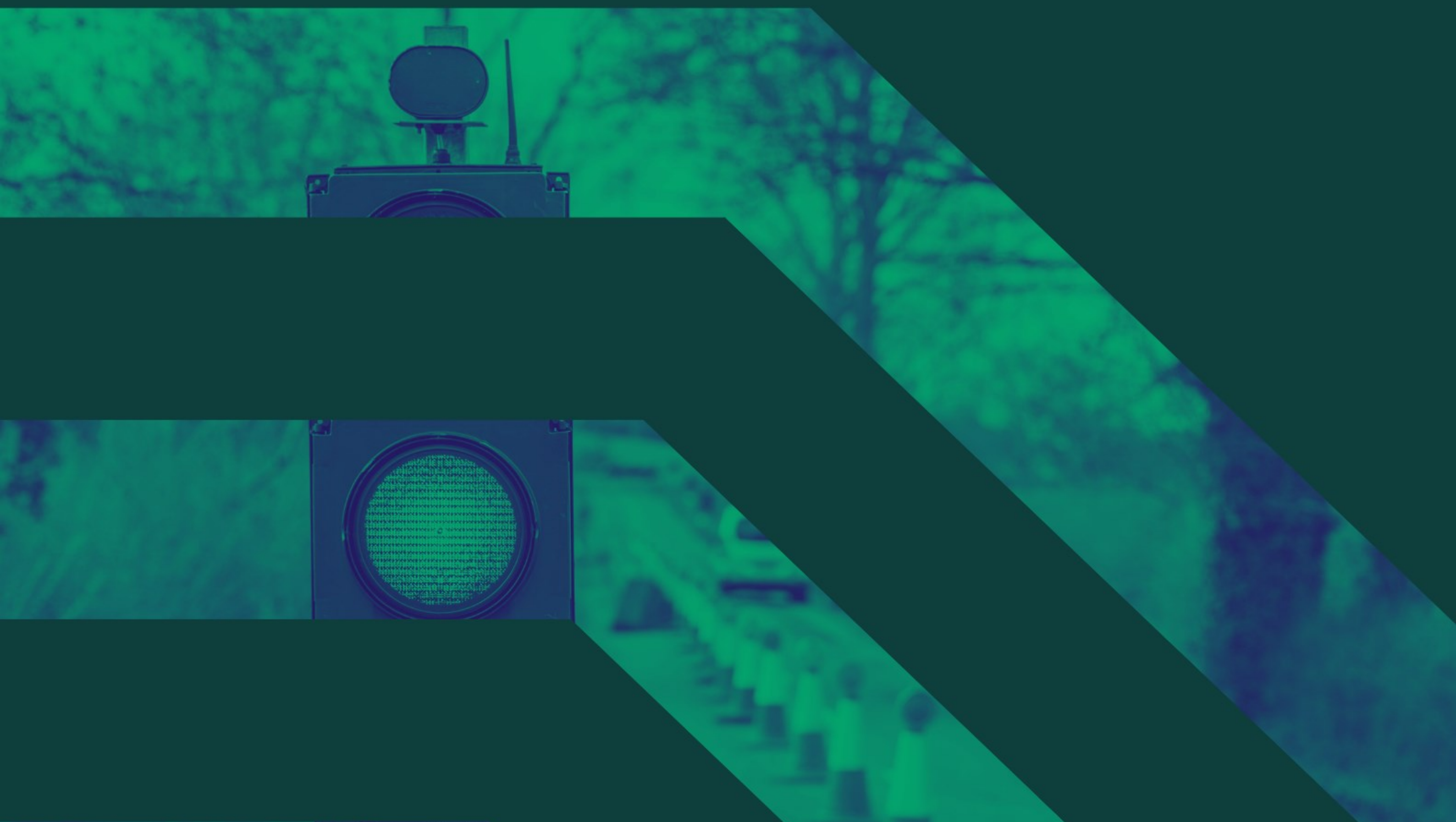
EVERYTHING COUNTS:

Why transport infrastructure emissions matter for decision makers

Greg Marsden, Kadambari Lokesh and Danielle Densley-Tingley

February 2022



DOI: https://doi.org/10.48785/100/142

Engineering and Physical Sciences Research Council

DecarboN8

Executive Summary *(Read time: 2 minutes)*

Policy Context

This briefing is set within the context of the climate emergency and the significant gaps which exist between stated ambitions and plans, and the necessary carbon trajectories to 'keep 1.5 °C alive'.

Very significant demands for new infrastructure are put forward by bodies at the National, Sub National and Local level, and the National Infrastructure Commission is beginning work for the second National Infrastructure Needs Assessment.

However, partly as a result of central government siloes, the carbon implications of infrastructure have not been adequately considered in the strategic cases advanced to date. This has to change and there is an appetite for this to happen.

Key findings

- All new transport infrastructure generates carbon emissions in its **construction, maintenance and operation**. The technical reports which sit behind this policy briefing quantify those emissions for typical road and rail schemes.
- Even with generous assumptions about the potential for technical innovations to decarbonise the construction process over time, there remains a core of emissions which is **hard to decarbonise**. Investment in innovation and pilot zones is critical to accelerate the gains which are possible.
- In the case of **roads**, the emissions from construction are **unlikely to be paid back** by operational improvements. In some cases, increased use of the road will also worsen the emissions burden.
- In the case of **public transport** infrastructure, one of the aims is to enable lower car use and therefore many schemes will be **more than able to 'pay off'** the emissions they generate in construction. However, here too, the 'pay back' period needs to be understood.
- The emissions from **maintenance of the existing network** are at least as significant as new build emissions and these must also be tackled.
- Some organisations are promoting the use of offsetting techniques to mitigate carbon from construction. Investing in solar and tree planting may be necessary, but such investments are not intrinsically linked or necessarily part of the case for any new infrastructure. They may be needed anyway. **No offsets should be counted in the case for infrastructure** with the focus being on reducing emissions at source.

Recommendations

1. The carbon impact of infrastructure counts and needs to be **counted as part of carbon budgets** of authorities promoting or maintaining infrastructure.

2. It is necessary to begin asking **‘what transport infrastructure will we need in a zero carbon future?’** and to stop asking whether investments can still be justified despite their carbon costs.
3. Getting to zero carbon is going to require a radically different set of policies. Even with full electrification at pace, **reductions in car miles will be necessary**, as will significant increases in public transport and active travel. This means we also need a different set of infrastructure investments to those currently planned.
4. Nowhere is yet on track to bring transport emissions down in line with the carbon budgets set out in legislation and national policy. **Funded and credible strategies and commitments** are needed before we can determine whether specific projects or programmes are appropriate in carbon terms.
5. It is critical that we **stop borrowing on the carbon overdraft** by building new infrastructure before we have established whether we can afford to pay it back.

Photo by [Illiya Vjestica](#) on [Unsplash](#)

DETAILED BRIEFING

Introduction

Arguments for new transport infrastructure are made to improve access to jobs and services, to cater for population growth and to open up new areas for development. However, such proposals are often controversial due to their impacts on the environment and communities. More recently, the UK's commitment to reach Net Zero by 2050 has placed infrastructure decisions under new and more intensive scrutiny. This briefing does not explore the trade-offs which are made when deciding what infrastructure schemes might be needed, but instead concentrates on how to make sure they are properly considered from a carbon perspective.

The construction and maintenance of new infrastructure involves the release of greenhouse gas emissions, in this case carbon dioxide. Emissions are released when fossil fuels are used to mine, refine, manufacture and transport materials, and to carry out the construction process. We refer to these emissions as 'embodied emissions'. There is also carbon released to fuel the operation of the infrastructure, e.g. lighting or signalling. At a national scale, the accounting responsibility for almost all these embodied emissions rests with the Department for Business, Energy and Industrial Strategy (BEIS), whilst the tailpipe emissions from vehicles rests with the Department for Transport (DfT). Promoters of new infrastructure schemes need to take account of both embodied and tailpipe emissions, yet integrated assessments are not commonplace, particularly at the early strategic stage in decision-making.

This briefing sets out the key findings from an analysis of the embodied carbon in road[1] and rail[2] infrastructure expansion, which have been applied to several case studies. The work has been conducted with Transport for the North (TfN) as a research partner and is contributing to their commitment to better integrate embodied emissions into recommendations on policy and infrastructure investment.[3] However, the findings and policy implications are those of the research team and should not be seen to be endorsed by TfN.

Road Schemes

In 2019 there were 35,768 km of major roads and a further 266,869 km of minor roads in England. This is an increase of 734 km (2.1%) and 4,800 (1.8%) since 2005.[4] In the RIS2 investment period 2020 to 2025 an anticipated £5.825 billion will be spent on capital maintenance and £14.118 billion on enhancements for the strategic road network.[5] Around 7% of the strategic road network receives maintenance every year, as well as just under 4% of the remaining roads, at a cost of around £2 billion per annum.[6]

The 'material production' phase is the dominant carbon contributor across the whole life of a road (~70%) with the key embodied carbon contributors being concrete and asphalt (Figure 1). The emissions from this phase come up-front, at the time of construction, and are dependent on the technologies approved and available for use. It is worth noting however, that whilst maintenance emissions are only 4% of the total embodied emissions for one kilometre of new build road, the scale of the existing road network relative to new build means that the total emissions from maintenance are just as important as the annual emissions associated with new infrastructure.

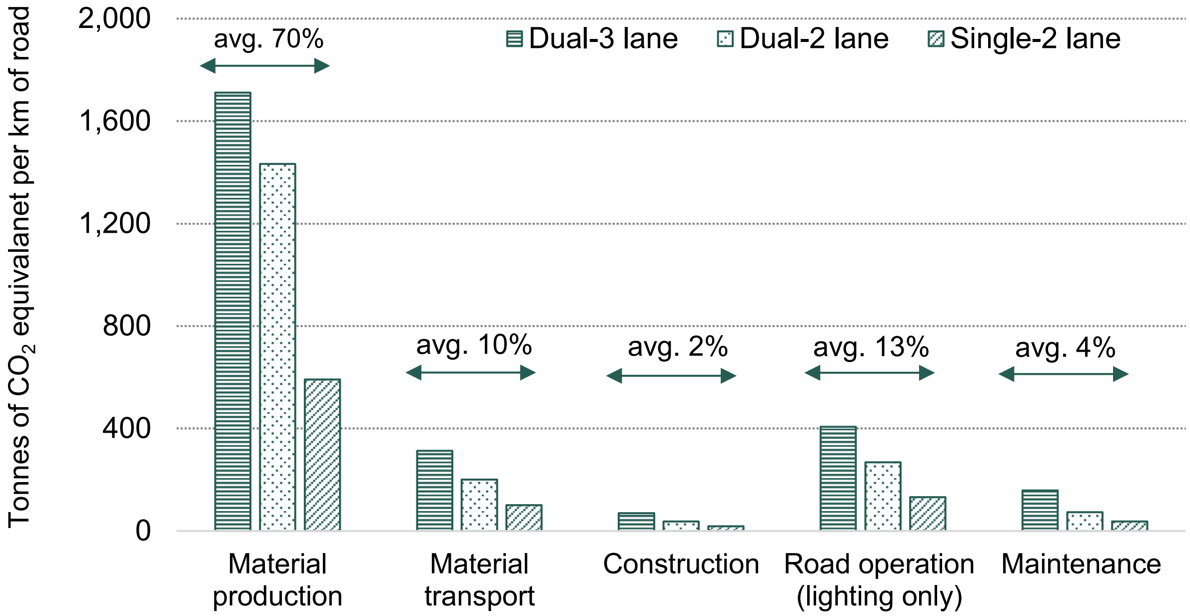


Figure 1: Estimates of embodied emissions from 1 km of different types of road

The role of innovation in reducing embodied emissions from road

It is essential to cut emissions from construction on a path to zero carbon emissions. This is reflected in National Highway's commitment to net zero by 2040.[7] However, there is a huge amount of uncertainty about how this will be achieved.

In our assessments, use of low-carbon alternatives and secondary (reclaimed) materials could reduce the whole life carbon of new roads by 2-12% over the asset's life period of 40 years (2020-2060). Using assumptions from National Grid's Future Energy Scenarios we estimate that a decarbonising energy grid could reduce the whole life carbon of new roads by 8-42% for over the asset's life period between 2030 and 2060, relative to the 2020 estimates. Uncertainty is high because there is little known about the extent to which promising new material innovations will have the same life-time durability as existing assets. The balance between domestically produced materials (counted in UK budgets) and imported (external to UK budgets) is also uncertain.

Even with our most optimistic assessments 10-30% of whole life carbon remains, meaning that to reach net zero these will need to either be eliminated, or they will contribute to the difficult-to-eliminate emissions for which we will need to develop large scale nature based solutions or negative emission technologies to balance at a whole economy scale.

Rail Schemes

The UK rail network comprises 31,251 km of track which covers a route length of 15,935 km. 5,835 km (37.9%) of the route length is electrified, with 179 km being added in 2020-2021.[8] In the period 2019-2024, Network Rail anticipates spending £19.6 billion on renewals, £9.6 billion on maintenance and £8.9 billion on expansion projects.[9]

Our work assessed the whole life carbon implications of key rail investments such as new tracks, bridges, overhead line equipment (OLE) and station upgrades. Over an assumed service life of 60 years, we estimate these to be a little over 2,000 tCO_2eq for ballasted track and almost 1,700 tCO_2eq for ballastless track. Ballestless track uses significantly more concrete than ballasted track and so incurs its carbon more up-front in the period but provides significant whole-life savings on maintenance relative to ballasted track (Figure 2).

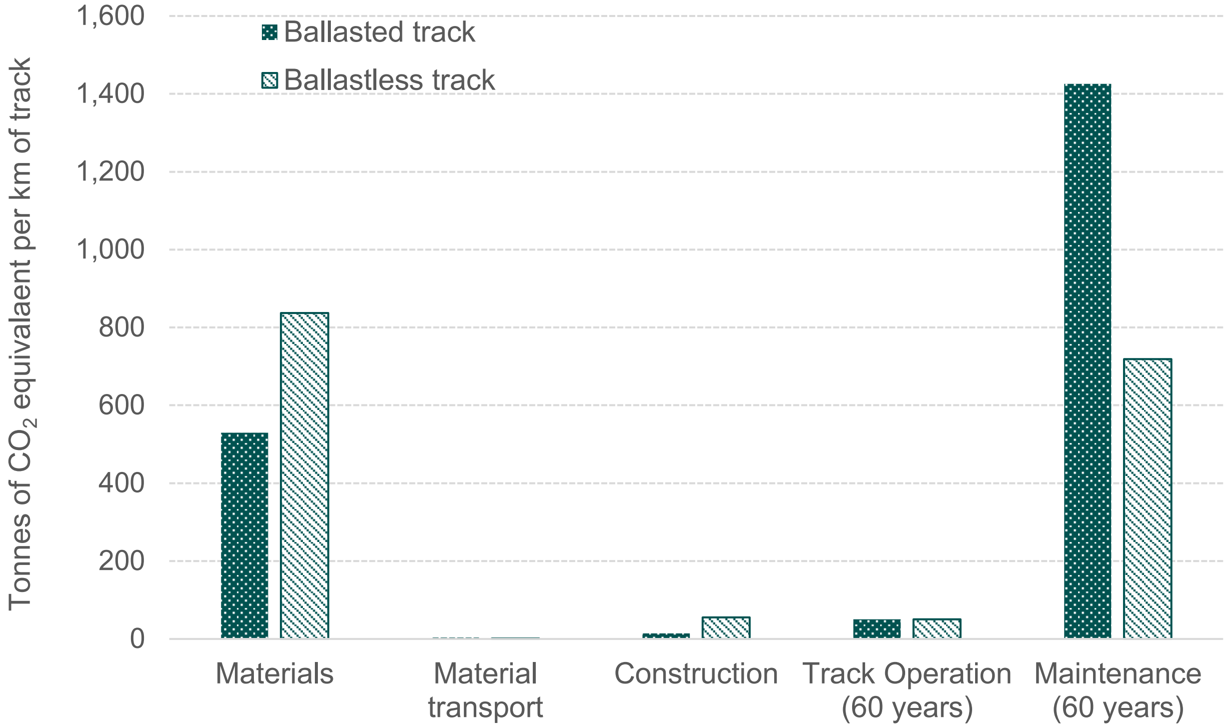


Figure 2: Estimates of embodied emissions from 1 km of different types of rail

Rail maintenance emissions are relatively more important than for road, where construction emissions dominate. For ballasted track, maintenance contributes 70% of the track's whole life carbon. The main embodied carbon contributor for the tracks is the steel in the rails, clips and the rebar in the sleepers (58% of the embodied carbon of 1 km track). Overhead line electrification also has high up-front embodied emissions in the catenaries and foundations.

The role of innovation in reducing embodied emissions from rail

We have assessed the potential for innovations with published impact projections to reduce the embodied carbon in rail. The use of low-carbon alternatives to the sleepers in new rail tracks reduces the whole life carbon by about 6-15% over the asset's life period of 60 years. There is potential to extend these savings to 20-35% when integrating more recycled steel into the rails and reinforced concrete structures. Using assumptions from National Grid's Future Energy Scenarios we estimate that a decarbonising energy grid could reduce the whole life carbon of rail by between 12% and 64.5% depending on the pathway assumed. The extent to which these savings are delivered will also depend on where materials are sourced from. Even with our most optimistic assessments of changes in the energy system, around 25% of whole life carbon remains for single track with overhead line equipment from 2040 and beyond. As with road, to reach net zero these will need to either be eliminated, or they will add to the stubborn emissions for which large scale nature based solutions or negative emission technologies are required.

Do the emissions make a difference?

It was argued by the Secretary of State for Transport during the court case on the RIS2 investment package, that the carbon emissions from new roads are insignificant compared with the total carbon budget for the UK.[10] This would be true also of the employment and journey time benefits on which the arguments for investment are based, if compared with a national scale.[11] The key question is: is there headroom within the carbon budgets set by organisations? If so, then the carbon from construction projects can be accommodated alongside other actions. If not, then this adds to the decarbonisation challenge.

Whilst it is necessary to calculate the volume of carbon released from asset construction and operation, this is a difficult metric to understand on its own. We have therefore converted the estimates from a typical one kilometre of road or rail into an equivalent number of car kilometres that would need to be taken off the network to ‘pay back’ the carbon from construction over two time periods, 10 and 20 years, if they were opened in 2020. It is assumed that an equal share of the emissions burden is paid back each year over the period.

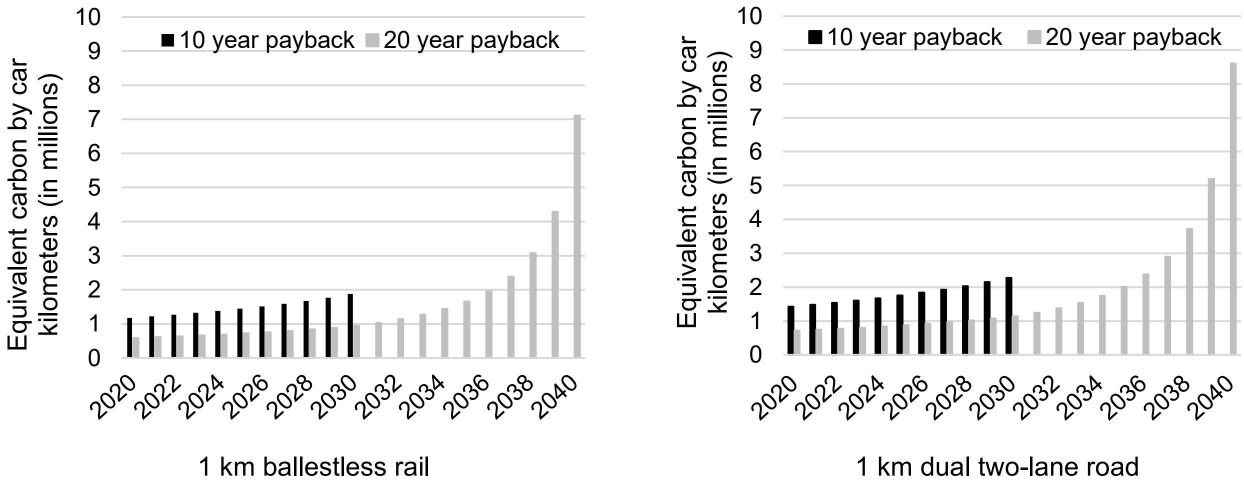


Figure 3: Payback of embodied carbon through taking car kilometres off the road

The charts show that the volume of car kilometres that would need to be removed grows over time, reflecting a move to a more electrified fleet. Average emissions from cars are assumed to fall from 141 g/km in 2020 to 87 g/km in 2030 and 11 g/km in 2040. By the end of this period, the ability to ‘pay back’ construction emissions by reducing car use becomes increasingly difficult.

For the kilometre of rail scheme shown here, a payback period of 20 years requires a removal of 0.58 million car kilometres per year in the opening year (2020), rising to 7.1 million by 2040. Over a 10 year payback period the figures are 1.17 million in 2020 rising to 1.88 million in 2030.

For the kilometre of dual lane road shown here, a payback period of 20 years requires a removal of 0.71 million kilometres per year in the opening year of 2020 rising to 8.6 million by 2040. Over a 10 year period the figures are 1.42 million in 2020 rising to 2.27 million in 2030.

To further put these figures in context, 1 million car kilometres is equivalent to:

- 1,757 fewer people commuting by car each year; or
- 314 people completely giving up car driving

As noted above, the later the opening period of any investment, the more substantial the reductions in driving would need to be to compensate for the equivalent carbon emissions generated in construction. This is clearly a significant factor for early stage infrastructure schemes being considered today, given that the lead time for construction could be a decade or longer.

Can Road Schemes Pay Back their Emissions?

It is often implied that new road construction may reduce emissions by smoothing traffic flow. In stop-start traffic at low speeds, increases in speed results in lower carbon emissions from internal combustion engine vehicles, although these improvements are generally very small. To put an individual junction improvement into context, there is even debate on whether fully automated cars that communicate with the signals can achieve any net carbon emission reductions.[12] Furthermore, where studies find positive impacts, these have been found to be in the range of 3% to 20%.[13]

At higher speeds, around 50 mph and above, increases in speed increase carbon emissions due to the energy required to overcome air resistance. Examination of the post-opening results of the A1 Dishforth to Leeming improvement reveals significantly increased speeds, which would in-turn increase tailpipe emissions and extend the amount of carbon required to be ‘paid back’. Speed gains coupled with capacity enhancement are a primary justification for road schemes and so this tension applies across a range of schemes.

As well as speed changes on the links that have been upgraded, the assessment of the emissions impacts of road expansion needs to include consideration of additional emissions from any induced traffic, knock-on effects on adjacent roads, and the impacts of delays during the construction process which are incurred up-front in the project lifetime.

Whilst appraisal methods can show road schemes as beneficial in carbon terms, this is usually in relation to a ‘do-minimum’ scenario rather than in absolute terms. A zero emission whole economy approach means reducing emissions, not making things worse more slowly. Road construction results in net increases in carbon emissions. It is not yet clear how those additional emissions will be removed, given progress on decarbonisation to date.

Can Rail Schemes Pay Back their Emissions?

Investments in rail support the mode shift of passengers from cars and freight from trucks. Unlike with road schemes, it is possible for investments in rail to pay back the carbon from construction and maintenance through these mode shift benefits.

A case study of potential expansion of a small stretch of route accessing Sunderland station

(350 m), to move from a two-track to a four track approach to the four platforms, estimated a whole life carbon cost of 3,867.4 tCO2eq. Allowing for improvements in car technology, 3.7 million car kilometres per annum would need to be taken off the road to pay this back in a decade. The population of Sunderland is 277,733. If 40% of residents took just one round trip journey to Newcastle by rail instead of car each year, then this would pay back the construction costs in carbon terms.

However, it should not be taken for granted that emissions from construction will definitely be offset. An analysis of an early stage airport spur proposal of 7.4 km of new track from the East Coast Mainline to Newcastle Airport found that for a payback period of 10 years, 30.3 million vehicle kilometres would need to be taken off the road on average each year. With an assumed round trip distance to the airport of 126 km this means attracting around 240,700 car trips to rail each year to break even.

The analysis conducted for this briefing helps us to understand the payback period for such investments – but much more in-depth feasibility studies are required to determine whether or not such mode shifts are achievable, and to provide more robust local comparators to understand the carbon payback.

Offsetting?

Some organisations argue for the potential for the embodied emissions from road and rail construction to be ‘offset’ by other investments. This could, for example, include adding solar panels to station roofs, building solar fields adjacent to motorways, tree planting, or additional investments in transport elsewhere to create more mode shift from private cars to public, shared and active modes.

We have explored some of these in our technical reports. Great caution must be observed in any offsetting mechanism. National Highways, for example, has estimated the amount of carbon extracted by trees and other natural capital on its estate. However, this is already counted elsewhere in our national accounts. How will it be ensured that the solar panels installed are additional to the existing planned solar capacity in the UK? Will any investment for mode shift really be additional, or will it double count funds that were already allocated? The mechanisms to demonstrate that these savings are real and additional, rather than enabling a deferral of real carbon reductions, do not yet exist. It is not the place of this report to explore how this could be done, or if it should be done. However, we see real risks of false accounting, however well intentioned, in the current policy approaches.

Integrating Infrastructure with Carbon Plans

As we set out in this briefing, there are many reasons why infrastructure may be perceived as desirable. This briefing focuses on the conditions in which new infrastructure might be justifiable now that a stringent carbon budget is acknowledged as a constraint within which we are committed to working. At present, emissions from infrastructure are not yet well integrated with strategic transport planning, however, the scale of these emissions demands that they should become a key criterion for whether a project proceeds or not. This requires thinking about future demand pressures and what types of infrastructure should be prioritised to accelerate progress to zero emissions.

Recognising the importance of embodied carbon is not the same as saying no new infrastructure should be built. Where the wider reasons for new infrastructure are important, and where other options cannot deliver those goals, then it may be that building is the right thing to do. However, such decisions still need to fit within the carbon budget for the area concerned – and that means adapting further in some other part of the economy.

The foreword to the Transport Decarbonisation Plan states that "We want to reduce urban traffic overall" whilst innovation through the pandemic and as a result of other policies offers the "opportunity for a reduction or at least a stabilisation of traffic overall".[14] Transport Scotland has adopted a commitment to achieve a 20% reduction in vehicle kilometres by 2030 across the whole of their network.[15] The Welsh Government has a moratorium on major road building.[16] Across the country, analysis after analysis shows that the only way of getting close to the carbon trajectory implied by the Climate Change Act is to reduce the amount we travel by car[17] alongside major shifts towards low-carbon technologies. Those analyses are based on the implications of tail-pipe emissions only. The additional emissions from construction which are identified here pose further challenges, particularly to justifying a road building programme.

The Covid-19 pandemic has been extremely damaging to public transport. Rail commuting and business travel in particular have been significantly reduced. However, growth in the use of rail instead of car is one of the key actions for the next decade of climate response. The Committee on Climate Change has suggested that 30% of emissions reduction has to come from mode shift and demand reduction for cars.[18] A third of carbon emissions from cars come from journeys over 35 miles in length, and rail is the main alternative for these journeys. In addition, the phase out date for internal combustion engine heavy goods vehicles is 2040, so there is likely to be a growing demand for rail freight solutions as companies seek to meet their net zero pledges. The decarbonisation case for rail investment remains, particularly early in the next one to two decades, but the balance of such investments may change.

Summary

New road infrastructure will almost certainly increase total carbon emissions. In contrast public transport schemes can be designed to reduce overall emissions through the mode shift they deliver. **If the carbon headway required to accommodate new infrastructure is to be provided then credible and quantified carbon reduction policy pathways need to be in place, with a clear schedule and guarantee of delivery. No organisation can argue that the additional emissions from construction are acceptable in the absence of such pathways**; that is not how carbon budgets work.

Modelling suggests that the decarbonisation of the energy sector and innovations in construction and materials all have a critical role to play in reducing embodied emissions. The evidence on the benefits of such innovations is very uncertain, as is their durability over long service lifetimes. This is a significant knowledge gap which can only be filled through close collaboration between research and practice over the coming decades. **The expansion of pilot areas which allow material experimentation and have robust monitoring processes is needed. It is essential that the UK develops, demonstrates and adopts the least carbon intensive construction and maintenance processes as early as possible.**

Whatever assumptions are made about future technologies, there remains a significant residual emissions burden from infrastructure for which solutions are not yet available. As tailpipe emissions from cars fall, so does the potential to pay back those emissions through mode shift or flow smoothing benefits. **Whilst domestic offsetting options are currently being proposed, there is a major risk that organisations are presuming that everyone has access to the 'net' part of net zero, essentially reducing the need to act. We recommend that offsetting is not counted as a scheme benefit until there is a clear national framework which accounts for offsetting across the whole economy.**

The division of responsibility for emissions from transport infrastructure and the vehicles which use that infrastructure is unhelpful to joined up decision-making on infrastructure carbon. The Climate Change Committee's (CCC's) 6th Carbon Budget Analysis does not make clear what assumptions on future infrastructure investment or maintenance are included. The Department for Transport's Decarbonisation Plan points to the need to work with BEIS. The Net Zero Strategy from BEIS, however, does not address this. The CCC needs to clarify how the embodied carbon from transport infrastructure should be identified and tracked through the system. This should also set the context for the second National Infrastructure Needs Assessment by the National Infrastructure Commission. At present, there is no clear ownership of the issue or tracing through of the consequences of the programmes proposed.

Although responsibility for embodied emissions and tailpipe emissions are split between BEIS and DfT, these findings show that it is essential that both these elements are clearly integrated into decision-making. Lower demand futures for car travel, which is increasingly recognised as necessary for cutting tailpipe emissions, needs to connect to assessments of infrastructure needs. This will almost certainly require bringing forward investments which promote mode-shift from the car to other modes whilst delaying road construction. The technical reports on which this briefing is based provide some transparent and usable early evidence through which organisations can begin to make such adjustments. **The National Infrastructure Commission must ensure that its second National Infrastructure Assessment takes full account of the whole life carbon implications of its proposals.**

Acknowledgements

DecarboN8 has received funding from the EPSRC Energy Programme, grant agreement EP/S032002/1.

The work has been conducted with Transport for the North (TfN) as a research partner and is contributing to their commitment to better integrate embodied emissions into recommendations on policy and infrastructure investment. However, the findings and policy implications are those of the research team and should not be seen to be endorsed by TfN. We would like to thank Network Rail for their support in data collection.

This briefing is the responsibility of the authors and does not imply endorsement by the funders. Any errors or emissions are those of the authors.

Further information

This briefing sits alongside two technical reports on **road** and **rail** infrastructure carbon. All three documents can be found at: https://DecarboN8.org.uk/EmbodiedEmissions

This briefing should be cited as:

Marsden, G., Lokesh, K. and Densley-Tingley, D. (2022) Everything Counts: Why transport infrastructure emissions matter for decision makers. Leeds: DecarboN8 Research Network. DOI: https://doi.org/10.48785/100/142

References

[1] Lokesh, K., Densley-Tingley, D. and Marsden, G., 2022. *Measuring Road Infrastructure Carbon: A 'critical' in transport's journey to net-zero*. Leeds: DecarboN8 Research Network.

[2] Lokesh, K., Densley-Tingley, D. and Marsden, G., 2022. *Measuring Rail Infrastructure Carbon: A 'critical' in transport's journey to net-zero*. Leeds: DecarboN8 Research Network.

[3] Transport for the North, 2021. Decarbonisation Strategy. [online] Available at: https://transportforthenorth.com/decarbonisation/ [Accessed 17 February 2022].

[4] Department for Transport, 2021. *Road lengths in Great Britain: 2020*. [online] Available at: https://www.gov.uk/government/statistics/road-lengths-in-great-britain-2020/ [Accessed 17 February 2022].

[5] Department for Transport and Highways England, 2020. *Road Investment Strategy 2 (RIS2): 2020 to 2025*. [online] Available at: https://www.gov.uk/government/publications/road-investment-strategy-2-ris2-2020-to-2025 [Accessed 17 February 2022].

[6] Asphalt Industry Alliance, 2021. *AIA's ALARM survey 2021*. [online] Available at: https://www.asphaltuk.org/wp-content/uploads/ALARM-survey-2021-FINAL.pdf [Accessed 17 February 2022].

[7] Highways England, 2021. *Net zero highways - Highways England*. [online] Available at: https://nationalhighways.co.uk/netzerohighways/ [Accessed 17 February 2022].

[8] Office of Road and Rail, 2021. *Rail Infrastructure and Assets 2020-21*. [online] Available at: https://dataportal.orr.gov.uk/media/2014/rail-infrastructure-assets-2020-21.pdf [Accessed 17 February 2022].

[9] Network Rail, 2021. *Our Delivery Plan for 2019-2024 - Network Rail*. [online] Available at: https://www.networkrail.co.uk/who-we-are/publications-and-resources/our-delivery-plan-for-2019-2024/ [Accessed 17 February 2022].

[10] Burges Salmon, 2021. *Legal challenge to the DfT's £27bn road building plan dismissed*. [online] Available at: https://www.burges-salmon.com/news-and-insight/legal-updates/legal-challenge-to-the-dfts-27bn-road-building-plan-dismissed [Accessed 17 February 2022].

[11] Goodwin, P., 2021. Carbon and the strategic roads programme. [Blog] *Transport Action Network*, Available at: https://transportactionnetwork.org.uk/carbon-and-the-strategic-roads-programme/ [Accessed 17 February 2022].

[12] Wadud, Z., MacKenzie, D. and Leiby, P., 2016. Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles. *Transportation Research Part A: Policy and Practice*, 86, pp.1-18.

[13] Pribyl, O., Blokpoel, R. and Matowicki, M., 2020. Addressing EU climate targets: Reducing CO2 emissions using cooperative and automated vehicles. *Transportation Research Part D: Transport and Environment*, 86, p.102437.

[14] Department for Transport, 2021. *Transport decarbonisation plan*. [online] Available at: https://www.gov.uk/government/publications/transport-decarbonisation-plan [Accessed 17 February 2022].

[15] Transport Scotland, 2021. *Mission Zero for transport*. [online] Available at: https://www.transport.gov.scot/our-approach/environment/mission-zero-for-transport/ [Accessed 17 February 2022].

[16] Welsh Government, 2021. *Freeze on new roads projects to be announced*. [online] Available at: https://gov.wales/freeze-new-roads-projects-be-announced [Accessed 17 February 2022].

[17] Transport for Quality of Life, 2021. *Radical Transport Policy Two-Pager #10: The last chance saloon: we need to cut car mileage by at least 20%*. [online] Available at: http://www.transportforqualityoflife.com/u/files/211214%20The%20last%20chance%20saloon%20to%20cut%20car%20mileage.pdf [Accessed 17 February 2022].

[18] Climate Change Committee, 2020. *Sixth Carbon Budget*. [online] Available at: https://www.theccc.org.uk/publication/sixth-carbon-budget/ [Accessed 17 February 2022].

Engineering and Physical Sciences Research Council

DecarboN8

DecarboN8.org.uk

DecarboN8 has received funding from the EPSRC Energy Programme, grant agreement EP/S032002/1