vs 2041 Baseline); these can be found in the Transport Evidence Report.

Important distinctions between the two approaches are as follows:

- The Transport Evidence Report has at the time of writing been based on the maximum growth scenario. In contrast, our work models all three scenarios reflecting the slightly different blends of location categories for each. We provide separate outputs for each where possible, so care should be taken when comparing graphs.
- The Transport Evidence Report includes some transport schemes that are assumed to be in place by 2041 based on the level of confidence in their delivery. Our modelling provides the two distinct scenarios below, hence care should be taken to check which is being displayed in our outputs:
    - Business As Usual – reflecting the CSRM assumptions
    - Zero Carbon – the best possible score for each given location for walking, cycling and public transport, and with 10% of private car journeys by EV.
- Carbon emissions of transport are based on the compounding factors of 'journey distance' and 'mode', hence this will produce a more exaggerated profile (range of results) compared to that for journey distance or mode share alone. Hence, our transport carbon scores have been balanced against the minimum and maximum baseline emissions for Cambridge and South Cambridgeshire (BEIS) which range more significantly than the Transport Evidence Report results discussed.

- Specifically for new settlements, the Transport Evidence Report includes all additional journeys generated, including those for surrounding settlements e.g. the 'draw' of incoming visitors from nearby villages who wouldn't have otherwise travelled to that location. Our own modelling is only focussed only on emissions created by the *new population* of the growth in question. We have adapted the car-based mode score for new settlements to reflect the CSRM mode share results, but ultimately our model is not designed to capture the full extent of additional journeys beyond the new population. Hence, we produce a lower profile of carbon emissions (under BAU policy and maximum growth) for this category of location compared to the CSRM trip distance chart when viewed in comparison. This point is further explored in the appendix below.

Appendix: caveats and limitations

New development only

The tool looks only at the anticipated carbon impact of new development and the travel of the population associated with that new development. It doesn't account for any changes in carbon emissions in existing buildings, or existing residents' lifestyles as a result of new development happening nearby.

For example, if enough new growth happens that a village becomes a town that attracts more facilities and better public transport, then the existing villagers' travel patterns could improve. Or if the developer of new buildings provides a large number of public-realm electric-vehicle charging points with reserved parking for EVs, that could help existing residents and workers switch to electric vehicles.

Our tool does not attempt to predict or model such effects. It should be noted that transport habits are notoriously difficult and slow to change, once established.

Transport

Our tool estimates the carbon emissions from transport behaviours in different development patterns by taking the best and worst per-capita transport emissions from BEIS data on real locations in Greater Cambridge (urban and rural) and ranks each spatial option on a sliding scale according to how similar it is to those best and worst scenarios. Only terrestrial transport is included. A switch to electric vehicles applies to the private fleet only (this is also linked to the reduction in carbon intensity of the electricity grid as per national projections). See also appendix on transport assumptions.

Embodied carbon

Our tool takes the typical embodied carbon of a building and divides it by a typical 60-year lifespan of a building (a standard industry assumption). This is so that it can be incorporated into the annual carbon figure generated by the tool. However, the plan period does not run for the whole 60 years, therefore the figure generated for carbon emitted within the plan period does not include the full embodied carbon amount which was actually generated up front. This would not make a difference to choices about spatial development options but would make a difference to policies or SPDs around sustainable building design or overall carbon targets. Embodied carbon covers buildings only, not vehicles.

Green infrastructure

The tool is not able to deal with the carbon emissions or sequestrations of the land use before and during development of greenfield sites. Grasslands and woodland are a net remover of carbon, while peatland can be a large emitter or remover of carbon depending on the state of the peat. Even when not actively removing carbon from the atmosphere, vegetation and soils are a 'carbon pool' (store). Drainage or excavation of carbon-heavy soil results in emissions as the soil organic matter breaks down; and can also prevent a site's ability to become a future carbon sink. It is not yet possible to incorporate this factor into the spatial tool, for two reasons. Firstly, it would be necessary to know the specific site in question. Secondly, we do not yet have reliable data on the sequestration potential were each site to be restored as peatland or planted as woodland. This kind of data would need to come from the Green Infrastructure Study.