Bioregional and Etude

Central Lincolnshire Local Plan: Climate Change Evidence Base

Task B: Carbon Emissions from Spatial Growth Options

Final Draft

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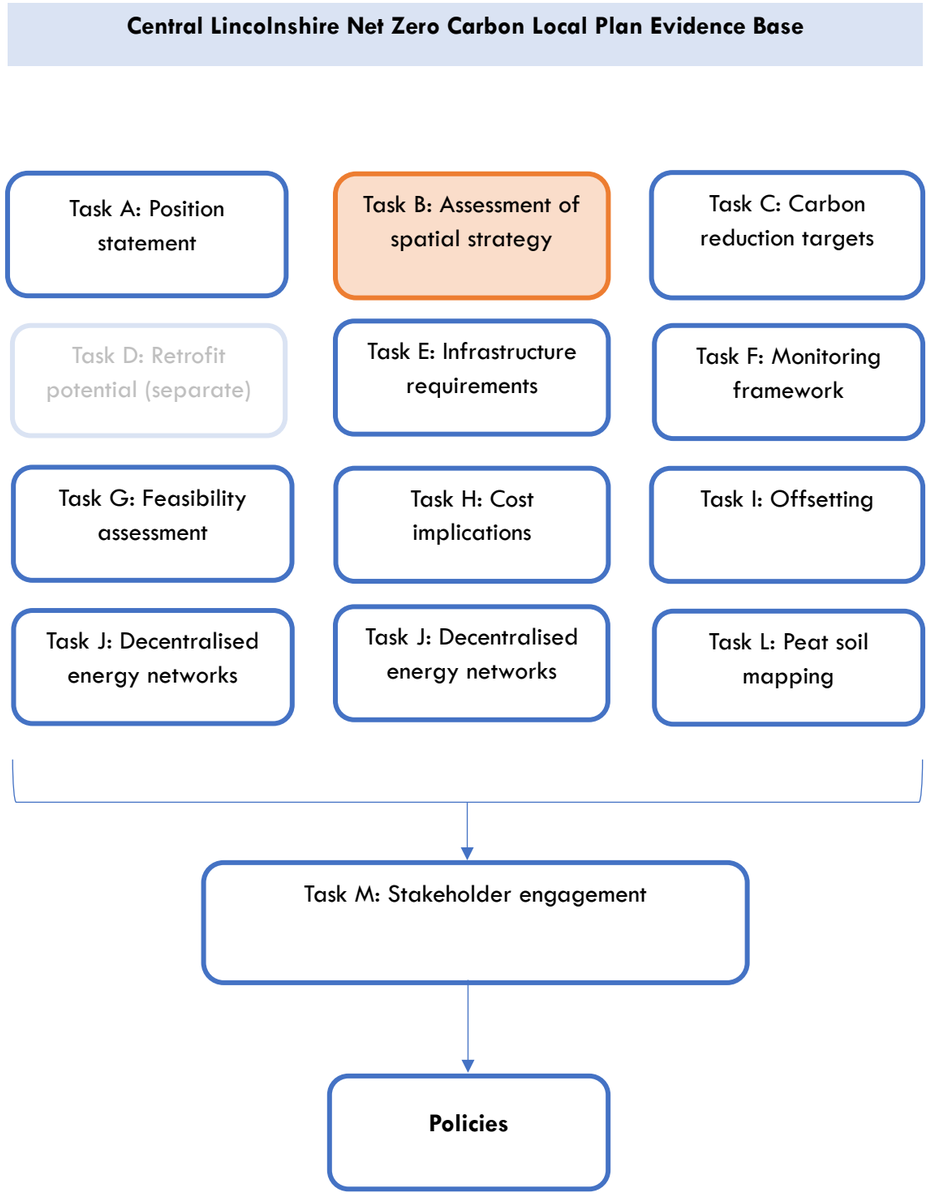
Task B: Assessment of carbon implications of the spatial strategy

This report presents a comparative assessment of the carbon emissions from the spatial options for allocating new growth within the plan period. These have been assessed in relation to reducing carbon emissions through the Local Plan and the potential of achieving net zero carbon.

This is part of a wider set of analyses (shown in diagram to the right) to support the relevant local authorities in their stated commitments to combat climate emergency by transitioning their entire areas to net zero carbon by 2030 (Lincoln and North Kesteven) or no later than 2050 along with the national legislated goal (West Lindsey, and Lincolnshire County Council). It is also relevant to Lincolnshire County Council's Green Masterplan[i].



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1. Overview of findings and recommendations

1.1. First and foremost, we recommend that a suite of zero carbon policies are adopted to cover the operational, embodied and transport carbon emissions from new development. The modelled policies are briefly presented below, and explored in more detail in Task C.

1.2. According to our modelling, a suite of zero carbon policies has the greatest impact potential on reducing emissions, over and above the selection of which specific locations are allocated for growth. On average, applying these would halve the total plan period carbon emissions for each growth option[1].

1.3. In terms of choice of spatial locations for growth, the urban locations have the lowest overall carbon emissions (city centre, urban and suburban) whereas the more remote locations have higher overall carbon emissions (village well connected and village less well connected). This is predominantly because total carbon emissions are dominated by transport, particularly if zero carbon building policies are deployed. Transport in more rural and less connected locations has a far greater use of private cars and over longer distances, consequently with higher associated carbon emissions – at least until the vast majority of cars on the road are ultra-low emissions, which is not likely to happen within the plan period.

1.4. It should be noted that the spatial options provided for analysis are not simple reflections of the location types above, but rather different combinations of various locations; each with a tendency to focus on one location category, but not exclusively[2]. For example, the Option 1 'Urban Focus' is led by urban and suburban growth but still puts over 40% of its growth in village locations.

1.5. As a result of this, the growth option (as opposed to location category) with the lowest total plan period carbon emissions is Option 4 – 'New Settlement'. This is the case for Business as Usual policy (179 $ktCO_2$) and Zero Carbon policy (87.5 $ktCO_2$) scenarios. This is closely followed by Option 1 – 'Urban Focus', for both policy regimes (Business as Usual: 185 $ktCO_2$, or Zero Carbon policy: 92 $ktCO_2$).

1.6. In contrast. Option 2 – 'Small sites' is the worst-performing at 209 $ktCO_2$ in Business as Usual (BAU), or 112 $ktCO_2$ with Zero Carbon policy (ZC).

1.7. The difference in carbon emissions between the highest- and lowest-emitting options is 14% (BAU) or 22% (ZC) .

1.8. Hence, we recommend further investigation and comparison of option 4 (New Settlements) and option 1 (Urban Focus); and avoiding Option 2 (Small Sites) if at all possible. We note that it may not be possible to deliver a new settlement within the plan period, but this is still a longer-term option to be considered for its sustainability merits. Where some rural or village sites are unavoidable, priority should be given to locations with good public transport connections with proximity to local amenities to help reduce the inevitable private car use this will induce.

Figure 1: Comparison of total carbon emissions within the plan period (tonnes of CO2) for each spatial option, with or without zero carbon policies applied

[1] Furthermore, a suite of ZC Policies could also be applied to some of the existing allocations (where they have not yet been granted planning permission), which would have a far greater impact, given that existing site allocations account for 23,556 homes, whereas the new spatial growth allocations modelled amount to 2,500 homes.

[2] With the exception of Option 4 which is entirely based on growth in the New Settlements location.

2. Report details

2.1. We have created a model to estimate the carbon emissions from new housing development, including the associated non-residential buildings that are required to support that housing, namely schools, nurseries, libraries, community centres, medical centres and commercial space.

2.2. The model covers the following sources of carbon emissions:
Embodied upfront carbon: building construction materials and processes.

Operational carbon: building heating and electricity usage.

Transport carbon: occupant and visitor transport.

2.3. The model provides results for two different policy regimes:

2.3.1. **Business as Usual (BAU):** conformity with current Building Regulations, and under current local conditions for transport options and infrastructure. The model assumes an energy performance gap by adding 50% to modelled domestic space heating demand.

2.3.2. **Zero Carbon Policy (ZC):**

- Best in class domestic space heating standards (15 kwh/sqm/y)
- Best in class non-domestic space heating standards (15 kwh/sqm/y)
- All new homes to use heat pumps, no domestic gas boilers
- All new non-domestic buildings to use heat pumps, no gas boilers
- On-site renewable energy generation on new buildings - PV
- Embodied carbon of new buildings – 40% reduction over baseline
- Some mitigation of the Energy Performance gap - (+25% on modelled energy)
- Transport: increased sustainable travel initiatives
- 10% Electric Vehicle usage on average

2.4. The model is based on allocating housing numbers to any combination of the following five categories of location:

1) **City Centre:** for Lincoln
2) **Urban:** for edge of city centre and centre of the main towns of Gainsborough and Sleaford
3) **Suburban:** for the Lincoln Urban Area, Sleaford, Gainsborough and other Market Towns.
4) **Village – well connected:** frequent buses, near railway station, or close to a major urban area
5) **Village – less well connected:** for all other villages
6) **New Settlement:** for new stand-alone settlement, not adjacent to a major built area

2.5. The following Spatial Options were provided for modelling, each presenting 2,500 homes distributed across various combinations of the above categories of location:

- **Option 1: Urban Focus**
- **Option 2: Small sites**
- **Option 3: Corridors**
- **Option 4: New settlements**
- **Option 5: Balance options 1-3**

2.6. As noted above, these spatial options each contain a mixture of the categories of location, except for the New Settlements category which purely located all 2500 homes in the category 6. Detail on the spread of homes across different location categories is given in a table in section 2.7.

Our methodology

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

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

1) Building construction materials and processes (embodied upfront carbon).

2) Building heating and electricity usage (operational carbon).

3) Occupant and visitor transport (transport carbon).

2.9. The tool produces an annual carbon emissions figure for a given amount of growth. Total plan period emissions are then provided, based on an assumption that growth is built out at an equal rate each year of the plan period. This affects the plan period emissions in that the earlier growth is built, the longer it is emitting carbon, and the higher its cumulative emissions will be within the plan period. In the absence of certainty about when construction will occur, an even build-out rate is reasonable.

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

Buildings data sources

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

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

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

- Bespoke energy modelling using Passivhaus Planning Package (total energy use including appliances) see Task G report for details.
- Densities for each location were provided by the Central Lincolnshire Planning Authority.
- Central Lincolnshire Developer Contribution SPD June 2018
- Central Lincolnshire Housing Need Survey April 2020
- Central Lincolnshire Local Plan affordable homes policy LP11
- Occupancy and population projections based on Census 2011 and latest housing needs report (2020).
- BEIS/DEFRA national data on electricity grid carbon intensity, including future projections to the end of the plan period and beyond
- Benchmark embodied carbon of contemporary buildings from LETI,2019.
- Carbon reductions (operational and embodied) that are typically achieved via changes to building design (fabric, heating system and solar panels) recommended by green building industry expert groups.

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Transport data and assumptions

2.13. Transport carbon emissions have been estimated using local BEIS and Census per capita carbon emissions data. This is then calibrated on a scale from 0 -10 representing the potential for each mode of travel in each location type, undertaken by an experienced transport consultant using insight on travel distances and modal share from census data and Greater Lincoln Transport Model data.

2.14. The tool starts with each local authority areas' per capita transport CO_2 emissions released annually by BEIS. Because there is in fact variation within local authority areas, our transport consultant then calibrated these emissions on a sliding scale of ten equal intervals from 'best' to 'worst' using data on commuting modal share and trip length in different local neighbourhoods. The consultant then made professional judgements on the potential improvements to carbon emissions if sustainable travel initiatives were enacted for each travel mode in each category of location. See appendix 2 for more detail.

Location categories represented in the model

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

1) City centre
2) Urban
3) Suburban
4) Village – well connected
5) Village – less well connected
6) New settlement.

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

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

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

Effects of zero carbon policy

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

1) Business as Usual (BAU) – based on current typical practice and transport.
2) Zero Carbon Policy (ZC Policies):
    a. Apply best in class space heating standards (15 kWh/sqm) in both homes and other buildings
    b. All new homes to use heat pumps, no domestic gas boilers
    c. All new non-domestic buildings to use heat pumps, no gas boilers
    d. On-site renewable energy generation at new buildings - PV
    e. Embodied carbon of new buildings – 40% reduction over baseline
    f. Energy Performance gap – medium level of mitigation in new builds (+25% on modelled energy)
    g. Transport: Potential – increased sustainable travel initiatives
    h. 10% of private vehicles are electric (average across plan period[3]). This links to the electricity grid carbon intensity for the selected year.

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

Tool outputs per unit of growth

2.19. To provide transparency about how the tool models an equal unit of growth in each location, the graphs below show the tool's modelled carbon emissions for 1 dwelling (plus accompanying facilities) in each of the **categories of location** within the model, with and without the zero carbon policy scenario applied. These are **not to be confused with the 5 Options for allocation of growth**, which each adopt a mixture of these locations.

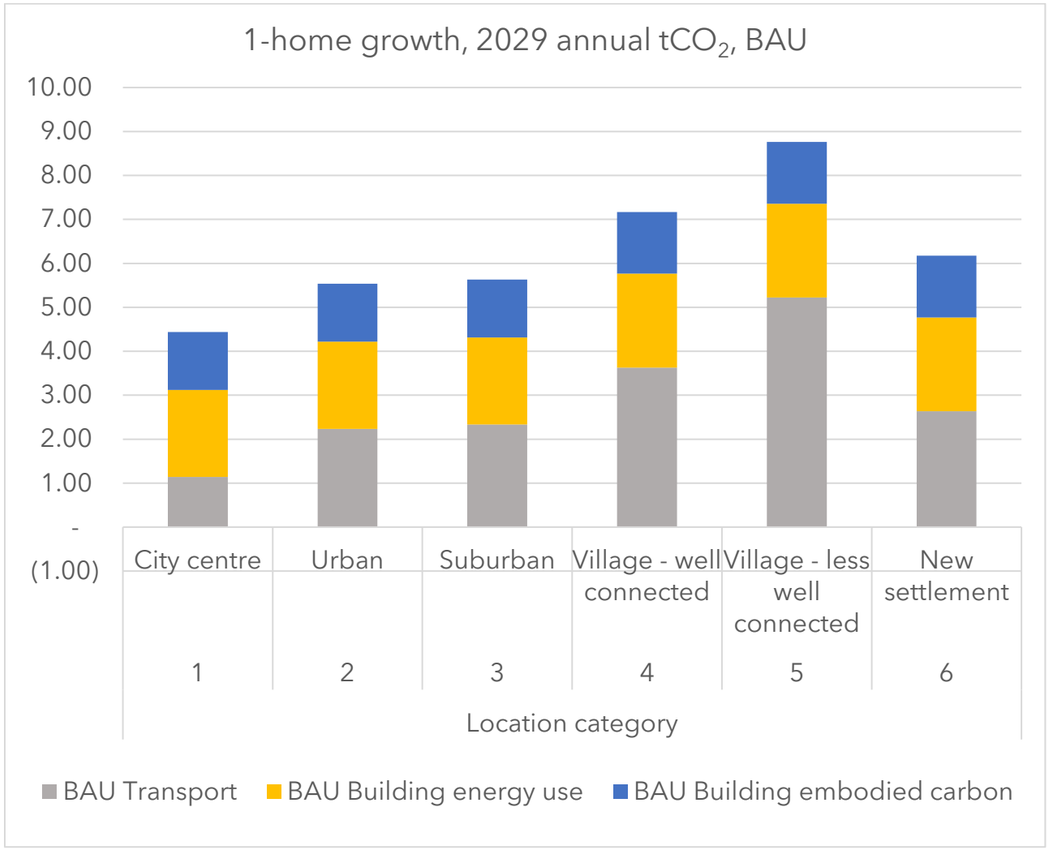

Figure 3: Annual carbon emissions created by the growth of 1 dwelling in each of the spatial locations modelled with Business as Usual policy in the year 2029 (mid-plan)

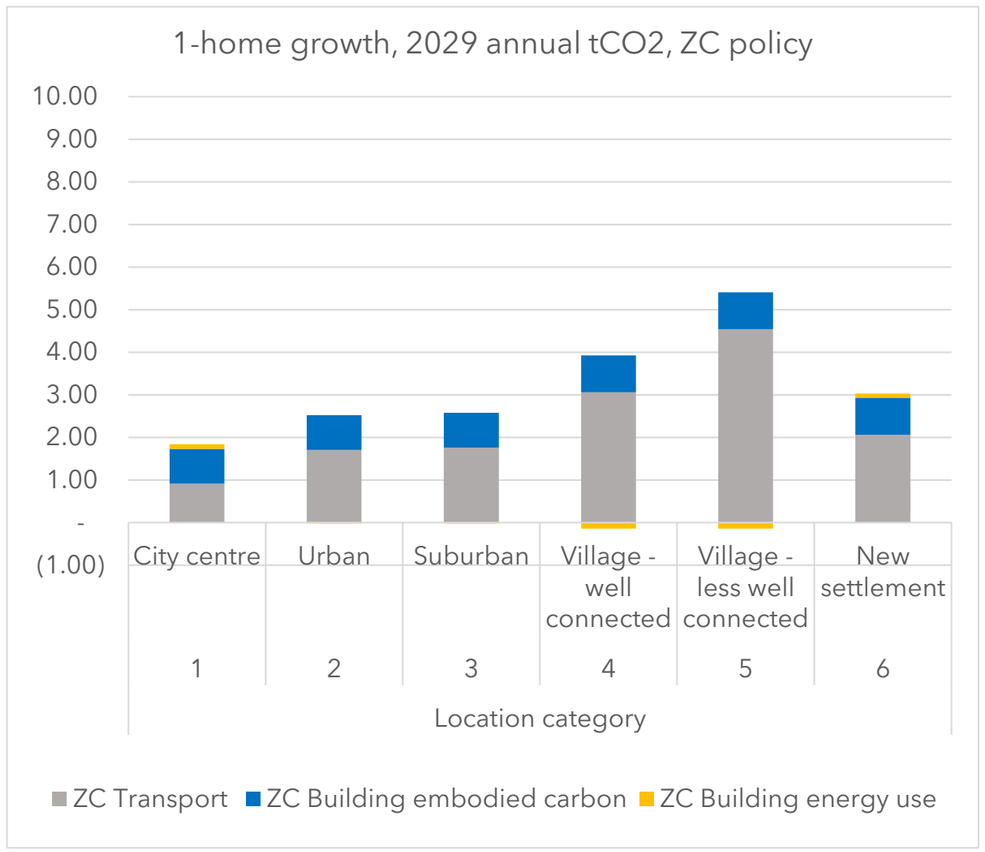

Figure 2: Annual carbon emissions created by the growth of 1 dwelling in each of the location categories modelled with Zero Carbon policy in the year 2029 (mid-plan)

How Central Lincolnshire's spatial growth options were entered into the tool

2.20. The Central Lincolnshire Local Plan team provided the five spatial options to accommodate the required 2,500 new homes plus supporting facilities. This included how the new growth would be spread across different locations. Some of these locations were general – e.g. 'new settlements' – but some were more specific - e.g. with specific towns in mind. Where possible, we sought information on locally specific factors such as presence of public transport or typical density of development. We also took the client team's advice on which category would be the appropriate match for each pocket of growth.

2.21. With this information, we entered the relevant numbers of homes into the location category in our tool that best matches the envisioned location. The following table shows how the new growth was distributed in each option, giving a good indication of how each option is actually a blend of both rural and urban sites (with the exception of Option 4 New Settlements, which is purely one location category).

Location category	**Option 1: Urban focus**	**Option 2: Small sites**	**Option 3: Corridors**	**Option 4: New settlements**	**Option 5: Balance options 1-3**
City centre	0	0	0	0	0
Urban	1,150	400	500	0	500
Suburban	300	50	200	0	200
Village – well connected	800	1,500	1,800	0	1,550
Village – less well connected	250	550	0	0	250
New settlement	0	0	0	2500	0
Total	**2,500**	**2,500**	**2,500**	**2,500**	**2,500**

Table 1: Overview of how growth in each option is spread across different location categories

Results, conclusions and reasons for recommendation

2.22. The lowest carbon-emitting options are Option 4 New Settlements followed by Option 1 Urban Focus, for both BAU and ZC policy scenarios, hence these are recommended. Option 2 Small Sites should be avoided, particularly if built out under BAU policies.

2.23. The difference between the lowest- and highest-emitting spatial option is 14% with Business As Usual, or 22% with Zero Carbon policy, as displayed in the following graphs. This is partly because the Zero Carbon policy regime has more effect on the emissions of buildings than of transport – as plan policies can make very specific requirements about buildings whereas their influence on transport is more subtle.

Spatial Option	tCO_2 per home	Narrative on factors in carbon performance in order of lowest-carbon option to highest-carbon option
4 - New settlements	179,006 or 87,582	This option has all homes located in a new settlement. The new settlement has been modelled with the assumption that its size will be sufficient to bring strategic new transport connections better than the 'well connected' villages. Its medium density gives it a tiny net export of PV energy.
1 - Urban focus	185,295 or 92,281	This option has most growth located in an urban setting (46%), plus 32% in well-connected villages, and the rest split across suburban areas and less connected villages. The urban and suburban homes give this option a relatively low transport carbon profile. The village homes add back some transport carbon, but their low density enables them a good ratio of solar energy generation to consumption.
3 - Corridors	194,696 or 98,952	This has 72% of new growth in 'well connected' villages, 20% in urban areas, and 8% in suburbs. As the villages are well connected, this option has a similar profile to the mix in Option 5, with identical solar PV export ability but with less transport carbon thanks to no remote village growth.
5 – Balance options 1-3	199,273 or 104,343	This puts 62% of new growth in well-connected villages, 20% in urban, 10% in less connected villages and 8% suburban. This makes it similar to 'corridors' but with slightly more transport carbon because of its less connected villages.
2 - Small sites	209,291 or 111,906	This option has almost all the growth in village locations. This pushes the transport carbon far up, even though 60% is in relatively 'well-connected' villages (alongside 22% in 'less connected' villages). This option also delivers 16% of its growth in an urban location, and 2% in suburbs. Because zero carbon policy has less effect on transport than on buildings, this option falls further behind the others in the ZC policy regime even though its majority low-density homes are able to be export a little more solar electricity.

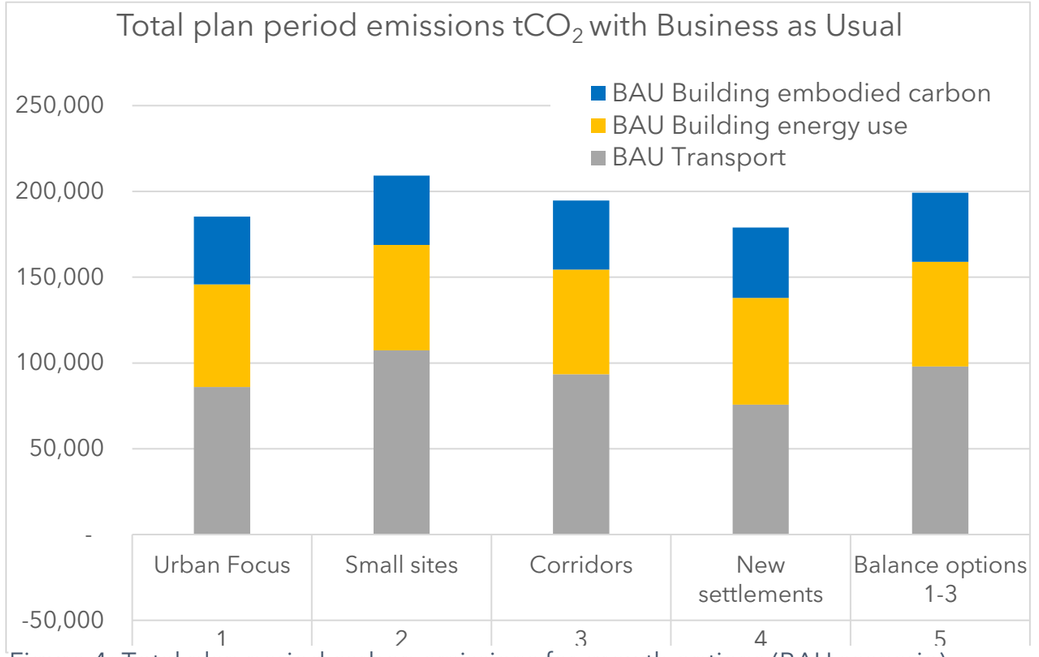

Figure 4: Total plan period carbon emissions for growth options (BAU scenario)

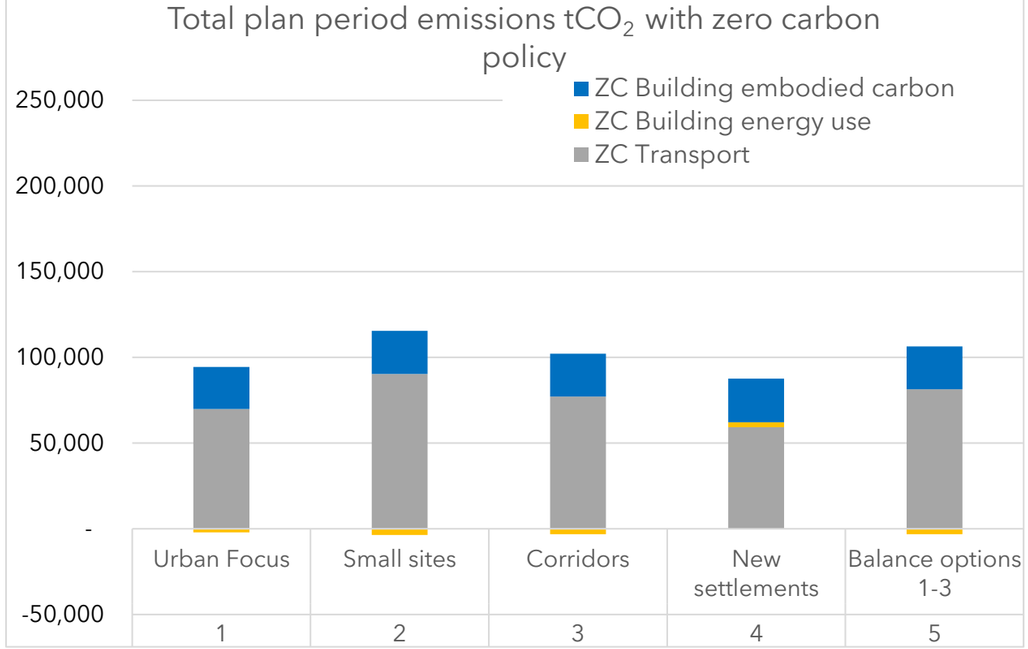

Figure 5: Total plan period carbon emissions for growth options (ZC policy scenario)

2.24. To put the results into perspective, it is helpful to understand that the energy and transport emissions from any one of the proposed growth allocations represent about a 1% increase against the background emissions of Central Lincolnshire, or a 12% increase against those that will occur from already allocated sites (assuming BAU policy and mid-plan grid emissions factors i.e. 2029), as demonstrated in the Figure 6.

2.25. Please note that this figure excludes embodied carbon, as there are no embodied carbon emissions data available for existing settlements. Embodied carbon has therefore been excluded in this chart as to make the modelled and existing emissions comparable.

2.26. Hence, the priority for a Local Plan compatible with a net zero carbon Central Lincolnshire should be to create ZC policies that can affect all new development wherever possible (not just the additional site allocations being proposed in the five spatial options), and also do what it can to encourage retrofit of existing buildings wherever possible and improve low-carbon transport for the existing population.

2.27. That said, there is a real opportunity to avoid significant amounts of carbon emissions through careful selection of the locations for additional new growth.

2.28. If some rural or village sites are unavoidable, priority should be given to locations with good public transport connections with proximity to local amenities to help reduce the inevitable private car use this will induce. Policy should also be in place to guarantee that all growth – but especially that outside urban locations – provides the right infrastructure to make it easy and attractive for all new residents and visitors to make the switch to ultra-low emissions vehicles (most likely electric).

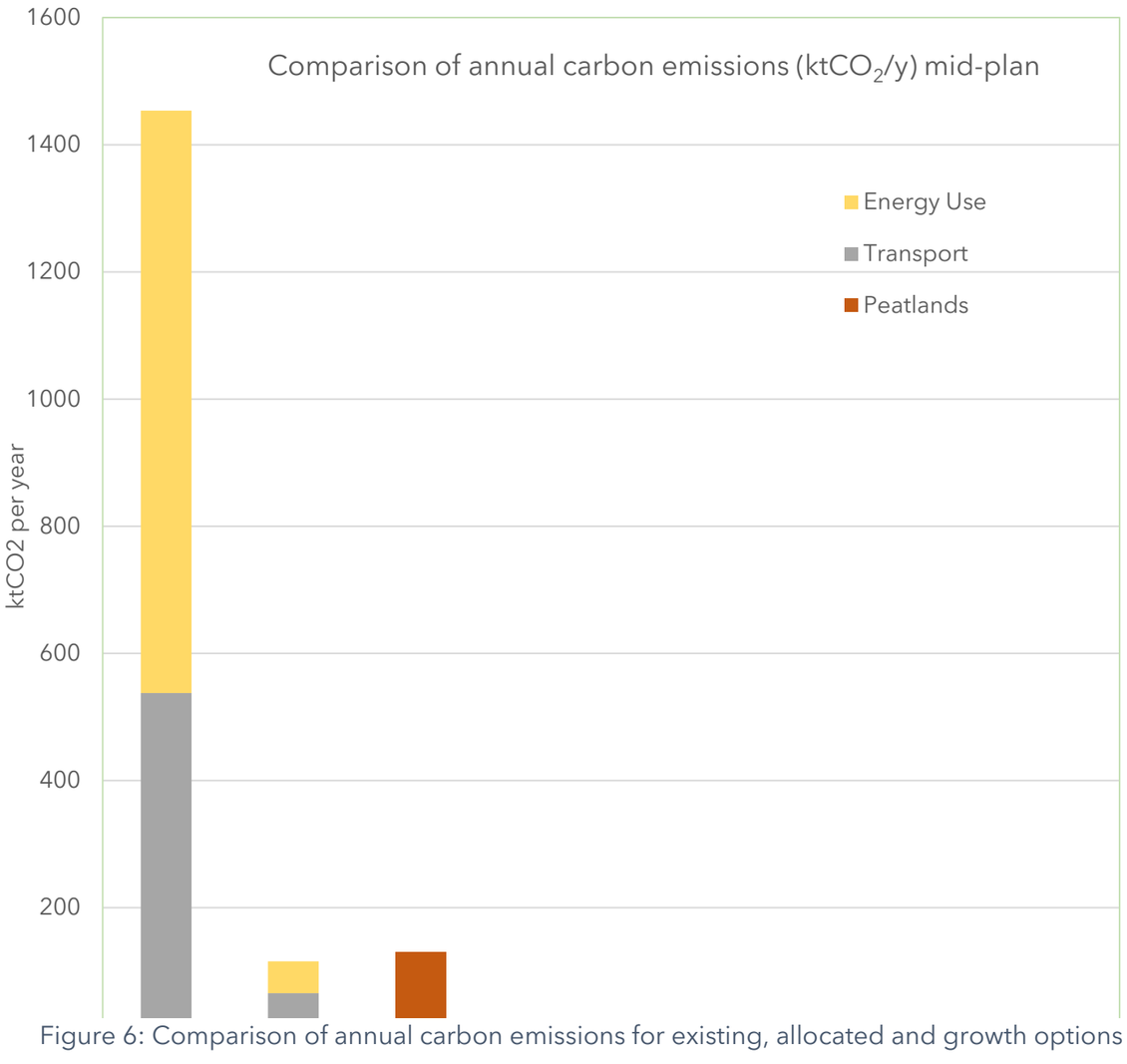

Figure 6: Comparison of annual carbon emissions for existing, allocated and growth options

3. Appendices

Appendix 1: carbon modelling tool methodology

This section outlines the methodology behind the spatial modelling tool.

3.1. It should be noted that this exercise is highly innovative in plan making, and to our knowledge, no commonly accepted approach exists. Hence, we have had to devise a new methodology using the available reliable data, and industry experience and judgement of the expert partners involved. To date, we have used this method for one other local planning authority, and we have updated the underlying assumptions and data to reflect the situation in Central Lincolnshire.

3.2. This is the first iteration of this modelling methodology in the Central Lincolnshire context, which will no doubt evolve over time.

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

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

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

1) **Embodied upfront carbon** from building construction materials and processes.
2) **Operational carbon** from building heating and electricity usage.
3) **Transport carbon** from occupant transport.

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

3.7. Operational carbon emissions are largely dependent on the above development mix factors multiplied by the energy use intensities (that is, energy use by type and use – domestic and non-domestic, regulated and unregulated, and so on). In the 'zero carbon policies' scenario, these are also conditioned by the ratio of internal space to roof space to accommodate solar panels.

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

Methodology

3.9. Development mix was established as follows:

a. Representative development densities (dwellings per hectare, dph) were provided by Central Lincolnshire Planning Authority.

b. The number of types, bedrooms was then based on the Strategic Housing Market Assessment and Housing Needs Assessment, sized according to the Nationally Described Space Standards, as no local space standard is in place.

c. The house types, bedrooms and the tenures were then converted into new population including people per household, adults, children, and so on, using various available data source including the latest Strategic Housing Market Assessment, Housing Need Assessment and Census data.

d. These estimated populations were then used to establish approximate infrastructure requirements (non-domestic buildings) referencing the Developer Contributions SPD.

e. The development mixes per spatial location were peer-reviewed by an experienced master planner (Perkins & Will).

3.10. Energy use intensities (EUI) were established as follows:

a. Domestic EUI was modelled using Passivhaus Planning Package (PHPP) for indicative housing types (detached, semi-detached, flats) based on actual recently approved planning permissions[4]. The baseline modelling was to current Part L Building Regulations compliant standard (nationally regulated minimum performance). This modelling included assumptions around occupancy and appliances to produce unregulated as well as regulated[5] emissions.

b. Non-domestic EUI was established using the DEC (Display Energy Certificate) database to download Central Lincolnshire postcode specific samples of recently completed buildings – no older than 5 years and EPC (Energy Performance Certificate) A to C, under the categories of Sports facilities, Community Centres, Offices, NHS, Schools and Nurseries.

c. These EUI are then converted into carbon emissions for a specific year within the plan period using Treasury Green Book data for greenhouse gas emissions for appraisal[6]. This takes into account what proportion of the energy

[4] For more detail, see the Task G report ('Feasibility Assessment') which used PHPP to understand the baseline energy and carbon performance of those developments, and analyse what fabric upgrades would be needed in order to meet their own energy demands with rooftop solar panels.

[5] 'Regulated' emissions are the emissions associated with 'regulated' energy use. Regulated energy use is the part of a building's energy use that is controlled by national building regulations – that is, space heating, hot water, ventilation and permanent lighting. 'Unregulated' energy use is due to plug-in appliances.

[6] Treasury Green Book data is available here.

use is gas, electricity or other, including the gradual decarbonisation of the electricity grid into the future.

d. Associated solar panel electricity generation was calculated for the following scenarios, assuming 350W per monocrystalline panel:

    i. Houses/non-residential: Duo roof archetype (average orientation: south-east; south-west/30 degrees) assuming use of 50% of roof area.

    ii. Flats: Flat roof archetype (average orientation: south-east; south-west/flat) assuming use of 80% of roof area.

e. Embodied carbon emissions were established as follows:

Embodied carbon factors for kilogrammes of CO_2 per square metre of the gross internal area were sourced from the London Energy Transformation Initiative Embodied Carbon Primer[7] which provides factors for residential, commercial and schools. Total upfront emissions were then divided by an assumed 60-year lifecycle to allocate a per-year emissions allowance for each building.

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

Appendix 2: transport assumptions

4.1. Our transport consultant devised a modelling method for how transport carbon emissions vary between different spatial locations in the plan area. This method is anchored in BEIS nationally reported benchmark data from the Central Lincolnshire area, further refined by using a rating scale of modal choices for each spatial location type.

4.2. These scales were further calibrated against outputs from the Greater Lincoln Transport Model. The car modal score corresponds directly with the car trip rates and vehicle kilometre distances by car to/from each of the site categories, including an allowance for the internalisation of car trips associated with SUEs. The car score has informed how other scores by other travel modes have been decided upon, notwithstanding the inherent mode share built into the baseline emissions data BEIS baseline emissions data and Census mode share data for the Local Plan area.

4.3. Our transport tool starts with the most recent annual per capita transport CO_2 emissions for the three local authority areas of Central Lincolnshire, from the subnational emissions figures released annually by BEIS. This is the best currently available data on the average person's transport emissions in these three locations.

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

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

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

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

4.8. The transport consultant then cross-compared the interim results with data from the Greater Lincoln Transport Model to make sure our modelling approach concurred in terms of profile across the different spatial locations.

4.9. The carbon values for transport are effectively an estimation based on a top-down allocation of a proportion of the regional average, based on localised travel data. In contrast, the carbon emissions for buildings are based on a 'bottom-up' modelling per building type. They also are not sensitive to 'tipping points' such as if a village were to grow into a town that can achieve more trip containment. However, because they are still anchored to actual

Location Category	Mode	Net Zero Carbon Score (0-10 from least carbon to most)		Noted Assumptions in relation to Mitigation / Initiatives		Carbon Value (kg NO2)	
		Standard Assumptions	Potential	Standard Assumptions	Potential Score Improvements	Standard Assumptions	Potential Score Improvements
Category 1:	Walking	0	0	Maximum potential for this travel mode, offering zero carbon in transport terms.	Limited potential for improvement, where inherently having the maximum potential.	504	416
Lincoln Central Area	Cycling	1	0	Excellent potential as a travel mode, capitalising upon an already relatively high share of total trips in the City. Offers zero carbon in transport terms. The potential for existing infrastructure to be enhanced should improvements further this as a mode is high, therefore placing this location category in a better position compared with others that may require more significant investment.	Potential for optimum scoring with further increased cycle infrastructure and availability of bicycles (e.g. sharing schemes, either development led or within the City).		
	Bus	1	0	Excellent potential as a travel mode, subject to exact site locations. Shorter bus journeys within the City compared with other location categories may better enable connecting rail journeys via Lincoln train station. Less investment is anticipated to further improve bus services in this location than others in terms of best enabling this as a travel mode. It is also assumed that any increased roll-out of 'cleaner' buses may be focused within the City, and therefore this location category perhaps has more immediate potential for bus travel as a travel mode being less carbon-intensive.	Potential for optimum scoring with improved bus services and a carbon neutral bus fleet.		
	Train	0	0	Excellent potential for this travel mode based upon the also very good potential of the above travel modes, offering a less carbon-intensive means of travel over greater distances .	Limited potential for improvement to achieve optimum scoring, recognising some site locations may inherently be less accessible to the train station (a zero score may however be achieable in certain circumstances on this basis).		
	Car	0	0	Maximum potential to limit car travel within the City itself, albeit subject to parking provision and other factors to discourage car travel to end destinations outside of the City, the peripheries and further afield, where more parking is available upon destination. Higher availability of car clubs and ride sharing may also contribute to reduced car ownership.	Potential for optimum scoring with car-free development proposals or in combination with lower carbon emitting vehicles with any car ownership		
	Aggregated total	0.4	0.0				
Category 2:	Walking	3	2	Good potential as a travel mode where walking will be feasible across towns, or at least to cover many end destinations, given the size of Gainsborough and Sleaford. Offers zero carbon in transport terms.	The potential for improvements may be realised through specific locations of sites in proximity with end destinations, or through significant improvements to off-site walking infrastructure	988	768
	Cycling	3	2	Good potential as a travel mode where cycling will be feasible to any destinations in Gainsborough and Sleaford, including to train stations. Offers zero carbon in transport terms.	The potential for improvements may be realised through specific locations of sites in proximity with end destinations, or through significant improvements to off-site cycling infrastructure and availability of bicycles (e.g. sharing schemes, either development led or within towns).		
Development in Towns	Bus	2	1	Very good potential as a travel mode, subject to exact site locations. Shorter bus journeys within towns compared with other location categories may better enable connecting rail journeys via relevnt train stations. Less investment is anticipated to further improve bus services in this location than others in terms of best enabling this as a travel mode.	Potential for excellent scoring with improved bus services and a carbon neutral bus fleet.		
	Train	2	1	Very good potential for this travel mode based upon the also very good potential of the above travel modes, offering a less carbon-intensive means of travel over greater distances.	Potential for better scoring either by specific site location, or through improved accessibility by walking, cycling or bus.		
	Car	3	2	Good potential to limit car travel, albeit subject to parking provision and other factors to discourage car travel to end destinations outside of towns, the peripheries and further afield, where more parking is available upon destination. Higher availability of car clubs and ride sharing may also contribute to reduced car ownership.	Potential for better scoring, subject to measures for significantly reducing car ownership and / or car dependency otherwise seen in the area, as well as lower carbon emitting vehicles with any car ownership.		
	Aggregated total	2.6	1.6				
Category 3:	Walking	2	1	Very good potential as a travel mode, although may vary considerably depending on proximity with major employment areas, as well as education. Offers zero carbon in transport terms.	The potential for improvements may be realised through specific locations of sites in proximity with end destinations, or through significant improvements to off-site walking infrastructure	1032	812
	Cycling	2	1	Very good potential for this travel mode, offering a more realistic mode of active travel over greater distances than by walking (e.g. radial trips into the City as well as across the City to key employment areas and education). This may increase in attractiveness through increased availability of electric alternatives (although not to the same extent as more remote locations).	The potential for excellent scoring may be realised through specific locations of sites in proximity with end destinations, or through significant improvements to off-site cycling infrastructure and availability of bicycles (e.g. sharing schemes, either development led or within the City).		
Lincoln SUEs and other Suburban	Bus	2	1	As per commentary for 'Category 1', albeit rail station proximity and investment factors are likely to be less positive due to range and reduction in density of the bus network, respectively (subject to specific site conditions).	Potential for optimum scoring with improved bus services and a carbon neutral bus fleet.		
	Train	5	4	Reasonable potential for this travel mode based on the range in potential of the above travel modes (factored by site-specific circumstances), offering a less carbon-intensive means of travel over greater distances. However, this may be subject to proximity with Hykeham train station in particular, or the quality of multimodal connections with Lincoln train station.	Potential for better scoring either by specific site location, or through improved accessibility by walking, cycling or bus.		
	Car	3	2	Good potential to limit car travel, albeit subject to parking provision and other factors to discourage car travel to end destinations outside of the City, the peripheries and further afield, where more parking is available upon destination. Higher availability of car clubs and ride sharing may also contribute to reduced car ownership (although to a lesser extent than for Central Lincoln).	Potential for better scoring, subject to measures for significantly reducing car ownership and / or car dependency otherwise seen in the area, as well as lower carbon emitting vehicles with any car ownership.		
	Aggregated total	2.8	1.8				
Category 4:	Walking	4	3	Reasonable potential as a travel mode on the basis of proximity with other towns or Lincoln, in addition to local facilities and amenities. Offers zero carbon in transport terms.	The potential for improvements may be realised through specific locations of sites in proximity with end destinations, or through significant improvements to off-site walking infrastructure	1604	1384
	Cycling	4	3	Reasonable potential as a travel mode on the basis of proximity with other towns or Lincoln, as well as close proximity to train stations	The potential for improvements may be realised through specific locations of sites in proximity with end destinations, or through significant improvements to off-site cycling infrastructure.		
Villages (Well Connected)	Bus	4	3	Reasonable potential as a travel mode where good quality bus services are available in accessing other towns or Lincoln. Less investment is anticipated to further improve bus services in this location than others in terms of best enabling this as a travel mode.	Potential for better scoring with improvements to existing good quality bus services (requiring less initial capital investment).		
	Train	5	4	Reasonable potential for this travel mode based upon inherent proximity to train stations by walking and / or bus, offering a less carbon-intensive means of travel over greater distances. Site specific factors may however raise need for improvements to the quality of connections, even if within close proximity of stations.	Potential for better scoring either by specific site location, or through improved accessibility by walking, cycling or bus.		
	Car	10	9	Whilst 'well connected' factors may considerably reduce car driver share, the potential for driving may remain high, especially over greater distances. Availability of car clubs and ride sharing is expected to be significantly less than other location categories, which may otherwise contribute to reduced car ownership.	Potential for improved scoring, subject to measures for significantly reducing car ownership and / or car dependency, as well as lower carbon emitting vehicles with any car ownership.		
	Aggregated total	5.4	4.4				
Category 5:	Walking	8	7	Reduced potential other than to local facilities and amenities, subject to local circumstances especially in relation to the availability of education facilities.	Limited potential for improvement unless site specific circumstances demonstrate otherwise.	2307	2087
	Cycling	7	6	Reduced potential unless within reasonable proximity of employment and education serviced by sufficient quality cycle infrastructure. It is however noted that the potential for electric powered bicycles (or similar modes) has the potential to reduce issues with range in terms of cycle uptake in these locations.	Limited potential for improvement without disproportionate investment. A single score reduction is however offered should site specific circumstances demonstrate otherwise and / or credible development led cycle schemes be available (including for instance e-bikes).		
Villages	Bus	9	8	Limited potential where this category inherently has a reduced bus service offering (or their potential to viably be improved by development or otherwise). Commentary as per other location categories remains relevant, albeit to a much lesser extent – i.e. increased distances to train stations in most cases, and likely less proportionate investment required to improve a lesser quality of service in terms of end destinations and frequency.	Some improvements may be realised with significant investment in bus improvements, including reducing carbon emissions of buses and / or in combination with site specific circumstances where existing or planned bus services are better than typical for this area category.		
(Less Well Connected)	Train	9	8	Limited potential for this travel mode where this category inherently is remote from train station options. It is anticipated that in most cases, reliance on car travel will remain high and traffic growth still occur on routes to train station car parks should train travel be adopted.	Limited potential for improvement. A single score reduction is however offered should site specific circumstances demonstrate otherwise and / or credible development led connectivity improvements be possible.		
	Car	10	9	Limited potential to limit car travel to end destinations for all journey purposes other than those associated with local facilities and amenities, and trip distances will be the longest. Availability of car clubs and ride sharing is expected to be significantly less than other location categories, which may otherwise contribute to reduced car ownership. Reliance on car is anticipated to remain high on the above basis, contributing towards traffic congestion on key routes.	Potential for improved scoring, subject to measures for significantly reducing car ownership and / or car dependency, as well as lower carbon emitting vehicles with any car ownership.		
	Aggregated total	8.6	7.6				
Category 6:	Walking	3	2	Good potential as a travel mode, although may vary considerably depending on proximity with major employment areas, as well as education. Offers zero carbon in transport terms.	The potential for improvements may be realised through specific locations of sites in proximity with end destinations, or through significant improvements to off-site walking infrastructure	1164	944
	Cycling	3	2	Good potential for this travel mode, offering a more realistic mode of active travel over greater distances than by walking, especially if more remote from the span of the town. This may increase in attractiveness through increased availability of electric alternatives (although not to the same extent as more remote locations).	The potential for better scoring may be realised through specific locations of sites in proximity with end destinations, or through significant improvements to off-site cycling infrastructure and availability of bicycles (e.g. sharing schemes, either development led or within towns).		
New Settlements	Bus	3	2	As per commentary for 'Category 3', albeit rail station proximity and investment factors are likely to be less positive due to range and reduction in density of the bus network, respectively (subject to specific site conditions).	Potential for optimum scoring with improved bus services and a carbon neutral bus fleet.		
	Train	4	3	Good potential for this travel mode based on the range in potential of the above travel modes (factored by site-specific circumstances), offering a less carbon-intensive means of travel over greater distances. However, this may be subject to proximity with train stations in particular, or the quality of corresponding multimodal connections.	Potential for better scoring either by specific site location, or through improved accessibility by walking, cycling or bus.		
	Car	4	3	Good potential to limit car travel, albeit subject to parking provision and other factors to discourage car travel to end destinations outside of towns, the peripheries and further afield, where more parking is available upon destination. Higher availability of car clubs and ride sharing may also contribute to reduced car ownership.	Potential for better scoring, subject to measures for significantly reducing car ownership and / or car dependency otherwise seen in the area, as well as lower carbon emitting vehicles with any car ownership.		
	Aggregated total	3.4	2.4				

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regional data on per capita emissions, trip lengths and car use, we believe they are still within a reasonable range. Most importantly, since the purpose of this modelling exercise is to compare spatial locations, rather than produce accurate absolute emissions factors, we feel this is an appropriate approach.

4.10. In the 'zero carbon policies' scenario, we assumed an average 10% of private vehicles are electric across the plan period. We believe this is reasonable given that it is currently less than 1%, and the proposed national ban on sales of new fossil fuel cars comes more than halfway through the plan period[8]. This ban does not affect the second-hand car market, and existing fossil fuel cars will remain on the road for circa 14 years from the first sale[9], causing a lag in the rate of change in the fleet.

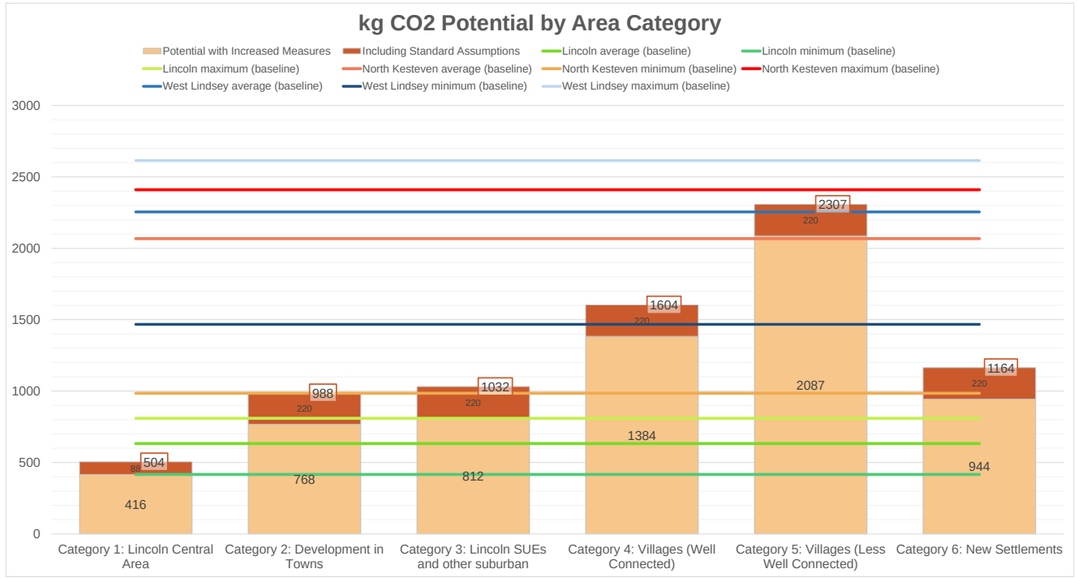

Figure 8: Transport Emissions Modelling comparison to local benchmark data

[8] At the time of writing, the ban on new fossil-fuel-only cars is s et to commence in 2030 (a decision made on 17th November 2020). Meanwhile, plug-in hybrid cars – which have been found to emit 250% more carbon dioxide in real life use than in lab tests – can be sold until 2035. https://www.newscientist.com/article/2260042-uk-10-point-climate-plan-bansnew-petrol-and-diesel-car-sales-by-2030/

[9] Society of Motor Manufacturers and Trades (2020), *2020 Automotive Sustainability Report: Average Vehicle Age*. https://www.smmt.co.uk/industry-topics/sustainability/average-vehicle-age/

Appendix 3: caveats and limitations

New development (and its population) only

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

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

5.3. Our tool does not attempt to predict or model such effects. However, it should be noted that transport habits are notoriously difficult and slow to change, once established (and once people have made investment, such as buying a car).

Transport

5.4. Our tool estimates the carbon emissions from transport behaviours in different development patterns by taking the best and worst per-capita transport emissions from BEIS and Census data on real urban and rural locations in Central Lincolnshire (cross-checked against the Greater Lincoln Transport Model data about car trips, distance and trip containment) and ranks each spatial option on a sliding scale according to how similar it is to those best and worst scenarios. Only terrestrial transport is included. A switch to electric vehicles applies to the private fleet only (this is also linked to the reduction in the carbon intensity of the electricity grid as per national projections). See also Appendix 2.

Embodied carbon

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

Green infrastructure

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