Net-zero Spatial Planning Support

Task 3. Comparative modelling of nine growth scenarios

West Oxfordshire District Council

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Task 3. Overview

Task 3 involved comparing nine potential growth scenarios. Housing numbers for growth scenarios and areas of consideration for each scenario were provided by the client. These were modelled using the Non-Spatial Planning Tool to evaluate carbon emissions from 2026-2041. To improve usability of the study's findings, both minimum and maximum thresholds of the anticipated local plan policies were modelled.

The following scenarios were provided by the client via email on the 29 January 2025.
Scenario 1 - Hierarchical approach

- 2 x strategic allocations would be made at Carterton and Witney
- 1x strategic allocation at Chipping Norton, which is partially in the ANOB
- 1x non-strategic allocation at each of the rural service centres
- 5% growth at each of the larger villages

Scenario 2 - Main Service Centre Focus (Witney, Carterton and Chipping Norton)

- 2 x strategic allocations at Witney and Carterton
- 2 x strategic allocations at Chipping Norton
- 5% growth at each of the Rural Service centres

Scenario 3 - Witney Focus

- The total residual housing requirement would be met at Witney

Scenario 4 - Carterton Focus

- The total housing requirement would be met at Carterton
- As the town boundary is tightly drawn around Carterton, it is recognised that any major development on the edge of Carterton would be located in neighbouring parishes of Brize Norton, Shilton and Alvescot

Scenario 5 - Dispersed Growth

- 15% growth attributed to major service centres
- 10% growth attributed to rural service centres and larger villages in West Oxfordshire

Scenario 6 - Village 'Clusters'

- Like Scenario 5, Scenario 6 is based on a dispersed approach to the future pattern of growth, but instead of villages being treated separately, they would be considered collectively in small groups or 'clusters' based on the services and facilities they are able to cumulatively offer.

Scenario 7a - New Settlement A
Scenario 7b – Mix of New Settlements A and B
Scenario 8 - Public Transport Focus

- Homes along the A40 corridor including at Carterton, Witney and 'elsewhere' along the A40 corridor

- Homes along the Cotswold and Cherwell Valley rail lines including on land adjacent to Hanborough Station and at the other rural service centres and larger villages along both lines

Further details on how this information was processed within the tool are provided in the methodology section below. The analysis evaluated both cumulative and annual carbon emissions across three categories: embodied carbon, operational energy, and transport. All scenarios were assessed using consistent environmental performance assumptions, enabling a direct comparison of the relative impacts arising from different location characteristics and development patterns.

Summary of Results

Across both minimum and maximum policy thresholds, Scenario 7b emerges as the most carbon-efficient overall, consistently achieving the lowest total cumulative emissions and emissions per dwelling. Compact, urban-centric scenarios, notably Scenario 3, also perform strongly, reinforcing that spatial form significantly influences carbon performance. Scenarios characterised by dispersed rural growth, particularly Scenario 5 and 6, consistently demonstrate the highest emissions, underscoring the critical role spatial development patterns play in carbon outcomes, irrespective of policy thresholds.

Transport Emissions

Transport emissions are strongly influenced by spatial patterns, travel demand, and vehicle usage. Scenario 7b consistently records the lowest transport emissions under both policy thresholds, benefiting from shorter cumulative travel distances facilitated by its delayed development timeline and gradual population growth. Scenario 3 also demonstrates strong performance due to its compact urban form promoting public and active transport use. In contrast, dispersed rural scenarios such as Scenarios 5 and 6 consistently generate the highest transport emissions across both thresholds, reflecting greater reliance on private, non-electric vehicles and longer travel distances. Despite significant reductions in absolute emissions under the maximum threshold due to higher electric vehicle uptake, relative rankings among scenarios remain stable, indicating that spatial planning has a greater impact than policy alone on transport emissions.

Embodied Carbon Emissions

Embodied carbon emissions remain primarily driven by spatial form and construction volume, but reductions are supported by higher policy ambition. Scenario 2 consistently emerges as the most efficient for embodied carbon across both thresholds, due to lower dwelling numbers and urban-focused development that supports compact, efficient construction typologies. Scenarios 5 and 6, featuring large volumes of dispersed rural growth, consistently produce higher embodied carbon emissions due to increased material demands and infrastructure requirements associated with lower-density development. Thus, reductions in embodied emissions are best achieved through prioritising compact urban development patterns combined with ambitious policy.

Operational Carbon Emissions

Operational carbon emissions significantly decrease under the maximum policy threshold due to improved building energy efficiency and full electrification. Nonetheless, spatial form continues to influence operational carbon performance notably. Scenarios with delayed development timelines, specifically Scenario 7a and Scenario 7b, perform exceptionally well, benefiting from later completion dates, resulting in lower cumulative operational emissions. Scenario 3 also consistently performs well, reflecting compact building typologies with reduced energy demands. Conversely, Scenario 5, with its early completion date and rural-focused development, consistently has the highest operational emissions under both thresholds. This demonstrates that spatial strategy significantly impacts operational carbon outcomes, even under ambitious energy efficiency standards.

In summary, spatial form and start/finish years decisively influence carbon outcomes across transport, embodied, and operational emissions regardless of policy ambition.

Although the results suggest that Scenario 7b (a new settlement) is the most carbon-efficient, contextual factors such as its later start and finish years should be considered when evaluating its relative merits compared to Scenario 3.

Methodology

For this task, The Non-Spatial Carbon Model was used, as the broad development areas were known whilst the detailed LSOA-level locations were undecided. This tool enables assessment and comparison of the carbon impacts of different growth scenarios before the specific development locations are identified. It does so by applying consistent environmental performance assumptions across all scenarios, based on input variables.

The tool provides cumulative carbon emissions outputs across three key categories: embodied carbon, operational energy, and transport. It 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 both embodied and operational energy.

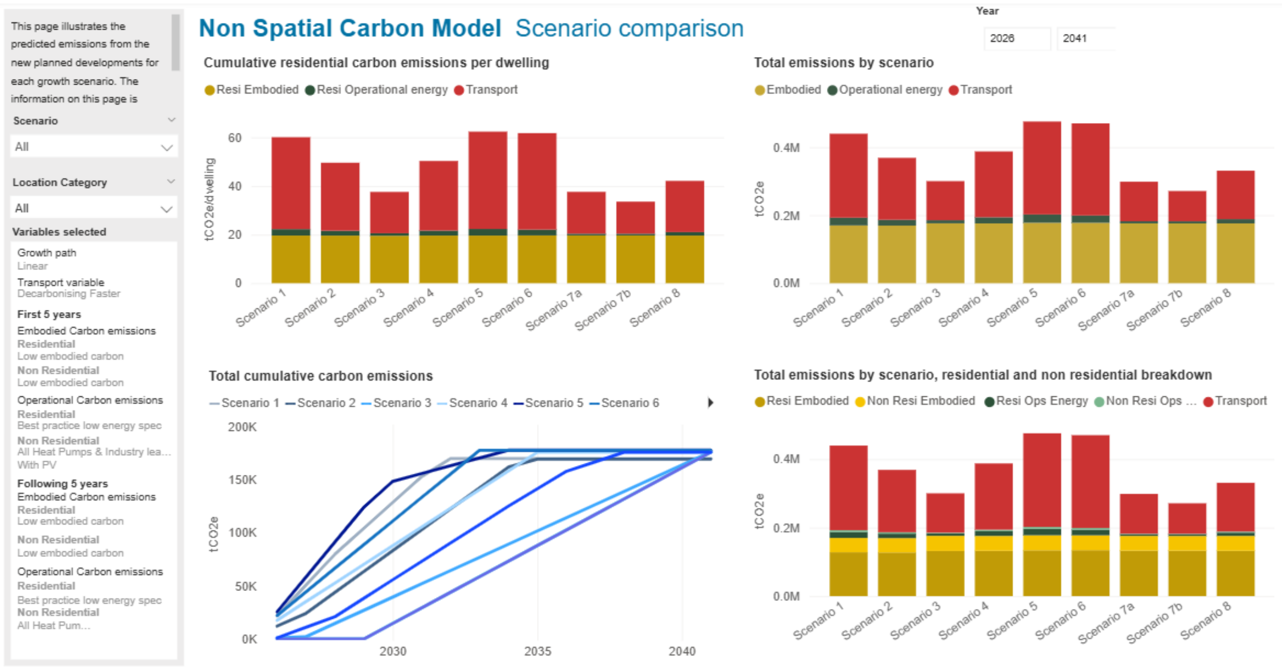

Figure 1. Scenario Comparison page of the Non-Spatial Carbon Model

The transport page outputs include cumulative emissions per dwelling, emissions by mode of transport, total annual emissions, and distances travelled by transport mode.

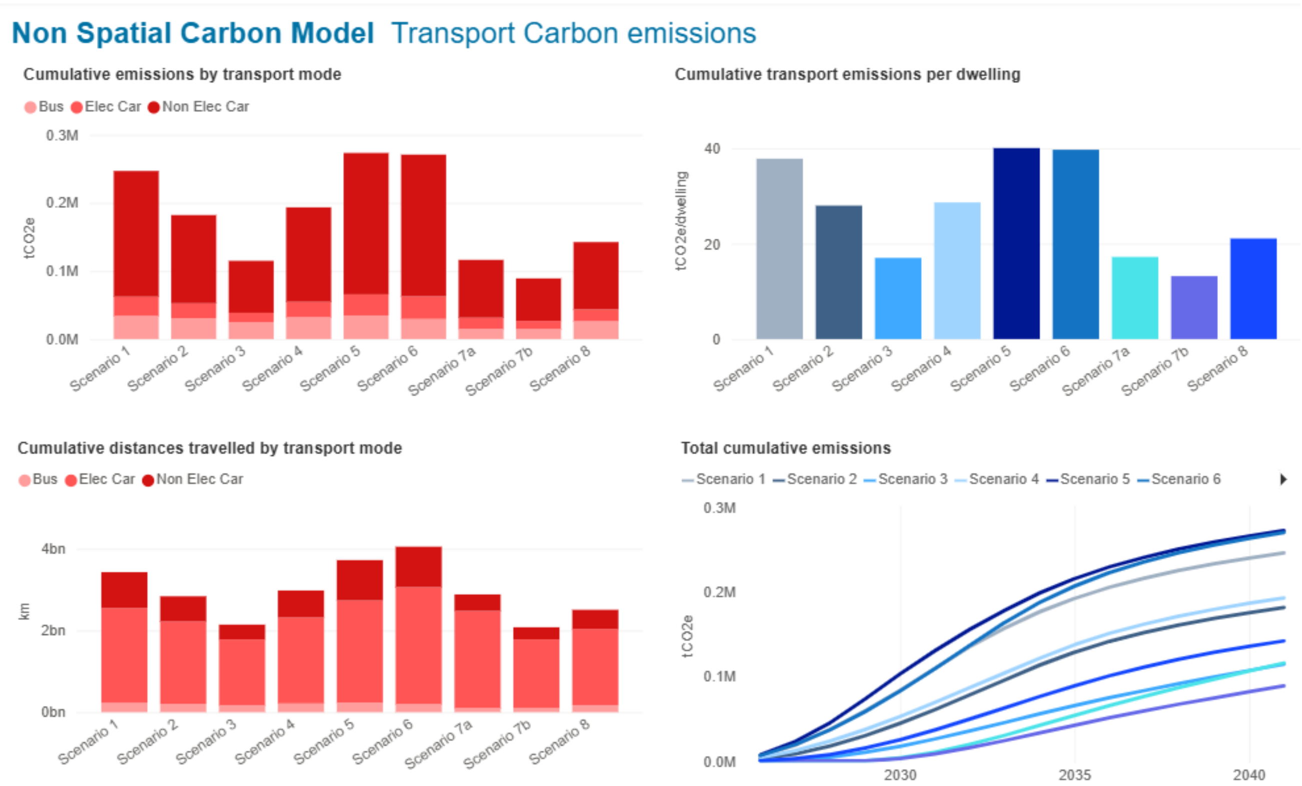

Figure 2. The Transport page of the Non-Spatial Carbon Model

The embodied carbon page focuses on cumulative emissions from construction materials and processes, including annual totals and emissions per residential dwelling.

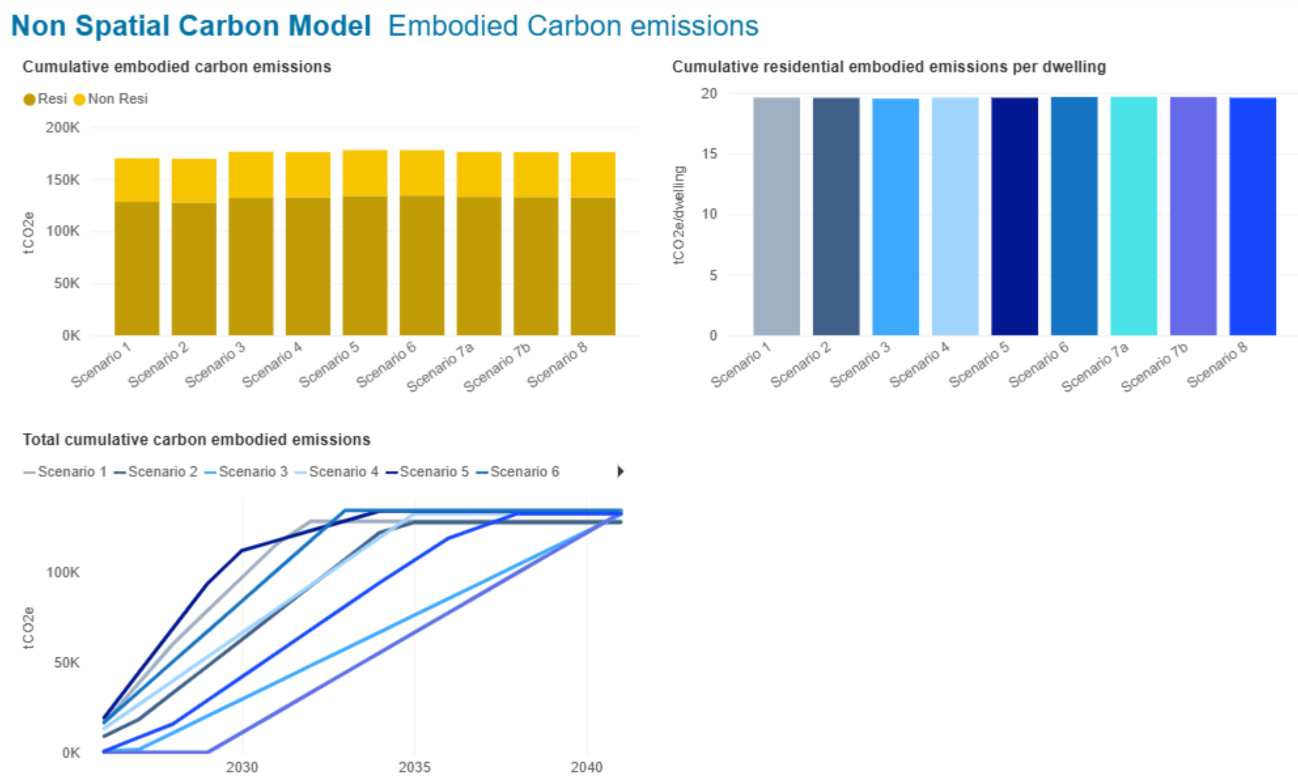

Figure 3. The Embodied Carbon page of the Non-Spatial Carbon Model

The operational energy page details cumulative energy-related emissions, distinguishing between residential and non-residential buildings, and shows annual energy consumption by source, such as gas and electricity.

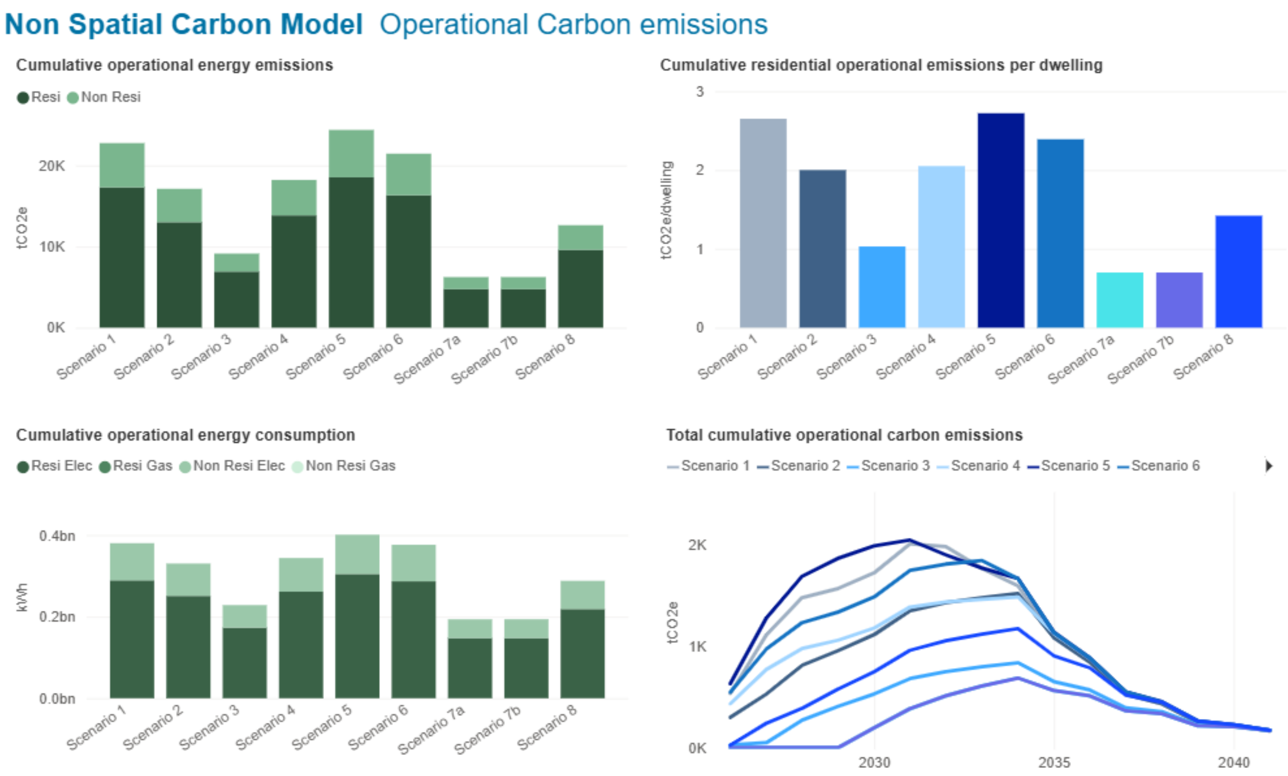

Figure 4. The Operational Energy page of the Non-Spatial Carbon Model

These outputs allow for an early-stage assessment of the relative carbon impacts of different growth strategies, supporting more informed strategic planning decisions. In response to client feedback, both maximum and minimum thresholds for anticipated policy impacts were modelled, resulting in two distinct sets of variables. The maximum threshold reflects the implementation of ambitious decarbonisation policies, while the minimum threshold assumes no additional measures beyond current Part L building regulations.

The variable settings applied in the model were informed by anticipated policy developments and client input:

Variable	Minimum	Maximum
Growth Path	Linear	
EV uptake	Decarbonising	Decarbonising Faster
Embodied Carbon Emissions (First 5 years)	Residential: Average	Residential: Low
	Non-Residential: Average	Non-Residential: Low
Embodied Carbon Emissions (Following 5 years)	Residential: Average	Residential: Low
	Non-Residential: Average	Non-Residential: Low
Operational Carbon Emissions (First 5 years)	Residential: Current New Build Home	Residential: Best Practice Low Energy Spec

	Non-Residential: Gas boiler with PV	Non-Residential: All Heat Pumps & Industry Leading Fabric Efficiency (With PV)
Operational Carbon Emissions (Following 5 years)	Residential: 75% reduction vs Part L 2013	Residential: Best Practice Low Energy Spec
	Non-Residential: All Heat Pumps (With PV)	Non-Residential: All Heat Pumps & Industry Leading Fabric Efficiency (With PV)

Figure 5. Table of variables for Task 2

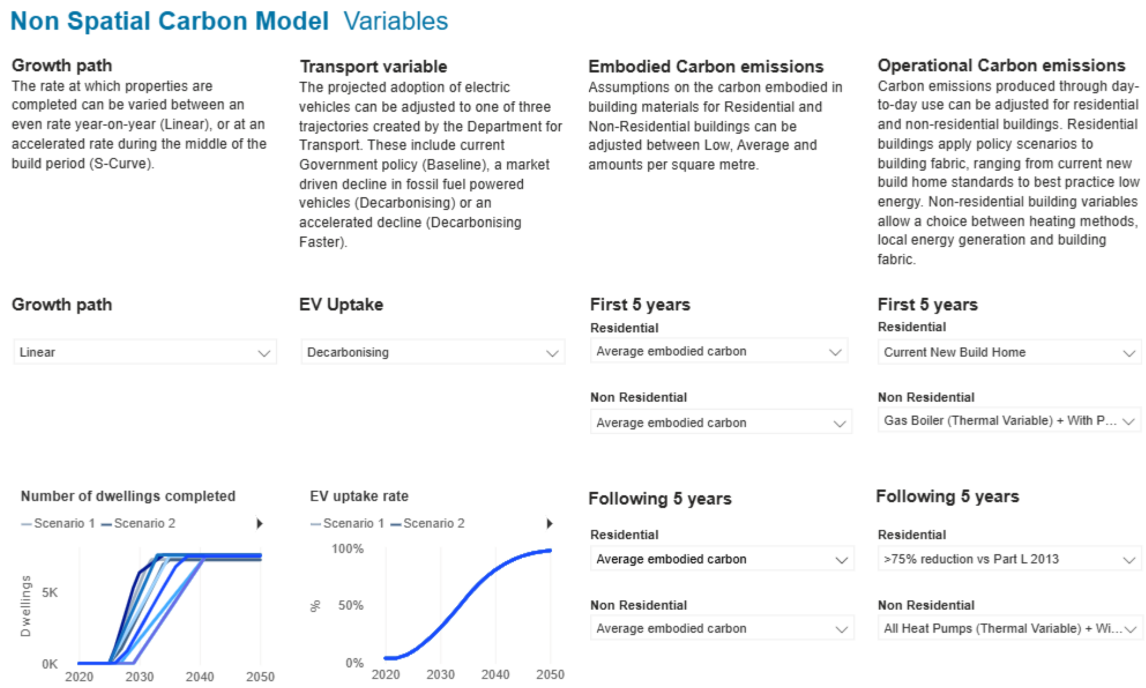

Figure 6. Non-Spatial Location tool variables panel settings for Task 2

It is important to note that the start and finish years of development, alongside the location categories, simultaneously influence emissions outcomes for each scenario. As a result, it is not possible to establish a direct correlation between a single variable and total emissions.

For this analysis, the locations specified under each client-provided scenario were first matched to their corresponding Lower Layer Super Output Area (LSOA) location categories. These categories comprise: urban conurbation, urban city and town, rural town and fringe and rural village and dispersed. Full definitions of these classifications are available in the accompanying methods document. Within each scenario, the number of dwellings within each location category was aggregated to determine the total housing count per category. For locations sharing the same category, an average development start and end years were calculated. A summary of this information is presented in the table below:

Scenario	Location Category	Total Housing Number for the Location Category	Average Start Year for the Location Category	Average Finish Year for the Location Category
1. Hierarchical	Urban conurbation	0	N/A	N/A
	Urban city and town	1420	2027	2031
	Rural town and fringe	4563	2026	2032
	Rural village and dispersed	542	2026	2028
2. Main service centre focus	Urban conurbation	0	N/A	N/A
	Urban city and town	2329	2028	2035
	Rural town and fringe	4175	2026	2034
	Rural village and dispersed	0	N/A	N/A
3. Witney focus	Urban conurbation	0	N/A	N/A
	Urban city and town	6075	2028	2041
	Rural town and fringe	0	N/A	N/A
	Rural village and dispersed	675	2026	2041
4. Carterton focus	Urban conurbation	0	N/A	N/A
	Urban city and town	2025	2026	2035
	Rural town and fringe	4725	2026	2035
	Rural village and dispersed	0	N/A	N/A
5. Dispersed growth	Urban conurbation	0	N/A	N/A
	Urban city and town	2245	2027	2034
	Rural town and fringe	3277	2026	2030
	Rural village and dispersed	1300	2026	2029
6. Village clusters	Urban conurbation	0	N/A	N/A
	Urban city and town	0	N/A	N/A
	Rural town and fringe	3776	2026	2033
	Rural village and dispersed	3045	2026	2033
7a. New settlement (single)	Urban conurbation	0	N/A	N/A
	Urban city and town	0	N/A	N/A
	Rural town and fringe	0	N/A	N/A
	Rural village and dispersed	6750	2030	2041
7b. New settlement (split across two)	Urban conurbation	0	N/A	N/A
	Urban city and town	0	N/A	N/A
	Rural town and fringe	3375	2030	2041
	Rural village and dispersed	3375	2030	2041
8. Public transport focus	Urban conurbation	0	N/A	N/A
	Urban city and town	2250	2029	2036
	Rural town and fringe	4163	2027	2038
	Rural village and dispersed	338	2026	2034

Figure 7. Table of scenarios

The Non-Spatial Growth Scenario Template was populated with data for all scenarios, which formed the basis of the analysis presented through the Power BI dashboard. It was assumed that around 6,500 homes would be delivered by each scenario over the 2026–2041 period.

Analysis (Minimum Policy Threshold)

Transport Emissions Analysis

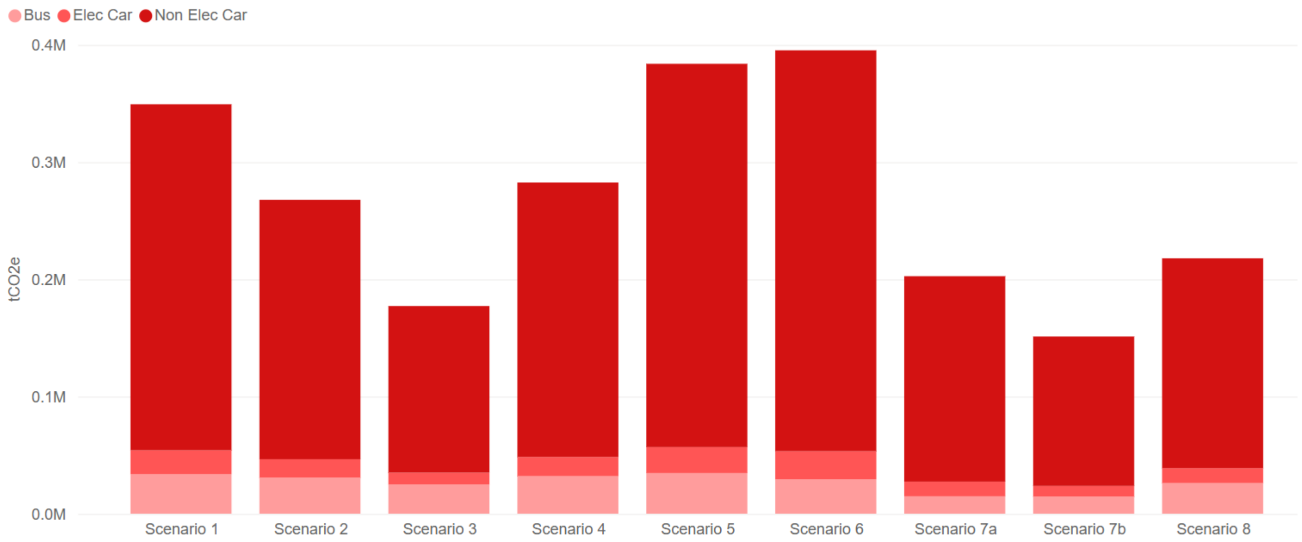

Figure 8. Cumulative emissions by transport mode

Transport emissions constitute a major portion of the total carbon output across all nine development scenarios. These emissions are largely influenced by the spatial distribution of development, the total distance travelled by residents, and the extent to which private vehicles dominate mode share. Cumulative transport emissions across the scenarios reveal substantial variation, reflecting the importance of development timelines and locations in shaping travel behaviour and associated carbon impacts.

Scenario 6 generates the highest cumulative transport emissions, reaching approximately 395,404 tCO_2e by 2041, which is roughly three times the emissions of the best performing scenario, 7b. This result is driven by high car dependency, particularly involving non-electric vehicles, and extensive travel distances caused by dispersed development patterns. In this scenario, non-electric cars alone account for over 1.6 billion km travelled, contributing 342,118 tCO_2e. Electric vehicles and buses also play a role but contribute significantly less to overall emissions across all scenarios. The early start and finish years, as well as high total dwelling numbers also contribute to this result.

Scenario 6 additionally records the highest emissions per dwelling at 57.92 tCO_2e, highlighting its inefficiency both in absolute terms and relative impact.

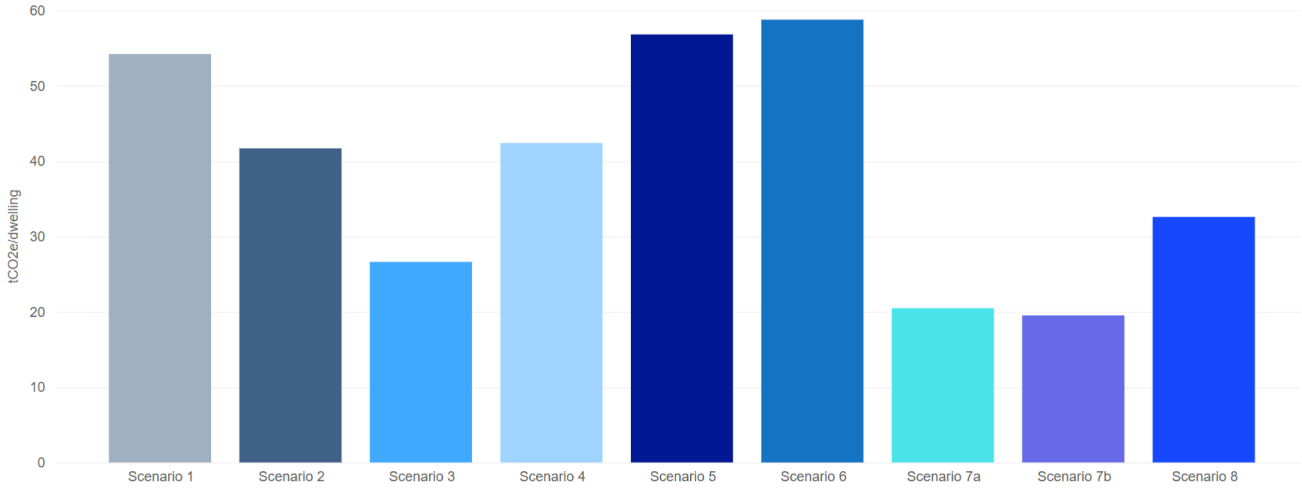

Figure 9. Cumulative transport emissions per dwelling

Scenario 5 closely follows Scenario 6, with total transport emissions of 383,882 tCO_2e. Similar to Scenario 6, Scenario 5 features spatial distribution that disperses growth across various location categories, including 'rural village and dispersed' areas with limited access to public transport and active travel infrastructure. When combined with an early finish year, this scenario generates extensive travel demand and high reliance on car-based travel, especially non-electric vehicles.

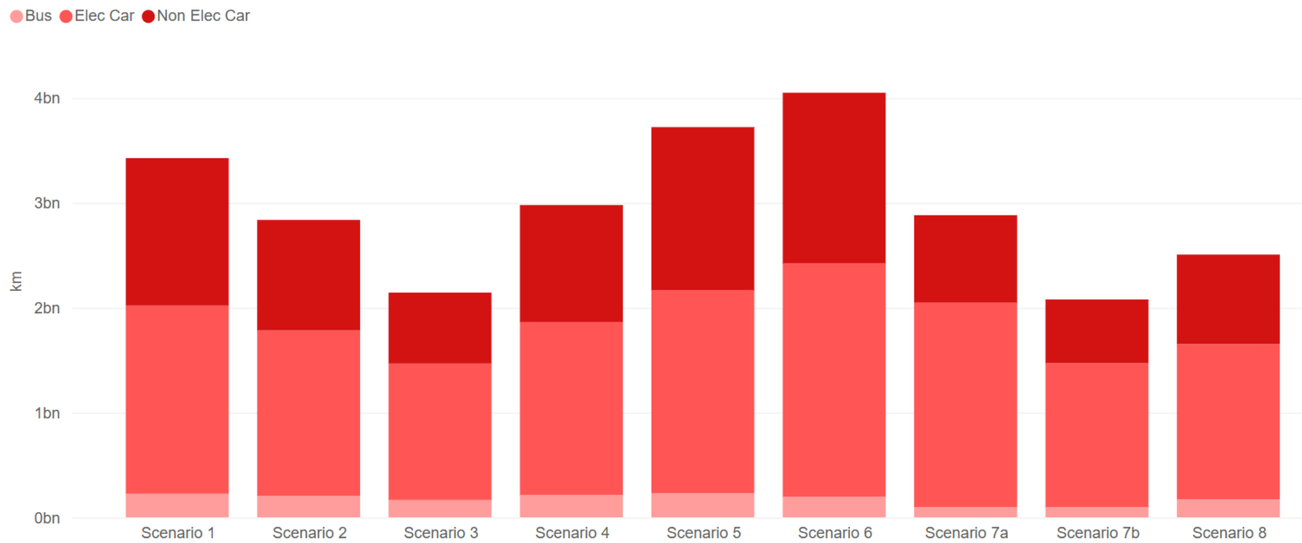

Figure 10. Cumulative distances travelled by transport mode

At the opposite end of the spectrum, Scenario 7b achieves the lowest transport-related emissions of all scenarios, with a cumulative total of 151,224 tCO_2e. On a per-dwelling basis, it is also the strongest performer, generating just 22.40 tCO_2e per home delivered.

Similarly, Scenario 7a achieves a cumulative total of 202,650 tCO_2e. These outcomes reflect reduced cumulative travel distances and assume that a later finish year allows for more effective policy implementation and delayed population growth. Notably, over 50% of travel in Scenario 7b and 7a is projected to be by electric vehicles, demonstrating the increasing prevalence of EV adoption over time and a significant reduction in reliance on conventional vehicles.

Scenario 3 yields similarly positive results, with total transport emissions of 177,209 tCO_2e. Its emphasis on compact, urban-focused development leads to shorter average trip lengths and improved transport efficiency.

Across all scenarios, non-electric vehicles remain the dominant source of transport emissions, accounting for at least 80% of the total. Scenarios characterised by early completion dates and a reliance on rural or dispersed growth patterns show significantly higher emissions, due to longer travel distances and limited uptake of electric vehicles. In contrast, scenarios that concentrate growth in urban centres and extend development timelines enable reduced car dependency and greater adoption of cleaner technologies.

In conclusion, Scenario 7b emerges as the most transport-efficient option, followed closely by Scenario 7a and Scenario 3. Scenario 6 performs least favourably, recording the highest emissions in both total and per-dwelling terms.

Rank	Scenario	Total carbon emissions
1	7b	151,224 tCO_2e
2	3	177,209 tCO_2e
3	7a	202,650 tCO_2e
4	8	217,901 tCO_2e
5	2	267,839 tCO_2e
6	4	282,588 tCO_2e
7	1	349,339 tCO_2e
8	5	383,882 tCO_2e
9	6	395,404 tCO_2e

Figure 11. Table of summary of transport carbon emissions

Embodied Carbon Emissions Analysis

Embodied carbon emissions represent a significant portion of total emissions across all development scenarios. These emissions are driven by both the quantity of dwellings delivered and the split between residential and non-residential development.

The cumulative residential embodied carbon emissions graphs show that embodied carbon emissions are highly concentrated in the early years of the plan period. Most of the embodied carbon emissions occur between 2026 and 2035, aligning with peak housing delivery. After this point, emissions flatten in line with an active reduction of construction.

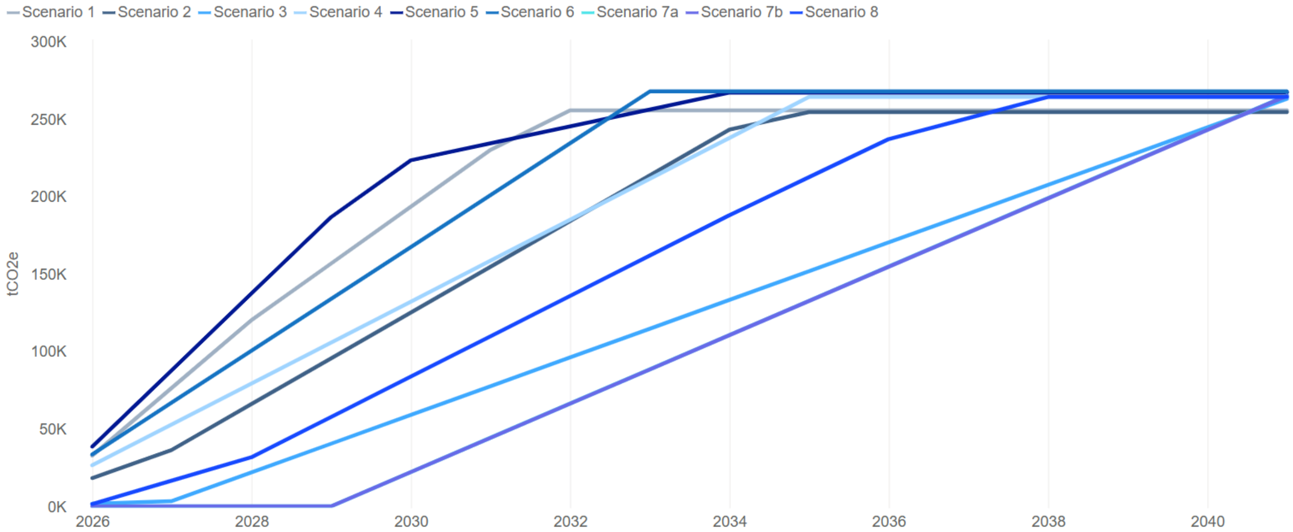

Figure 12. Cumulative residential embodied carbon emissions

Scenario 5 records the highest embodied carbon emissions, with cumulative emissions of 336,448 tCO_2e. This outcome is largely driven by the scenario having the highest total dwelling number and focusing on delivering a high proportion of dwellings within rural areas, typically resulting in higher embodied carbon per unit due to lower construction densities and increased infrastructure demands associated with rural development. Approximately 265,076 tCO_2e of the total is attributed to residential buildings, while non-residential components contribute just over 69,372 tCO_2e.

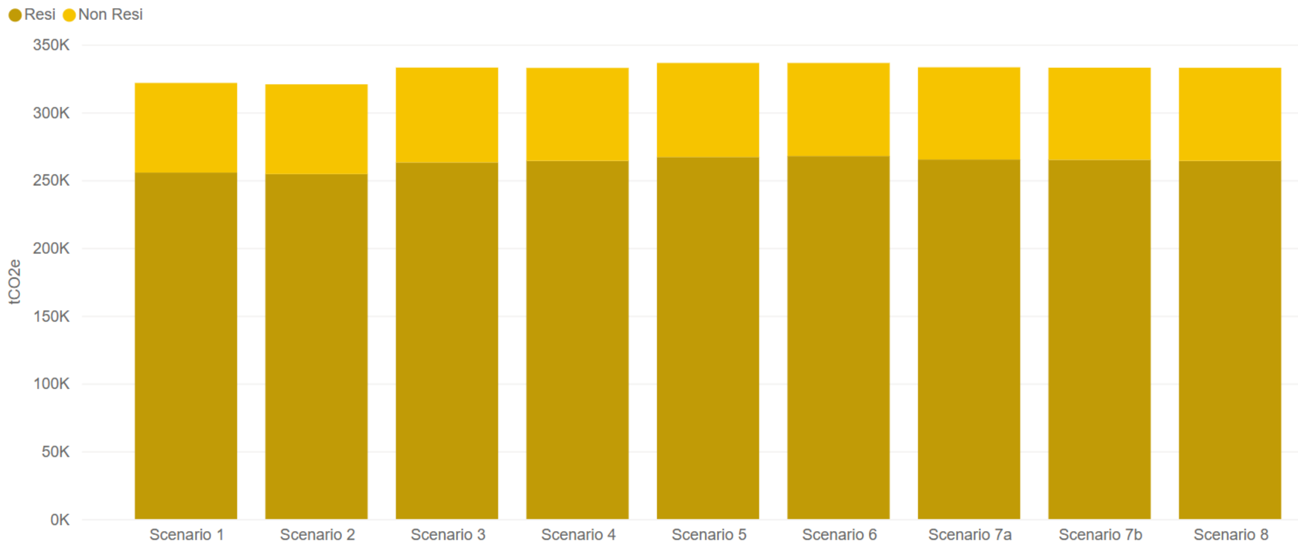

Figure 13. Cumulative embodied carbon emissions

Scenarios 6 and 3 follow closely, each generating over 333,000 tCO_2e in embodied emissions. Scenario 6 reflects both a large volume of development and concentrated growth in rural village and dispersed areas, resulting in similar inefficiencies as Scenario 5, which has greater dwellings but has some development in rural town and fringe.

In contrast, Scenario 2 achieves the lowest total embodied carbon emissions at 320,676 tCO_2e, partly attributable to having the smallest number of dwellings. However, it does not perform the best on a per-dwelling basis, although differences between scenarios are minor. Scenario 3 performs best in terms of residential embodied carbon per dwelling, reflecting compact, efficient building typologies that reduce material use per unit and enable shared infrastructure.

In summary, scenarios that focus on compact, urban development tend to deliver significantly lower embodied carbon emissions, whereas those promoting dispersed, low-density rural growth consistently show higher emissions. As total emissions impact is the primary focus here, the following table is ordered by cumulative embodied carbon emissions.

Rank	Scenario	Total carbon emissions
1	2	320,676 tCO_2e
2	1	321,711 tCO_2e
3	4	332,787 tCO_2e
4	8	332,874 tCO_2e
5	7b	332,957 tCO_2e
6	3	333,030 tCO_2e
7	7a	333,222 tCO_2e
8	6	336,430 tCO_2e
9	5	336,448 tCO_2e

Figure 14. Table of scenarios ranked by embodied carbon emissions

Operational Energy and Carbon Emissions Analysis

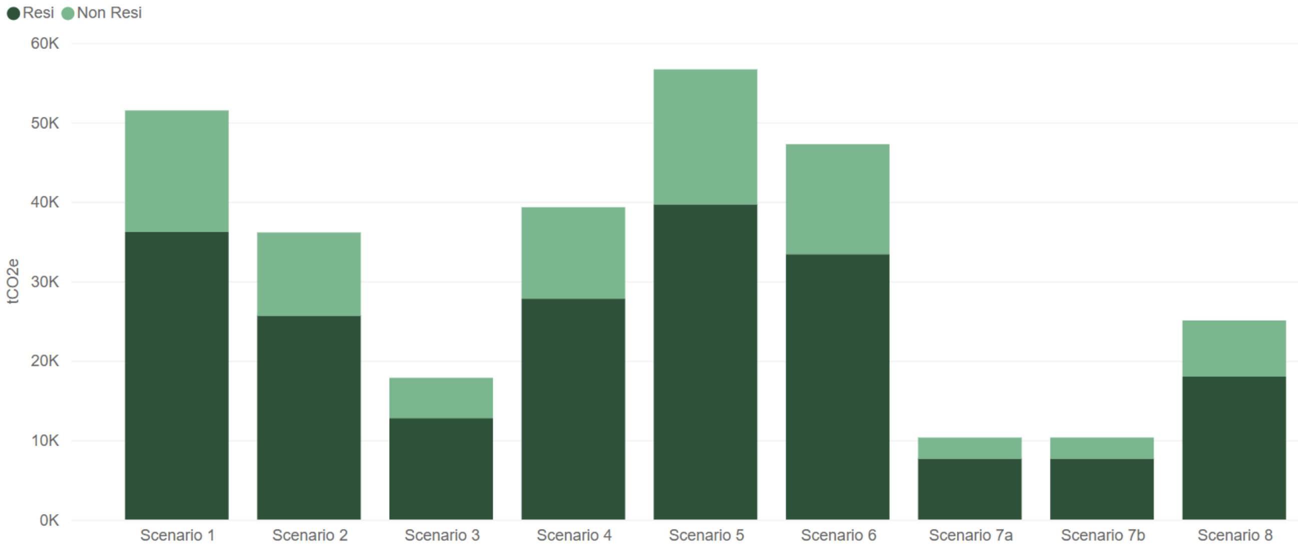

Figure 15. Cumulative operational energy emissions (tCO2e)

Operational energy emissions vary significantly across the nine development scenarios, influenced by the distribution of dwellings between residential and non-residential categories and the choice of energy sources. Scenario 5 generates the highest operational carbon emissions, exceeding 56,600 tCO_2e, driven primarily by substantial electricity and gas consumption across both sectors.

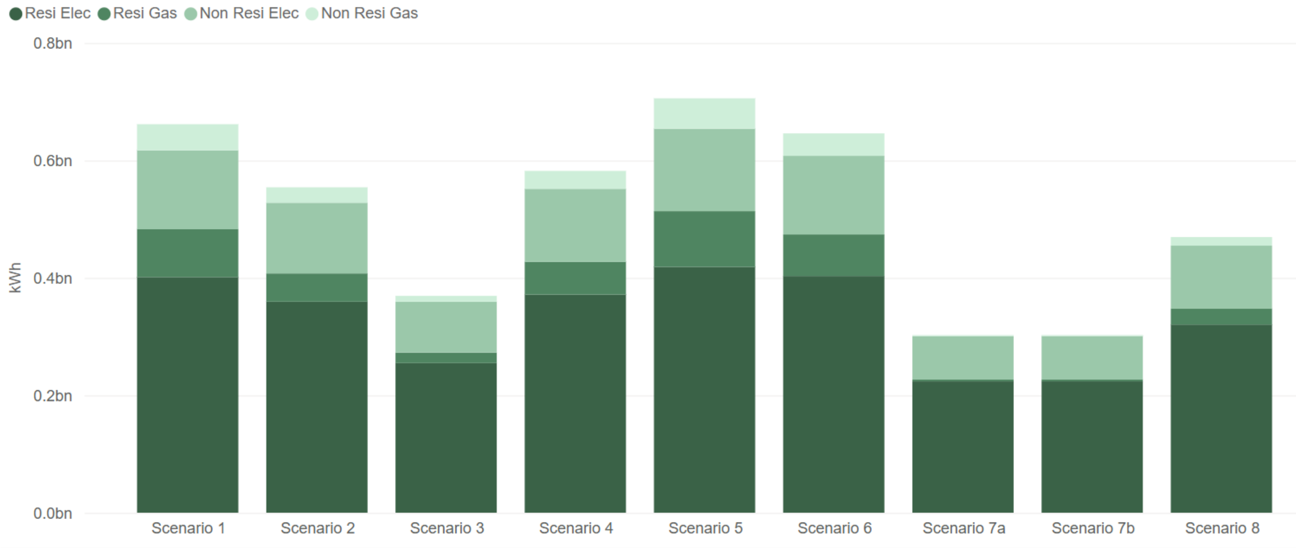

Figure 16. Cumulative operational energy consumption (kWh)

Scenario 1 follows closely with operational emissions surpassing 51,500 tCO_2e, largely due to high residential gas consumption. Scenario 6 also displays elevated operational emissions, around 47,000 tCO_2e, reflecting an early finish year, contributing to prolonged operational emissions and rural development locations.

Conversely, Scenarios 7a and 7b are the most operationally efficient, maintaining emissions below 10,300 tCO_2e despite comparable dwelling numbers. This efficiency results from later development timelines, lower gas use, and increased reliance on cleaner electricity-based systems as the grid decarbonises. These scenarios record the lowest cumulative residential emissions per dwelling (1.14 tCO_2e).

Operational energy consumption data supports these findings. Scenarios 5 and 1 report the highest cumulative energy use, exceeding 0.66 billion kWh, primarily from residential electricity and gas. In contrast, Scenarios 7a and 7b use less than 0.30 billion kWh, highlighting superior operational energy efficiency.

Cumulative operational emissions rise steeply between 2026 and 2030 across scenarios, marking policy transitions at the 5-year plan review. After this peak, emissions gradually decline due to fewer dwellings and grid decarbonisation. Scenario 5 maintains the highest cumulative total, while Scenarios 7a and 7b sustain low emissions trajectories through 2041.

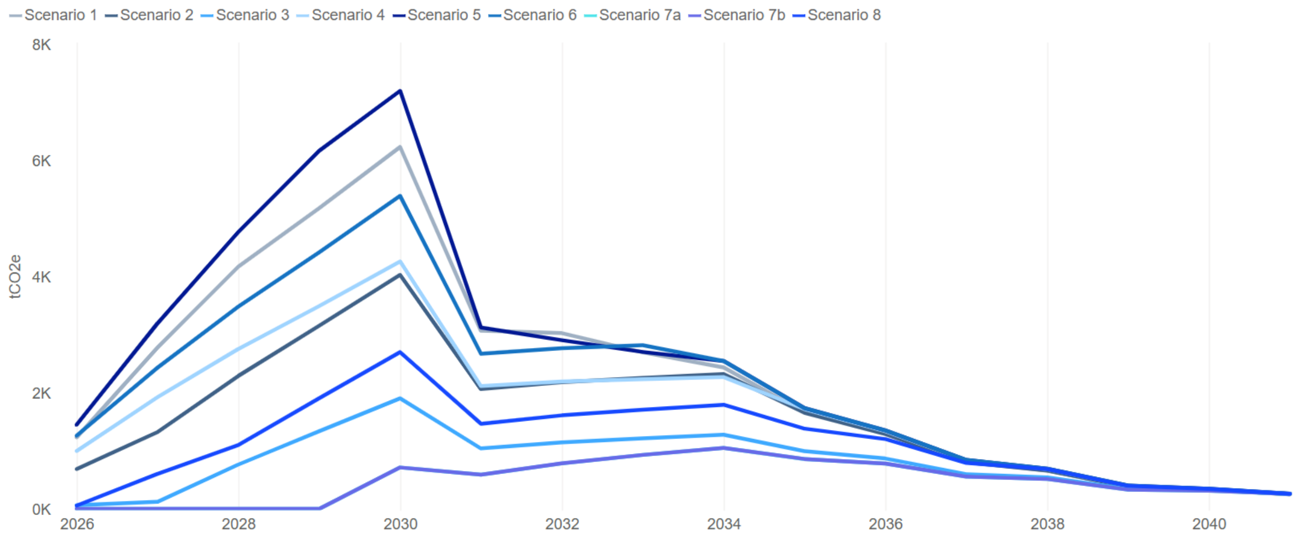

Figure 17. Total annual operational carbon emissions (tCO2e) by scenario

Rank	Scenario	Total carbon emissions
1	7a	10,329 tCO_2e
2	7b	10,331 tCO_2e
3	3	17,845 tCO_2e
4	8	25,067 tCO_2e
5	2	36,152 tCO_2e
6	4	39,328 tCO_2e
7	6	47,265 tCO_2e

8	1	51,514 tCO_2e
9	5	56,683 tCO_2e

Figure 18. Table of scenarios ranked by total operational carbon emissions

Conclusion

Scenario 7b emerges as the most carbon-efficient option overall. It achieves the lowest total cumulative emissions and maintains low emissions per dwelling across transport and operational energy categories. Scenario 7b especially benefits from reduced car dependency, shorter travel distances, and minimal gas consumption due to its later finish year. Although there are scenarios that perform better than Scenario 7b in terms of embodied carbon emissions, its lower transport emissions place them behind it. Scenario 3 performs comparably well, benefiting from concentrated urban growth and moderate emissions across all categories.

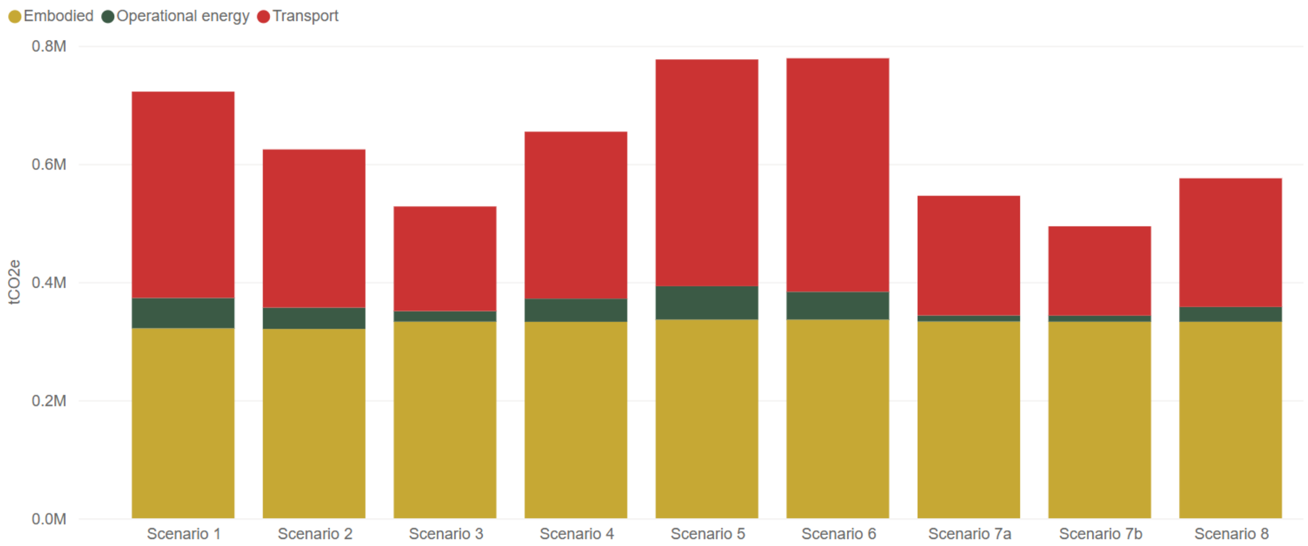

Figure 19. Total cumulative emissions by scenario (tCO2e)

In contrast, Scenario 6 records the highest total emissions, driven by elevated carbon emissions across all categories. Overall, Scenario 7b represents the most effective strategy for supporting a transition to net zero, delivering substantial housing growth with the lowest overall emissions and balanced outcomes across embodied, operational, and transport domains.

Rank	Scenario	Total carbon emissions

1	7b	494,512 tCO_2e
2	7a	528,084 tCO_2e
3	3	546,201 tCO_2e
4	8	575,842 tCO_2e
5	2	624,667 tCO_2e
6	4	654,703 tCO_2e
7	1	722,564 tCO_2e
8	5	777,013 tCO_2e
9	6	779,099 tCO_2e

Figure 20. Table of scenarios ranked by total carbon emissions

Analysis (Maximum Policy Threshold)

Transport Emissions Analysis

Under the maximum policy threshold, transport emissions significantly vary across scenarios, primarily influenced by travel demand and modal share.

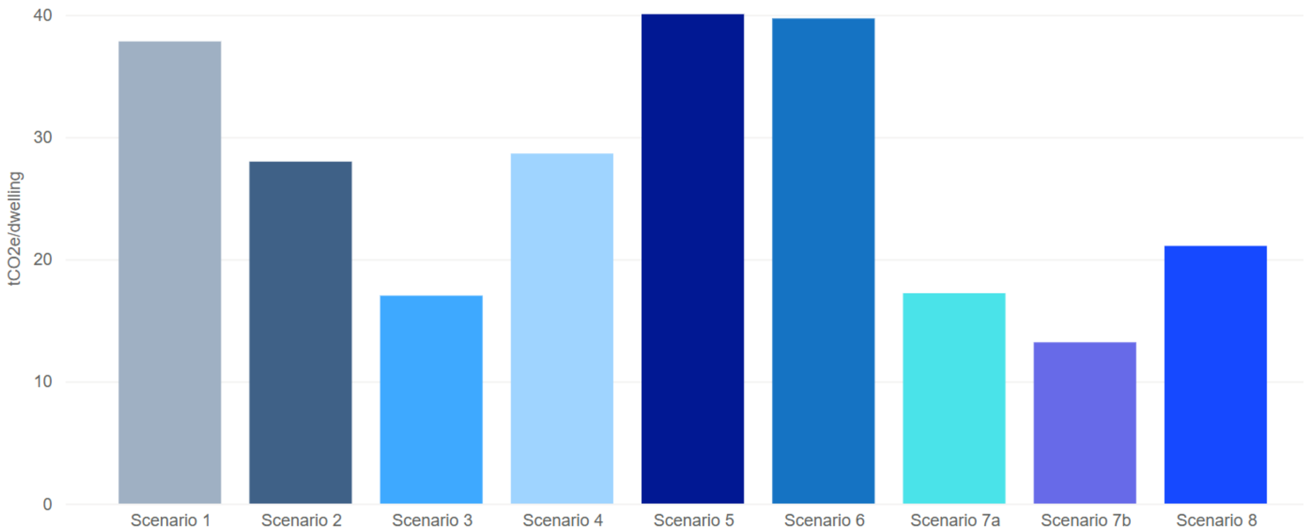

Figure 21. Cumulative transport emissions per dwelling

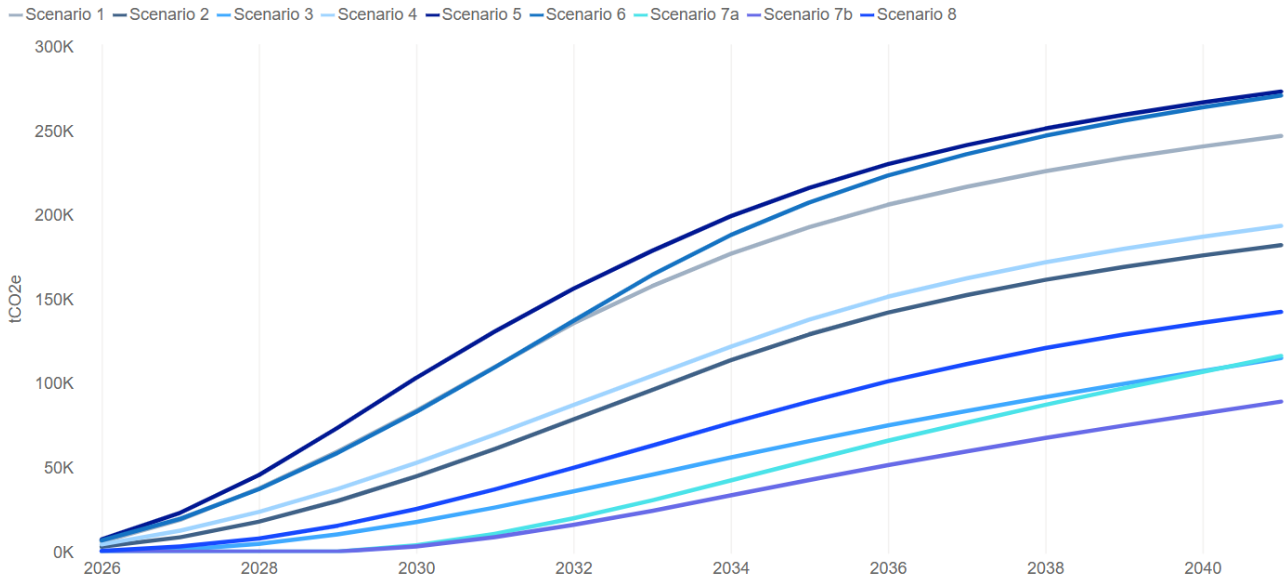

Figure 22. Annual transport emissions

Transport emissions vary dramatically across the nine spatial growth scenarios, but one clear pattern emerges: non-electric vehicles (non-EV cars) are overwhelmingly the primary driver of total transport carbon. There is an almost perfect linear relationship between total transport emissions and non-EV car emissions, meaning that virtually all of the variation in total transport carbon across scenarios can be explained by differences in non-EV car usage.

When examining each scenario's breakdown, non-EV cars account for between 66% and 77% of total transport emissions. Even the lowest-carbon scenarios, 7a, 7b, and 3, derive more than two-thirds of their transport emissions from non-EV cars. Scenario 7b emits the least transport carbon overall (89,076 tCO_2e), of which 62,380 tCO_2e (70%) is attributable to non-EV cars. In contrast, the highest emitters, Scenarios 5 and 6, produce over 270,000 tCO_2e each, with non-EV car emissions comprising roughly 76% of that total.

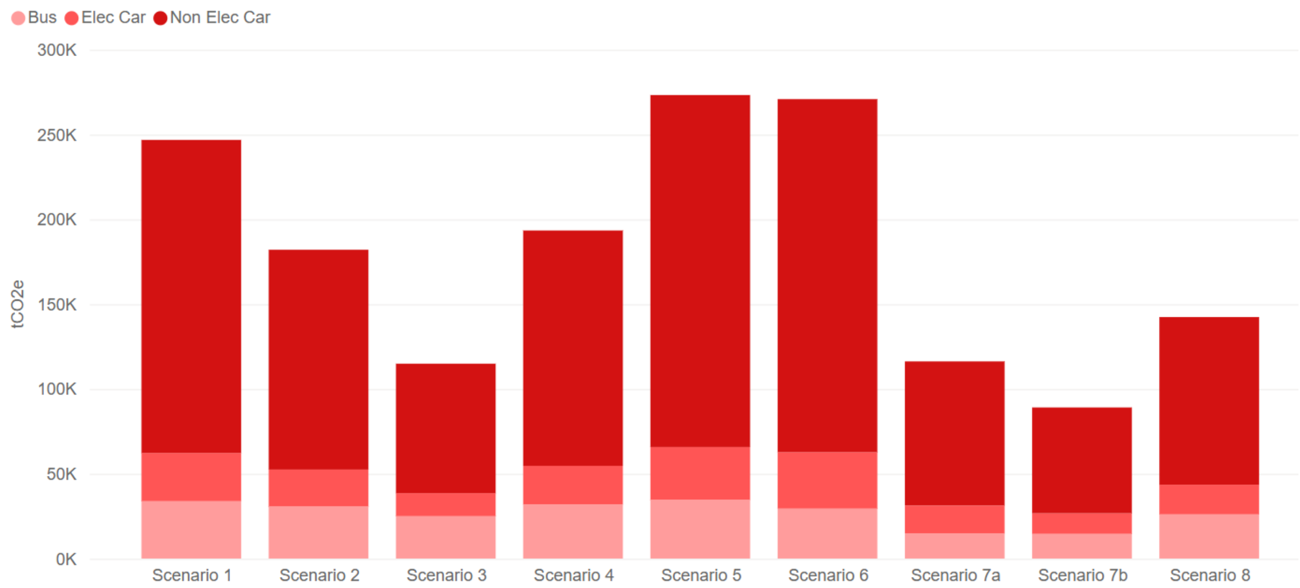

Figure 23. Cumulative emissions by transport mode

The overwhelming dominance of non-electric vehicles across all scenarios highlights a critical leverage point for reducing transport-related emissions: minimising car-based travel yields the most significant carbon savings. Even in scenarios with high levels of electric vehicle adoption, non-EVs consistently remain the largest single source of transport emissions. This underscores the importance of spatial strategies that reduce car dependency, particularly through higher-density development in 'urban city and town' locations, which facilitate greater uptake of public and active transport options. This dynamic plays a key role in explaining the strong performance of Scenario 3, where compact growth patterns significantly limit reliance on car travel. Scenario 7b performs slightly better than Scenario 3 in terms of transport emissions, achieving the lowest total transport emissions of all scenarios: 89,076 tCO_2e in total, or just 13.20 tCO_2e per dwelling. This performance also relates to the fact that Scenarios 3, 7b, and 7a succeed in minimising car kilometres more effectively, potentially due to a longer development period and slower associated population growth. However, it is important to interpret these results with caution. While Scenario 7b outperforms others based on transport emissions alone, its practical feasibility should be assessed alongside these contextual constraints as this is a new settlement.

Rank	Scenario	Total carbon emissions
1	7b	89,076 tCO_2e
2	3	114,891 tCO_2e
3	7a	116,249 tCO_2e
4	8	142,374 tCO_2e

5	2	182,962 tCO_2e
6	4	193,419 tCO_2e
7	1	246,824 tCO_2e
8	6	270,866 tCO_2e
9	5	273,272 tCO_2e

Figure 24. Table of summary of transport carbon emissions

Embodied Carbon Emissions Analysis

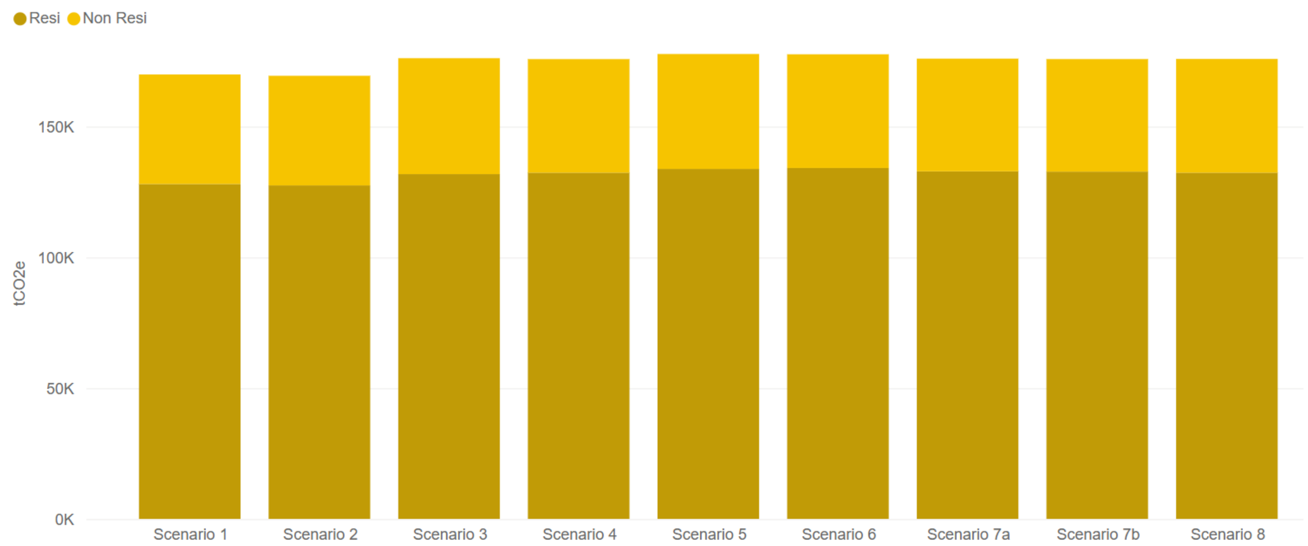

Figure 25. Cumulative embodied carbon emissions

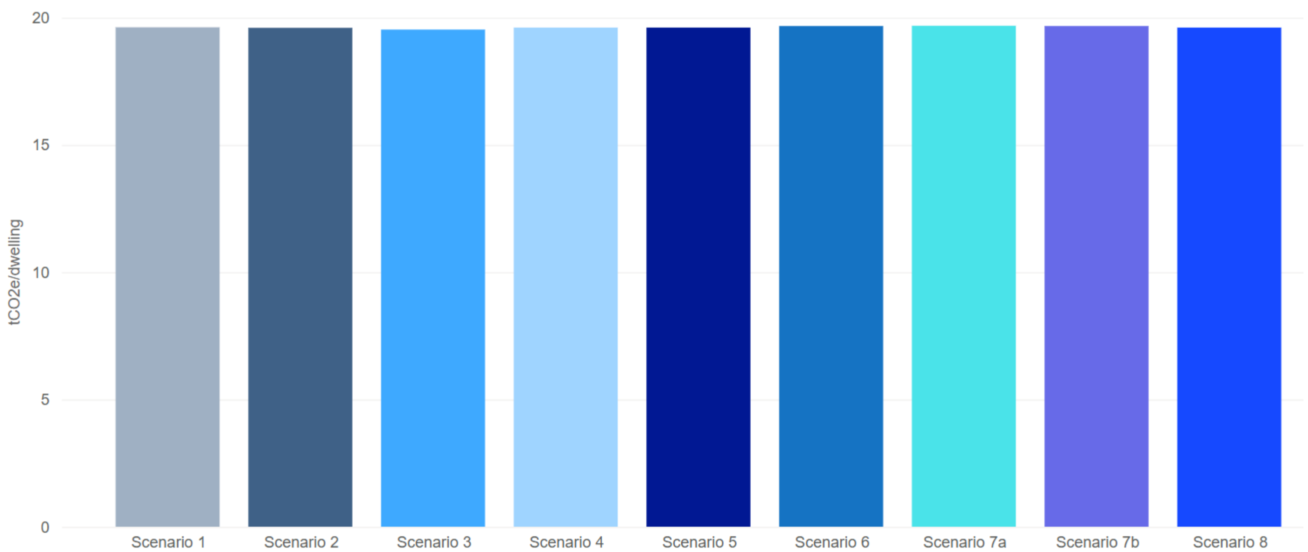

Figure 26. Cumulative residential embodied carbon emissions per dwelling

An analysis of embodied carbon emissions across the nine development scenarios reveals a range of insights that go beyond total emissions figures alone.

Scenario 2 emerges as the most carbon-efficient in terms of embodied emissions, generating the lowest total (169,384 tCO_2e). This is marginally more efficient than Scenario 1, which records a cumulative total of 169,887 tCO_2e over the plan period.

Beyond these two scenarios, a cluster of mid-performing options, including Scenarios 4, 7b, and 8, reveals further nuance. Cumulative embodied carbon emissions gradually increase from Scenario 4 to 7b to 8. However, when focusing purely on residential embodied carbon emissions, emissions increase in the order of 8, 4, and 7b. This suggests that even though Scenarios 3 and 7a delivers housing more material-efficiently, other scenarios involve greater non-residential embodied carbon due to proximity to urban areas, ultimately resulting in high total embodied carbon emissions. Scenario 8 outperforming Scenario 4 for residential emissions can be explained by the fact that Scenario 4 has the highest dwelling numbers. The relationship between Scenario 8 and 7b's residential emissions can be explained by 7b concentrating growth in rural areas, which tend to require more material inputs per unit of housing delivered.

Although the residential versus non-residential split remains broadly consistent across scenarios (approximately 75% residential and 25% non-residential), the location of development and development period play a more decisive role in shaping embodied carbon outcomes. Therefore, Scenarios 5 (197,434 tCO_2e) and 6 (197,338 tCO_2e) clearly perform poorly in this respect. Both scenarios have the highest dwelling numbers, with a considerable portion allocated to rural areas, including the "rural village and dispersed" category. Their significantly higher emissions, both total and per dwelling, suggest they should only be considered where a strong policy rationale exists to support expansive built forms or higher volumes of non-residential floorspace.

Rank	Scenario	Total carbon emissions
1	2	169,384 tCO_2e
2	1	169,887 tCO_2e
3	4	175,759 tCO_2e
4	7b	175,771 tCO_2e
5	8	175,820 tCO_2e
6	7a	175,940 tCO_2e
7	3	176,106 tCO_2e
8	6	177,602 tCO_2e
9	5	177,714 tCO_2e

Figure 27. Table of scenarios ranked by embodied carbon emissions

Operational Energy and Carbon Emissions Analysis

Operational carbon analysis: Operational carbon emissions under the maximum policy threshold vary considerably across the nine development scenarios, reflecting the interaction between spatial form, building density, and energy efficiency. While all scenarios assume fully electrified buildings and benefit from grid decarbonisation, the differences in total emissions and per-dwelling carbon intensity remain substantial.

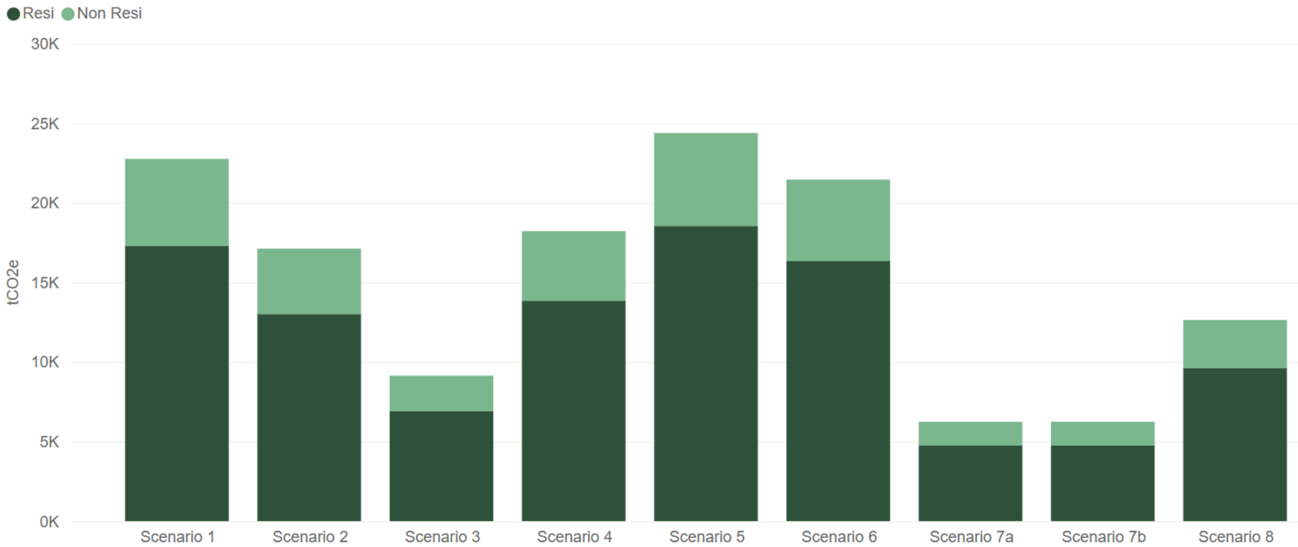

Figure 28. Cumulative operational carbon emissions (tCO2e)

The clearest pattern to emerge is the consistent outperformance of scenarios with later finish years. Scenario 7a performs the best, closely followed by Scenario 7b. Both scenarios start development in 2030 and finish in 2041, as much as 10 years later than other scenarios. This significantly impacts operational carbon as dwellings' cumulative contribution to operational carbon emissions decreases with later finish years, due largely to grid decarbonisation and delayed population growth. Their total operational emissions remain around 6,200 tCO_2e, and their cumulative residential emissions per dwelling are among the lowest at approximately 0.7 tCO_2e. The difference between Scenarios 7a and 7b (4 tCO_2e) is largely due to Scenario 7b emitting greater non-residential operational carbon as it has some dwellings allocated near urban areas ("rural town and fringe"). Aside from these two best performers, Scenario 3 demonstrates relatively lower residential and non-residential operational carbon emissions, driven by its late finish year (2041).

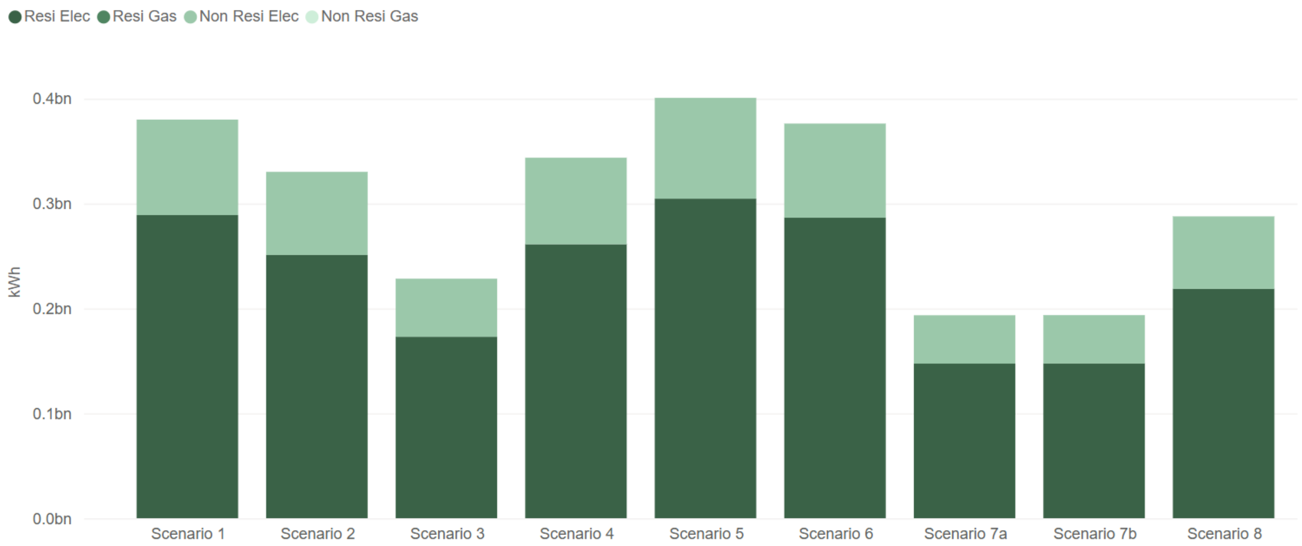

Figure 29. Cumulative operational energy consumption (kWh)

By contrast, Scenario 5 stands out as the poorest performer in this category. It generates over 24,000 tCO_2e in total operational emissions, nearly 4 times that of the best-performing scenarios, and records the highest per-dwelling emissions as well. This is likely to be due to early finish year of 2031 and highest total dwelling numbers on top of considerable portion allocation in rural areas.

Scenarios with moderate finish years (2035 and 2036) such as Scenario 2, Scenario 4, and Scenario 8, all fall in the middle of the spectrum. These scenarios distribute growth across a combination of urban and rural locations, resulting in operational emissions that sit between the high and low extremes. While their per-dwelling emissions are higher than those of the most efficient scenarios, they remain significantly below the levels recorded in Scenario 5. This suggests that moderate-density developments can achieve acceptable operational performance, though they may not realise the full carbon savings associated with compact urban growth.

In conclusion, Scenarios 7a, closely followed by Scenario 7b, offer the strongest operational carbon performance, both in absolute terms and on a per-dwelling basis. The findings suggest that under an ambitious policy environment, the timing of development has a more pronounced impact.

Rank	Scenario	Total carbon emissions
1	7a	6,238 tCO_2e
2	7b	6,242 tCO_2e

3	3	9,137 tCO_2e
4	8	12,635 tCO_2e
5	2	17,120 tCO_2e
6	4	18,219 tCO_2e
7	6	21,454 tCO_2e
8	1	22,759 tCO_2e
9	5	24,382 tCO_2e

Figure 30. Table of scenarios ranked by total operational carbon emissions

Conclusion

The cumulative emissions profile of each scenario highlights the significant influence of spatial form on the carbon lifecycle of new development. Scenario 7b emerges as the most carbon-efficient, delivering the lowest total carbon emissions across most dimensions at 271,089 tCO_2e. Unsurprisingly, Scenario 7a follows closely behind, as both scenarios benefit from strong performance in operational and transport emissions, largely influenced by their later finish years, which allow more time for decarbonisation policies to take effect. However, both scenarios are outperformed in the embodied carbon category, as their focus on rural development results in a higher material footprint associated with dispersed, low-density growth.

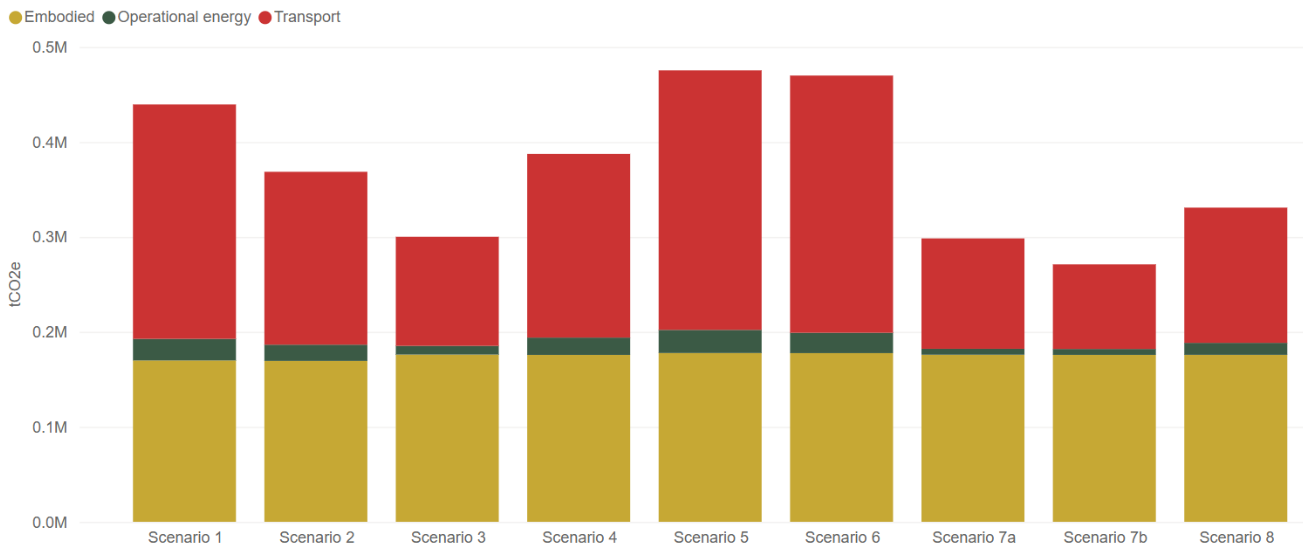

Figure 31. Total cumulative emissions by scenario (tCO2e)

In contrast, Scenario 5 presents the least favourable outcome in terms of total lifecycle emissions, with a cumulative footprint of 475,368 tCO_2e, which is approximately 75% higher than that of Scenario 7b. This result reflects a more dispersed and carbon-intensive spatial strategy, marked by extensive reliance on rural settlements and low-density forms. A detailed breakdown reveals that transport emissions alone account for 273,272 tCO_2e, or roughly 60% of total emissions, highlighting the inefficiencies of early development that inevitably result in greater non-electric car dependency.

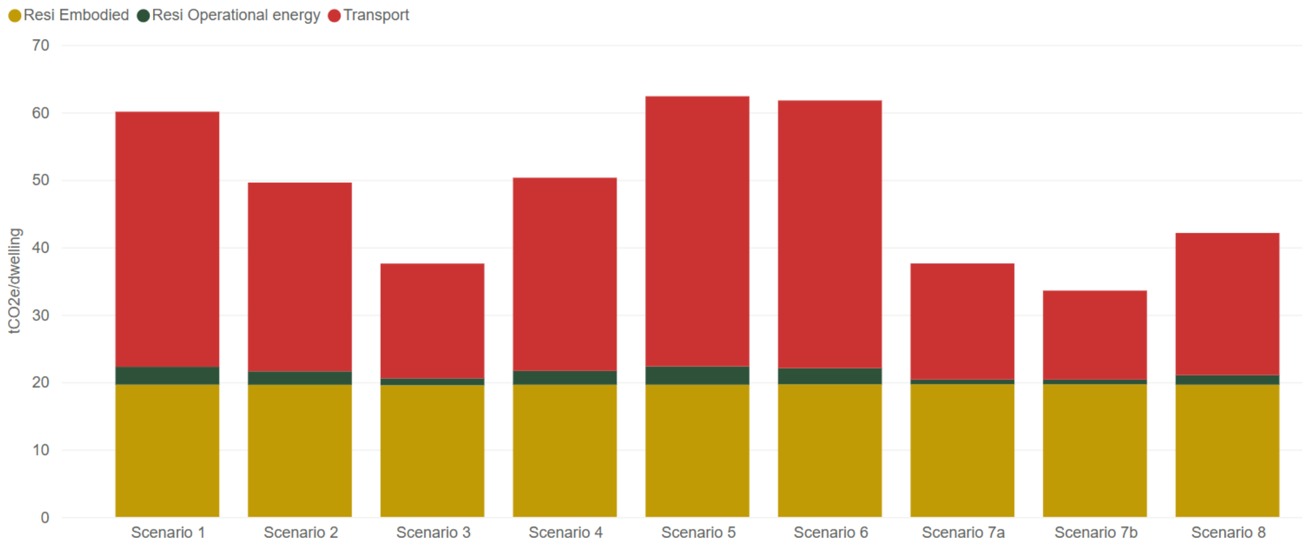

Figure 32. Cumulative residential carbon emissions per dwelling

When examining per-dwelling emissions for residential development, the difference between Scenario 1 and Scenario 5 decreases. This is primarily due to their earlier finish years, indicating a more rapid population influx that contributes to higher cumulative operational and transport emissions.

In conclusion, based on total carbon emissions, Scenarios 7b and 7a are the most favourable options, aligning with findings under the minimum policy threshold scenario. Their compact, urban-focused strategies and later development timelines offer the greatest potential for achieving low-carbon growth.

Rank	Scenario	Total carbon emissions
1	7b	271,089 tCO_2e
2	7a	298,427 tCO_2e
3	3	300,134 tCO_2e
4	8	330,828 tCO_2e
5	2	368,565 tCO_2e
6	4	387,397 tCO_2e
7	1	439,470 tCO_2e
8	6	469,922 tCO_2e

9	5	475,368 tCO_2e

Figure 33. Table of scenarios ranked by total carbon emissions