Net-zero Spatial Planning Support

Carbon implications of spatial scenario Golf

South Warwickshire Local Plan

May 2026

V6.0

Contents

1 Overview

1.1 Stratford-On-Avon District Council and Warwick District Council have commissioned Bioregional to assess the potential carbon emissions that will arise from new development options considered by their Local Plan development process. It is intended that this report will inform the new South Warwickshire Local Plan (SWLP).

1.2 An analysis of the current spatial growth scenario, scenario Golf, has been completed to assess the potential carbon emissions associated with planned development. Within the scenario, specific sites have been modelled, and a site level analysis is available separately. This analysis has been carried out using the Net-zero Spatial Planning Tool developed by Bioregional and Space Syntax. This report summarises the results of the analysis.

1.3 Scenario Golf has been modelled to assess the carbon impact of the planned growth options for housing growth in different locations across the South Warwickshire Local Plan area. The growth sites and associated dwelling numbers are found within table 5. The dwelling numbers and construction start and end dates used within each scenario have been provided by the South Warwickshire Local Plan team. Scenario Golf uses a set of policy variables, set by the SWLP team.

1.4 This analysis has been completed using the spatial carbon model within the Net-zero Spatial Planning tool, which assesses the carbon emissions associated with new development at a site-specific level. Throughout the analysis, the broad spatial model within the tool was also used to test outputs and sensitivity. Site location data was provided by the South Warwickshire Local Plan team; the total dwellings for each site have then been attributed proportionally between the output areas within the wider site boundaries available at the time of this analysis.

1.5 Further details on how this analysis was completed are provided within the methodology below. This report analyses both the cumulative and annual carbon emissions from:

- Operational energy – The emissions associated with the expected energy use of the new dwellings, from gas and electricity.
- Embodied carbon – The emissions associated with the construction materials and processes of building the dwellings modelled and assumed associated non-residential buildings.
- Transport related emissions – The emissions associated with the total additional transport distances from car and bus use of the residents of the new dwellings.

1.6 This analysis should be interpreted as a strategic carbon assessment of current spatial and policy assumptions, rather than as a site suitability assessment. Transport results reflect current accessibility, integration and infrastructure characteristics and do not fully capture the potential effects of future infrastructure, on-site services, public transport improvements or trip internalisation within new settlements.

2 Summary of Results

Transport Emissions

2.1.1 Transport emissions display the total carbon emissions associated with car and bus travel from the modelled new dwelling growth. Transport emissions represent the greatest proportion of the total carbon emissions from scenario Golf. Cumulative transport emissions across the scenarios reveal substantial variation, reflecting the impacts of development timelines and locations in shaping travel behaviour and associated carbon impacts.

2.1.2 For scenario Golf, **transport emissions** account for the single largest source of carbon emissions with a cumulative total of **978,710 TCO_2e**. Transport emissions are largely influenced by population increase, spatial distribution and the locational characteristics that influence the required transport distances.

2.1.3 Transport emissions from scenario Golf are primarily driven by two sites: B1 and E1, the transport analysis shows that sites B1 and E1 have lower level of integration than other areas of South Warwickshire. This results in a greater number of transport kilometres and consequently higher transport related carbon emissions. Sites B1 and E1 both show high transport carbon emissions as they have the locational characteristics associated with higher drive-to-work mode shares and longer travel distances. Across all LSOAs in the country, areas with similar regional and urban connectivity characteristics to B1 have a median drive-to-work mode share of around 75%. Across all LSOAs in the country, areas with similar regional and urban connectivity characteristics to E1 have a median drive to work mode share over 75% accompanied by significantly longer travel distances.

2.1.4 Site B1 produces the highest cumulative emissions across scenario Golf. The high carbon emissions are primarily driven by two factors. Firstly, high population within the early stages of the local plan period, driving higher cumulative transport emissions. Scenarios B1 and E1 have a projection of dwellings built by 2050 of 4000 and 4500 respectively with a construction start date of 2032 for B1 and 2033 for E1. Resulting from the higher projected population, both sites B1 and E1 are assumed to have a greater number of trips from an early stage in the local plan period. As such, the cumulative impacts are compounded. In addition, sites E1 and B1 have high transport emissions resulting from locational factors. Based on current infrastructure sites B1 and E1 are both classed as low integration at both 10km and 100km. Furthermore, utilising the broad spatial planning tool, which compares the impact of a consistent development scenario across all LSOAs, the locations of site B1 and E1 are both within the worst 4 preforming LSOAs. As a result of lower transport integration, sites B1 and E1 will result in more transport kilometres, however, it is important to note that cumulative emissions are also impacted by larger site capacity and build out rates.

2.1.5 Table 1 shows the breakdown of predicted transport emissions and kilometres from scenario Golf over the plan period, which is up to 2050.

Scenario	Total dwellings	Total transport emissions (TCO_{2e})	Electric car kilometres	Non-electric car kilometres	Bus kilometres
Golf	31,918	978,710	33,599,207,281	2,749,690,552	2,552,971,124

Table 1. Transport carbon emission summary over the plan period (2050)

Embodied Carbon Emissions

2.1.6 Embodied carbon describes the carbon emissions associated with the materials used in construction and site-based construction emissions. Embodied carbon emissions used within this analysis represent modules A1-A5 emissions[1], accounting for the embodied carbon of the raw materials, manufacturing processes, transport to the construction site and site-based construction emissions.

2.1.7 Embodied carbon emissions are driven by the total sum of all new dwellings built across the local plan period, with non-residential emissions assumed based on the number of dwellings within a scenario. Scenario Golf has been modelled with 31,918 new dwellings being built throughout the local plan period.

2.1.8 Most embodied carbon emissions are associated with residential development. However, ~24% of the total embodied carbon emissions will result from the non-residential development predicted by the spatial carbon model, representing social infrastructure induced by development such as health facilities, schools, and other non-residential spaces.

Scenario	Total dwellings	Total embodied carbon (TCO_{2e})	Total per dwelling embodied carbon (TCO_{2e})	Residential embodied carbon (TCO_{2e})	Non-residential embodied carbon (TCO_{2e})
Golf	31,918	739,872.23	17.48	558,020	181,852

Table 2. Embodied carbon emissions summary over the plan period (2050)

Operational Carbon Emissions

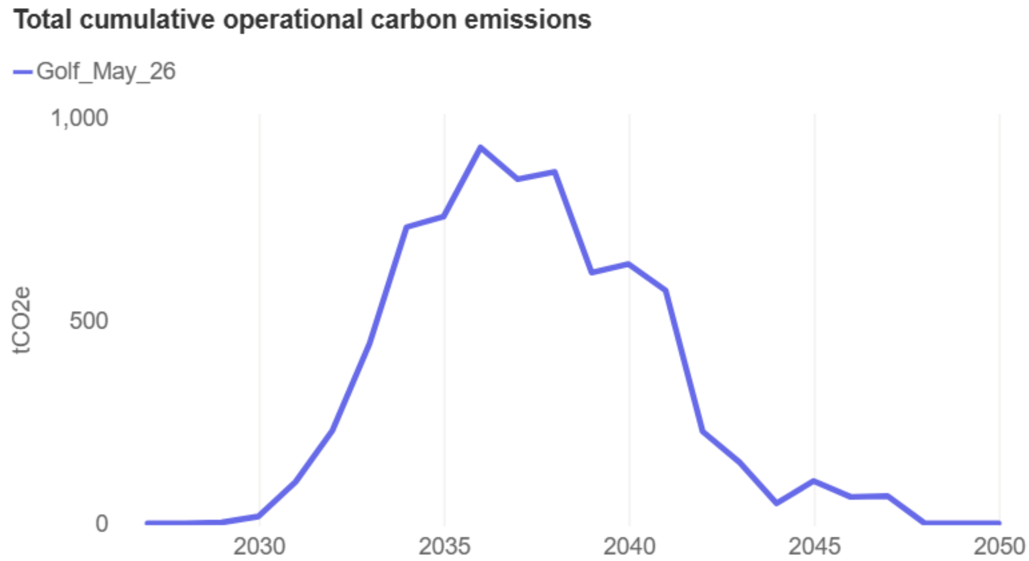
2.1.9 Operational emissions are the carbon emissions associated with the energy use of both residential and non-residential buildings. Emissions from both electricity and gas

[1] See RICS guidance on Whole Life Carbon Assessment Modules in Section 2.1: https://www.rics.org/content/dam/ricsglobal/documents/standards/Whole_life_carbon_assessment_PS_Sept23.pdf

consumption are measured within the Net-zero Spatial Planning Tool. However, because of the variables selected relating to decarbonisation of new buildings, both residential and non-residential buildings are assumed to utilise electric heating, therefore no gas emissions are produced under scenario Golf.

2.1.10 Similarly to the embodied carbon emissions, the emissions associated with operational energy track with the total number of new dwellings modelled.

2.1.11 Based on the provided construction start and end dates and the assumed build out variable of S-Curve, which assumes development at each site starts slowly, ramps up and tapers off towards the construction completion date, annual emissions from scenario Golf peak in 2036. Graph 1 shows operational energy emissions then decline because of grid decarbonisation, with a minor secondary peak between 2039 and 2041 as a significant number of new dwellings are built.



Graph 1. Annual operational carbon emissions TCO_2e.

Scenario	Total operational energy emissions (TCO_{2e})	Total dwellings
Golf	10,841	31,918

Table 3. Operational energy emissions summary over the plan period

3 Methodology

3.1 Use of the Net-zero Spatial Planning Tool outputs

3.1.1 The Net-zero Spatial Planning Tool allows for three levels of analysis, where the granularity of analysis is the differentiator:

a) Broad spatial location model

This model provides a high-level overview of a district, assuming 1000 homes are built in each Lower Super Output Area, allowing for a high-level "level playing field" comparison between locations. This allows locations to be compared on a like-for-like basis and helps identify areas that are currently more or less integrated, and where transport-related carbon emissions may be higher or lower. These outputs are useful for understanding spatial context and mitigation priorities, but they should not be interpreted as a definitive ranking of individual site suitability.

b) Non-spatial carbon model

This model allows users to select how growth will be distributed across four location types, derived from the DEFRA rural urban categorisation[2].

c) Spatial carbon model

This model allows users to attribute growth scenarios to specific output areas, allowing for more detailed modelling. The site-specific spatial carbon model applies the actual scenario Golf site boundaries, dwelling numbers and build-out assumptions. This produces the site-level carbon outputs used in the main analysis. These outputs are affected by both locational characteristics and development-specific assumptions, including the number of dwellings, construction start and end dates, and the assumed build-out trajectory. For this reason, site-level cumulative emissions should be interpreted alongside per-dwelling figures and one-year emissions, rather than viewed in isolation.

3.1.2 Since the site locations and growth numbers were known, the **spatial carbon model** was used for this analysis. The spatial carbon model requires users to input the specific number of new dwellings that will be built within an Output Area and the start and end dates of construction for each site. The outputs of this tool allow the carbon emissions from development at specific sites to be compared.

3.1.3 The tool provides outputs that display both annual and cumulative emissions across three key areas:

- Operational energy
- Embodied carbon
- Transport emissions

3.1.4 By default, most outputs display the cumulative emissions across the local plan period of 2025 - 2050. The summary page within the tool presents a visual comparison of total cumulative emissions by scenario, with further breakdowns showing emissions by type and by building use (residential and non-residential) for embodied and operational energy. These outputs allow for an assessment of the relative carbon impacts of different growth strategies, supporting more informed strategic planning decisions.

[2] https://www.gov.uk/government/collections/rural-urban-classification

3.1.5 The Scenario comparison outputs of the tool, shown below in Figure 1, include a summary of the emissions relating to operational energy, embodied carbon and transportation for scenario Golf.

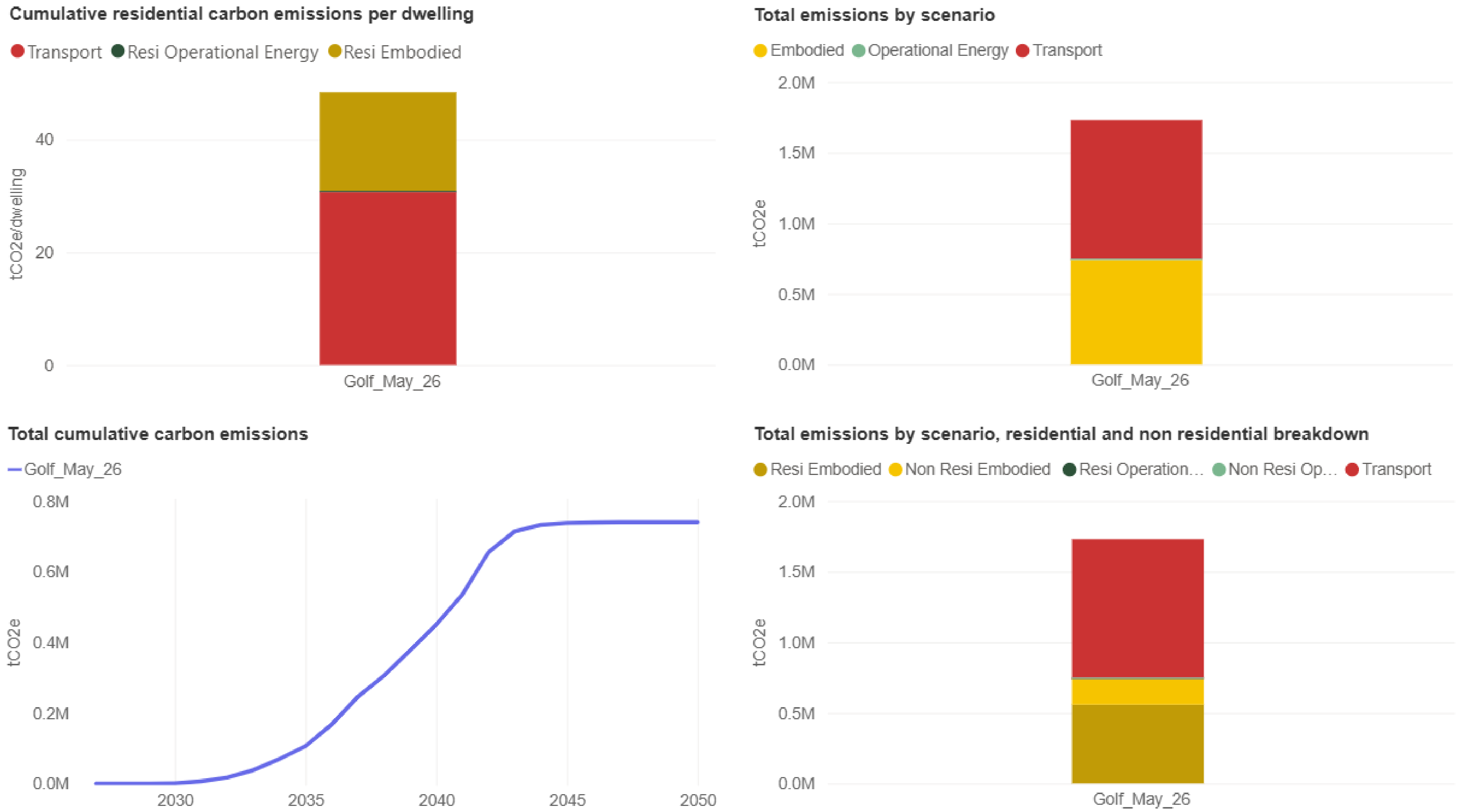


Figure 1. Scenario comparison page of the spatial carbon model

3.1.6 The Transport page outputs of the model, shown below in Figure 2, include cumulative emissions per dwelling, emissions by mode of transport, total annual emissions, and distances travelled by transport mode.

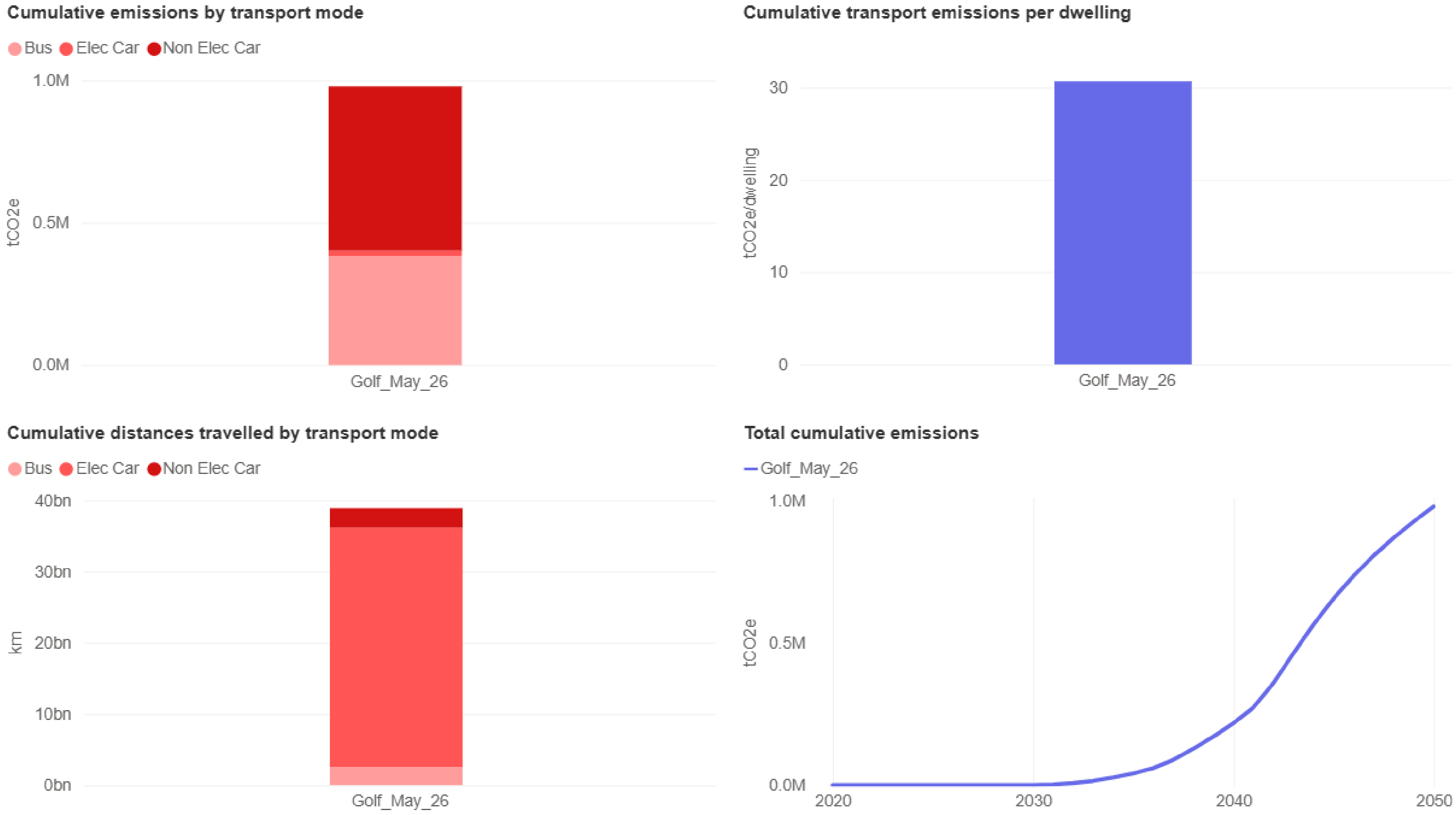


Figure 2. Transport emissions page of the spatial carbon model

3.1.7 The Embodied carbon page outputs of the model, shown in Figure 3, include cumulative emissions from construction materials and processes, including annual totals and emissions per residential dwelling.

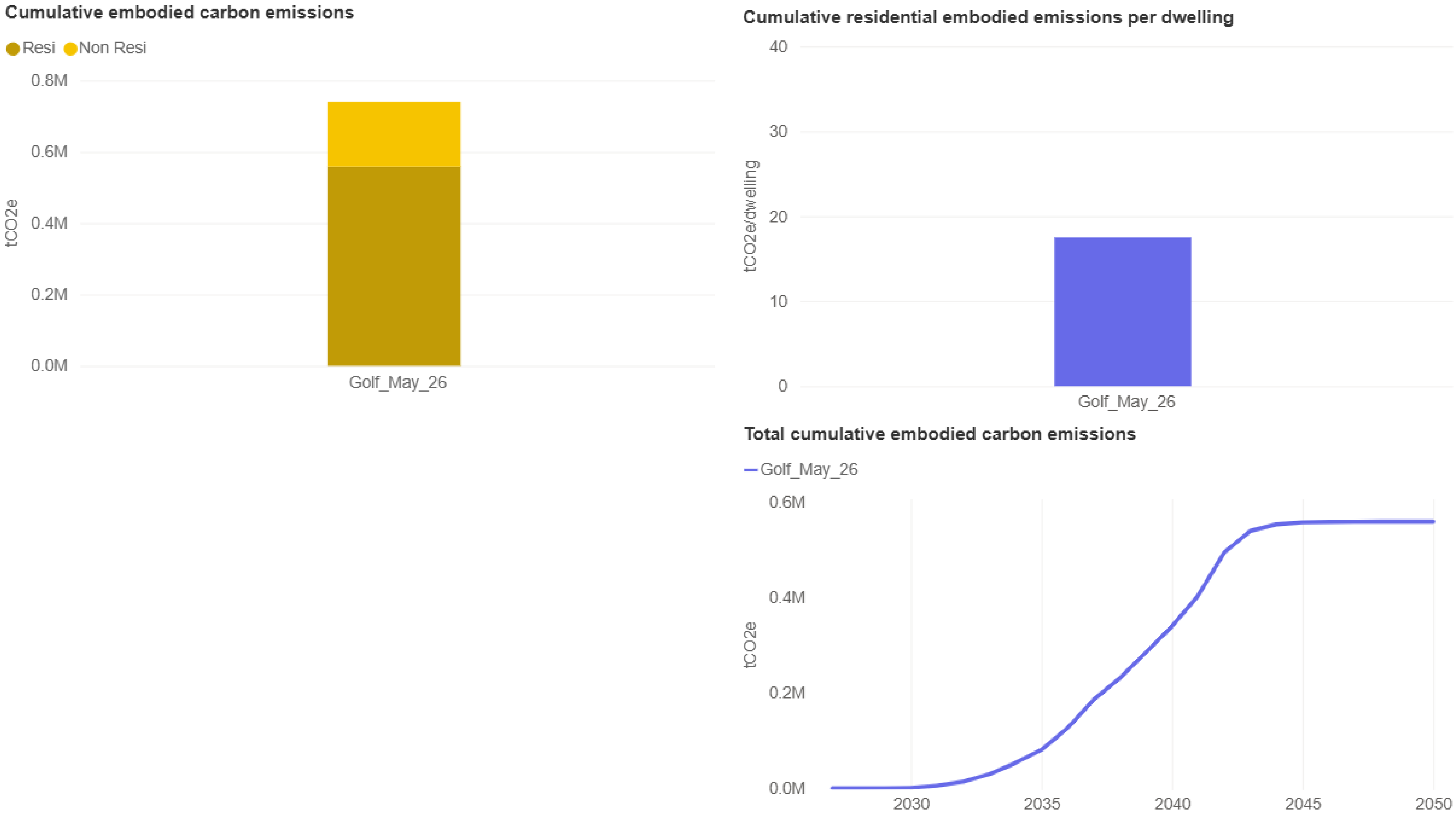


Figure 3. Embodied carbon page of the spatial carbon model

3.1.8 The Operational energy page outputs of the model, shown in Figure 4, include the predicted cumulative energy-related emissions from both residential and non-residential buildings, including annual energy consumption by source (gas and electricity).

Figure 4. Operational energy page of the spatial carbon model

3.1.9 Consistent environmental performance assumptions have been applied based on the selected variables. Variables have been selected in collaboration with the South Warwickshire Local Plan team based on current and emerging policies contained within the Warwick Net Zero Carbon Development Plan Document[3] and emerging South Warwickshire Local Plan.

3.1.10 Table 4 below shows the variables that have been used within this analysis. Variables have been consistently applied to all scenarios.

Variable type	Variable selected
Growth Path	S-Curve
Electric vehicle transportation	Decarbonising
Embodied Carbon residential first 5 years	Low
Embodied carbon residential after 5 years	Low
Embodied Carbon non-residential first 5 years	Low
Embodied carbon non-residential after 5 years	Low
Operational energy residential first 5 years	Mainstream low energy
Operational energy residential after 5 years	Mainstream low energy
Operational energy non-residential first 5 years	All heat pump with PV
Operational energy non-residential after 5 years	All heat pump with PV

Table 4. Variable selection

3.1.11 The growth path variable of 'S-Curve' was chosen based on the anticipated build out rates of the sites for scenario Golf. The S-curve growth path assumes that a small number of a site's total dwellings are built in the first years of construction, with development ramping up significantly during the middle years of construction and tailing off as the site nears completion.

3.1.12 The electric vehicle (EV) uptake variable of 'Decarbonising' was chosen based on the likely uptake of electric vehicles within South Warwickshire. This variable mirrors the Department for Transport's Ready for Net Zero electric vehicle uptake[4]. This variable only affects the split between electric and non-electric car kilometres; it does not alter the total predicted car kilometres from a site.

3.1.13 For both the 'first 5 years' and 'after 5 years' variable types, the embodied carbon variable of 'Low' was chosen. This variable adjusts the embodied carbon associated with each new dwelling in kg/CO2e/m2. The variable of 'Low' has been chosen based on the anticipated embodied carbon policies being brought forward through the emerging South Warwickshire Local Plan.

3.1.14 The residential operational energy variable for both the 'first 5 years' and 'after 5 years' variable types has been set to 'Mainstream low energy'. This variable has been chosen based on the anticipated operational energy policies being brought forward

[3] https://www.warwickdc.gov.uk/info/20799/development_plan_documents/1713/net_zero_carbon_development_plan_document
[4] https://www.gov.uk/government/publications/transport-decarbonisation-plan

through the emerging South Warwickshire Local Plan. This specification assumes dwellings are built with standard fabric, an Air Source Heat Pump (ASHP), a Waste Water Heat Recovery (WWHR) system, a Mechanical Ventilation with Heat Recovery (MVHR) system, solar photovoltaic (PV) panels and a diverter.

3.1.15 The non-residential operational energy variable for both the 'first 5 years' and 'after 5 years' variable types has been set to 'All heat pump with PV'. This variable has again been chosen based on the anticipated operational energy policies being brought forward through the emerging South Warwickshire Local Plan. This variable assumes non-residential buildings will have a standard fabric rather than best-in-class, utilise heat pumps and solar PV.

3.1.16 The graphic below illustrates the variable selection page in the spatial carbon model.

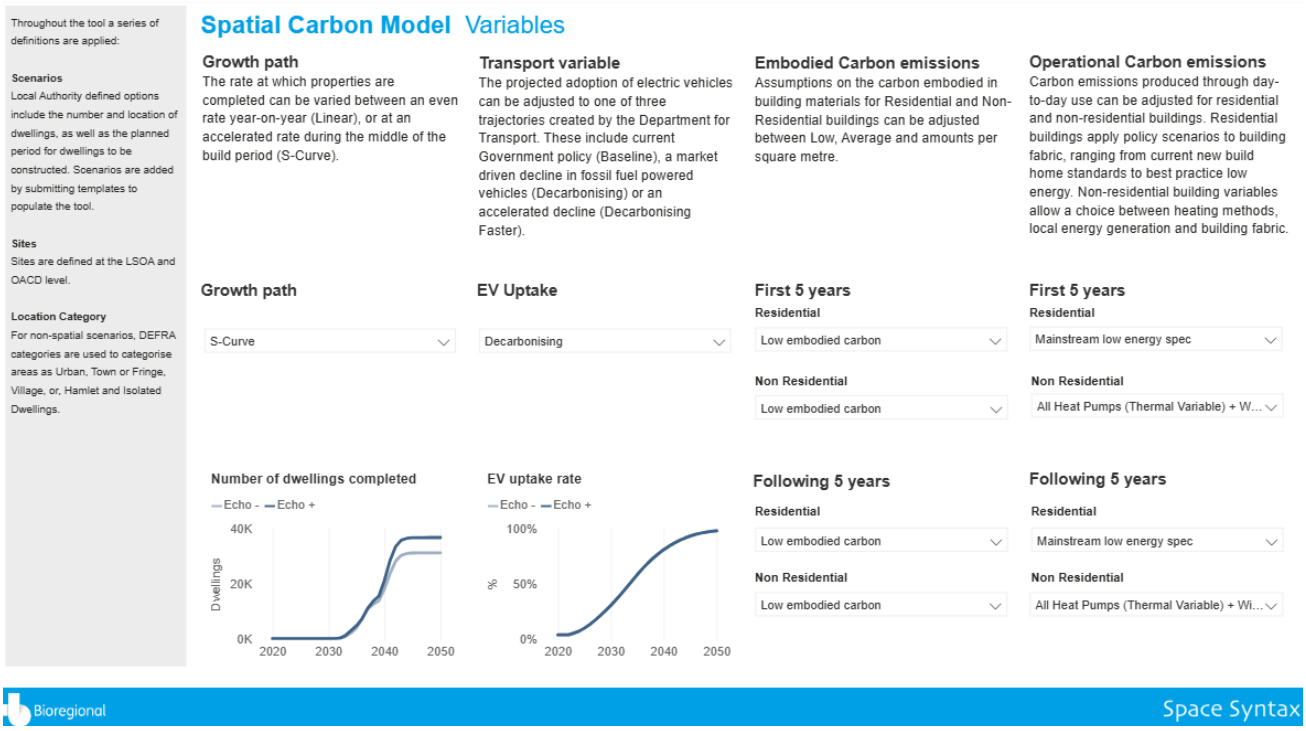


Figure 5. Variable selection page

3.1.17 Shapefiles identifying the location of the proposed locations of sites for development scenario Golf were provided by the South Warwickshire Local Plan team. The sites were then cross mapped with 2011 Output Areas to identify the inputs required for the Spatial planning tool.

3.1.18 Where sites crossed multiple Output Areas, dwellings were attributed proportionally based on the size of the Output Areas within the site boundary. It is important to note that data is displayed at the Lower Super Output Area (LSOA) level; however, data is input at an Output Area level to allow for greater precision when selecting site locations. Where Output Areas made up a small part of the site in which development would be unlikely, these were excluded.

3.1.19 Table 5 below shows the total number of dwellings associated with each site for scenario Golf up to 2050.

Site name	**Total number of dwellings**	**Construction start date**	**Construction end date**
SG01	3940	2029	2049
SG04	751	2029	2036
SG05	916	2031	2040
SG06	1784	2030	2041
SG08	493	2031	2040
SG09	558	2030	2037
SG10	1550	2028	2040
B1	4000	2032	2050
SG12	3086	2028	2045
SG15	1331	2033	2042
SG18 North (north of the A422)	768	2029	2037
SG18 South (south of the A422)	687	2027	2035
SG19	2585	2030	2048
SG20	3000	2033	2050
SG23	1969	2029	2044
E1	4500	2033	2050

Table 5. Golf modelling inputs

3.1.20 Every LSOA within the South Warwickshire Local Plan area has been assigned a Rural Urban category based on the Department for Environment, Food & Rural Affairs classification, and include:

- Urban conurbation
- Urban city and town
- Rural town and village
- Rural village and dispersed

3.1.21 Rural Urban categories are used in the non-spatial location model when housing numbers are allocated across the area on a broad, policy-based, non-specific basis. For example: 1,000 houses in Urban City & Town, 2,000 in Rural Town & Village. These numbers are then split between all LSOAs in each category.

3.1.22 Each LSOA is also assigned one of four spatial location categories based on its spatial integration values at urban and regional scales. This is assigned based on how integrated an LSOA is within the wider street network at 10 kilometres and 100 kilometres. These spatial location categories have also been found to relate to both the commute mode share and distance travelled, and include:

- High 100k, High 10k
- High 100k, Low 10k
- Low 100k, High 10k
- Low 100k, Low 10k

3.1.23 The integration levels are determined based on a 'Closeness Centrality' calculation which has been run on the street network of Great Britain. The integration value calculates, for every street segment, how many other street segments are within a defined distance, and how easily it can be reached from them. Space Syntax has published a map of Closeness Centrality which can be accessed in this link **here**. Integration at 100 kilometres shows how well connected an area is nationally, with 10-kilometre integration describing how well integrated an area is more locally.

3.1.24 Once an LSOA has a spatial location category assigned, a mode share model for that category of LSOA can be applied. Mode share models were developed based on analysing how Census and National Transport Survey Data could be predicted based on spatial integration information; Space Syntax's Walkability index; access to public transport; and household size and income. These models have been developed at LSOA level across the entire country and cover over 30,000 separate areas using more than 2 million data points.

3.1.25 After mode share models are applied to calculate the number of journeys that will be carried out, these are translated into a distance travelled. A unique average commute distance has been extracted from Census data at Middle-layer Super Output Area (MSOA) level, and these distances are applied. Following this distance calculation, it is translated into carbon emissions based on national government values for the kWh of electricity consumption/fuel consumption per kilometre of travel.

4. Assumptions and Limitations

4.1 Early-stage analysis

4.1.1 At the time of writing this report, the specific location of housing within site boundaries was not available. As such housing has been attributed proportionally between the Output Areas that intersect with a specific site. This approach has been taken to increase the level of granularity within the analysis.

4.1.2 While emerging South Warwickshire Local Plan policies have not yet been adopted at the time of writing, the analysis and variables used reflect the anticipated level of ambition of the new policies. Should any policy changes occur, subsequent analysis can be conducted with an adjusted set of variables.

4.1.3 This analysis includes sites from two local authorities: Warwick District Council and Stratford-On Avon District Council. To run this analysis, an input form was required which provides information on the anticipated level of affordable housing and the anticipated characteristics (based on bedroom size) of housing growth in different location categories.

4.1.4 Two distinct input forms, one reflecting information for Warwick District Council and one reflecting information for Stratford-On Avon District Council were provided. To reflect the entirety of the South Warwickshire Local Plan area and make analysis and further iterations of the study clearer and more robust, an average of both input forms was used. The consultant team analysed the impact of using averaged data compared to local authority-specific results, resulting in a difference of approximately 4%. This difference was deemed low impact by council officers; therefore, the average data was used for the analysis.

4.1.5 Many results are displayed as cumulative values; these values account for all years between the first construction in 2030 and the end of the plan period in 2050.

4.1.6 Additionally, transport emissions are based on the characteristics of an LSOA as they are seen at the time of writing this report. The model does not account for any future infrastructure provisions provided within a LSOA. Similarly, the transport model does not account for trip internalisation from infrastructure that does not currently exist. As discussed in paragraph 3.1.23, the Spatial Location categories have been developed at a Great Britain level based on 'Closeness Centrality' and split into four categories. As a result of the scale of data used, it is likely that there are LSOAs across the country where trips have been internalised. The impact of any internalisation across the country is likely to have influenced Spatial Location category data. Consequently, some level of trip internalisation is accounted for within the transport results, however not at an LSOA specific level for infrastructure, which is not currently usable.

5. Analysis

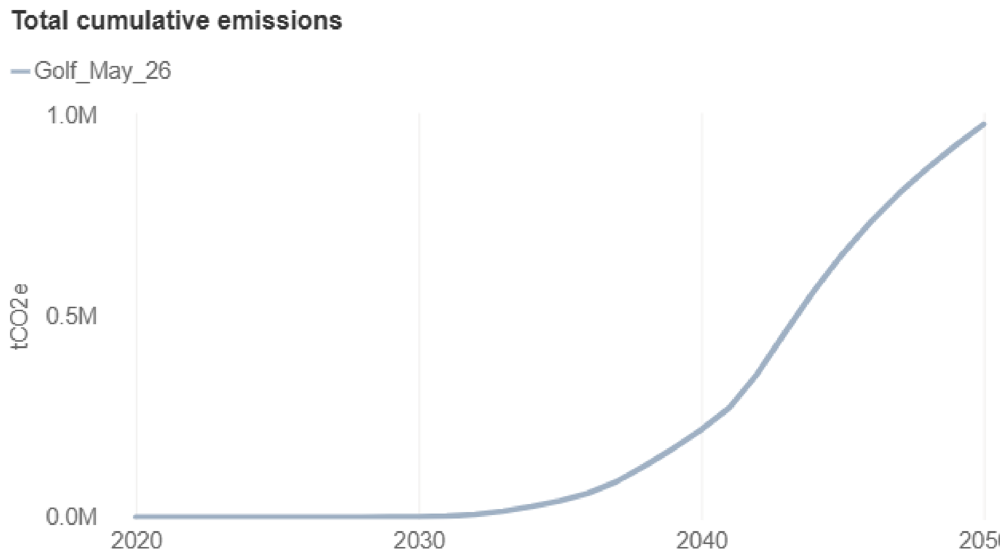
5.1 Transport Emissions Analysis

5.1.1 Transport emissions display the total carbon emissions associated with car and bus travel from the modelled new dwelling growth. Transport emissions represent a significant proportion of the total carbon emissions from scenario Golf. Cumulative transport emissions across the scenario reveal substantial variation, reflecting the importance of development timelines and locations in shaping travel behaviour and associated carbon impacts. Transport emissions are also influenced by the percentage of electric vehicles on the road in each year. The transport variable of 'decarbonising' has been set for scenario Golf.

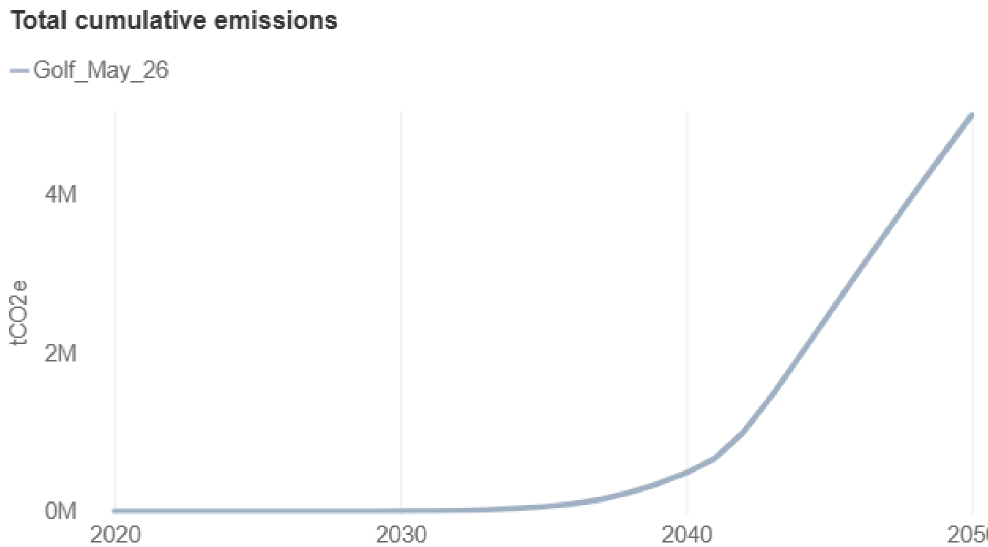
5.1.2 For scenario Golf, transport emissions account for the single largest source of carbon emissions with a cumulative total of 978,710 TCO2e over the local plan period. Transport emissions are largely influenced by population increase, spatial distribution and the locational characteristics that influence the required transport distances.

5.1.3 It should be noted that if the analysis period is lengthened, transport emissions will continue to grow. Transport emissions scale with the increased population and continue every year after the development has been completed. Population estimates increase with the predicted number of dwellings built each year, with the full population reached once construction has completed. As such, the transport emissions from a fully occupied site are only displayed in the years after the construction completion date. Any sites with a construction completion date of 2050 are only showing the impact of the total estimated population for one year. This can result in a site completing in 2043 having higher cumulative transport emissions than a comparable site with the same population completing in 2050.

5.1.4 Graph 2 shows the total transport related carbon emissions from scenario Golf. As can be seen, transport emissions rise slowly between 2030 and 2038 before increasing more rapidly between 2039 and 2043. The rapid increase in transport emission between 2039 and 2043 aligns with the predicted population growth across the scenario.



Graph 2a. Cumulative transport carbon emissions over the plan period – Decarbonising carbon pathway policies applied

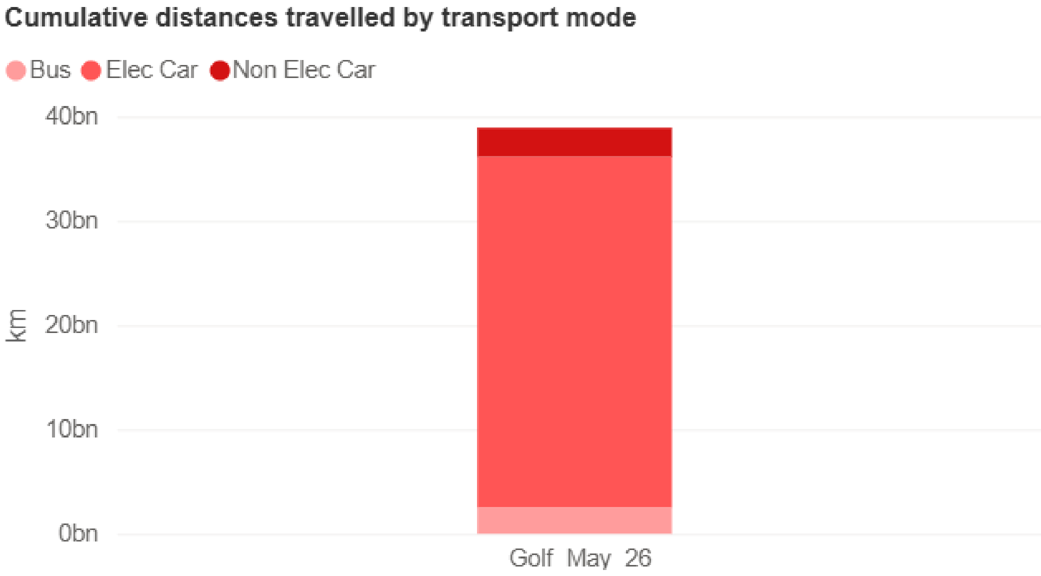


Graph 2b. Cumulative transport carbon emissions over the plan period – BAU policies applied

5.1.5 The total carbon emissions directly correlate with the estimated vehicle kilometres generated by each scenario. As can be seen, most vehicle kilometres for both scenarios are from electric vehicles. This results from the variable for electric vehicles being set to 'decarbonising,' increasing electric vehicle uptake throughout the local plan period. Scenario Golf results in over 32 billion kilometres (32,164,169,492 km) travelled by electric car across the local plan period. Non-electric vehicle travel is responsible for the fewest vehicle kilometres, with just 2.2 billion kilometres (2,292,218,569 km).

5.1.6 The comparison between Graph 2a and Graph 2b shows that the decarbonisation trajectory substantially reduces cumulative transport emissions compared with BAU. While the same dwellings and build-out assumptions are applied in both cases, the BAU trajectory continues to increase sharply to 2050, whereas the decarbonisation pathway levels off from the mid-2040s as vehicle emissions fall. This highlights the importance of national vehicle decarbonisation and EV uptake in reducing transport carbon. Further reductions would depend on site-specific transport measures, including improved public transport, active travel infrastructure, local service provision and trip internalisation within larger new settlements.

5.1.7 The remaining vehicle trips are made by bus with 2.4 billion kilometres (2,415,076,762 km) travelled across the local plan period. Graph 3, below, visualises the transport kilometres by mode from scenario Golf across the local plan period.



Graph 3. Total transport km by transportation mode

5.1.8 Within scenario Golf, several sites have significant transport emissions, with sites B1 and E1 being the most carbon intensive. Sites B1 and E1 both show high transport carbon emissions as they have the locational characteristics associated with higher drive-to-work mode shares and longer travel distances. Across all LSOAs in the country, areas with similar regional and urban connectivity characteristics to B1 have a median drive-to-work mode share of around 75%. Across all LSOAs in the country, areas with similar regional and urban connectivity characteristics to E1 have a median drive to work mode share over 75% accompanied by significantly longer travel distances.

Site name	Dwellings	Total transport emissions per site (TCO_{2e})	Cumulative transport emissions per dwelling (TCO_{2e})	One-year emissions in 2050 (TCO_{2e})
B1	4,000	377,529	94.4	29,051
E1	4,500	89,550	19.9	6,561
SG01	3,940	38,236	9.7	2,005
SG04	751	12,071	16.1	182
SG05	916	9,195	10.0	256
SG06	1,784	19,747	11.1	553
SG08	493	7,519	15.3	209
SG09	558	11,006	19.7	143
SG10	1,550	28,241	18.2	566
SG12	3,085	129,920	42.1	4,049
SG15	1,331	22,589	17.0	786
SG18 North	768	34,629	45.1	624
SG18 South	687	38,231	55.6	343
SG19	2,585	69,441	26.9	3,786
SG20	3,000	29,761	9.9	2,220
SG23	1,969	61,044	31.0	1,909

Table 6. Total transport emissions by site

5.1.9 As can be seen in Table 6, sites B1 and E1 are responsible for a significant proportion of scenario Golf's total transport emissions, ~50%. Site E has been classified as a Rural village with a dispersed location and a low level of integration at both 10 and 100 kilometres. This results in higher per-dwelling transport emissions as compared to locations that are currently better integrated.

5.1.10 When reviewing the broad spatial model heat map from transport emissions, Figure 6, which assumes 1,000 homes are built within each LSOA between 2020 and 2050, the LSOA that site E1 sits within has predicted pre-dwelling transport emissions of 42 TCO_2e. This compares to the average across South Warwickshire of ~14.3 TCO_2e, indicating that development within site E1 will result in greater reliance on private motor vehicles than a comparable average site by a factor of ~2.92.

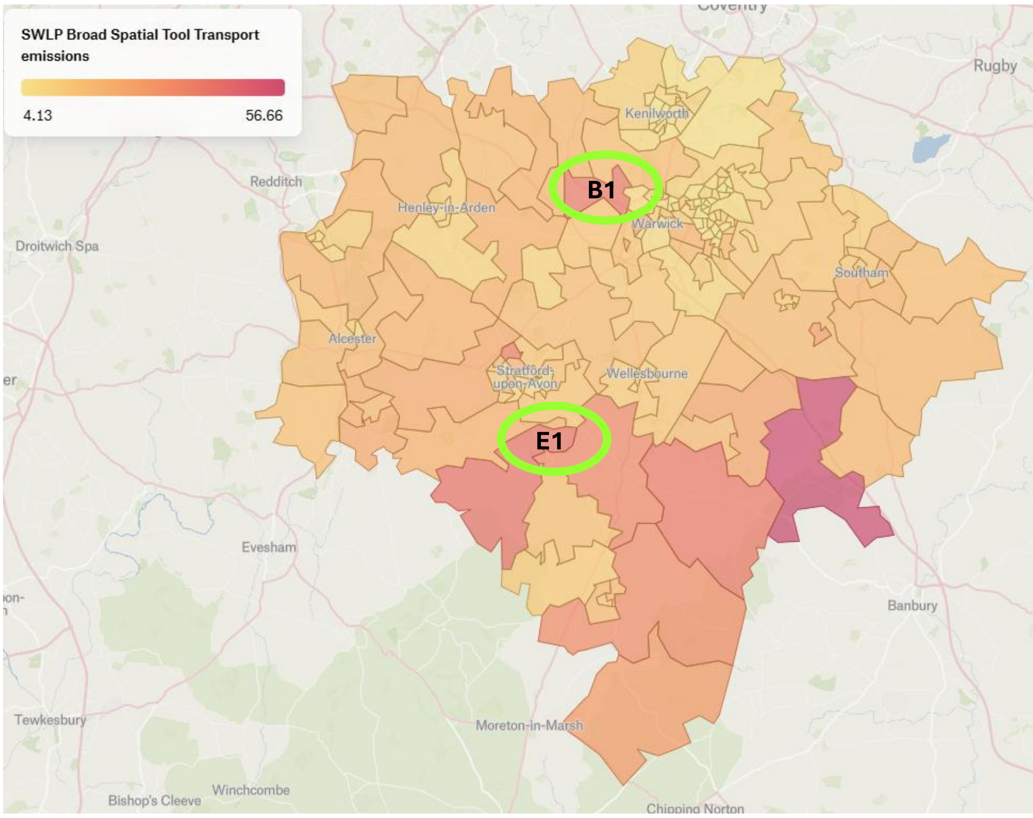


Figure 6. General locations of scenario Golf sites B1 and E1, presented on a heatmap of transport carbon emissions intensity.

5.1.11 Site B1 has the highest transport carbon emissions from any site in scenario Golf, being responsible for ~39% of all transport emissions in scenario Golf. Within the broad spatial model, the LSOA site B1 sits within has predicted pre-dwelling transport emissions of 39.4 TCO_2e. This is the 4th highest LSOA within the South Warwickshire region.

5.1.12 Both sites B1 and E1 have predicted growth during the plan period of 4000 and 4500 dwellings respectively, making them the largest two sites within scenario Golf. This compounds the impact of the location, resulting in a greater assumed population taking a higher than average number of trips.

5.1.13 It should be noted that both sites B1 and E1 are predicted to be amongst the first sites to begin construction in 2033 and the last to finish construction in 2050. In combination with the larger population on both sites.

Site name	Broad Spatial Model - transport carbon per dwelling (TCO_{2e})
B1	39.4
E1	42
South Warwickshire average	24.4

Table 7. Broad Spatial Model - transport carbon per dwelling

5.1.14 A comparison of the one-year emissions from 2050 when all dwellings across the plan period have been constructed provides a more comparable transport emissions figure, found in Table 6. This provides a more accurate comparison of the individual site's transport carbon impact by removing variables such as construction rates and construction start dates.

5.1.15 The results for 2050 "in year" emissions follow the same trends as the cumulative emissions with scenario Golf. As with the cumulative emissions, the primary drivers of emissions in scenario Golf are sites B1 and E1. For the one-year emissions, this is primarily driven by the total population and the site's location at an LSOA level. However, it should be noted that the mode split between B1 and E1 is slightly different with site B1 resulting in greater transport use from every mode, including bus emissions. Bus emissions do not decarbonise across the Local Plan period; therefore, greater bus use is partially responsible for higher total emissions in 2050 for site B1.

Scenario	Total transport emissions (TCO_{2e})	Electric car kilometres	Non-electric car kilometres	Bus kilometres
SG09	11,006	215,629,673	42,581,608	10,067,027
SG04	12,071	189,391,479	43,096,509	16,138,765
SG08	7,519	153,757,183	22,959,578	16,378,334
SG05	9,195	188,209,495	28,067,639	20,044,841

Table 8. Total transport carbon from the 4 least intensive sites

5.1.16 Table 8 above shows the four sites with the lowest associated transport emissions. All sites shown in table 8 are below 1000 dwellings. The locational impacts of the LSOA a site is situated within will impact the total number of trips taken by a new household annually. However, sites with fewer overall dwellings can show comparatively fewer transport emissions, even in less integrated areas, as a larger site in a more integrated location may result in more absolute vehicle trips and thus more transport emission over the local plan period.

5.1.17 The transport results for scenario Golf are shown below. Transport distances are driven by several factors, including population growth rates and site location.

Scenario	Total transport emissions (TCO_{2e})	Electric car kilometres	Non-electric car kilometres	Bus kilometres
Golf	978,710	33,599,207,281	2,749,690,552	2,552,971,124

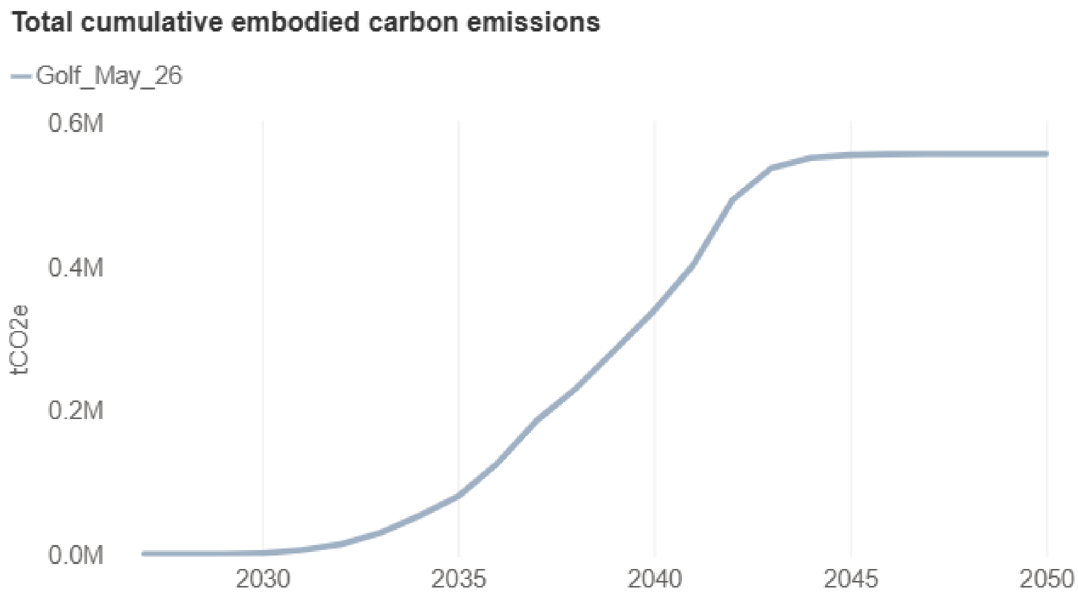
Table 9. Transport carbon emission summary

5.2 Embodied Carbon Emissions Analysis

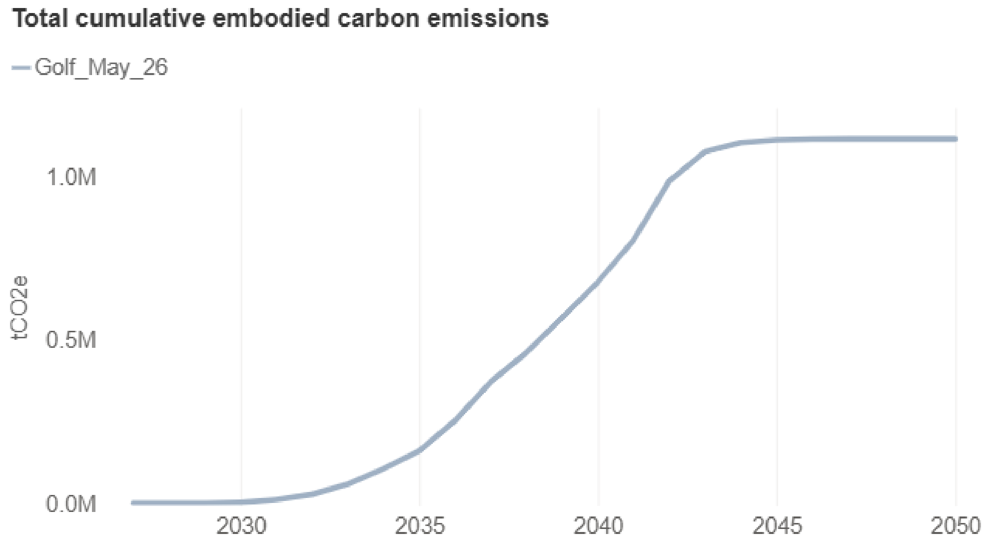
5.2.1 Embodied carbon is the carbon emissions associated with the materials used in construction and site-based construction emissions. Embodied carbon emissions shown within this analysis represent modules A1-A5 emissions, accounting for the embodied carbon of the raw materials, manufacturing processes, transport to the construction site and site-based construction emissions. For scenario Golf, embodied carbon emissions represent a significant portion of the overall cumulative scenario carbon emissions.

5.2.2 Graph 4a and 4b show the cumulative embodied carbon emissions associated with scenario Golf from only residential sources. Cumulative embodied carbon emissions rise in line with the number of houses built in each year, levelling out once all houses have been built across the scenario. Graph 4a and 4b show the difference between the business as usual/standard building regulations (BAU) baseline and the low embodied carbon pathway used in scenario Golf. Since the same number of homes and the same build-out profile are applied in both cases, the difference reflects the assumed embodied carbon performance of new development rather than changes in delivery timing.

5.2.3 The BAU trajectory totals approximately 1.4 million tCO_2e by 2050, compared with a total of approximately 0.73 million tCO_2e under the low embodied carbon pathway. This highlights the importance of introducing embodied carbon requirements early, as these emissions are largely locked in at the point of construction.



Graph 4a. Cumulative residential embodied carbon emissions over the plan period – low embodied carbon pathway policies applied

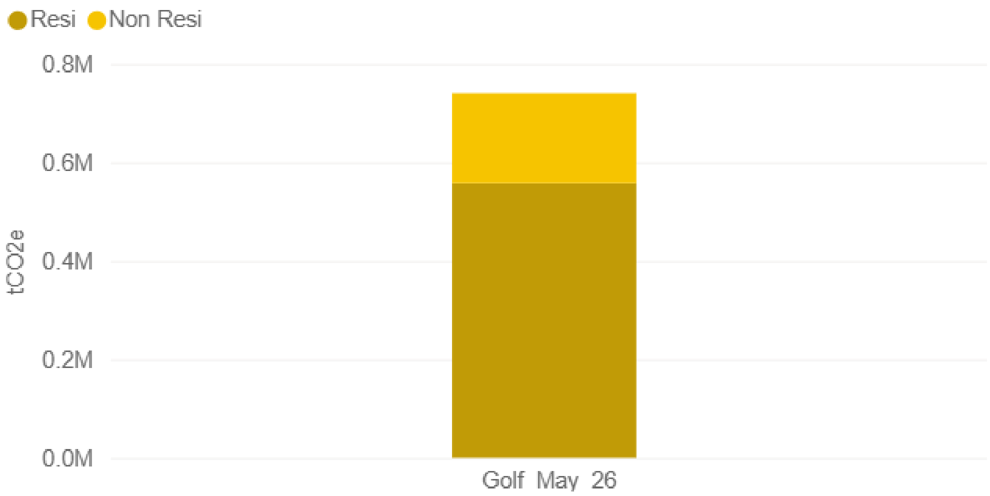


Graph 4b. Cumulative residential embodied carbon emissions over the plan period – BAU policies applied

5.2.4 Graph 5 shows the total embodied carbon associated with scenario Golf, including residential and non-residential carbon emissions. Scenario Golf results in 181,852 TCO_{2e} from non-residential sources. The required GIA of non-residential buildings is assumed within the tool based on the total number of dwellings input at a specific location.

5.2.5 Scenario Golf results in 558,020 TCO_{2e} from the 31,918 residential buildings, built before 2050.

5.2.6 Total embodied carbon emissions, from residential and non-residential sources, from scenario Golf are predicted to be 739,872TCO_{2e}.



Graph 5. Cumulative residential and non-residential embodied carbon emissions

Scenario	Total embodied carbon (TCO_{2e})	Total per dwelling embodied carbon (TCO_{2e})	Residential embodied carbon (TCO_{2e})	Non-residential embodied carbon. (TCO_{2e})
Golf	739,872	23.2	558,020	181,852

Table 10. Embodied carbon emissions

5.3 Operational Energy and Carbon Emissions Analysis

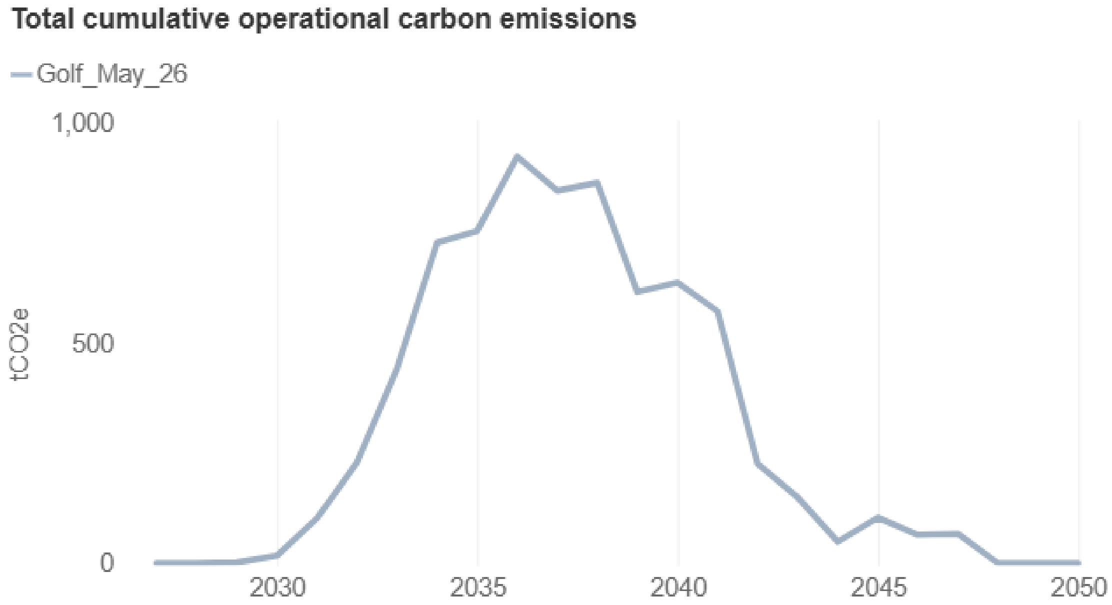
5.3.1 Operational emissions are the emissions associated with the energy use of both residential and non-residential buildings. Emissions from both electricity and gas consumption are measured within the Net-zero Spatial Planning Tool. However, because of the variables selected indicating a decarbonisation trajectory, both residential and non-residential buildings are assumed to utilise electric heating; therefore, no gas emissions are produced under either scenario.

Operational energy residential first 5 years	Mainstream low energy
Operational energy residential after 5 years	Mainstream low energy
Operational energy non-residential first 5 years	All heat pump with PV
Operational energy non-residential after 5 years	All heat pump with PV

Table 11. Operational energy variables selected

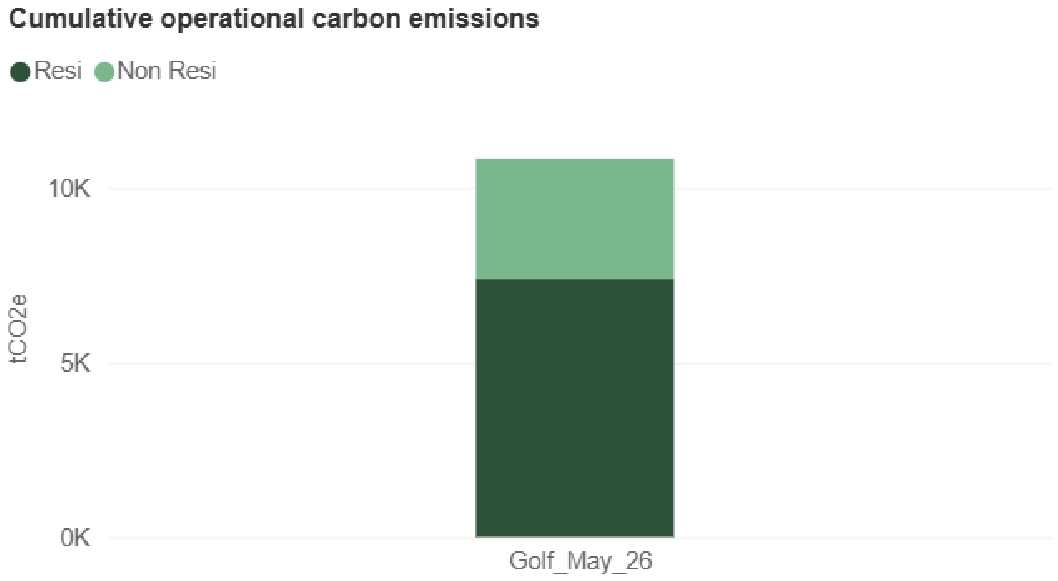
5.3.2 Overall operational carbon emissions represent a small portion of the total site emissions compared to transport and embodied carbon emissions. Since there are no modelled gas emissions, and the grid decarbonises, operational emissions also decarbonise, reducing their cumulative and annual impact. For scenario Golf, operational emissions are the smallest single source of carbon emissions.

5.3.3 Graph 6 shows operational emissions rising with the number of new dwellings built in each year, peaking in 2036 before slowly declining as the grid decarbonises. Operational emissions increase again between 2039 and 2041 as a significant number of additional dwellings are built before decreasing again in line with grid decarbonisation. Annual operational emissions increase during the main build-out period, reflecting the increasing number of completed and occupied dwellings rather than a deterioration in building performance.



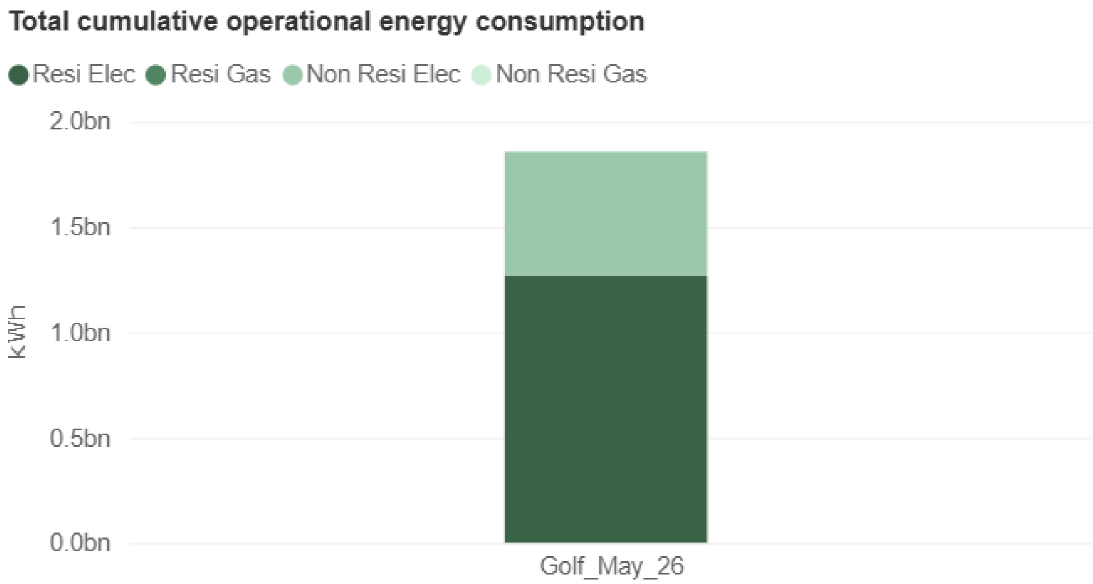
Graph 6. Annual operational carbon emissions TCO_2e (mainstream low energy trajectory)

5.3.4 Graph 7 shows the cumulative operational emission from scenario Golf. Both emissions from residential sources and non-residential sources are shown within this graph. Scenario Golf will result in a total operational energy consumption of 1,856,344,662 kWh. As with embodied carbon, these results track the total number of dwellings built within the local plan period.



Graph 7. Cumulatative operational energy emissions TCO_{2e}

5.3.5 This same trend is reflected in the cumulative **energy consumption** figures shown in Graph 8.



Graph 8. Cumulative energy consumption, kWh

5.3.6 As can be seen in Graph 8, there are no emissions related to the consumption of gas. This results from the variables chosen, which deem that all heating from residential and non-residential new buildings will not utilise gas systems.

5.3.7 The majority of the electricity consumption across the local plan period is from residential sources, which results in 1,268,247,430 29 kWh of electricity consumption from scenario Golf.

5.3.8 As expected, the total non-residential energy consumption is significantly lower over the local plan period, with 588,097,232 kWh of electricity consumption from scenario Golf.

Scenario	**Total operational energy emissions (TCO_{2e})**	**Residential electricity consumption (kWh)**	**Non-residential electricity consumption (kWh)**
Golf	10,841	1,268,247,430	588,097,232

Table 12. Operational carbon emission summary

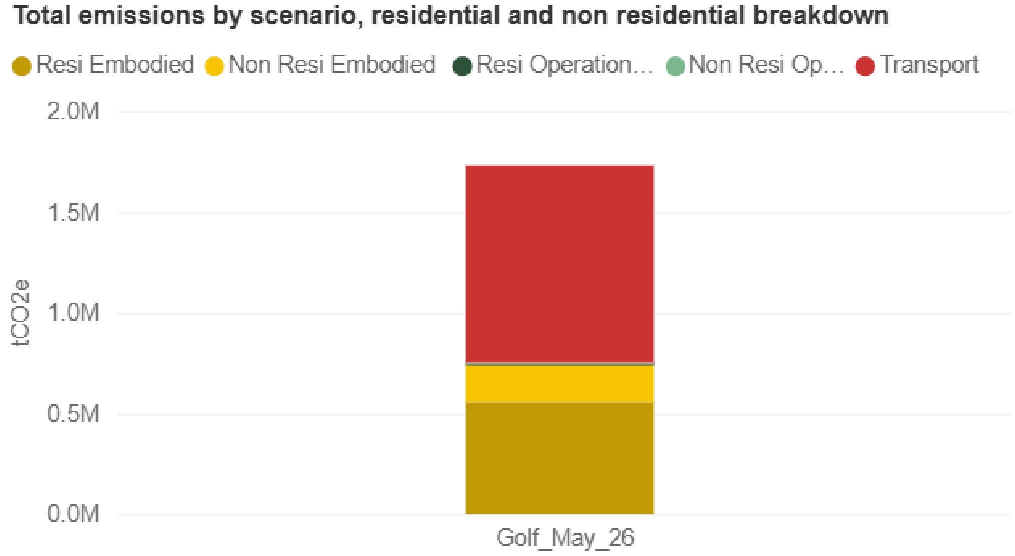
6. Conclusions

6.1 Within scenario Golf, Transport emerges as the largest source of emissions, exceeding Embodied carbon emissions by 238,838 TCO_{2e}. While Operational energy accounts for just ~0.63% of all emissions modelled for scenario Golf.

6.2 This analysis highlights the importance of transport emissions throughout the local plan period. Transport emissions are responsible for ~56.6% of all emissions modelled from scenario Golf. Transport emissions are impacted by site location, population and construction start and end dates. Transport emissions are primarily driven by two sites B1 and E1. Both sites B1 and E1 are located within LSOAs with lower levels of transport integration compared to the South Warwickshire average. However, it should also be noted that B1 and E1 have the largest number of housing units modelled within scenario Golf, 4000 and 4500 dwellings respectively, which compounds the cumulative carbon emissions associated with these sites.

6.3 Embodied carbon emissions account for ~42.8% of all emissions modelled from scenario Golf. Embodied carbon emissions track the total number of dwellings built, with non-residential embodied carbon emissions are assumed based on the total number of dwellings allocated to a site. It should be noted that only modules A1-5 have been modelled within this analysis, with the inclusions of whole life carbon modules B-C total embodied carbon emissions would increase.

6.4 Operational energy emissions account for the smallest fraction of all emissions across scenario Golf, being responsible for just 0.63% of all emissions. Operational energy emissions track with grid decarbonisation, and consequently, operational energy emissions decrease throughout the local plan period, despite operational energy use increasing in line with the number of completed dwellings.



Graph 9. Total cumulative emissions by source