Bioregional, Etude, Currie & Brown, Mode

Greater Cambridge Net Zero Carbon Evidence Base
Non-technical summary

August 2021, Revision 1

1. Introduction

Our tasks and their purpose

We were appointed by Greater Cambridge Shared Planning (GCSP) service to provide a 'local plan net zero carbon evidence base'. The local plan shapes how Greater Cambridge will grow and change to meet people's needs in the twenty-year period from 2020 onwards.

Our aim is to give GCSP the information it needs to make decisions about:

- Where to allow the new growth in buildings and facilities to happen,
- What kind of policies the local plan could use to enable the transition to zero carbon across the whole local area.

To make these decisions possible, we explored the following questions:

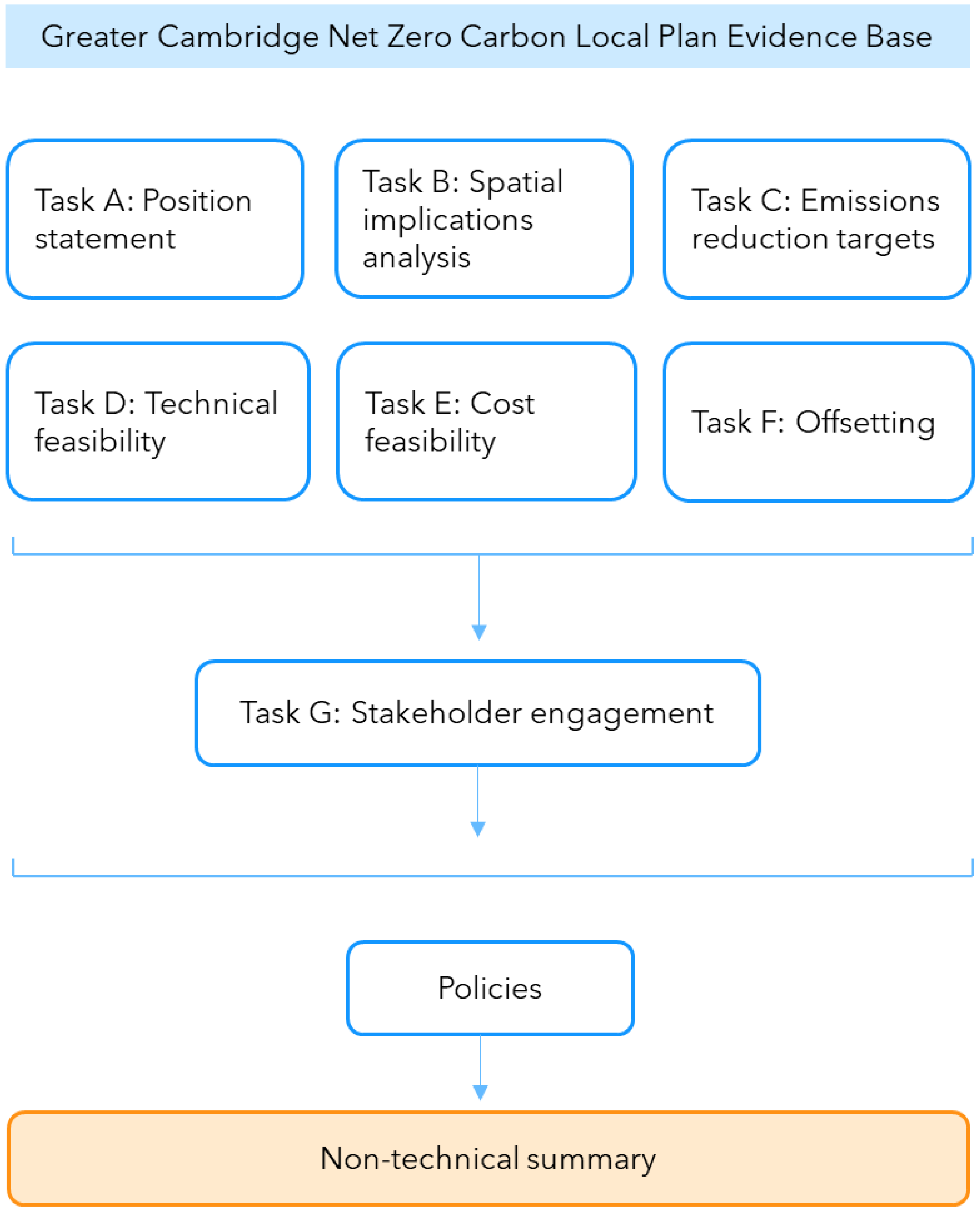
- What does 'net zero carbon' mean, why do we need it, how is it measured, and what power does the local plan have to make it possible? (Task A)
- Will there be different levels of carbon emissions depending on where the local plan allows new homes and facilities to be built? (Task B)
- What carbon reduction targets should be set for Greater Cambridge, and what kind of standards in new buildings and zero-carbon energy would enable this? (Task C)
- Is it technically possible to build net zero carbon new buildings today, and what would this involve? (Task D)
- Is it much more expensive to create new net zero carbon new buildings? (Task E)
- Could 'offsetting' help Greater Cambridge reach net zero carbon status – that is, making payments that allow someone else to prevent or remove our carbon? (Task F)
- What do local experts think of our results and initial policy ideas? (Task G).
- What local plan policies may deliver the best results? (Standalone list of policies).

Our full suite of reports is also shown as a diagram here. Please note that although each individual report is fully referenced, the references will not be fully reproduced here.

Who produced this work?

This work was undertaken by the following organisations in collaboration:

- Bioregional – Environmental charity with experience in all-round sustainability, sustainable construction and policymaking from local to international level
- Etude – Engineering firm with expertise in energy, construction and architecture
- Currie & Brown – Quantity surveyors/cost consultants with experience of advising central and local government on cost implications of the transition to low carbon
- Mode – transport planners
- Perkins & Will – architecture and master planning experts.



Contents

2. Net zero carbon and what the local plan should do about it

This section will include information from the following of our longer reports:

- Task A: Position statement
- Task C: Emissions reduction targets.

Why do we need to think about net zero carbon?

Global climate change is already happening. **We are already feeling the effects of a 1˚C rise** in global average temperature compared to the pre-industrial climate (before 1850). This is resulting in unprecedented temperature spikes at the poles, loss of polar ice, loss of glaciers that are the vital fresh water supply in many places, droughts, forest fires, crop losses, and floods. If global average temperature only rises 1.5˚C, the effects will still be serious, but far less intense than if it rises 2˚C.

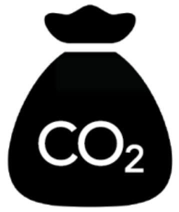
Recognising the climate risk, the UK and 196 other countries signed the **UN Paris Agreement** in 2015. This agreement commits all signatories to ensure that global average temperature increases reach **no more than 2 ˚C** more than what it was in pre-industrial times, and to aim for 1.5˚C. This is based on recommendations from the Intergovernmental Panel on Climate Change, an independent global organisation which monitors climate change, carbon emissions and the latest climate science. To achieve this, there is a limited amount of greenhouse gas that can be emitted. This is called a **'carbon budget'**. Unfortunately, at the moment the countries of the world are on track to emit far too much carbon, so that we are likely to hit at least a 3 ˚C change by 2100.

In the Paris Agreement, countries that have more money and technology are responsible to make carbon reductions much faster than countries with less money and technology.

Recognising this, in 2019 the UK declared 'climate emergency' and updated the Climate Change Act to make it a legal obligation for the UK to achieve net zero carbon status by 2050. As part of the Climate Change Act, our parliament also sets legally binding five-yearly carbon budgets based on the advice of the UK's Committee on Climate Change. The Committee on Climate Change has noted that in order for the UK to meet its legally binding targets, all new buildings need to be at or near net zero carbon from 2025 onwards (and have a very low heat demand set at 15 to 20 kilowatt hours per square metre per year). This is because it is already a huge challenge to tackle our existing emissions, and our carbon budget cannot afford to have more carbon emissions locked-in by new buildings.

Both the City of Cambridge and the district of South Cambridgeshire have also declared climate emergency. South Cambridgeshire's climate emergency declaration included a pledge that "all strategic decisions, budgets and approaches to planning decisions by the council are in line with a shift to zero carbon".

At global level ...



900,000

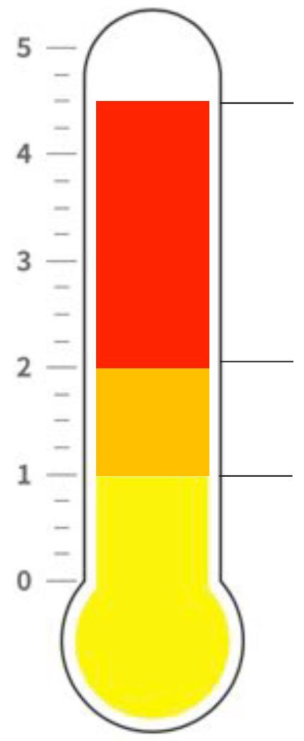
$MtCO_2$

Estimation of **remaining global carbon budget** for staying well below 2C rise.

10-14

years

The number of years it would take to **consume our entire global carbon budget** at current global emissions rates for a good chance of limiting temperature rises to below 2C.



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

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

1C The temperature rise already created

What does 'net zero carbon' mean and how will we know when it is achieved?

At global level, 'net zero carbon' means that emissions of greenhouse gases (caused by human activities) are balanced by an equal amount of greenhouse gas removals.

Humanity's greenhouse gas emissions happen mostly when we burn fossil fuels for energy and transport, but they are also caused by some of our other activities - for example, the digestive systems of our cattle and sheep, the chemical reaction when we make cement, and the breakdown of soil when we drain or plough it. We can remove greenhouse gas from the atmosphere by growing plants. Researchers are developing removal technologies, too.

'Carbon' is used as shorthand for several key things. There are several gases that have a greenhouse effect. The main greenhouse gas (in terms of quantity and overall effect) is carbon dioxide, whose chemical symbol is CO_2. Other gases can have a stronger climate-changing effect, but are released in smaller amounts and may not stay in our atmosphere the same length of time that carbon dioxide does. These include methane (CH_4), nitrous oxide (N_2O), and several refrigerant gases (chemical symbols HFC, PFC, SF_6 and NF_3). Not all of these contain carbon, but the term 'carbon emissions' can still include all of them because they all contribute to the overall climate change effect.

When people talk about 'carbon emissions' it can mean carbon dioxide only, or it can mean the total amount of all the different greenhouse gases. When talking about all the gases together, we convert them into the equivalent amount of carbon dioxide, based on the warming effect each gas would have over a period of 100 years. This is 'CO_2e': 'carbon dioxide equivalent'.

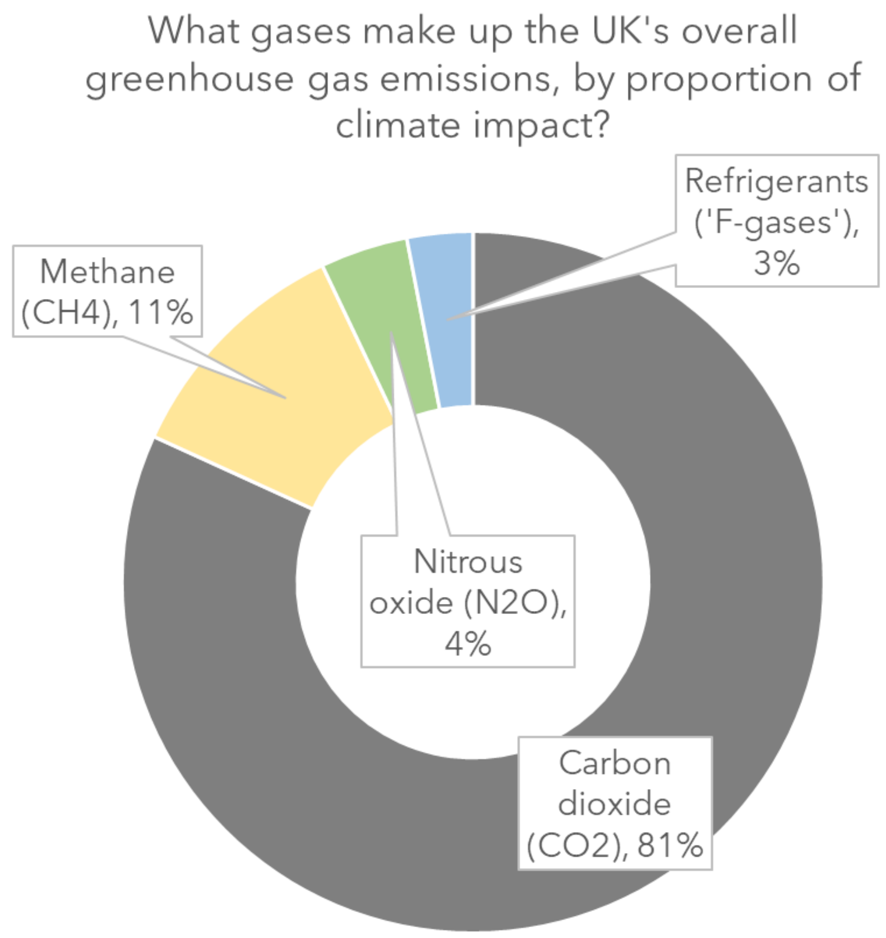
At the local level, because vehicles, goods, money and energy move across borders between different areas, we need logical methods to decide which area 'owns' each unit of greenhouse gas emissions. The same is also true for removals of greenhouse gas from the atmosphere, or actions taken to prevent greenhouse gases being emitted in the first place. This is called 'greenhouse gas accounting' or 'carbon accounting'.

If different local areas account for their carbon emissions and removals differently, there could be a risk of double-counting – for example when one local area produces energy and another local area consumes some of that energy. To understand when 'net zero carbon' has been achieved, a carbon accounting methodology is needed.

Accounting for carbon at the local level

We examined several 'carbon accounting' methodologies that can work for a geographical area to understand its carbon emissions and required reductions. The methodologies are:

- The GHG Protocol for Cities
- PAS2070 – Specification for the Assessment of Greenhouse Gas Emissions of a City
- Tyndall Centre carbon budget tool
- SCATTER – Setting City Area Targets and Trajectories for Emissions Reduction
- Cambridge University Science and Policy Exchange – Net Zero Cambridge report
- BEIS annual report on local authority area CO_2 emissions.



These different methodologies each work in a slightly different way. Differences include:

- Whether they count carbon dioxide only, or some of the other greenhouse gases too
- Whether they cover emissions from energy use only, or from other activities too (like land use, livestock or cement production).
- Whether they cover all sectors, or only certain sectors that emit most of the greenhouse gas and have data available to calculate this
- How they treat cross-boundary emissions – that is, carbon emissions that happen elsewhere as a result of activities and spending inside the city
- Whether they allow 'carbon offsets' to be part of the calculation
- Whether they are designed only to *account* for the emissions, or to *set reduction targets* in line with climate science.

These differences arise from what each methodology was designed to do, and what data is expected to be available on different activities that happen in the local area.

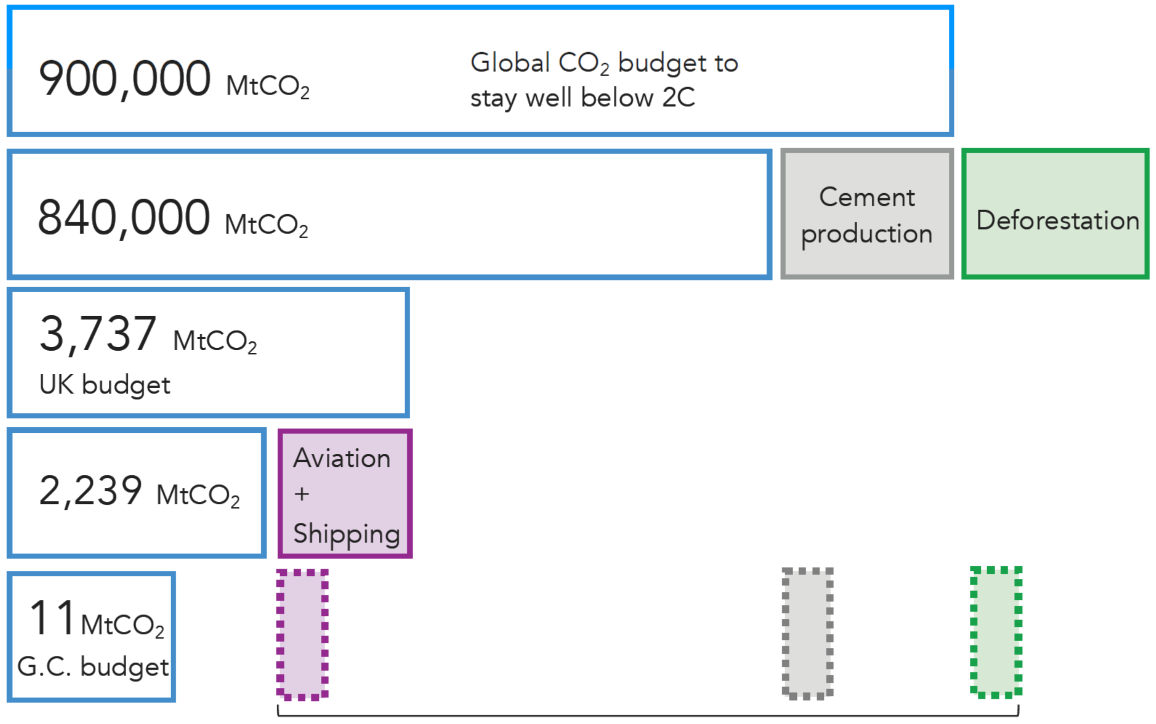
For example: the **Tyndall Centre** carbon budget tool is designed to help local areas in the UK understand how quickly their carbon emissions must fall in order to pull their fair weight towards the UK's fulfilment of the **Paris Agreement**. To do this:

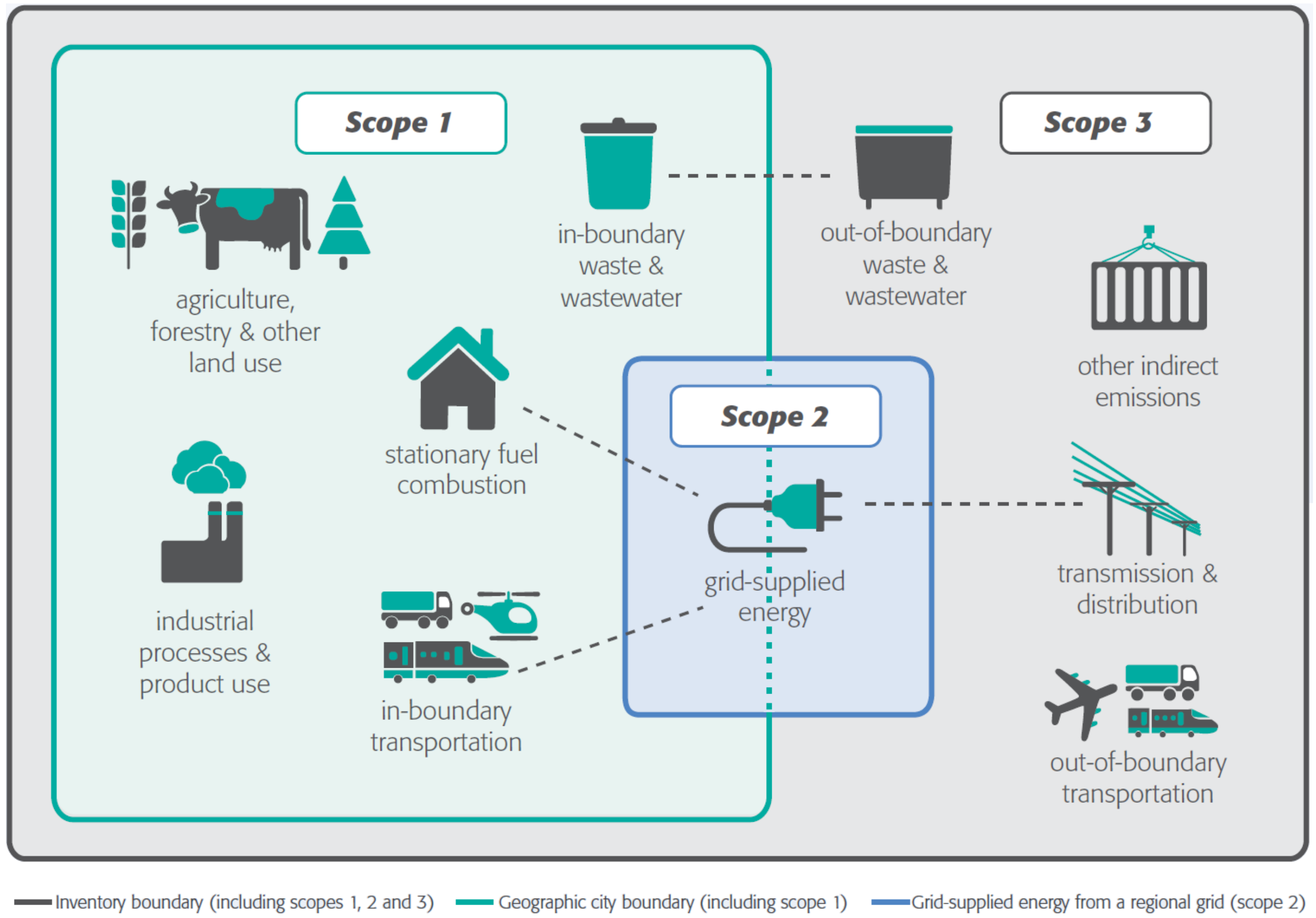
- Tyndall Centre starts with the best available scientific estimate of the global carbon budget: how much carbon can be emitted without causing 2˚C of climate change.
- This is **carbon dioxide only**, because that is the main greenhouse gas caused by human activities in terms of quantity and effect – and because other greenhouse gases have different lifetimes in the atmosphere and have a less predictable effect on climate.
- Tyndall Centre then allocates a fair portion of the global carbon budget to the UK, and then divides that up between local areas.
- It also looks only at emissions from **energy use only**, because that is the main source of human-induced emissions. This means all use of energy – not just in buildings, but also for transport and industry. However, it excludes aviation because this is outside the local area.
- Because Tyndall only looks at energy use, it does not include carbon removals by land use – so it **can only recognise ' zero', not '*net* zero'** with emissions balanced by removals.

Therefore, 'zero carbon' within the Tyndall Centre budgets means something quite different from 'net zero carbon' accounted for in some of the other budgets. For example, the GHG Protocol for Cities recommends counting all 7 greenhouse gases and all sectors – but it leaves the reporter to decide exactly what to include based on the data available and the purpose of the report. It also offers three 'scopes' reflecting how much influence the local area has.

All of the carbon accounting methodologies agree that 'carbon offsets' are not the same as carbon reductions. Carbon offsets for a local area would mean paying someone outside the area to achieve carbon removals. The Tyndall Centre, SCATTER and CUSPE do not recognise offsets at all. The GHG Protocol for Cities and PAS2070 allow you to report offsets, but these must be reported separately, not deducted from the total sum of carbon.

Local carbon budgets allocation within the UK, Tyndall Centre





Global Greenhouse Gas Protocol for Cities: Three scopes of emissions

Accounting for the carbon emissions of building projects

At the level of the building plot, there are different methods to calculate buildings' energy use and/or define a 'net zero carbon building'. The methods we investigated include:

- **Building Regulations Part L** and 'Standard Assessment Procedure' (SAP) or 'Simplified Building Energy Model' (SBEM): This is the national method that must legally be used by all new buildings. SAP is used for homes and SBEM is used for non-residential buildings. These produce an estimated energy use (kWh per square metre per year), and a carbon emissions rate, but it is not very accurate in estimating the actual energy and carbon.
- **Chartered Institute of Building Services Engineers '[TM54' method](#)**: This tool is used to estimate the energy use of new buildings much more accurately than the Building Regulations method above. These energy use calculations could be combined with information about the type of energy supplied in order to calculate carbon emissions.
- **UK Green Building Council (UKGBC)** – [Net Zero Carbon Buildings Framework Definition](#): the purpose of this is to provide a common industry understanding of buildings that are net zero carbon. This has two scopes: carbon emissions caused by the energy that the building uses, and also embodied carbon[1].
- **London Energy Transformation Initiative (LETI)** [Net Zero Operational Carbon](#): This one-pager summarises the industry consensus on what features a new building needs in order to have net zero carbon emissions from energy use.
- **Passivhaus Planning Package (PHPP):** This tool uses detailed physics models and occupancy data to predict total operational energy use of a building. It is used to design and deliver buildings that meet the strict limits on heat demand and air tightness that are required for the Passivhaus Standard. As with CIBSE (above), these energy use models could be used to accurately calculate the building's operational carbon emissions.

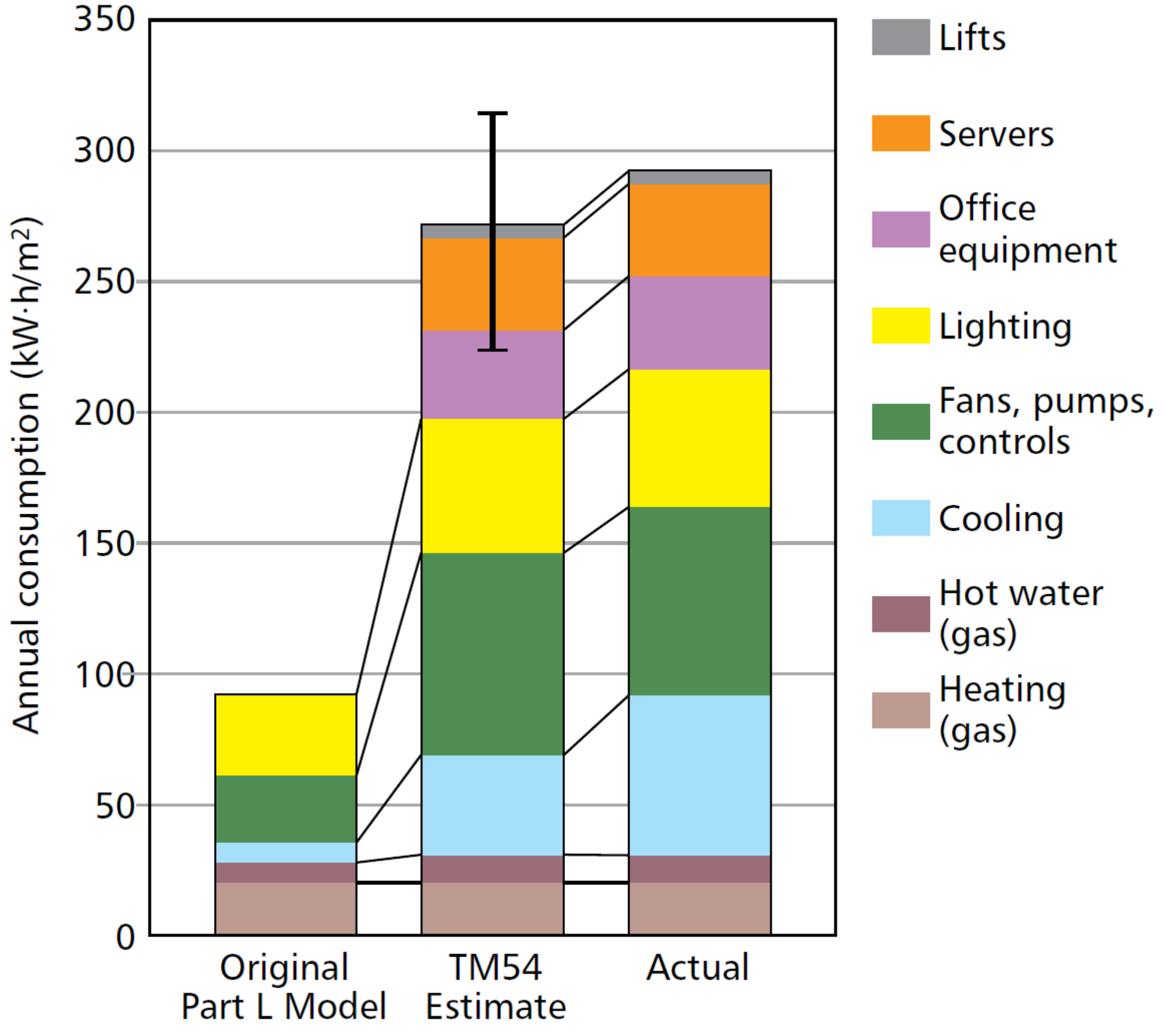
The general consensus is that **a building achieves 'net zero' operational carbon** when it matches all its energy use with zero-carbon energy. It can do this by:

- **Generating its own zero-carbon renewable energy**, usually with solar panels, and:
  - Either storing this renewable energy so that the building can use it later (because we often need energy at times when the panels aren't producing, like at night),
  - Or taking energy from the electricity grid when it needs more than it can produce, but balancing this out by exporting just as much energy to the grid at other times when it is producing more than it needs – like in the middle of the day in summer. This makes the total 'net' zero over each year, because each 1 unit of exported zero carbon energy cancels out the need for generation of 1 unit in power stations using fossil fuel.
- **Sourcing its energy** from zero-carbon sources off site. This cannot just be a renewable tariff – it must be from renewable energy plants that would not otherwise be built. This is called '**additionality**' (see text box, next page).

Why not just use Building Regulations Part L (SAP or SBEM) to define net zero carbon buildings?

Building Regulations Part L calculation is not reflective of reality because it only accounts for 'regulated' energy. That is the part of the building's energy use that is covered by building regulations. This includes fixed energy uses such as heating, permanent lighting, ventilation and so on. It does not include plug-in appliances, which can represent a large share of the total energy use.

Another reason is that the current calculations are simply not very good at modelling the actual physical thermal performance of the building.



Graph showing the predicted and actual energy use of a building. CIBSE, 2015

[1] Embodied carbon means the carbon that was emitted during the production and transport of materials used in the building, and the carbon emitted during construction. It can also include the carbon emitted as a result of maintenance of the building (such as replacing broken elements, or repainting).

Most of the above frameworks agree that there should be limits on energy use intensity before renewable energy is added to create a 'net zero carbon' building. Energy use intensity means the amount of energy per square metre of interior building space per year. Part L sets this limit in relation to an imaginary 'notional' building. Others set exact limits for all buildings:

- PHPP: space heat demand 15kWh/m^2/year; air tightness 0.6 air changes per hour.
- LETI: space heat demand of 15kWh/m^2/year, and *total* energy use intensity of 35kWh/m^2/year in homes (or 65 in schools, or 55 in offices).
- UKGBC does not yet have targets like this, but has stated it will add them in 2021/22.

These limits on space heating are in line with the UK Committee on Climate Change (CCC) recommendations. The CCC sets the five-yearly carbon budgets that become legally binding via the Climate Change Act. The CCC found that in order to fulfil the Climate Change Act, new homes from 2025 need to have a heat demand of only 15-20kWh/m^2/year. This figure was set when the UK's goal was an 80% reduction in carbon emissions by 2050. The lower level of 15kWh/m^2/year would be more suited make new homes fit for the new net zero goal.

With a heat pump, a heat demand of 15kWh/m^2/year can be cut to an actual heat energy use of 5kWh/m^2/year. This is because heat pumps can deliver three times as much heat as they use in electricity. This is key to achieving the LETI total energy use limit of 35kWh/m^2 year.

Only one of the above frameworks, UKGBC, includes embodied carbon as part of the total definition of a net zero carbon building. It defines 'net zero carbon construction' as:

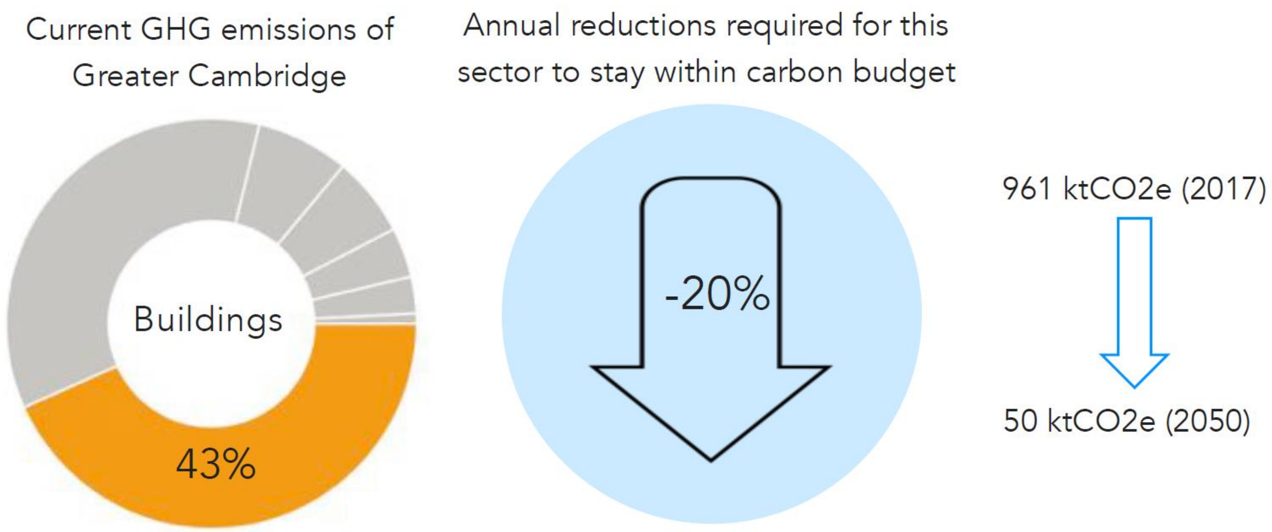
> "When the amount of carbon emissions associated with a building's product and construction stages up to practical completion is zero or negative, through the use of offsets or the net export of on-site renewable energy".

This means the developer would have to calculate how much carbon was emitted during the production and transport of materials, and the construction process itself. This calculation must use the methodology produced by the Royal Institute of Chartered Surveyors. This must then be offset via a 'recognised offsetting framework'[2] and independently audited. Offsetting can also include exporting zero-carbon energy from the site during construction (removing the need for an equal amount of energy in the grid that would otherwise be made with fossil fuel).

Embodied carbon is important and can represent a large proportion of a building's whole-life carbon emissions. However, it may not be effective for the local plan to simply require reductions. There can be trade-offs between embodied carbon and operational carbon. For example, investing in thicker walls, durable materials, solar panels or efficient heating systems could result in a 'higher' embodied carbon figure – but can save carbon in the long term.

None of the definitions of a 'net zero carbon building' includes the emissions from transport that will be caused in the lifestyle of its residents due to location, parking, cycle storage or electric vehicle charging points. Therefore, Greater Cambridge will not achieve true zero carbon *new growth* simply with a policy that only requires net zero carbon *new buildings*.

[2] Named 'recognised frameworks' are the Clean Development Mechanism and Gold Standard. These are international, which would not help the UK or Greater Cambridge reach net zero.



What is 'additionality' in carbon accounting?

'Additionality' means that your actions achieved something that would not have happened anyway.

Renewable tariffs with most ordinary energy suppliers only use 'renewable energy guarantee of origin' certificates (REGO). REGO certificates are generated when a unit of renewable power is generated, but the certificate is not linked to that unit of power and can therefore be sold separately. At the moment, there are more REGO certificates created than there is demand for renewable tariffs. This means there is no guarantee that the generator will be able to sell them. This makes the certificates very cheap, and the tariffs are not incentivising the market to install more renewable energy generation capacity. There is no 'additionality' because that energy would have been generated whether or not someone bought the REGO certificate with it.

'Additionality' in renewable energy can be shown through a **renewable energy power purchase agreement (PPA)**. This is suggested by LETI and UKGBC. A PPA is a promise to buy power from a particular source at a set price. This gives the supplier certainty that it is worth the investment to install more renewable energy equipment, and can even oblige them to do so.

What duties and powers does the local planning service have to act on achieving 'net zero carbon' in their local area?

Local plans have a legal **duty to help achieve the Climate Change Act target of net zero carbon by 2050**. This duty flows from this legislation and guidance:

- **Planning & Compulsory Purchase Act 2004**, section 19: "Development plan documents must (taken as a whole) include policies designed to secure that the development and use of land … contribute to the **mitigation** of, and **adaptation** to, **climate change**".
- **National Planning Policy Framework** (2021[3]) paragraphs:

152. "The planning system should support the transition to a low carbon future [and] shape places in ways that contribute to radical reductions in greenhouse gas emissions"

153. "Plans should take a proactive approach to mitigating … climate change"; (footnote 53: "in line with the objectives and provisions of the Climate Change Act")

154. "New development should be planned for in ways that … reduce greenhouse gas emissions, such as through its location, orientation and design. Any local requirements for the sustainability of buildings should reflect the Government's policy for national technical standards"

155. "To help increase the use and supply of renewable and low carbon energy and heat, plans should … provide a positive strategy for energy from these sources … [and] consider identifying suitable areas for renewable and low carbon energy sources, and supporting infrastructure".

However, there is **conflict** between these **duties**, and the local plan's **powers to enforce all the necessary changes** to achieve net zero carbon.

- **The Planning and Energy Act 2008** paragraph (1) gives the local plan the power to impose "reasonable requirements"[4] for new developments to:

(a+b): supply a portion of their energy from renewable or low-carbon sources.

(c) have energy efficiency standards that exceed national building regulations.

This means that the local plan could require all new developments to be supplied with 100% renewable energy. We believe this can be considered 'reasonable' in light of climate emergency and the need to make sure that new housing growth does not worsen the challenge of transitioning the entire country to net zero carbon.

It also means the local plan can also require higher energy efficiency standards – such as a lower energy use intensity and heat demand, as described previously.

However, the Planning and Energy Act defines 'energy efficiency standards' as ones that are 'set out or referred to in regulations made by the [Secretary of State]' or 'set out or endorsed in national policies or guidance issued by the [Secretary of State'].
This is also repeated in National Planning Policy Framework paragraph 154.

This could mean that the local plan can only set policies that are based on the calculations used in building regulations. It could be argued that this would prevent the local plan from fulfilling its duty to mitigate climate change in line with the national transition to net zero carbon – because of the inadequacies of the building regulations Part L calculation.

Also, if carbon emissions are not sufficiently mitigated in the UK and worldwide, we will face such a severe degree of climate change that it will be near-impossible to 'secure … adaptation to climate change' as per the duty laid out in the Planning and Compulsory Purchase Act 2004.

Our research has not been able to find any examples of this conflict being legally tested. It is not yet clear whether it is the Climate Change Act, Planning and Compulsory Purchase Act, or Planning and Energy Act that holds the most weight. For the best chance of achieving net zero carbon development that contributes to a net zero carbon UK, the choice would be to both:

- Require deliver low-energy buildings using the most reliable and accurate method possible, including a low heat demand and total energy use intensity,
- Require delivery of renewable energy generation to match the new buildings' demand.

Many other local plans have set 'net zero carbon' new buildings requirements using the Building Regulations existing calculations. However, these only require the figure to be reduced by 35-40% and then the rest offset by a 'Section 106' payment[5] to the local authority that goes into a fund that should be put towards carbon-reducing actions.

In the past, national government guidance had stated that local plans could only require a reduction on the Building Regulations carbon emission rate to the equivalent of the withdrawn Code for Sustainable Homes Level 4 (which would be a 19% reduction on Building Regulations 2013). The existence of successfully, legally adopted local plans that require up to 40% reduction indicates that the previously stated limit no longer applies. The government response to the Future Homes Standard consultation recognises the existence of the local plans that go further, and confirms that local planning authorities retain the power to do so.

Viability is a consideration, but does not completely limit what requirements that the local plan can set. Viability means the right of property developers to make a profit, including the costs of building to all the required standards. However, National Planning Practice Guidance clarifies:

> "The price paid for land is not a relevant justification for failing to accord with relevant policies in the plan. Landowners and site purchasers should consider this when agreeing land transactions".

[3] Please note: our original reports use paragraph numbers from the 2019 version.
[4] "Reasonable requirements" is not defined.
[5] Section 106 payments are made by developers to fund actions that can make an otherwise unacceptable development acceptable. Many local planning authorities use Section 106 payments as a way for developers to fulfil requirements for 'zero carbon' new developments, by paying into an 'offset' fund that the council can use to reduce carbon elsewhere in the area.

The carbon emissions of the existing buildings are an even greater issue than new development. Most of the buildings that we will use in 2050 are already built, and the vast majority of these are still heated with fossil fuels and are often poorly insulated. The local plan cannot *require* the necessary changes[6] – but it can help to remove barriers, principally by:

- Set policy emphasising that changes to buildings that result in significant energy and carbon improvements will be welcomed
- Explain which of these changes do not need permission, and how these changes can be made acceptable if permission is needed
- Use the spatial strategy to proactively identify land where development of renewable energy generation and distribution will be welcomed, to help decarbonise the energy that existing buildings use – this could be electricity, or fossil-free heat networks
- Consider using Section 106 carbon offset payments from new developments to create a fund that helps remove financial barriers to energy retrofit, and/or delivers community renewable energy generation projects that supply energy to existing buildings
- Consider using Local Development orders to bring forward all of the above changes. Local Development Orders give default permission to certain types of development, which can be limited to certain locations or have conditions attached.

Beyond buildings, transport is a key issue for a local plan looking to enable net zero carbon. Transport is the largest source of carbon emissions in the UK. Small gains in vehicle efficiency have been eclipsed by an overall increase in driving[7]. To help, the local plan can:

- Set a spatial strategy that only permits development in locations that minimise the need to travel by car (National Planning Practice Guidance confirms that the location and the mix of development are appropriate steps to reduce carbon emissions)
- Safeguard land to be used for expansion or improvement of car-free transport infrastructure, including train lines, cycle lanes and bus lanes
- Raise funds to pay for sustainable transport using the Community Infrastructure Levy on new developments (and not spend CIL funds on infrastructure that promote car use)
- Require provision of enough electric car charging points in new development to enable unavoidable car trips to be zero-emissions (subject to viability and grid capacity)

Land use and green infrastructure are the final key issue that the local plan can affect with regards to carbon emissions. Green infrastructure means natural or semi-natural features that provide a service. The way we use unbuilt land can emit or remove carbon. Ploughing or draining carbon-rich soils – like Cambridgeshire's peatlands – can cause their carbon to be emitted into air. Wet peatlands can capture large amounts of carbon, as can woodlands and some grassland. The local plan cannot change how people use their existing land, but it can:

- Use the spatial strategy to steer development away from peatland and forest areas
- Use the green infrastructure strategy to identify features that remove carbon, and consider requiring these to be compensated if development causes unavoidable loss.

Case study: Entopia Building

EnerPhit retrofit

Passivhaus certified triple glazed replacement windows

Solar photovoltaic panels

82% reduction in whole life carbon (expected)

Case study: New Court, Trinity College

Grade I listed building

88% reduction in carbon emissions

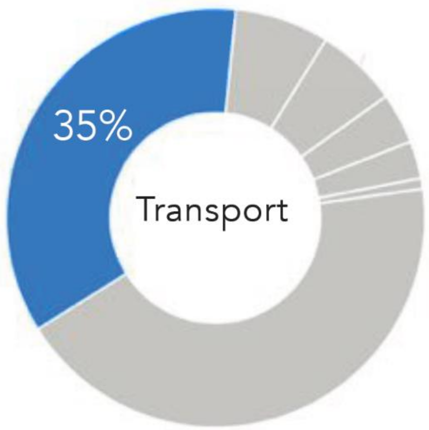
75% reduction in energy demand

Internal wall insulation

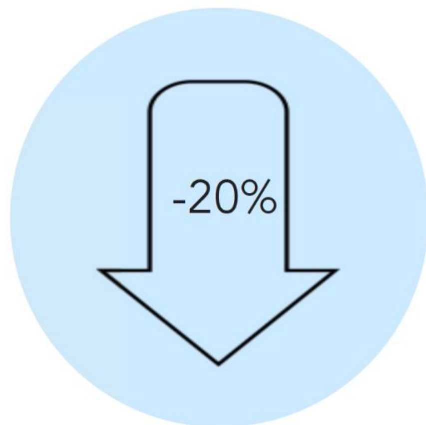
Low temperature underfloor heating

New mechanical ventilation with heat recovery system

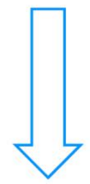
Current GHG emissions of Greater Cambridge



Annual reductions required for consistency with carbon budget



786 ktCO2e (2017)



15 ktCO2e (2050)

6Necessary changes include insulation to walls (which may be external); insulation to roofs; replacement with modern windows; addition of solar panels and heat pumps which may be visible.

[7] This increase in driving continued until the COVID-19 pandemic – after which there may be a bounce-back in driving if people have become uncomfortable with public transport.

Therefore, what position should the local plan take on 'net zero carbon' for Greater Cambridge?

We recommend that **all greenhouse gases and their sources are included when defining a 'net zero carbon' future for Greater Cambridge** that the local plan aims for. This should cover the emissions defined by the Greenhouse Gas Protocol as 'scope 1' and 'scope 2'. This should be based on real reductions, with offsets only as a last resort and never from outside the UK.

In practice, it **may not be possible to perfectly monitor and enforce reductions in non-CO_2** greenhouse gases that could result from new development within the local plan. Examples include methane from food production and waste. Nevertheless, policies can be set with the aim to enable reductions in these, even if the impact cannot be monitored – such as by planning for food separation and types of waste treatment that reduce methane emissions.

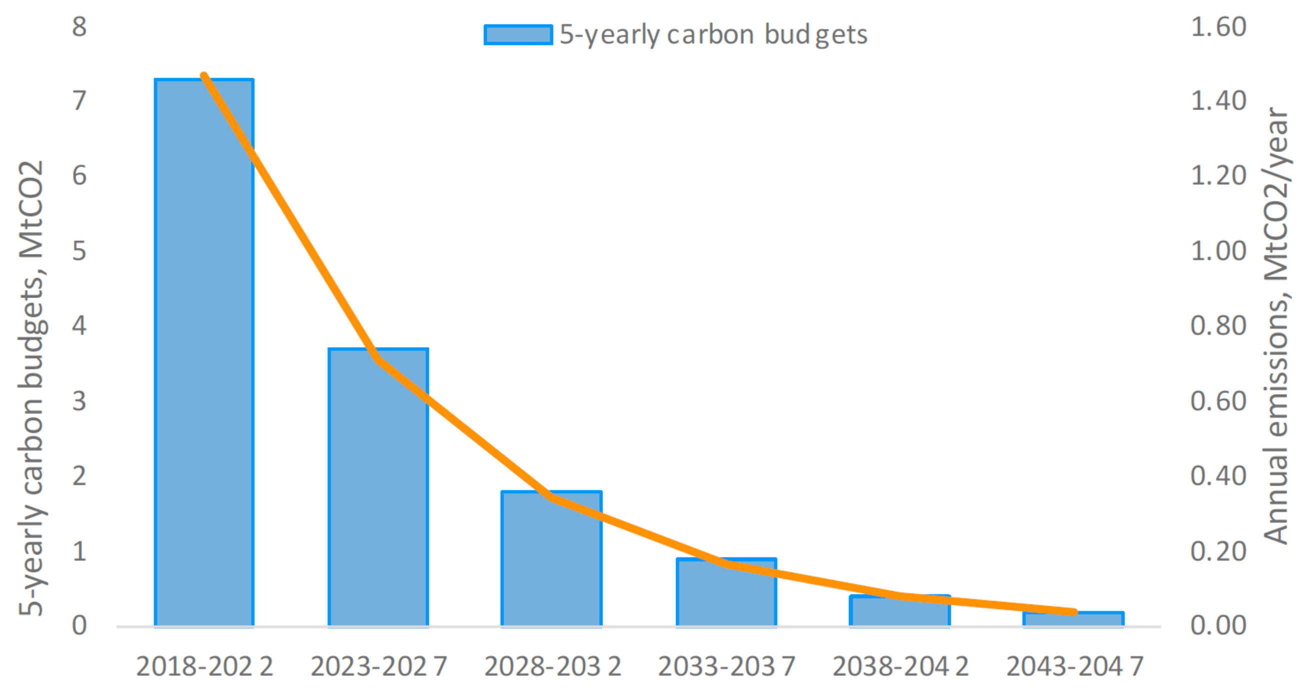
We also **recommend that intermediate targets are set (and action taken) to limit the total amount of carbon dioxide from energy use** that is emitted between now and the net zero end date, in order to ensure Greater Cambridge pulls its weight towards a world where global average temperatures do not rise more than 2˚C, and aiming for under 1.5˚C (Tyndall Centre).

This would require:

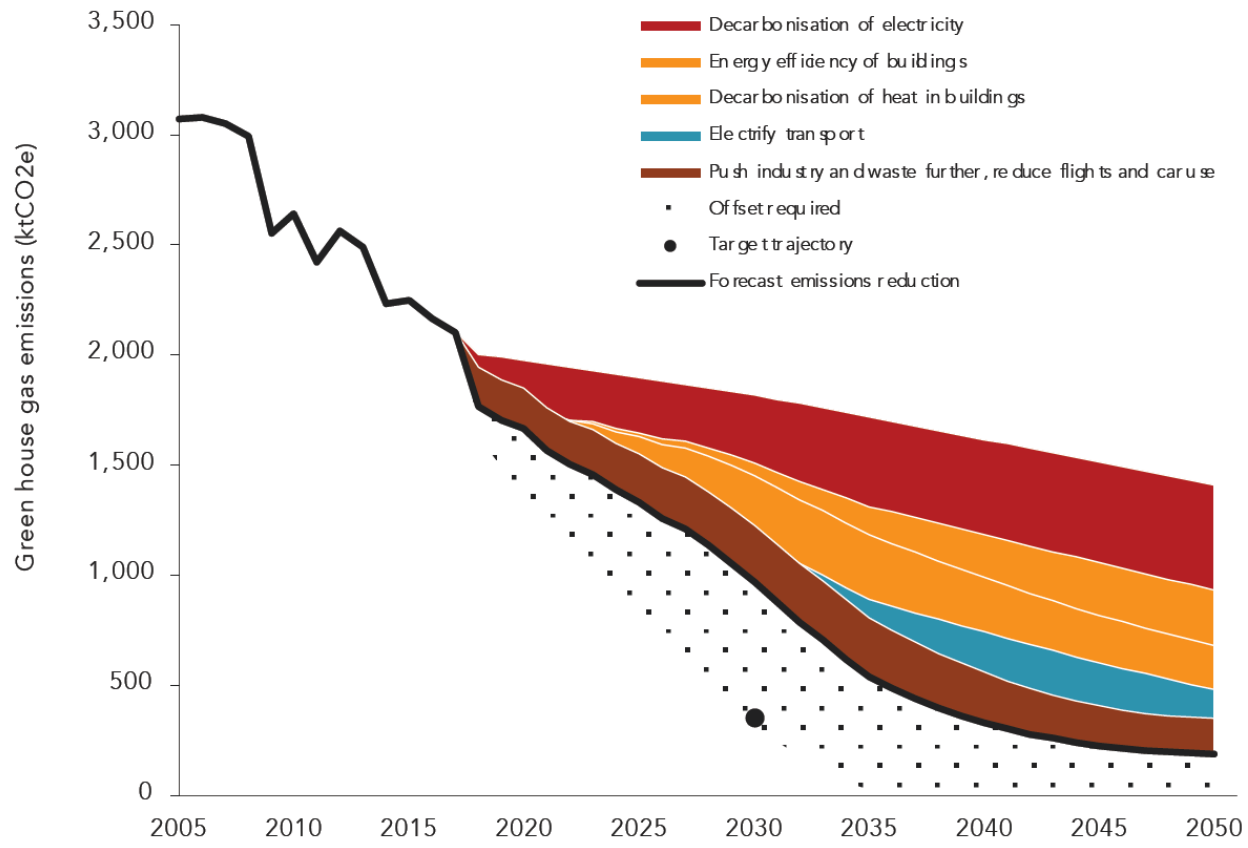
- All new buildings to be net zero carbon (especially homes), defined by having a space heat demand of 15kWh/m²/year and enough renewable energy generation capacity deployed with those buildings to match their energy needs over the course of a year
  - Calculated using a reliable and accurate methodology – but falling back on the Building Regulations Part L calculation if the inspector does not permit this
- No gas or other fossil fuel heating in new buildings;
- Seeking the use of heat pumps to slash the heat demand by two-thirds and make it possible to achieve the low total energy use metrics recommended by LETI and others
- Identifying enough land suitable for installation of enough renewable energy generation capacity to represent Greater Cambridge's fair share of the increase in renewable energy needed for the national transition to net zero carbon
- Directing growth to locations that minimise or eliminate most car use
- Requiring electric vehicle charging points for new buildings in locations that can be expected to create some unavoidable car use
- Policies that explicitly encourage, and guide energy retrofitting in existing buildings

In addition to the above actions necessary to stay within the carbon dioxide budgets for a 2˚C world, it would be positive to also:

- Have new development away from peatlands, woodland and carbon-rich grassland
- Require compensation for unavoidable loss of any of those types of green infrastructure, seeking replacement or net improvement of the carbon removal function alongside the 'biodiversity net gain' that will soon be mandatory in all new developments under the Environment Bill (for example by restoring peatland so it regains its carbon-capturing ability, and create new woodland or bring land into management that captures carbon)
- Encourage developers to reduce embodied carbon, but without setting specific targets;



Five-yearly carbon budgets for energy use that would allow Greater Cambridge to pull its weight towards the UK's fulfilment of the Paris Agreement.



Historic and forecast emissions for Greater Cambridge 2005 - 2050, showing change in each sector. Some further reductions or offset requirements remain. Etude, 2020

3. Understanding carbon emissions resulting from choices about where Greater Cambridge's new growth happens

This section will include information from the following of our longer reports:

- Task B: Spatial implications analysis.
- Task D: Technical feasibility.

For carbon emissions, why does it matter where new homes go?

The carbon emitted by each person in their daily life is heavily affected by where they live. The location where we live can affect our carbon emissions because it affects:

- Whether we choose to drive a lot, because of long distances or lack of other attractive options to get around
- Whether it is quick, safe and pleasant to walk or cycle to work, school, shops and doctors
- Whether it is quick and easy to walk to public transport stops with regular fast services, so that we can avoid driving for most journeys
- How large our home is – which affects how much energy we need for heating and light, and how much material goes into making our home (because carbon was emitted to create those materials)
- What shape our home is – which affects how much energy is lost through the walls and roof (for example if it is detached or terraced), and how many solar panels we can fit on our roof compared to how much floor space we have to heat and light
- Whether there are nearby facilities that we can share (like GPs, schools and so on) – or whether new facilities have to be built to serve us, using more energy and materials.

In the local plan, Greater Cambridge has a legal duty to enable a certain amount of new homes. This number of new homes is based on the expected amount of population growth, and the number of existing residents who need another home either because they are homeless or because they currently live in overcrowded or otherwise unsuitable homes. This number can be limited by issues such as whether there is physically enough space to create these homes and enough water to support the residents. Still, the planning service must provide for as many of the necessary new homes as reasonably possible (and accompanying facilities to support the new residents).

Therefore, Greater Cambridge Shared Planning Service must decide where the new homes and facilities should be permitted. This decision is made based on a wide variety of factors including land availability, water availability, presence of heritage assets (natural or manmade), and presence of other valuable features like high-quality farmland or wildlife-rich habitats.

Carbon emissions are one of the pieces of information on which this decision is based. To create that information, Bioregional built a tool to work out how much carbon is likely to be emitted depending on where Greater Cambridge's new buildings are created.

How do we work out the carbon emissions of allowing new buildings in each location?

Building our modelling tool

Firstly, we were asked by Greater Cambridge Shared Planning Service to divide the different possible growth locations into six different categories. Within each of these categories, carbon emission can be expected to be roughly similar because of similar transport needs, average home sizes and forms. The six categories are:

Category 1: Densification of existing urban areas

Category 2: Edge of Cambridge: Outside Greenbelt

Category 3: Edge of Cambridge: Greenbelt

Category 4: New settlements

Category 5 Villages

Category 6: Public transport corridors

We then researched to find out what the average home size, home type, other building types and energy use, and transport patterns are for new builds in each of these categories.

We found evidence for **new building size and type** in the following places:

- Existing local plan guidance on how many homes should be built per hectare in different locations, cross-checked against real recent planning applications
- Existing local plan guidance on types of building, numbers of bedrooms, space standards and percentage of homes that must be 'affordable' – this helped us work out the amount of internal space that must be heated and lit, and how much roof space would be available to accommodate solar panels
- Existing local plan assumptions about how many people will live in each home type (for example, there will be fewer empty bedrooms in social homes than market homes) to estimate how many people will live in these new developments
- Using this estimated number of new people to work out how much new infrastructure will be needed alongside homes (such as schools, healthcare and so on) – based on what the existing local plan requires developers to deliver per person in the new homes, and cross-checking this against real recent planning applications.

We then had all of our above estimates reality-checked by an experienced architect and master planner.

We used the following evidence to work out **how much energy** each of these buildings will use (and the carbon that would have been emitted to produce the materials used):

- The government's open database of certificates for how energy-efficient buildings are, looking at ones built in this area in the last 5 years – this tells us how much energy is likely to be used for the building itself - like heating, hot water, permanent lighting, ventilation
- Cambridgeshire data on how much electricity and gas is used in each small local area – this allows us to work out how much additional energy is used for plug-in appliances and other energy uses that are not covered by the government's building energy certificates.
- These two pieces of information, combined with the information on size of building and number of occupants, allow us to work out roughly how much energy is being used per metre of floor space in homes and other buildings in Greater Cambridge
- Industry expert evidence-based guidance on the amount of carbon normally emitted in the production and transport of the materials used in buildings, per square metre of internal space. This is called 'embodied carbon'. We then divided this by 60 to get an annual figure, because buildings today are typically designed for a 60-year lifespan.

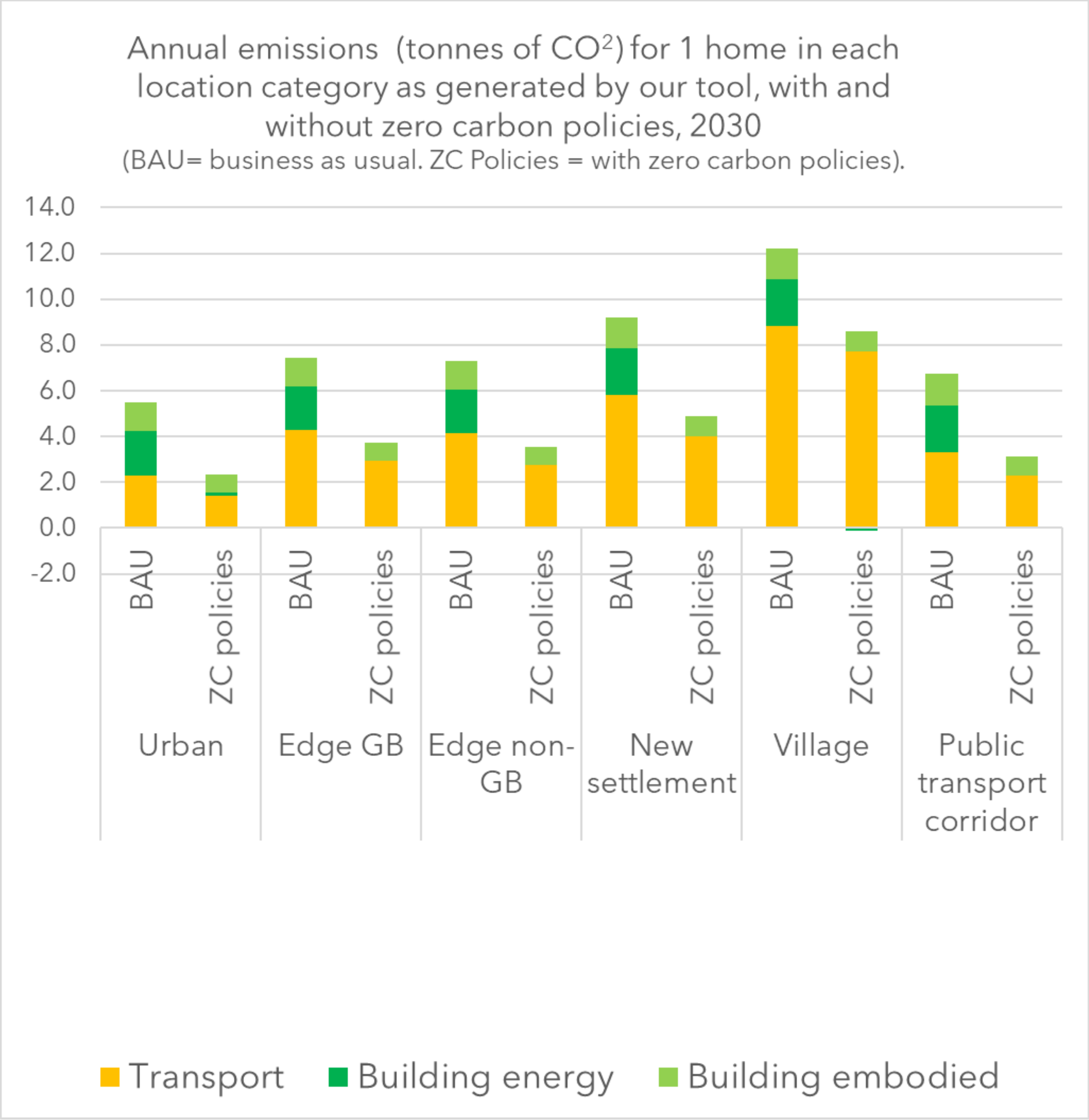
We combined the information on *amount* of energy with information on the *type* of energy used (gas, electricity or other). Along with the information on materials and construction, this gives us an amount of carbon emitted per square metre of floor space per year, for today's normal buildings in Greater Cambridge. We built our tool to reflect that electricity will continue to get cleaner as fossil fuel power plants are replaced with renewables.

We found evidence for how much carbon is likely to be emitted from **transport** in each of the different locations using the following sources:

- Data on carbon emissions coming from each local authority area that are released every year – (which confirm that transport carbon in the city of Cambridge is much lower than in South Cambridgeshire) – divided by the number of people, to get a per-person figure
- Creating a simple scale for the lowest carbon to highest carbon location, based on our transport planner's expert knowledge based on experience, and informed by local data on car ownership and existing surveys of what transport people use for their trips
- Cross-checking this against the existing transport model that is used by the planning service, that was built specifically for this region.

The tool then generates a carbon dioxide figure per home per year for each location category.

We then built-in options to reflect what difference **zero-carbon local plan policies** could make. For buildings, the options are to apply the best building techniques available today to reduce buildings' heat demand, use the most efficient heating system (heat pumps), low-carbon materials, and add solar panels to as much of their roof as possible. For transport, the tool can reflect what would happen if the local plan policy does all it can to promote walking, cycling, public transport, and electric vehicles (taking into account that the local plan cannot make all of these things perfect and that there is still individual choice involved in transport).



Using the tool to show the carbon emissions of Greater Cambridge's eight spatial options

Greater Cambridge Shared Planning Service provided us with information about different options for where they were considering allowing the new growth and how much of it.

The different options included:

- Three different **levels of growth**:
  - Low growth: 3,900 homes
  - Medium growth: 9,800 homes
  - High growth: 26,300 homes
- Eight different options for where the growth could happen (the '**spatial options'**):
  1. Densification of existing urban areas
  2. Edge of Cambridge – outside the Green Belt
  3. Edge of Cambridge – including some Green Belt sites
  4. New settlements
  5. Villages
  6. Public transport corridors
  7. Supporting a high-tech corridor by integrating homes and jobs
  8. Expanding a growth area around transport nodes.

Each of the eight spatial options above is named for the type of location where *the largest chunk* of the growth would happen. However, most of the options have some growth happening elsewhere too. For example, option 2 "Edge of Cambridge outside the Green Belt" included some growth in central urban and village locations too.

Figures provided by GCSP showed how the new homes would be distributed across a number of different locations. Some of these locations were specific – such as Cambridge Airport or Waterbeach. Some were more vague but still had certain characteristics described, such as 'minor rural centres', 'new settlement on road network' or 'villages on public transport corridor'.

We entered the number of homes into our tool, in the most appropriate categories of location that our tool offers as described previously. We chose the tool category that most closely matched the characteristics of the location that GCSP described – for example, if there are homes to be built at a village that is on a train line, we entered them as a 'public transport corridor' not as a generic 'village'.

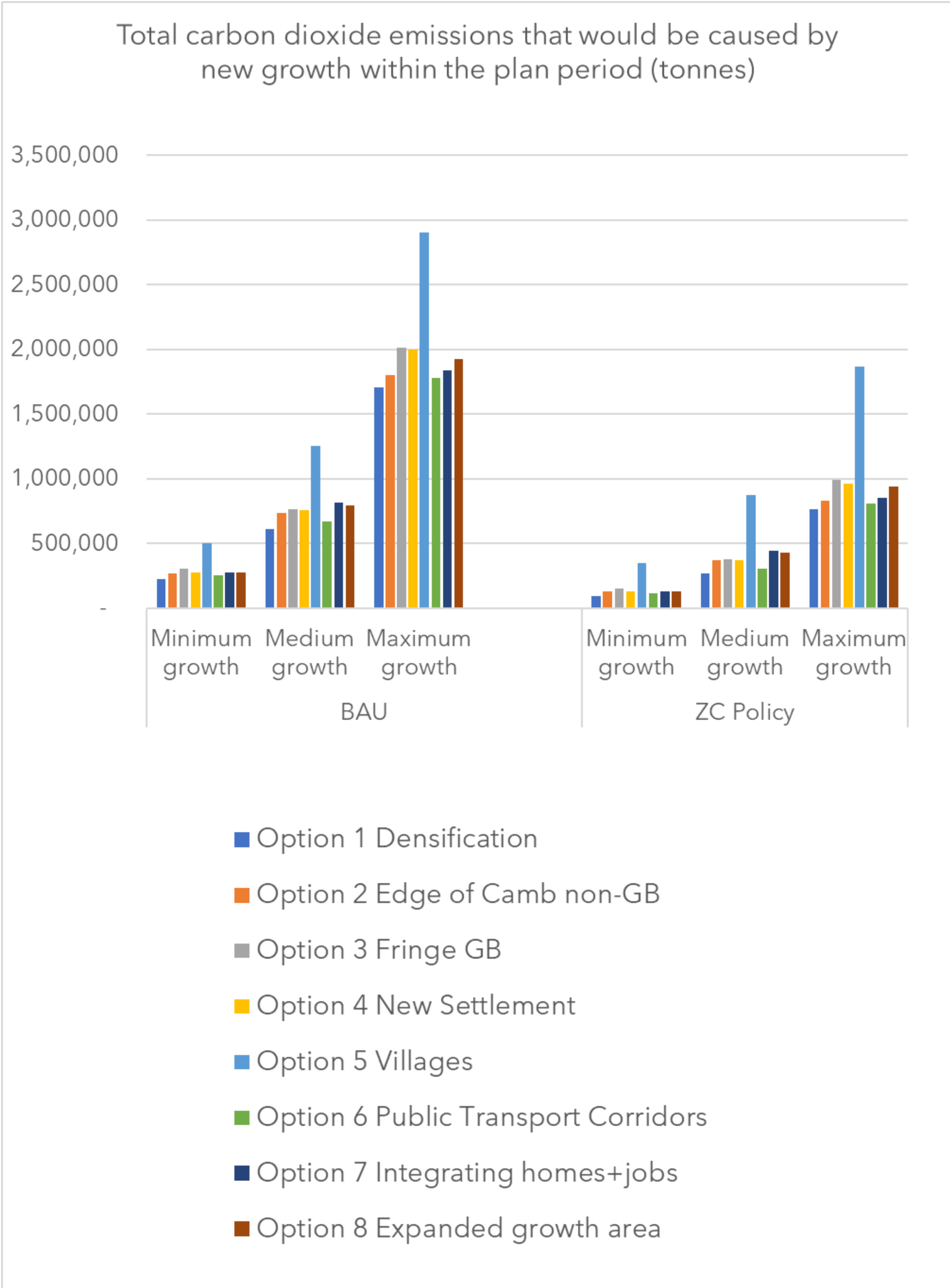
For each combination of number of homes and locations, we ran the tool twice:

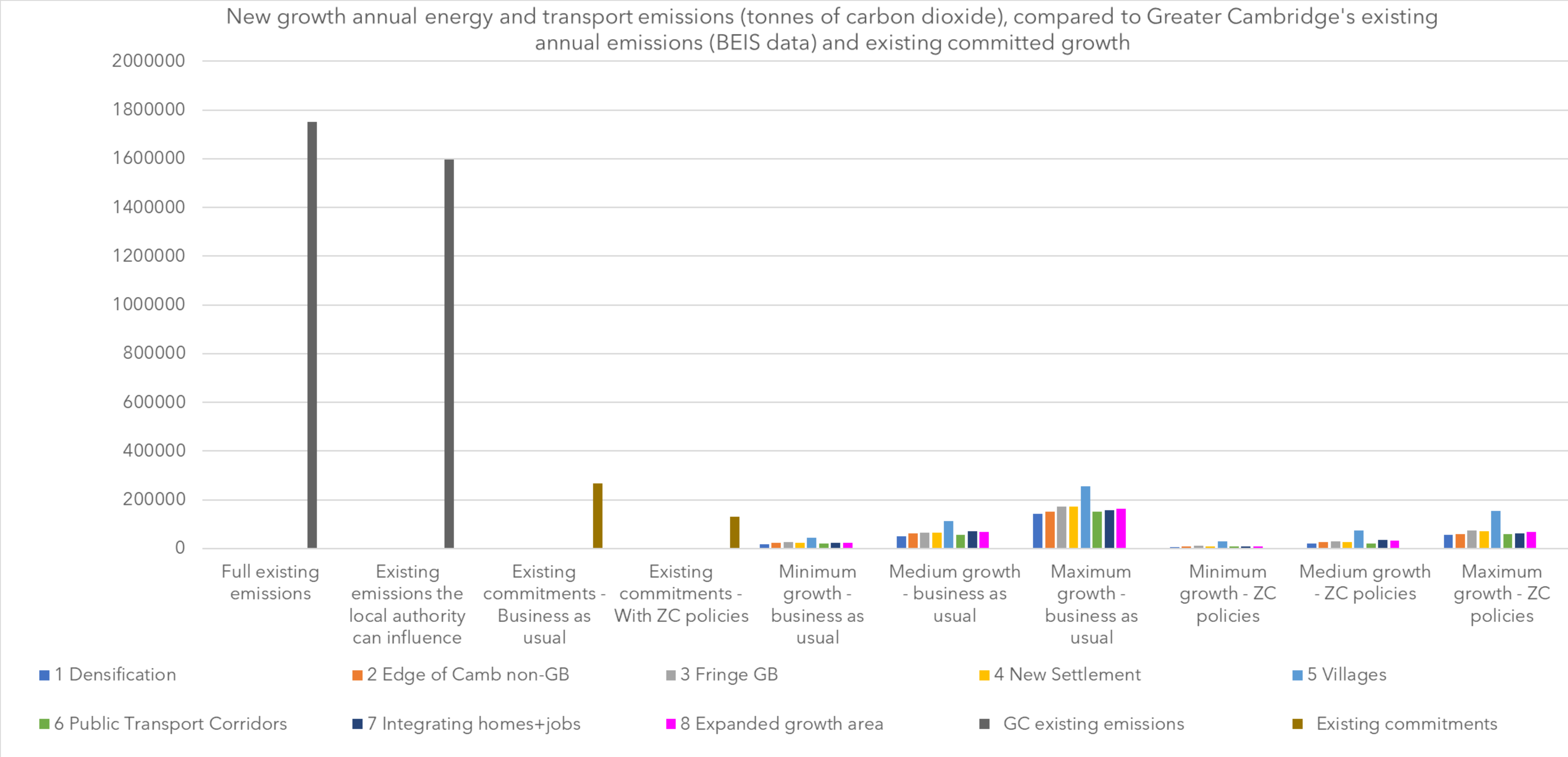
- With normal practices in construction and transport as they exist today
- With a set of 'zero carbon policies' as described previously, to minimise buildings' energy needs, increase renewable energy, and improve sustainable transport use.

We added together the annual emissions per year to work out the emissions for the whole plan period that would be caused by new growth (assuming an even rate of new homes each year)

To put new growth into perspective, we also modelled the new growth as if built in year 2020 (to compare it with the existing carbon emissions of Greater Cambridge). See figure overleaf.

Results





For these figures, we did not include the 'embodied carbon' of new growth, because that is not part of the carbon dioxide data for local areas that we used to show the 'existing emissions'.

This chart shows us that unless maximum growth is pursued, the new growth will represent quite a small increase on existing annual emissions already caused by lifestyles in Greater Cambridge. This is the case in all of the eight spatial options except the 'villages' option. For a medium level of growth, if zero carbon policies are applied, the increase on existing emissions could be as little as 1% (if the 'urban densification' option is chosen) or 2% if the highest-carbon non-village option is chosen (option 8, 'expanded growth area'). If the villages option is chosen, even with zero-carbon policies applied this would result in an increase of 4.2% on Greater Cambridge's existing annual carbon dioxide emissions, due to the heavy use of cars that is induced by rural living (despite our zero-carbon policy suite assuming a much higher rate of electric vehicle use than is currently the case). This is a reasonable expectation because even though *new* fossil fuel cars may be banned from 2030, people continue using their *existing* fossil fuel cars for about 14 years from first purchase.

If choosing a spatial option purely based on climate impact, the best choice would be urban locations or public transport corridors, and to apply zero-carbon policies to make sure the new buildings have such little need for energy that they can mostly meet this with solar panels on their own roofs.

4. Is it technically possible to create net zero carbon new buildings, and how much would it cost compared to ordinary buildings today?

This section will include information from the following of our longer reports:

- Task D: Technical feasibility
- Task E: Cost feasibility.

Defining a net zero carbon building in Greater Cambridge

Our energy experts (Etude) examined the technical standards of construction that would be required to make a building meet the following targets previously identified to be necessary:

- Having ultra-low energy needs
  - space heating demand of 15-20kWh per square metre per year (kWh/m2/year)
  - total metered energy use of 35-65kWh/m2/year for most building types
- Using low-carbon heat (heat pumps, possibly supplemented with direct electric heating – no gas boilers to be installed within the local plan)
- Matching the remaining energy needs with new renewable energy generation, ideally on site but off site if needed.

What steps can be taken to make a building with ultra-low energy needs?

A building's space heating needs can be improved with the following steps:

- A simple form reduces the external surface area of the building that is exposed to colder outdoor temperatures, and reduces complex junctions that can be poorly installed
- Insulation to walls, roofs, floors
- High-performance glazing (windows; roof lights) and doors
- Air-tightness – making sure the building is not 'leaky'
- Recovering heat from stale air that is removed by ventilation.

We can then reduce the energy needed to heat this building even further, by using a heat system that is more than 100% efficient. At present, only heat pumps can do this.

Buildings' lighting needs can be reduced to some extent by designing windows to catch good amounts of daylight. This needs to be carefully balanced against how much heat will come into the building with that daylight, to avoid the need for more energy for cooling and ventilation.

Smart controls can also make a difference to help a building avoid wasting energy. These will vary depending on the building uses, but one example is motion-controlled lighting.

There are also special processes that can be followed in design and construction to ensure that the building actually is constructed as it was designed. This makes it likely that the building will use the amount of energy (and achieve the zero carbon emissions) that it was designed for. These are called 'assured performance processes' to reduce the 'energy performance gap'.

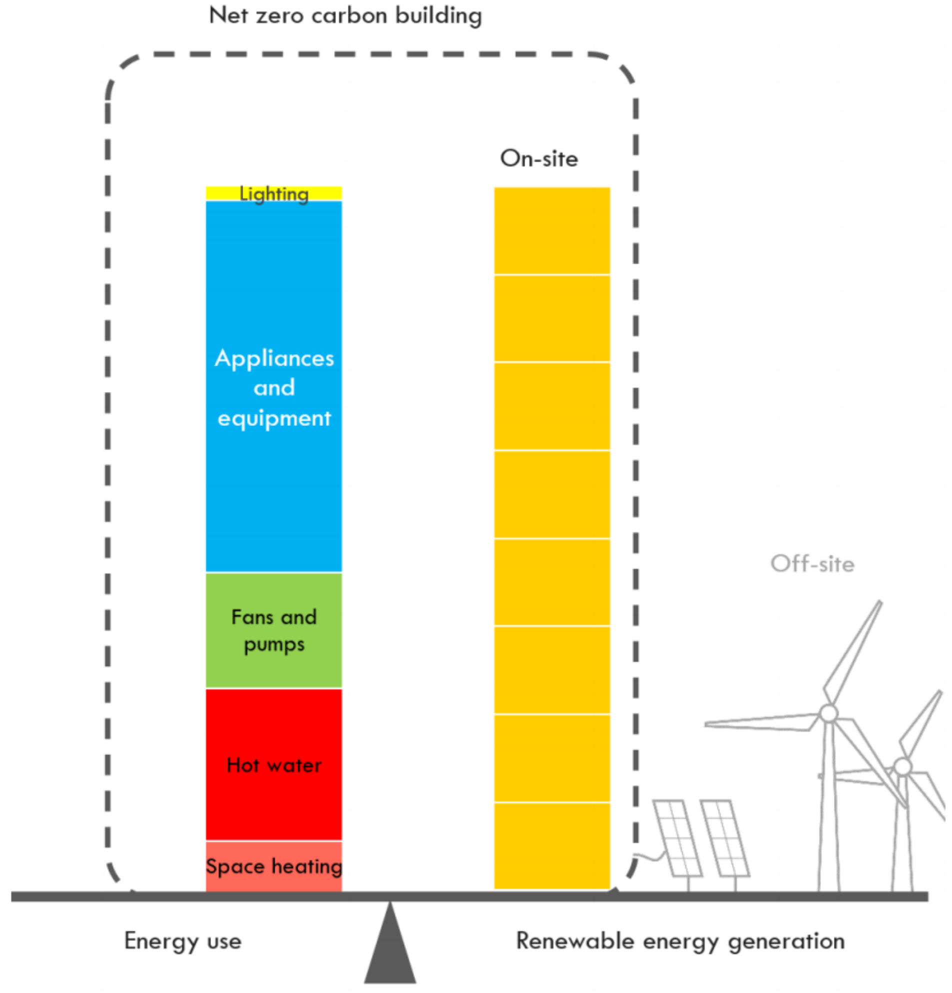
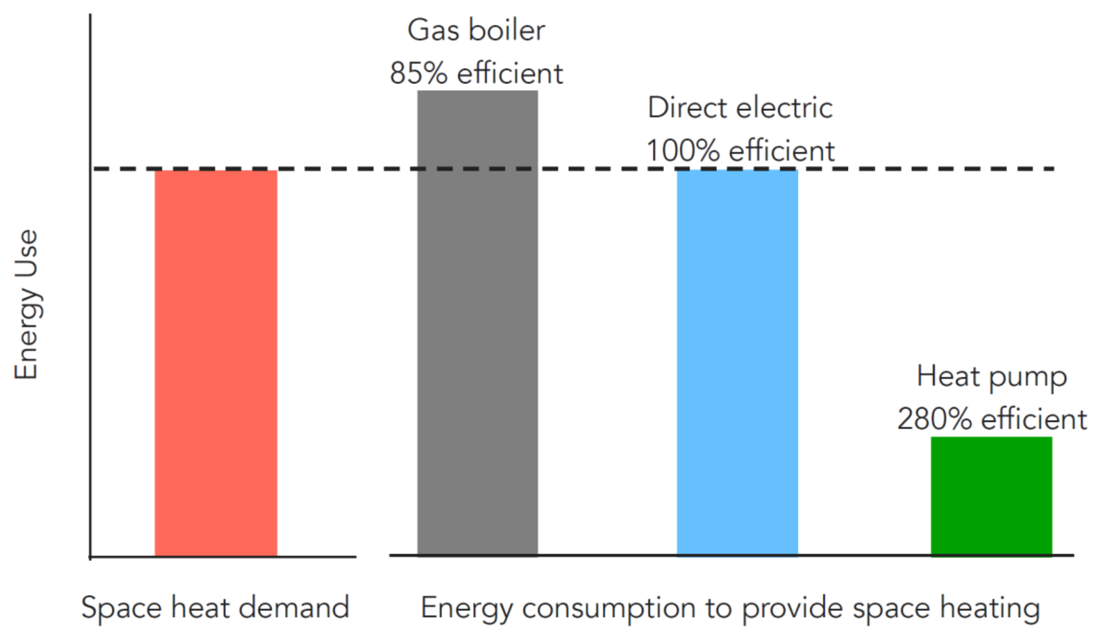


Diagram showing the energy use profile of a new building matched by renewable energy to achieve net zero carbon. The profile is for an efficient home with heat pump. Each yellow block equals 1 solar panel. In this case, no offsite energy is needed.



What heating systems are suitable for a net zero carbon building?

We consider two types of heating to qualify as 'low-carbon' or compatible with net-zero carbon: heat pumps and direct electric. Both of these become lower-carbon as they are supplied with cleaner electricity. Heat pumps are preferable as they can deliver about 3 times as much heat energy as they consume in electricity, because they borrow energy from outdoors. Direct electric heating consumes 1 unit of electricity for 1 unit of heat delivered.

Heating systems that use carbon-based fuels are excluded. This includes gas, oil, and biomass. The net balance of carbon that results from burning biomass is highly variable and complex to calculate. We also exclude hydrogen because the production, storage, transport and conversion of hydrogen into useful heat is an inefficient process. The Committee on Climate Change indicates that hydrogen is unlikely to play a significant role in heating new buildings.

What are the best ways for a building to generate its own renewable energy?

We consider solar photovoltaic (PV) panels to be the only universally suitable on-site renewable energy for new buildings. We did not explore solar water heating, because the electricity generated by PV panels is more valuable than hot water, and PV systems are more reliable. Small wind turbines typically perform poorly in turbulent urban / suburban settings.

The amount of energy generated by a solar panel depends on the amount of light directly hitting the panel. We will get the most energy out of each panel if they face south towards the sun. However, if one side of the roof faces south, then the other usually faces north and cannot be used for solar panels – or on a flat roof, the panels are spaced apart to avoid shading each other. This only uses part of the roof space and does not get the maximum possible energy.

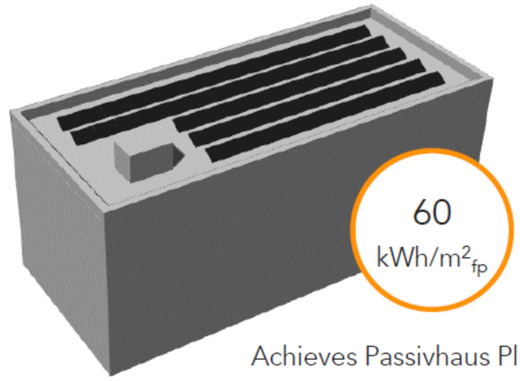
We can get more solar panels onto a roof if the panels face east-west, so that the east-facing ones receive direct light in the first half of the day and the west-facing ones receive the direct light in the second half of the day. Alternatively, we can have a 'monopitch' south-facing roof – designed specifically to get maximum solar panels at the optimum angle to the sun.

The height of a building affects its ability to meet its own needs using rooftop solar panels. Energy consumption increases with every storey added, but the roof area does not change. If solar panels are only mounted to rooftops it would mean that the taller a building is, the more difficult it becomes to meet energy consumption through on-site panels. One solution is vertical solar panels on external walls, if the building has an unshadowed façade facing south.

Another approach is to make sure that buildings *on average* meet their own demands – so that although tall buildings cannot do so, there are enough other buildings that can generate *more* energy than they need, and send this into the electricity grid. This would need policies that require low-rise developments to include more solar panels than they need[8], so that the excess can be exported. This way, Greater Cambridge will not need to use up its precious land to create even more stand-alone renewables to meet the energy needs of new buildings[9].

Flat roof - business as usual

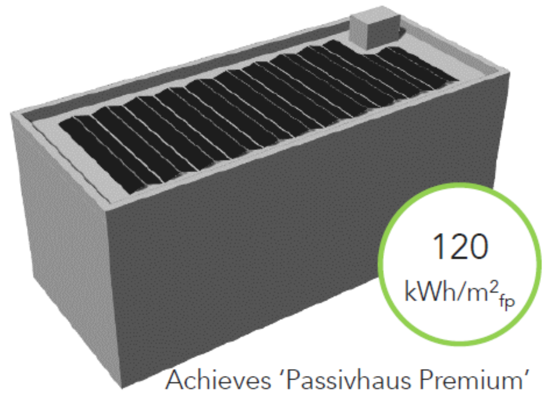
The solar panels are positioned at a 30 degree tilt angle and oriented South. Energy generation per panel is maximised, but the large gap required between rows to avoid shading results in poor utilisation of the roof for energy generation.



Achieves Passivhaus Plus

Flat roof - good practice

Improved approach where the solar array is at a 10-15 degree tilt angle and oriented to the East/West (+/- 45 degrees). This results in lower energy generation per panel, but much higher panel density for the roof, significantly increasing energy generation.



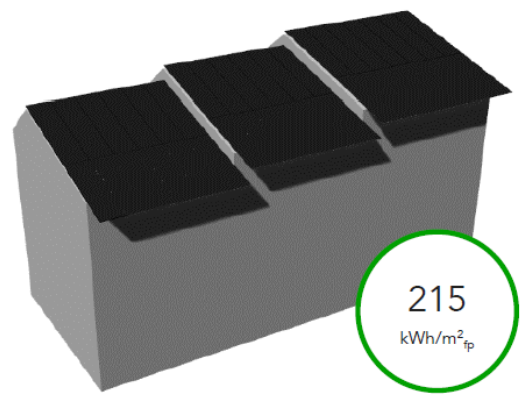
Achieves 'Passivhaus Premium'

✓ Net zero possible up to four storeys

Best practice

The roof is designed specifically to maximise solar generation. Large monopitch planes allow high panel density with no shading.

Plant areas, stair cores and lift overruns are located in a strip along the north side of the building, partially covered by the solar roof structure. Any terraced areas are located under the solar array.



✓ Net zero possible up to six storeys

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[8] This would require some kind of funding mechanism between low-rise and high-rise developments (discussed later in the offsetting section).

[9] However, Greater Cambridge will still need some stand-alone renewables to meet the zero carbon energy needs of *existing* buildings and electrified transport.

Do we have to change everything about our new buildings to meet this standard, or can 'normal' new buildings be adjusted to achieve it?

We took a real-life based approach to understanding what buildings in Greater Cambridge would need to do to achieve our net zero carbon standard and our accompanying recommended targets for heat demand, total energy use, and renewable energy generation.

We started by taking building designs from recent planning applications in Greater Cambridge. We did this because we want our calculations to reflect what is currently being built in the region, so that we can test whether net zero carbon is achievable without changes to the form and aesthetic of the building. This is important because in some locations, the shape of the site plot and heritage/aesthetic considerations may limit the ability to design the shape and orientation of the building purely for the purposes of carbon and energy.

To ensure our approach works for a range of different kind of buildings, we found designs for the following building types:

- **Semi-detached house** with dormer window, 3 storeys including room in pitched roof
- **Terraced house**, 2 storeys plus pitched roof, no dormer window
- **Block of 40 flats,** 4 storeys
- **School** – based on Darwin Green Primary School.

To understand how much extra insulation and airtightness that these buildings would need to get close to our suggested energy targets and meet our zero-carbon standard, we modelled the buildings in Passivhaus Planning Package. This is the best available method to predict buildings' actual energy demand, as it uses detailed building physics models based on how much energy the home will lose to the cold outdoor air or ground, and how much it will gain from sunlight hitting the building. This is a much more reliable predictor of energy demand than the national standard energy performance certificates.

With this modelling, we identified a reasonable level of upgrades to the 'building fabric' – that is, the insulating value of walls, floors, roofs, windows, and building air-tightness – compared to the levels suggested in the planning applications for these buildings. We did this without changing the actual form or shape of the building, including the window size and shape. We also added heat recovery to their ventilation systems.

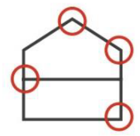
The building fabric levels we recommend vary between building types. Our upgrades are significant but achievable. For the houses, our recommended building fabric values are not much different to the Government's proposed Future Homes Standard that will be enforced from 2025 – except that we need more insulated walls, and better air tightness.

We then looked at how many solar panels could fit on the roof of the buildings, and whether this would generate enough energy to match the building's energy needs over the course of each year. This was firstly based on what the building could achieve with solar panels on its roof in the existing orientation of the building. We then also explored how much better the building could perform, if it were rotated so that its roof faced east-west so that the whole roof could be covered in solar panels that would receive some light all day (east-west).

Building Form - A simple building form minimizes the area of the building exposed to cold air and reduces the number of complex junctions. This reduces heat loss, often for little to no cost.
(This should be done when designing a building from scratch, but we did not make changes to the form in our modelling, as we wanted to explore how to make existing designs net zero carbon.)

High Performance Glazing – Triple glazing and insulated window/door frames are combined with careful optimization of glazing proportions to utilize solar gains in winter, while reducing the impact of summertime overheating.

Insulation – Excellent levels of insulation are combined with thermal bridge free design to minimize heat loss through floors, walls, roofs, and junctions between parts of the building.



Airtightness – An airtight thermal envelope is required to limit heat loss due to infiltration of cold outdoor air. With good design, it can offer a very cost-effective way of reducing energy consumption.

Heat Recovery Ventilation – Ventilation is essential to a healthy indoor environment. Mechanical Ventilation with Heat Recovery provides fresh air while recovering up to 90% of heat from the outgoing air.

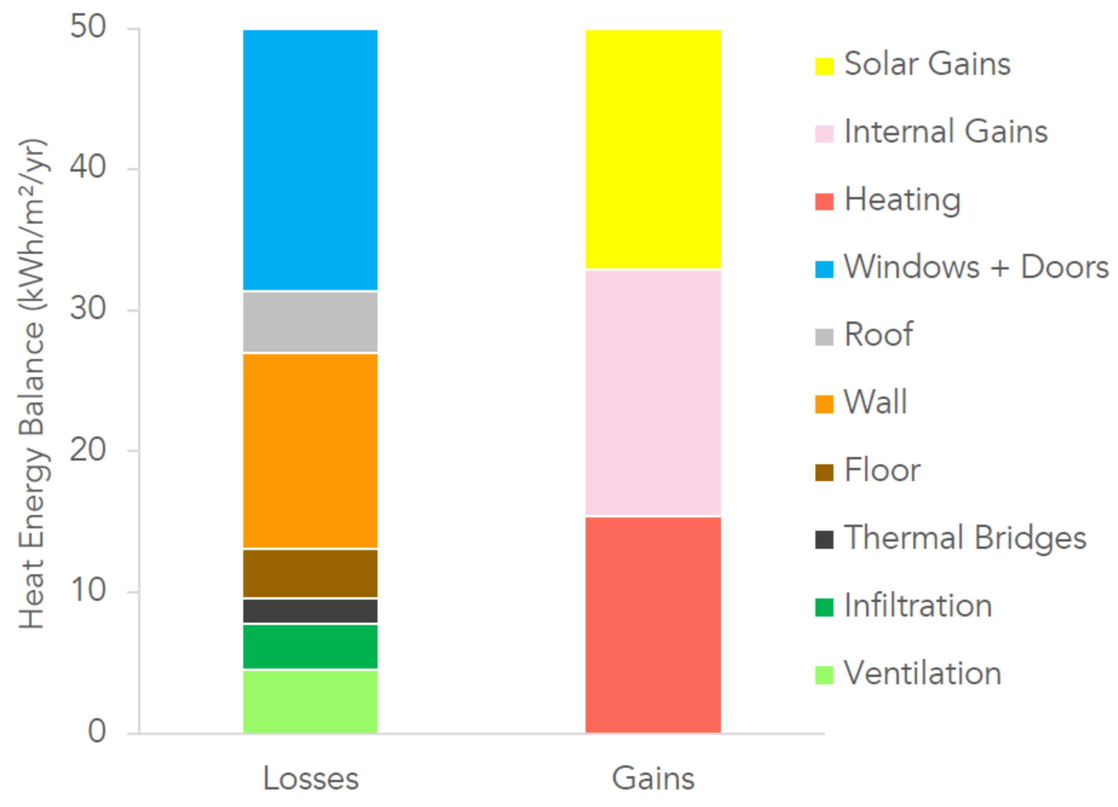


Diagram showing a typical example of how Passivhaus Planning Package helps us understand how a building loses heat, or gains heat, from different sources. This helps us make improvements to different parts of the building to ensure there is a balance. Image © Etude.

Modelling results

We found that **all three home types and the school can reach our net zero carbon standard** (being so energy efficient that they can generate at least as much energy as they use).

We also found that **if the maximum possible solar panels are added** to the roof in an east-west orientation, **all of the homes and school can generate more energy than they need** – thereby becoming net exporters of energy and helping to decarbonise the electricity grid.

All of the buildings can reach our total energy use target[10] **if they have a heat pump** as well as the upgrades to walls, floors, roofs, windows and so on. This is because a heat pump can slash the energy needed for heating by about 60%, compared to direct electric. This is thanks to the fact that heat pumps can deliver about 3 times as much heat energy as they consume in electricity, because heat pumps borrow energy from outdoors.

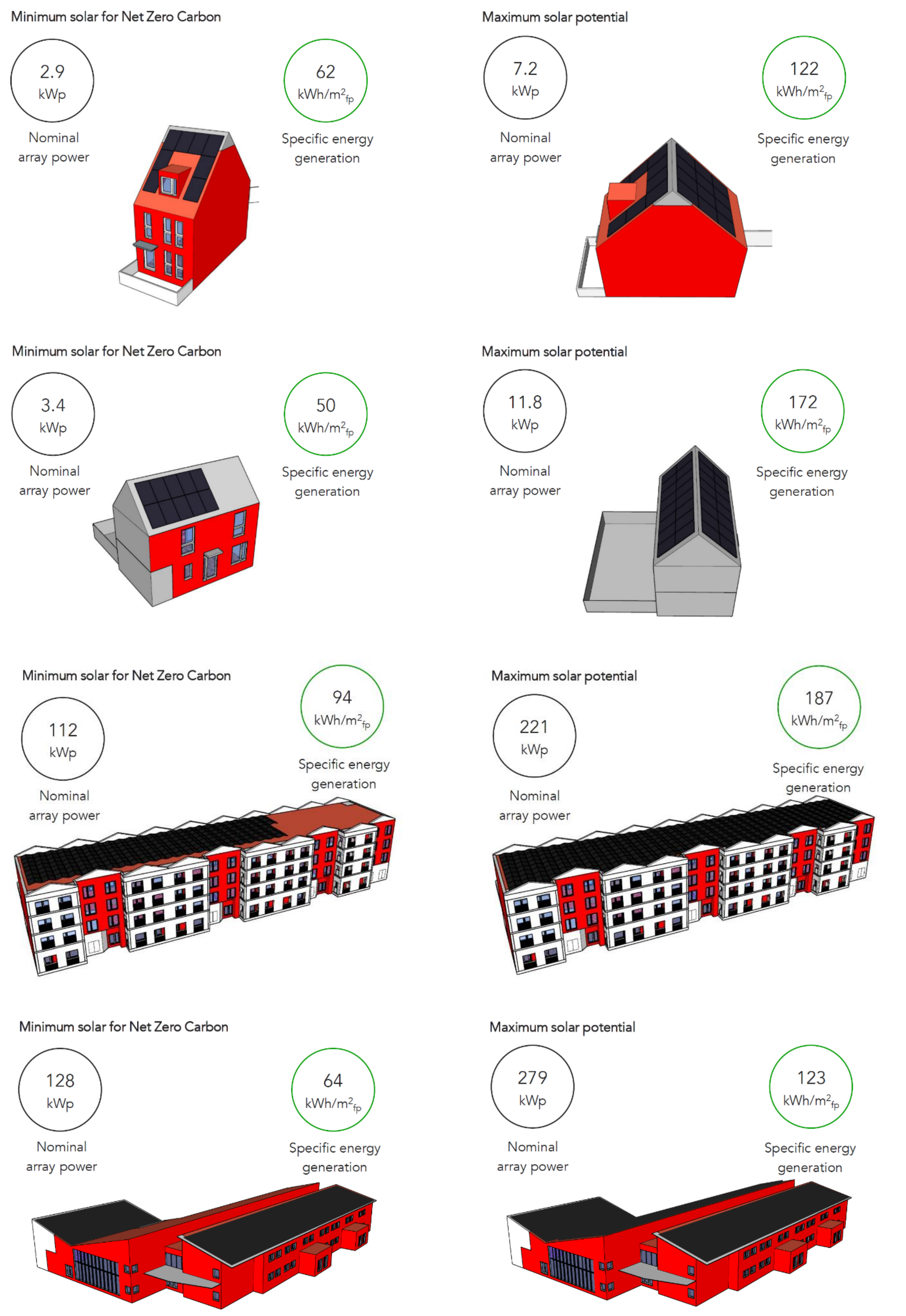
Homes with **direct electric heating will not reach our total energy use target**, but they **can still meet the net zero carbon standard** by adding more solar panels onto their own roofs.

The flats and school can reach a heat demand of 15kWh/m^2/year which meets the stricter end of our recommended range, using reasonable upgrades to building fabric.

Using our recommended reasonable upgrades to building fabric, both types of house achieve a heat demand of 21kWh/m^2/year – just outside our recommended range (15-20kWh). It is possible for them to achieve our heat target with more upgrades to walls, roof and floor – or with changes to building form such as a less steep roof or single-pane windows instead of split.

With a heat pump and reasonable upgrades to building fabric, buildings perform as follows:

- **The semi-detached house can achieve net zero carbon with just 8 solar panels** (about one-third to one-quarter of its roof space). It could generate more than it needs (195%) if the roof is oriented east-west and has 20 solar panels (the maximum amount that would fit without removing the dormer window). If the form of the house is slightly adjusted (a less steep roof), it could achieve our low heat target with less insulation.
- **The terraced house can achieve net zero carbon with 10 solar panels** (about one-third of its roof space). It can generate more than three times as much as it needs (374%) if the roof faces east-west with 32 panels (the maximum that would fit).
- **The block of flats could achieve net zero carbon with 328 solar panels** (8.2 panels per flat), taking up about three-quarters of the building's flat roof if the panels are arranged in a 'concertina' pattern facing east and west. If the maximum solar panels are added, the block could generate 200% of its annual energy use. This could be difficult if roof space is needed for other uses – such as for ventilation equipment, or roof gardens.
- **The school could achieve net zero carbon with 376 solar panels**, about three-fifths of its roof space. If the maximum solar panels are installed and the building rotated so that the panels face east and west, it could more than twice as much as it needs (215%).

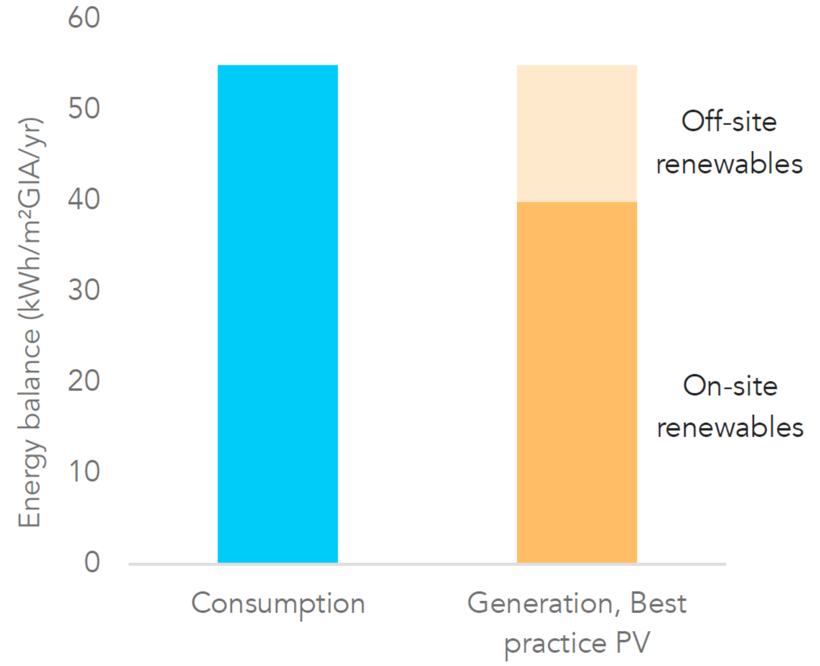


[10] Our total energy use target is 35kWh/m^2/year for homes; 55kWh/m^2/year for schools

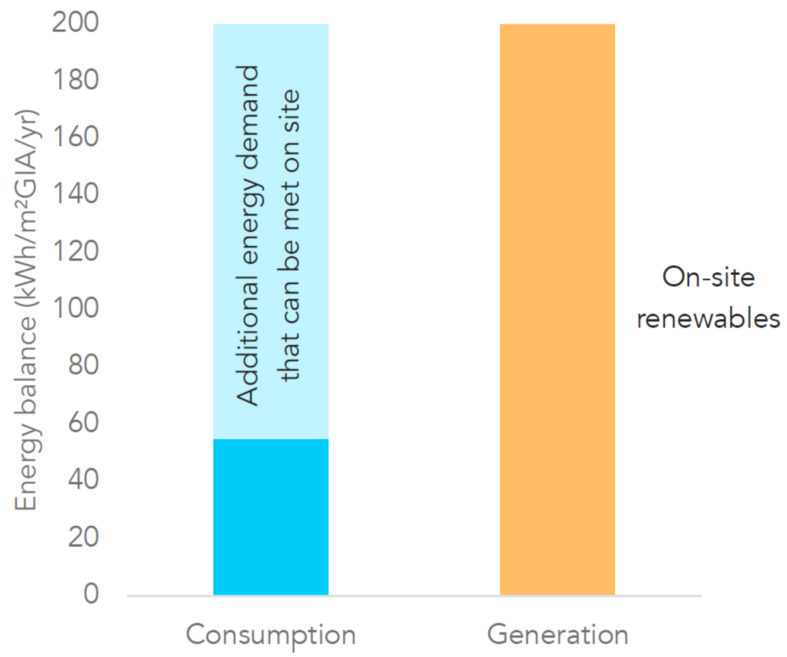
Other types of buildings (case studies and benchmarks, not modelled)

We also investigated several other common building types in Greater Cambridge. Due to time and budget, these were not modelled as the homes and school were. However, we identify some possible targets for heat demand, energy use, solar energy generation and other features. Our suggestions are based on professional experience, and case studies.

- **Offices:** Up to 2 storeys, offices can be expected to meet the net zero carbon standard using solar panels on their own roofs. They should achieve the same limit on heat demand that we seek in other buildings (15kWh/m^2/year). Care should be taken with the amount of glazing, to avoid overheating which then requires energy use for cooling. They could aim for a total energy use limit of 55kWh/m^2/year. Offices of 3+ storeys are likely to need to add some off-site renewable energy as well as their own rooftop solar.
- **Tall block of flats:** These can be expected to perform similarly to the 4-storey block of flats modelled previously, except that they would need quite a lot of off-site renewables to meet the net zero carbon standard (in addition to their own rooftop solar panels).
- **Student blocks** will perform similarly to blocks of flats. They may need special solutions to meet their high hot water demand as lots of residents are likely to shower at the same time. They could use centralised 'hotel-style' hot water stores, with careful insulation to the hot water distribution pipes to prevent too much heat loss from pipes.
- **Retail units** are highly varied. Tenants will not take the units if the design compromises sales. Their heat needs could be double our recommended standard set for other building types because they may have large entrance/loading bay doors that are often opened. Still, one supermarket in Germany has a heat demand of only 12kWh/m^2/year. Some retail units also have high energy use for refrigeration. Retail units might be expected to aim for a total energy use of 55+ kWh/m^2/year.
- **Light industrial units** are very variable in their uses and energy needs. In warehouses, it may be better to use radiant panel heaters in the small areas where staff spend time, instead of heating the whole space with heat pumps. Like retail units, they could aim for a total energy use of 55+ kWh/m^2/year. They tend to be low-rise so can generally have enough solar panels to make them net zero carbon if designed efficiently.
- **Leisure centres** are expected to be able to achieve net zero carbon on site with their own rooftop solar panels if they do not have a pool, but are likely to need some off-site renewable energy too if they do have a pool. They have high energy demands but also tend to be low-rise. Efficient ventilation is the key to keeping their energy demands low – and either heat pumps or waste heat sources are ideal for keeping pools at temperature.
- **Research facilities** are superficially similar to offices, but can have extremely high energy use for specialist equipment such as fume cupboards. Most will need off-site renewables as well as rooftop solar panels. A low heat demand can still be achieved.
- **Existing buildings** are very varied. Heat pumps can often be added to 'wet' heating. The 'EnerPhit' standard is a good whole-building approach, using Passivhaus components.



Typical net energy balance for a **3-storey office building** that has already achieved best-practice energy efficiency by being well-insulated, using heat pumps, and designing glazing to avoid overheating. This building would need some off-site renewables.



Light industrial units: With ideally oriented solar panels on the whole roof, this single storey building could meet a basic energy demand of 55kWh/m^2/year plus a further 145kWh/m^2/year for the industrial processes on site. If the actual on-site energy needs for industrial uses are higher, the building would need to come with some off-site renewable energy to be zero-carbon.

Ensuring residents get good benefits from the solar panels installed

Residents of homes with solar panels on roofs can benefit from:

- Reduced energy costs, if they use or store the energy at the time it is generated
- Export tariff payments if they export electricity to the grid – if there is a mechanism in place for this (such as the Smart Export Guarantee or former Feed-in Tariff)

Typically, homes use around 15 - 30% of their own solar energy, though 50-70% is possible with smart control of space and water heating. Energy-efficient buildings enable better impact from smart heating controls because the building holds its heat, so the heating can be run when free solar energy is available and does not need to be turned up again when the outdoor temperature drops. Excess solar energy can also be stored as heat in an insulated water tank.

Surplus solar electricity could also be used for charging an electric vehicle, which typically requires around 2,500 kWh per year. This could and save the residents even more in bills.

In flats, the greatest benefits are typically offered by setting the building up as a microgrid. Flats receive a blend of solar and grid electricity. The building's total bill only reflects energy bought from the grid. This will be significantly reduced due to on-site solar. The balance owed is divided between each flat based on their energy consumption, measured by individual meters. Revenue from any solar export tariff payments can be divided between flats.

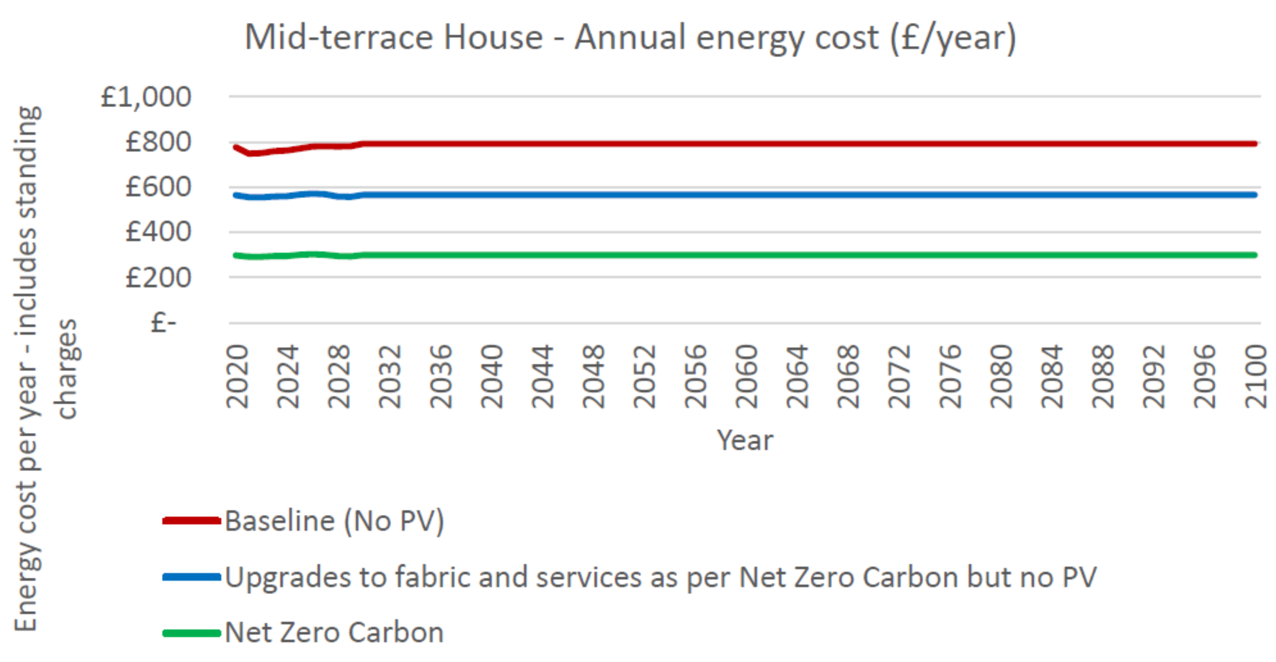
What it costs to make these changes, compared to basic national building standards

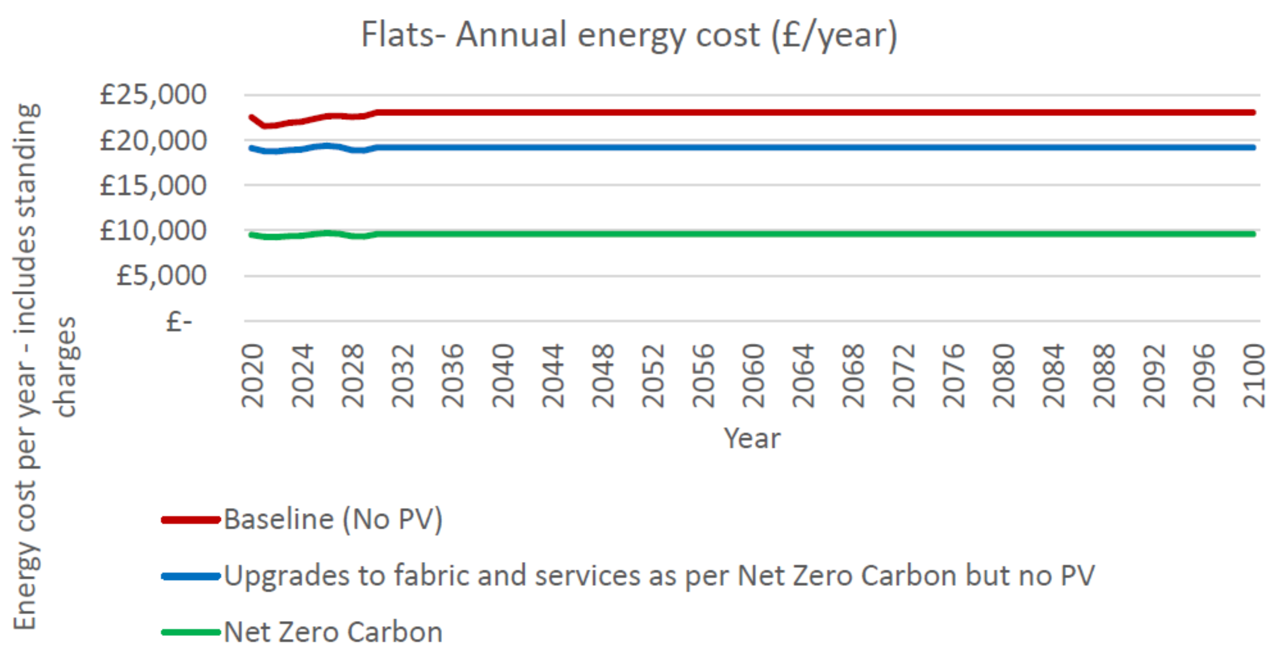
We calculated what the difference would be for our 'net zero carbon' standard buildings, compared to if they were built to the current national standards (Building Regulations 2013) with a gas boiler. The running costs assume that homes use 30% of their own solar electricity.

- **Semi-detached house:** build cost uplift is 10%. The saving in running costs would be over £400/year (roughly 50% saving).
- **Terraced house**: build cost uplift is around 13%. The saving in running costs would be nearly £500/year (over 50% saving).
- **Block of flats:** build cost uplift is 5%. The savings in running costs would be around £13,000/year (£325/year per flat) (roughly 57% saving).
- **School:** the build cost uplift is around 3%. The savings in running costs would be approximately £13,500/year (over 60% saving).

These estimates are for buildings that just meet our net zero carbon standard – not the cost of adding the maximum possible solar panels. However, because a large part of the cost of installing solar panels is the scaffolding and labour, it would not cost much more to add more panels at the same time (benefitting also from economies of scale when bulk-buying panels).

These cost estimates were produced before the government announced its incoming improvements to the building regulations, which will happen in 2021 and 2025. This means that our cost estimates are now an over-estimation of the cost impact of net zero carbon buildings, because the basic national standard is about to be higher (so there is less difference between the cost of achieving our standard compared to achieving the new national standard).





5. Could offsetting help with Greater Cambridge's journey to net zero carbon?

This section will include information from the following of our longer reports:

- Task A: Position statement
- Task C: Emissions reduction targets
- Task F: Offsetting.

What does 'offsetting' mean?

If a building cannot be operated, or a journey made, or an industrial process carried out without exceeding an acceptable level of carbon emissions, it can still be allowed to continue if the person causing the emissions pays someone else either to reduce their emissions further than they may have otherwise done, equivalent to the 'extra' emissions, or to remove that amount of carbon from the atmosphere. This payment process is generally called 'offsetting'.

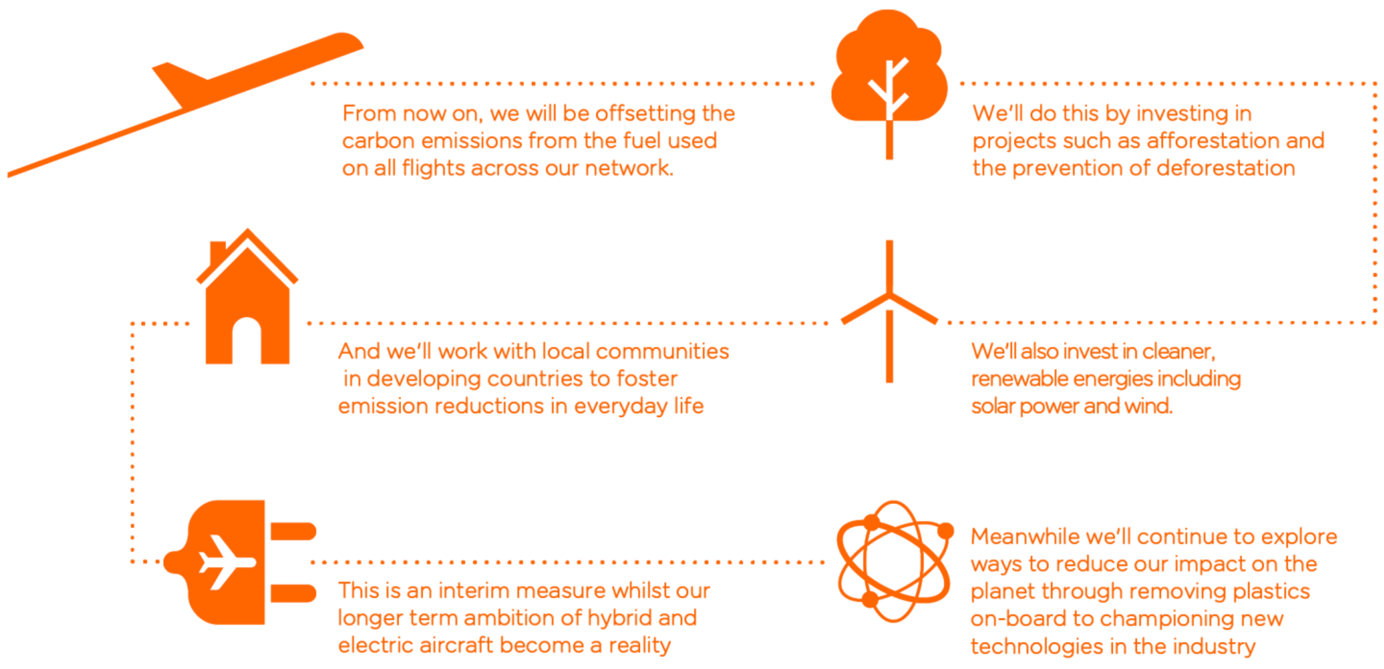
The most familiar form of offsetting is associated with transport. For example, some airlines offer to their customers the possibility of offsetting the carbon emissions associated with their trip by paying into a carbon offset fund which will aim at saving an equivalent amount of carbon elsewhere – most often through tree planting schemes.

How would it work?

There is generally a negative perception around carbon offsetting, sometimes for good reasons. It is sometimes seen as a method for an organisation to achieve a carbon standard without complying with its spirit and as a way to save money and avoid/reduce the organisation's responsibility in addressing its carbon emissions in the first place.

In order to avoid such problems, an offsetting scheme needs to be based on some core principles.

1. **Sustainability:** in order to achieve Net Zero by 2050 (at the latest) and enable a 1.5 degree world, Greater Cambridge will need to limit carbon emissions in line with its carbon budgets. It is therefore important that offsetting accelerates progress in actual emissions reductions, rather than slowing this progress down. This is a significant risk with offsetting which has the potential to displace responsibility for pollution and unnecessarily delay important decisions.
2. **Additionality:** ensuring that measures funded by the offset fund would not have happened without it (or at least that they are not double counted). This is particularly important concept which will be discussed in the context of the Net Zero Carbon trajectory for all sectors.
3. **Transparency and measurability:** showing where the funding has been spent and what it has achieved is critical, as offsetting is often criticised for being opaque and not effective.



One widely recognised form of carbon offsetting: An airline's carbon offsetting scheme (Easyjet)

Who pays and why?

The main application of offsetting relevant to the Greater Cambridge Local Plan is as a **planning policy compliance mechanism.** This principle has been used by several local planning authorities in the UK for over a decade now.

We suggest a similar role for Greater Cambridge: it could be a way for buildings with limited solar electricity generation ability to comply with the 'Net Zero Carbon' policy.

Is offsetting compatible with a net zero carbon objective?

There are two important factors when designing an offset scheme that is compatible with a net zero carbon target: when is offsetting permissible and how will the money be spent?

Offsetting should be a mechanism which enables buildings which **cannot technically achieve** Net Zero Carbon on site to be 'deemed compliant' with planning policy. For example, as it is not currently technically possible for a 10-storey block of flats to generate as much renewable energy as it uses, the developer could agree to make a contribution to the offset fund and achieve a successful planning consent.

However, **it is crucial that offsetting is only accepted in very specific circumstances**, and when the following conditions are met:

1. The proposed building must not use fossil fuels for heating.
2. It must have a total metered energy use compliant with the targets set in the Local Plan.
3. On-site renewable energy generation (e.g. through PVs) should be maximised and at least achieve the required minimum level in the Local Plan.

Within these constraints, offsetting can be compatible with an overall target of net zero carbon in Greater Cambridge, ensuring new buildings will not have to be retrofitted within 30 years.

The projects that are funded by money from the offset scheme are crucially important, if the whole process is to help rather than hinder meeting the overall objective.

New renewable energy generation (either large scale schemes that are not associated directly with a building, or on other new buildings) will help to address the shortfall between the energy used and the energy generated in Greater Cambridge and are therefore suitable uses for the offset fund.

Using new buildings' carbon offsets to install renewable generation on existing buildings would make it much more difficult for the whole sector of existing buildings to become net zero carbon, which they must. This is because the existing buildings must become 'net zero carbon' anyway in order for the whole local area and country to do so, therefore this may not be 'additional' to what must happen anyway. New buildings, as one of the least challenging sectors in meeting net zero targets, should not foist their carbon reduction responsibility onto other sectors in the economy. Similarly, using new build 'offset' money to refurbish existing buildings, or plant trees, moves the obligation to achieve the carbon emission reductions from one sector (new buildings) to another (existing buildings, or agriculture and therefore may be incompatible with an overall target of net zero carbon for Greater Cambridge.

Reduced operational energy consumption	**Achieve an Energy Use Intensity lower than the Energy Use Intensity (EUI) required in the Local Plan** (e.g. $35\ kWh/m^2_{internal\ area}/yr$)	✓
Low carbon energy supply	**No gas connection or fossil fuel consumption on site** (or connection to heat networks using fossil fuels)	✓
On-site renewable energy generation	**Achieve an electricity generation intensity over the requirement in the local plan** (e.g. $120kWh/m^2_{building\ footprint}/yr$)	✓
Net Zero Carbon energy balance	**Zero annual carbon balance** for the whole development showing predicted energy consumption and renewable energy generation on-site.	✗ (offset role)

Planning offsetting scheme. A new building would have to comply with most Net Zero Carbon planning requirements before it can be deemed 'Net Zero Carbon policy compliant' through offsetting.

How much should it cost to offset carbon emissions?

The cost of offsetting is most often expressed as an amount (£) per tonne of carbon dioxide emitted over a set period (usually 30 years in other local plans that have done this – this would also take us to the UK's net zero carbon goal year of 2050). The total carbon emissions from the building for that period have to be calculated by the developer and then any carbon savings that they achieve through renewable energy generation are subtracted. The difficulty with this approach is that the amount of carbon that is both emitted and deducted changes over time, as the carbon 'embedded' within electricity in the National Grid changes.

We recommend a simpler calculation, which is based on a cost per kWh of energy used that is not matched by renewable energy generated on site.

As the money is to be used primarily to pay for the installation of new solar photovoltaic panels, the amount charged can be based on the cost of the PV panels needed to match the deficit in generation.

How will the offset fund be set up and managed?

To date, offset funds have generally relied upon agreements and obligations agreed under Section 106 of the Town and Country Planning Act of 1990. There are limitations and potential future changes to Section 106 agreements that may have to be considered at some point, but at the present time we don't yet know what these may be, so we advise basing the fund on S106 for the time being.

There are a number of offset funds already being operated by Local Planning Authorities in the UK. It is important that their advice is considered in the development of the Greater Cambridge offset fund.

There are 4 key elements:

Validation of contributions – to ensure that the projects that are paying into the fund have met the minimum standards required by the Local Plan on site before the offset amount is calculated.

Identification of projects – finding suitable uses for the monies raised is one of the most critical and often most difficult aspects of operating an offset fund.

Delivery – identifying organisations that can deliver the offset projects and also setting standards for those projects to be certain that they achieve the carbon emission reductions needed are critical actions for Greater Cambridge's team.

Validation of emissions reductions – public confidence in the scheme relies upon showing in a clear and understandable way exactly how much carbon emission reduction has actually been delivered by the scheme, and that it does indeed match the emissions intended to be offset.

6. Proposed policy options

This section will include information from the following of our longer reports:

- Policies

What policies are required in a net zero carbon compliant local plan?

Using the evidence set out in the whole report, we have developed a set of policies to meet the requirement for the new local plan to be consistent with the national target of being zero carbon by 2050 and the science-based target of the Paris Agreement. The policies have been developed with the specific aim of reducing greenhouse gas emissions from Greater Cambridge.

What can a local plan do?

The local plan has the greatest influence over new development. However, this report shows that it is possible for the local planning authority and constituent Councils, through the Local Plan and through engagement with other bodies, to have a wider influence, beyond matters under its direct control. Indeed they should aim to do, so in order to support a net zero carbon Greater Cambridge.

National policy and building regulations will play an important role in reducing emissions and Greater Cambridge should seek to influence these, especially to highlight areas where they currently can be a barrier to progress towards zero carbon goals.

Avoiding unintended consequences.

A very narrow focus only on reducing carbon emissions could lead to policies which, in a wider sustainability and environmental context, could lead to unhelpful outcomes. We used the 'One Planet Living' framework developed by Bioregional as a 'sense check' against each suggested policy and highlighted any areas where the policy could be actively helpful, or where there could be conflicts that need to be carefully considered.

What are the proposed policies?

The following tables summarise the policies areas around which we recommend specific policy wording is written to form part of the Local Plan.

Please note that the full version of our 'policies' report includes local plan mechanisms, a recap of the evidence of need for each policy, and ways to monitor implementation and progress. The full version of our 'Task D: Feasibility' report also includes a range of possible policy options for targets for space heat demand, energy use intensity and renewable energy demand. For the interests of brevity, we here only reproduce our recommended set of policies (including the relevant targets) rather than reproducing all options considered.

Policy code	Suggested policy name and description
A.1.0*	**Net zero carbon new buildings** All buildings should be net zero carbon and comply with policies A.1.1, A.1.2, A.1.3 or, where A.1.3 cannot be achieved, with A.1.4.
A.1.1*	**Net zero carbon new buildings: Space heating**
A.1.1.a*	- All dwellings should achieve a space heating demand of 15-20 kWh/m^2/yr.
A.1.1b*	- All non-domestic buildings should achieve a space heating demand of 15-20 kWh/m^2/yr.
A.1.1c*	- All heating shall be provided through low carbon energy (not fossil fuels).
A1.1.d*	- No new developments shall be connected to the gas grid.
A.1.2*	**Net zero carbon new buildings: Energy Use Intensity (EUI) targets** All dwellings should achieve an Energy Use Intensity (EUI) of no more than 35 kWh/m^2/yr (as calculated by TBC) Non-domestic buildings should achieve an Energy Use Intensity (EUI) of no more than the following, by building type: • Offices – 55 kWh/m^2/yr • Schools – 65 kWh/m^2/yr • Multi-residential (e.g. student accommodation) – 35 kWh/m^2/yr. • Retail – 55 kWh/m^2/yr • Leisure – 100 kWh/m^2/yr • Research facility – 150 kWh/m^2/yr • HE Teaching facilities – 55 kWh/m^2/yr • Light industrial units – 110 kWh/m^2/yr • GP surgery – 55 kWh/m^2/yr • Hotel – 55 kWh/m^2/yr • Student accommodation – 35 kWh/m^2/yr
A.1.3*	**Net zero carbon new buildings: Renewable energy** Renewable energy should be generated on-site for all new developments. The amount of energy generated in a year should match the predicted annual energy demand of the building. I.e. Renewable energy generation (kWh/m^2/yr) = EUI (kWh/m^2/yr).
A.1.4*	**Net zero carbon new buildings: Offsetting** In the first instance, Requirement A.1.3 should be met. Where this is not possible, the development can be made compliant through payment into an offset fund to balance the shortfall in renewable energy provision.

A.1.5	**Net zero carbon new buildings: Assured Performance** All developments (domestic and non-domestic) must demonstrate use of an assured performance method in order to ensure that the buildings' operational energy performance reflects design intentions.
A.2.0	**New buildings: Reducing overheating** All future dwellings to be designed to achieve a Low Overheating risk using the Good Homes Alliance Overheating Risk Assessment Method
A.3.0	**New buildings: Promoting sustainable materials**
A.3.1	**New buildings - Promoting sustainable materials: embodied carbon** Embodied carbon of all new buildings to be calculated and minimised in line with latest Net Zero Carbon whole life guidance
A.3.2	**New buildings - Promoting sustainable materials: disassembly and re-use** All new buildings to be designed with principles of easy dis-assembly at end-of-life, in order that materials are more easily re-used or recycled, in line with the latest best-practice guidance.
A.4.0	**New buildings: Efficient use of water**
A.4.1	**Requirement A.4.1 – Water consuming fittings shall be specified with consideration to water efficiency.** - (preferred) Residential - Residential developments should minimise the use of mains water in line and achieve mains water consumption of 80 litres or less per head per day. (alternative) Residential – Residential developments should minimise the use of mains water in line with the Optional Requirement of the Building Regulations, achieving mains water consumption of 105 litres or less per head per day (excluding allowance of up to five litres for external water consumption) (*this policy is subject to consideration as part of the Integrated Water Management Study evidence base).*
B.1.0	**Maximising renewable energy**
B.1.1	Identify areas suitable for large scale solar photovoltaic installations.
B.1.2	Identify areas suitable for onshore wind turbine installations.
B.1.3	Identify suitable areas for large scale energy storage to meet the needs of a decarbonising grid.
C.1.0	**Supporting zero emissions transport**
C.1.1	Electric charging points to be included in each development: 50% active / 50% passive
C.1.2	Cycle storage to be included on each development in line with with best practice/guidance
C.1.3	Preference will be given to developments which are located and designed so as to reduce the need for car travel, and support journeys made on foot, bicycle or public transport. / PTAL score based.
C.1.4	Applications for new developments must demonstrate that the local electrical infrastructure is able to support increased electrical demand from the new development (including car charging). Where this is not the case, new electrical charging infrastructure and capacity must be supported or provided in collaboration with the local District Network Operator.
C.1.5	Enhanced pedestrian and cycle routes in strategic plans

D.1.0	**Facilitating a zero waste, circular economy**
D.1.1	Large developments above [threshold to be agreed] should show a strategic approach to waste management.
E.1.0	**Supporting land based carbon sequestration and biodiversity**
E.1.1	All developments above [threshold to be agreed] hectares will be required to provide a site soil carbon analysis and demonstrate that development with neither cause the land to release a significant amount of stored carbon, nor have significant potential as a carbon sink.
E.1.2	Material consideration – All developments above [threshold to be agreed] hectares should achieve Urban Greening Factor in new developments should target > 0.5, or similar.
E.1.3	Areas should be identified for the creation of new woodlands, in order to support an increase woodland cover by at least a factor of two by 2041.
E.1.4	Material consideration - Development on degraded peatlands will not be supported where those peatlands can be restored. New development on peatland sites will be required to demonstrate that there is no potential for the site to become a carbon sink.

How will we know if the policies are being implemented successfully?

There are two key points at which it can be checked that the policies are being implemented successfully

- **Planning submission:** during pre-application discussions and during the review of the planning application, compliance with all planning policies will be verified. It is very important to establish which policies should not be subject of negotiation (e.g. Net Zero Carbon building) as it would threaten the overall legal obligation to achieve Net Zero by 2050. Those policies have been marked with a * on the policies list.
- **Discharge of planning conditions:** it is crucial that the low carbon emissions promised at planning stage are delivered. This is an area that deserves more attention. The information that will be required from applicants to discharge these conditions should therefore be explained clearly, including exactly when in the development process the information is to be provided. Planning conditions requiring the reporting of energy and carbon during the first five years of occupation should also be introduced. This is particularly crucial as the actual energy performance is what really matters.

The overall progress of the adoption of policies should be monitored and reported annually and strategies for enforcement of the policies need to be put in place.

Checking whether the policies are helping to reduce carbon emissions is also a vital part of the process. We recommend the creation of a simple data gathering and analysis system so that progress can be checked and reported.

How will compliance with policies be checked?

Current building regulations require little of the information that is needed to be sure that the net zero carbon policies are being properly implemented. An additional Quality Assurance check will be necessary. This could be a third-party 'Assured Performance' process, such as Passivhaus or AECB certification, or an in-house system could be developed and implemented.

Whichever method is adopted, it is very important that the process focuses on the building as it is built, rather than only as it is designed, in order to avoid a stark difference between what is expected and what is delivered. This difference is currently common in many buildings and is referred to as '**The Performance Gap'.**

How will future changes in National Policy affect the Local Plan policies?

It is possible that future changes to the national Planning Policy Framework, or to Building Regulations could conflict with some of the policies recommended in this report. There are changes that are expected, such as the Future Homes Standard 2025 but the details of these are not known now and are unlikely to be confirmed in the short term. Therefore the specific wording of policies may need to allow some flexibility to allow adaptation to new standards as and when they are implemented.

Passivhaus Certification

Passivhaus is a leading comfort and energy efficiency standard for buildings.

Key requirements include meeting targets for space heating demand and total energy consumption. These metrics must be calculated using the "Passivhaus Planning Package" (PHPP) software.

An independent Passivhaus Certifier will then carry out quality checks on the design calculations and inspect evidence captured during construction.

AECB Standard

The AECB Building Standard aims to help deliver "high-performance buildings at little or no extra cost". It aligns quite closely with the Passivhaus methodology.

Energy calculations are carried out in PHPP, ideally by an experienced energy consultant who can also review the design and construction details.

The key difference is that the energy consultant can self-certify the project.

AECB

SAP & SBEM calculation

SAP and SBEM calculations are used to assess the energy and environmental performance of new residential and commercial buildings respectively. They are the basis for illustrating compliance with Part L of the UK building regulations.

SAP and SBEM calculate energy use for heating, cooling, lighting and ventilation systems, but ignore other building energy uses such as those associated with lifts, specialist equipment and small power loads.

TM54 calculation

CIBSE published TM54 "Evaluating Operational Energy Performance of Buildings at the Design Stage" in 2013 to help tackle the performance gap of low energy buildings. It provides guidance on how to calculate the total energy consumption of a new building more accurately at design stage. The guide suggests heating and cooling analysis should be done with dynamic simulation modelling. It also provides methodologies for calculating other areas of energy consumption using steady state calculations.

CIBSE