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Transport Scotland Net Zero Route Map

Operation, Maintenance & Improvement of the Trunk Road Network

Contents

Ministerial Foreword

Scotland is facing a global climate emergency, with the impacts of climate change already being felt across our communities, economy, and environment. Transport is currently Scotland's largest source of greenhouse gas emissions, accounting for 37% of the national total. The Scottish Government is committed to reaching Net Zero emissions by 2045, and the transport sector has a critical role to play in achieving this ambition.

The Scottish Trunk Road Network is one of Scotland's most significant national assets. Extending over 2,300 miles and valued at more than £30 billion, it connects our cities, towns, ports, and airports and supports economic activity across the country. The safe operation, maintenance and improvement of this network is essential, but these activities also generate greenhouse gas emissions that must be addressed if we are to meet our climate targets.

Transport Scotland's Fourth Carbon Management Plan sets out our commitment to achieving Net Zero emissions across our corporate activities by 2027. This Net Zero Route Map builds on that commitment by addressing emissions associated with the operation, maintenance, and improvement of the Trunk Road Network, including those generated across our supply chain. Tackling these emissions will require new approaches, strong leadership and close collaboration with our Operating Companies and industry partners.

The Route Map establishes a robust emissions baseline and sets out a clear and credible pathway to achieving Net Zero by 2045. It identifies the key sources of emissions and the interventions required to reduce them, with a strong focus on early action to support deep emissions reductions by 2030. This reflects the urgency of the challenge and the need to act now to deliver meaningful change.

Developed collaboratively with industry, the Route Map recognises the importance of embedding carbon reduction into everyday decision making. It addresses emissions from materials, transport, plant and fleet, depots, and operational activities, alongside the policies, processes and behaviours needed to enable long term change.

This Route Map is an important step forward in delivering a more sustainable Trunk Road Network. Achieving Net Zero will require continued effort, innovation and learning as technologies and markets evolve. By working in partnership and maintaining a clear focus on delivery, we can ensure the Trunk Road Network continues to support Scotland's communities and economy while contributing to a fairer, greener future.

Fiona Hyslop

Cabinet Secretary for Transport

Introduction

The Trunk Road Network

The Trunk Road Network (TRN) is a strategic network of major roads and motorways connecting Scotland's cities, major towns, airports, and ports. Extending over 2,300 miles and valued at more than £30 billion, it includes a wide range of assets such as carriageways, bridges, structures, and associated infrastructure.

Transport Scotland is responsible for the operation, maintenance, and improvement of the TRN, working in partnership with private sector Operating Companies who oversee, coordinate, and undertake cyclic and routine maintenance, winter service, and emergency response. In addition, Transport Scotland undertakes structural road maintenance, bridge strengthening and maintenance, safety and condition inspections, road safety, and minor improvement schemes.

A Net Zero Trunk Road Network

Activities associated with operating, maintaining, and improving the trunk road network generate greenhouse gas emissions through the energy used, materials consumed and waste produced. The Scottish Government has committed to achieving Net Zero greenhouse gas emissions by 2045, and the transport sector has a critical role in delivering this ambition.

Transport Scotland aims to achieve Net Zero emissions from the operation, maintenance, and improvement of the trunk road network by 2045. To support this ambition, the Net Zero Route Map sets out the actions required to reduce emissions across the TRN in line with national climate targets.

Development of the Net Zero Route Map

Baseline Greenhouse Gas (GHG) emissions (in tonnes of carbon dioxide equivalent (tCO_2e)) were estimated for financial years 2021-22 and 2022-23 and averaged across the two years. Transport Scotland emissions were used as well as those generated by our supply chain through work on our behalf (Scopes 1, 2 and 3 according to the Greenhouse Gas Protocol). The scope of the study was kept to the emissions directly attributable to the operation, maintenance, and improvement of the TRN; emissions associated with running our organisation are counted within our corporate reporting.

Data to inform the baseline was sourced from our Asset Management Performance System (AMPS), which captures detailed information about the work carried out by our Operating Companies. This was used to understand the materials used on different schemes, and assumptions were applied on how far they have been

transported based on the locations of our materials suppliers. Further data was provided by our Operating Companies in Annual Reports which contain sustainability metrics such as fuel, electricity and water use in plant, fleet, and depots. The most appropriate emission factors were applied from a range of authoritative sources including Inventory of Carbon and Energy and UK Department for Energy Security and Net Zero (DESNZ) to attribute GHG emissions to all these activities.

Using the baseline, a Business-as-Usual projection to 2045 was generated, assuming no further decarbonisation interventions are applied beyond background reductions such as UK electricity grid decarbonisation.

Collaborative workshops were led by industry experts with representatives from Operating Companies and Transport Scotland to identify the key opportunities for decarbonisation of the TRN. The following themes were considered which aligned with our main emissions sources; materials, fleet & plant, depot & asset operation, and finally policy, process, and behaviour “enablers” to drive emissions reductions. These emissions reductions were set out in a timetable from 2025 through to 2045 to deliver reductions which are ambitious and challenging, but not unachievable.

A bespoke Route Map model was developed to carry out calculations at all stages of the process, from baseline data entry through to the Route Map pathway output.

Delivery of the Net Zero Route Map

Delivery of the Net Zero Route Map is overseen by Transport Scotland, implemented through Operating Companies and the supply chain, and monitored through defined governance and assurance arrangements.

Baseline emissions

Operation, maintenance, and improvement of the TRN have net emissions of 110 $ktCO_2e$ per year. That is the equivalent of driving the length of Scotland over 1,700 times in a small diesel car and equates to around 31 tCO_2e per km of road.

Of the three activity areas, maintenance is the largest source of emissions, accounting for 81% of the total. Improvement activities contribute 10%, while operation accounts for the remaining 9%. Operational emissions are partially offset by carbon sequestration from land owned by Transport Scotland, excluding any tree planting undertaken for corporate offsetting purposes.

Figure 1 shows overall emissions are dominated by materials, which account for approximately 77% of total net emissions (or 71% excluding land sequestration). These are primarily embodied emissions generated during the extraction, processing, and manufacture of construction materials.

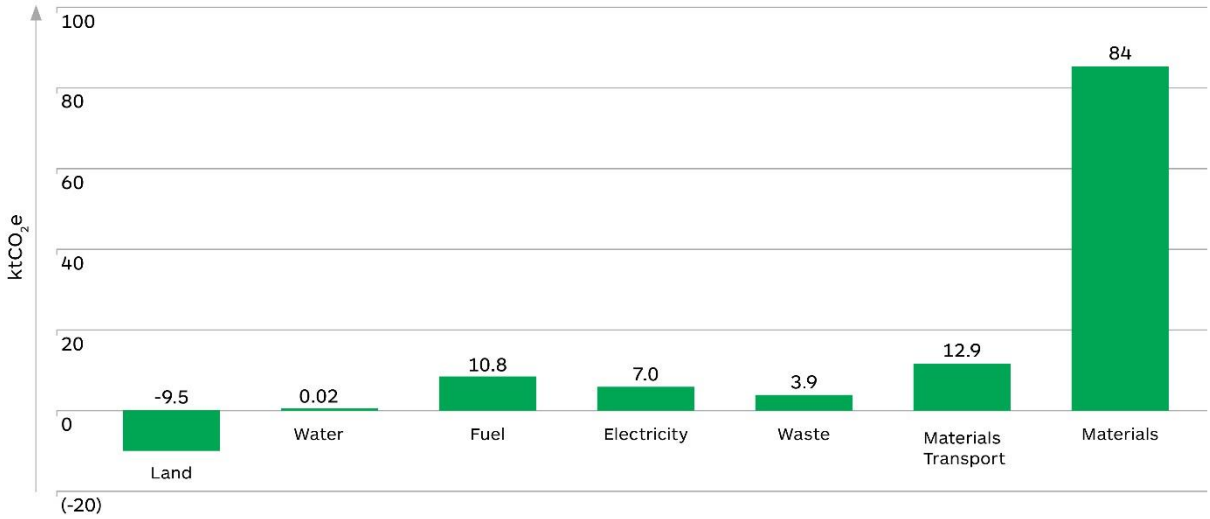


Figure 1 – Graph showing total annual emissions of TRN (ktCO2e) presented by emission source

Operation includes regular inspections, cleaning, grass-cutting and routine maintenance activities, as well as the running of depots and vehicles, and the energy consumed by lighting signage on the network. Lighting is an important emission source in our operation of the TRN and so is included in our baseline emissions, although it is already officially reported to Scottish Government as part of our corporate accounting. Operation emissions also include emissions and removals from the atmosphere from Transport Scotland owned land.

Maintenance activities are individual and non-routine. Examples include resurfacing and reconstruction, maintenance and replacement of kerbs and fences, works to bridges, earthworks and drainage.

Improvement activities go beyond maintaining existing assets, to provide enhancement, for example works to adapt the TRN to a changing climate.

Business as Usual

Without any further decarbonisation interventions, it was estimated that emissions would decrease by 6% by 2045 due to background decarbonisation of the UK electricity grid. That is not sufficient to support Scottish Government in achieving its Net Zero commitments and it is clear that action is required.

Maintenance & Improvement

As shown in **Figure 2**, maintenance and improvement activities have very similar emissions profiles and are characterised by a high proportion of embodied carbon. Materials account for more than 80% of emissions in this category.

Asphalt is the single largest contributor, reflecting the volumes used and its carbon intensive production process. Thermoplastic road marking materials are the next largest source. Transport of materials to site contributes approximately 14% of emissions, while waste management accounts for less than 4%. Improvement activities have a higher contribution from steel, reflecting the nature of enhancement works.

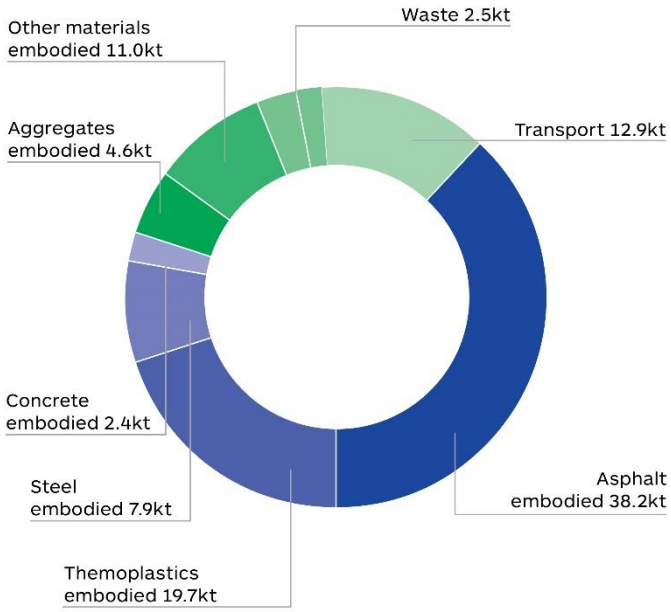


Figure 2 – Diagram showing Maintenance & Improvement emissions (ktCO2e)

Operation

Figure 3 shows operational emissions are primarily associated with energy use, with the largest contributions coming from electricity and white diesel.

Electricity powers our Operating Company depots, but also our roadside electrical assets such as streetlighting and signage. This latter use accounts for over 92% of our electricity use.

Red diesel and gas oil used for plant and generators accounts for 12% of our operation emissions. This is fuel for the plant and generators used in maintenance and improvement activities.

Waste management accounts for 8% of our operation emissions. The majority of waste is recycled with minimal waste going to landfill.

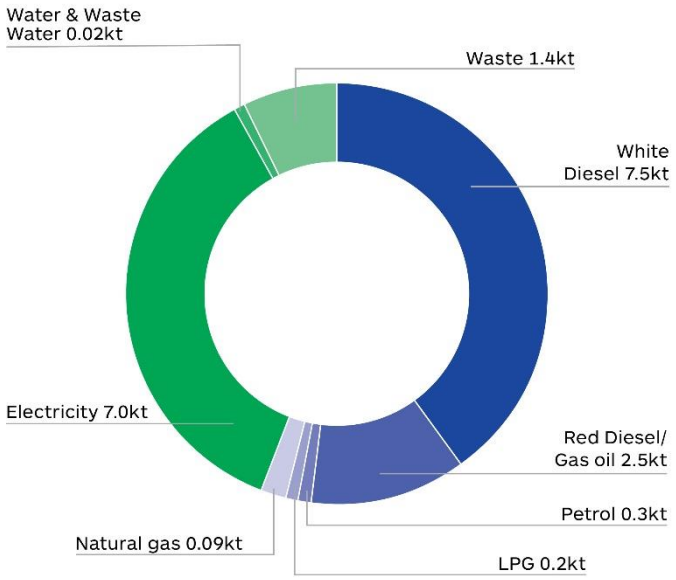


Figure 3 – Diagram showing Operation emissions ($ktCO_2e$)

Materials

Figure 4 shows the embodied emissions of asphalt contribute almost half of total material emissions. Thermoplastic screed used in road markings also contributes a large number of emissions. Remaining emissions arise from a wide range of materials used in smaller quantities, including metals, resins, and timber.

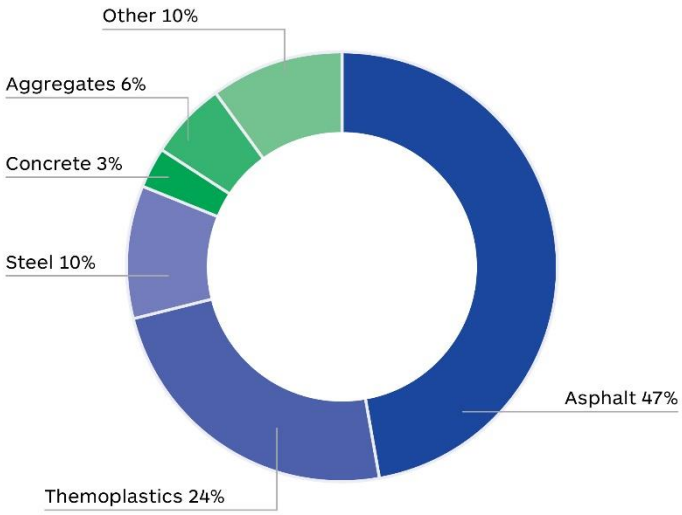


Figure 4 – Diagram showing Material embodied emissions ($ktCO_2e$) presented by material

Land

Land owned by Transport Scotland is estimated to remove and store around 9,500 tCO_2e per year, primarily through woodland sequestration. Other land uses, such as agricultural land, are likely to generate emissions. Estimates for land use impacts are currently high level, and further work is underway to improve understanding of this contribution.

Decarbonisation Pathway

The Decarbonisation Pathway in **Figure 5** sets out how emissions associated with the operation, maintenance and improvement of the Trunk Road Network will be reduced between now and 2045. It reflects a structured transition from the emissions baseline to Net Zero, informed by evidence, collaboration with industry and an assessment of technology readiness.

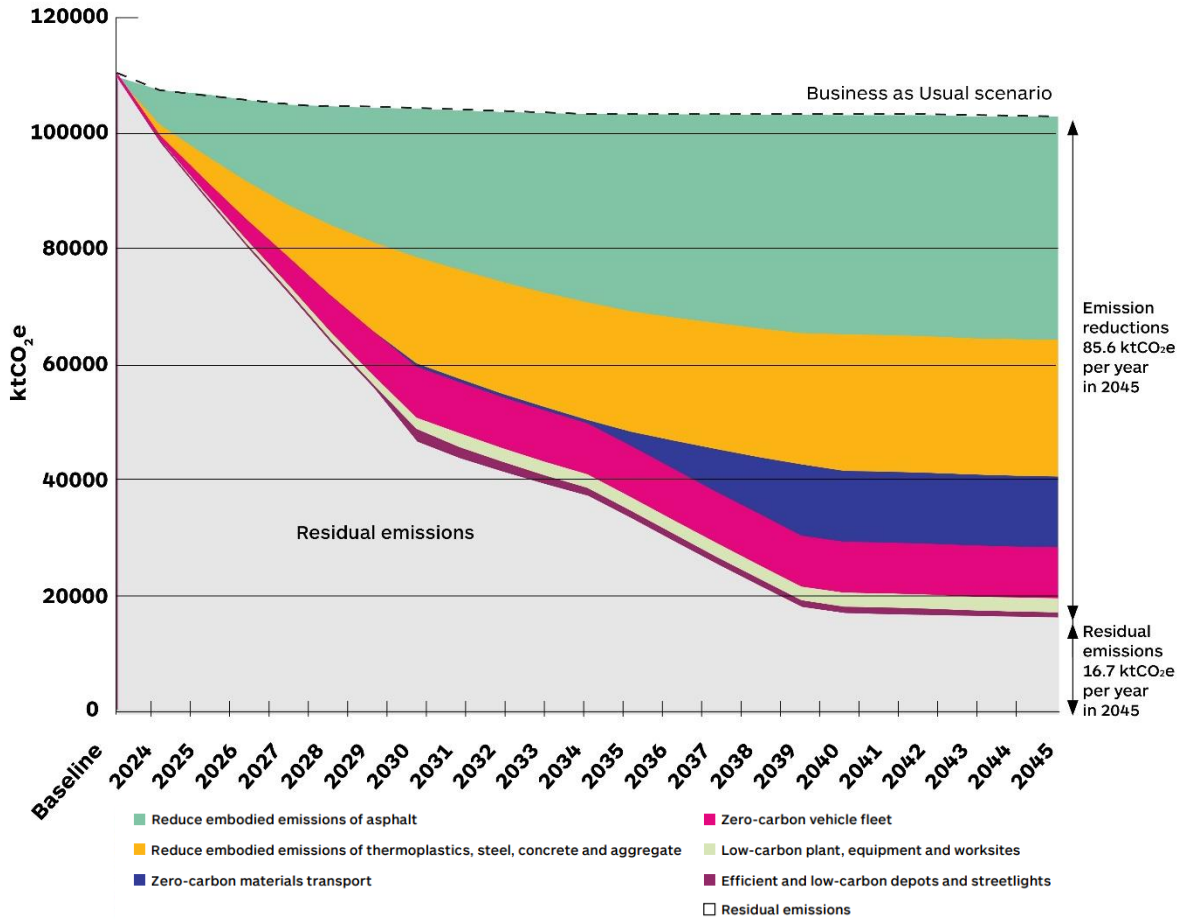


Figure 5 – Graph showing the decarbonisation pathway, showing emissions reductions (ktCO2e) against the Business-as-Usual scenario for different groups of interventions

A suite of targeted interventions has been developed in partnership with Operating Companies and industry carbon specialists. These interventions address the main sources of emissions across materials, transport, plant and fleet, depots, and operational activities, supported by enabling policy, procurement, and behavioural change measures.

Together, the interventions in the Route Map reduce annual net emissions by approximately 85% by 2045, leaving a small volume of residual emissions. This results in emissions of approximately 16.7 $ktCO_2e$ per year in 2045, equivalent to around 4.5 tCO_2e per kilometre of trunk road. These residual emissions will be addressed through responsible offsetting, alongside efforts to maximise carbon sequestration on land owned by Transport Scotland.

Phasing and Pace of Reductions

The pathway follows a front-loaded approach, with rapid early reductions where proven technologies and practices are already available. Emissions are expected to reduce by around 50% by 2030, reflecting the Scottish Government's ambition for deep emissions cuts this decade.

The rate of reduction then tapers through the 2030s as the remaining sources of emissions become more difficult to address. Progress during this period increasingly depends on the development, availability and affordability of emerging technologies and lower carbon materials. This approach balances ambition with realism, ensuring the pathway is challenging but achievable.

Key Drivers of Emissions Reductions

The largest emissions reductions are expected to come from decarbonising materials, reflecting their dominant contribution to the baseline. In particular, significant reductions are delivered through changes to asphalt, steel, and road-marking materials.

Zero emission vehicles also play an important role, both in the transport of materials from suppliers to site and in the transition of Operating Company fleets and plant. Improvements in logistics, energy efficiency, and depot operations further support emissions reductions across all activity areas.

Innovation and the Future

The Route Map recognises that not all future solutions can be fully defined today. Improvements in materials science, vehicle technology, energy systems, and construction practices are expected to deliver additional emissions reductions over

time. The pathway therefore allows for continued innovation, learning and adjustment as evidence and technologies evolve.

The Route Map is intended to be reviewed annually to reflect updated data, market developments, and policy requirements, while maintaining a clear trajectory towards Net Zero by 2045.

A summary of interventions for Maintenance and Improvement and Operations is found in **Appendices 1 and 2**.

Route Map - Achievements at 5-year Milestones

Achieving Net Zero Operation, Maintenance and Improvement of the TRN will require substantive changes to the way we operate and ongoing implementation of decarbonisation actions over an extended period of time.

The Route Map sets out a clear sequence of milestones covering the period from 2025 through to 2045, describing what we expect to have achieved at five-year intervals. The initial milestone period to 2030 reflects the Scottish Government's ambition for rapid and substantial emissions reductions, with a target to halve emissions by the end of this decade. Many of the actions required to meet this goal can begin immediately, using existing technologies and practices that are already available or emerging at scale.

Beyond 2030, the pace of emissions reduction is expected to slow as the remaining sources of carbon become more difficult to address. Progress during this period will increasingly depend on the availability of new technologies, the development of low carbon materials and fuels, and the maturity of relevant markets, all of which carry a degree of uncertainty. As a result, the Route Map adopts a phased approach that combines early actions with longer term interventions as solutions become viable.

Throughout the 2025 to 2045 period, the delivery of these milestones depends on the parallel implementation of the organisational and behavioural enablers set out later in the document. Improvements to policy, data, asset management, procurement, skills, and collaboration are essential to unlocking emissions reductions and ensuring sustained progress towards Net Zero.

2030 Milestone – 50% Emissions Reduction

By **2030**, a **50% reduction in emissions** will have been achieved through a combination of early action, technology deployment, and improvements in operational practice.

Materials Transport

- Logistics management has been reviewed and improved, resulting in a **5% reduction in transport related emissions**.
- Operating Companies are **trialling zero emission heavy vehicles** where they are operationally feasible.

Materials

- **Warm mix asphalt** is used for the majority of surfacing works, delivering emissions reductions of approximately **15%**.
- The use of **recycled asphalt planings** has increased to **35%**, with trials underway to expand use where it is not currently permitted.
- **Biogenic products** are used for all road markings, reducing associated emissions by approximately **73%**.
- **Lower carbon steel alternatives** are being procured where available.
- Use of **recycled aggregates** has increased to **80%**.

Depots

- **Electric vehicle charging infrastructure** has been installed at depots to support small fleet zero emission vehicles, with future provision for HGV charging under investigation.
- **Energy efficiency audits** have been completed, with measures implemented to maximise benefits, including improved insulation, occupancy sensors and upgraded controls.
- **Air source heat pumps and solar photovoltaic systems** have been installed where feasible to generate onsite renewable energy.
- **Certified renewable electricity** is purchased to meet remaining depot energy demand.

Streetlighting and Roadside Assets

- All roadside electrical assets, including **streetlighting and illuminated signs**, are powered by **certified renewable electricity**.

Plant and Fleet

- The **small fleet (cars and vans)** transitions fully to electric vehicles by the end of 2030.
- **Drones and other innovative technologies** are increasingly used to reduce mileage associated with inspections.

- Emissions from **diesel used in construction plant and site compounds** have been reduced by **80%** through the adoption of low- and zero carbon alternative fuels.

2035 Milestone – 60% Emissions Reduction

By **2035**, a **60% reduction in emissions** will have been achieved as technologies mature and low carbon practices become more widely established across the trunk road network.

Materials Transport

- Preparatory work is underway for **zero carbon materials transport**, including engagement with suppliers and support for emerging vehicle and fuel technologies.

Materials

- The use of **recycled asphalt planings** has increased to **55%**.
- Trials are underway for **evolving lower carbon materials**, including alternative binders and low carbon concrete.
- Continued expansion of **biogenic road marking products** and **lower carbon steel** use.

Plant and Fleet

- For the small proportion of plant and equipment where full electrification is not viable, **appropriately certificated low carbon alternatives** are in use.
- All depots are equipped with the **charging or fuelling infrastructure** required to support full fleet transition.

2040 Milestone – 80% Emissions Reduction

By **2040**, an **80% reduction in emissions** will have been achieved, supported by widespread availability of zero emission transport, lower carbon materials, and mature supply chains.

Materials Transport

- **Zero emission transport** of maintenance and improvement materials to site has been achieved, using vehicles powered by renewably generated electricity and green hydrogen.

Materials

- **Alternative lower carbon asphalt binders**, such as biobinders, account for **25%** of asphalt use.
- **Low carbon "green" steel** accounts for **70%** of steel used.
- **Low carbon concrete** is used in **50%** of applications.

Plant and Fleet

- Nearly all heavy vehicles within contracted fleets are **zero emission**, with a clear programme in place to replace any remaining diesel vehicles as they reach the end of their operational life.
- Increased use of **drones and digital technologies** has reduced mileage driven for inspections by **50%**.

2045 Milestone – Net Zero Emissions (with Insetting)

By **2045**, **Net Zero emissions** will have been achieved across operation, maintenance, and improvement of the trunk road network, with residual emissions addressed through high integrity insetting.

Materials

- **Alternative lower carbon asphalt binders** account for **50%** of binder use, building on earlier material innovation and market maturity.

Offsetting and Sequestration

- The **carbon sequestration potential of Transport Scotland land** has been enhanced as far as practicable.
- **Residual emissions** that cannot be avoided are addressed through **responsible offsetting**, in line with Scottish Government principles.

Looking Beyond 2045

- Ongoing efforts continue to identify new opportunities to reduce emissions further as **technology, materials and practices evolve**, with the aim of moving as close as possible to absolute zero.

Enablers

Achieving Net Zero operation, maintenance and improvement of the Trunk Road Network will require substantive changes to how activities are planned, procured, and delivered. These organisational and behavioural measures are referred to as “enablers.” While they do not in themselves deliver quantifiable emissions reductions, they are critical to unlocking and sustaining the reductions set out in the Route Map.

Policy

In the short term, policies, standards, and processes will be reviewed to improve the integration of greenhouse gas emissions management into decision making. A gap analysis will be carried out against PAS 2080:2023 Carbon Management in Buildings and Infrastructure to clarify the actions required of Transport Scotland in its role as Asset Owner.

This review will include engagement with Operating Companies to identify any existing policies, specifications or requirements that may limit the effective implementation of the Route Map, including restrictions on the use of lower carbon materials or approaches.

Improving our Data

The development of this Route Map has provided valuable insight into the current carbon data landscape and has highlighted areas where data quality, coverage and assurance can be strengthened. Ongoing improvements to data collection and management will support effective implementation of the Route Map, enable progress to be tracked consistently over time, and provide greater confidence in reported emissions information.

Asset Management

Asset management approaches will be reviewed and updated with the aim of developing an Asset Management Strategy aligned with the Trunk Road Adaptation Plan. Key objectives include extending asset life, improving resilience to the impacts

of climate change, and reducing the long-term need for maintenance and improvement activities, thereby supporting emissions reduction over the asset lifecycle.

Depots

The current operating model, in which depot facilities are often shared with other organisations, presents challenges in fully quantifying and managing emissions. This model will be reviewed to assess opportunities for greater control over depot assets, including potential changes to ownership arrangements where appropriate.

Alongside this work, surveys will be undertaken to assess the feasibility of depot electrification, on-site renewable energy generation and the provision of infrastructure to support the charging of fleet vehicles.

Supply Chain & Procurement

Operating Companies will be expected to operate Carbon Management Systems aligned with PAS 2080:2023 and to commit formally to emissions reduction targets in support of the Route Map, for example through initiatives such as the Science Based Targets initiative.

The approach to assessing greenhouse gas emissions within contracts will also be reviewed, including opportunities to strengthen requirements through carbon budgets, internal carbon pricing, or the use of Key Performance Indicators to encourage desirable outcomes. These changes will be developed collaboratively with Operating Companies and the wider supply chain to ensure they are practical, proportionate and deliverable.

Behaviour Change

While technological solutions are essential, people and behaviour play a central role in delivering Net Zero. Building on commitments within the Carbon Management Plan, carbon literacy will be increased across Transport Scotland and its supply chain through targeted engagement and upskilling.

In addition to general awareness raising, specific training needs will be identified for roles with a direct influence on emissions, such as fleet and plant operators. Ongoing communication will support staff and partners to understand new developments and embed low-carbon practices in day-to-day activities.

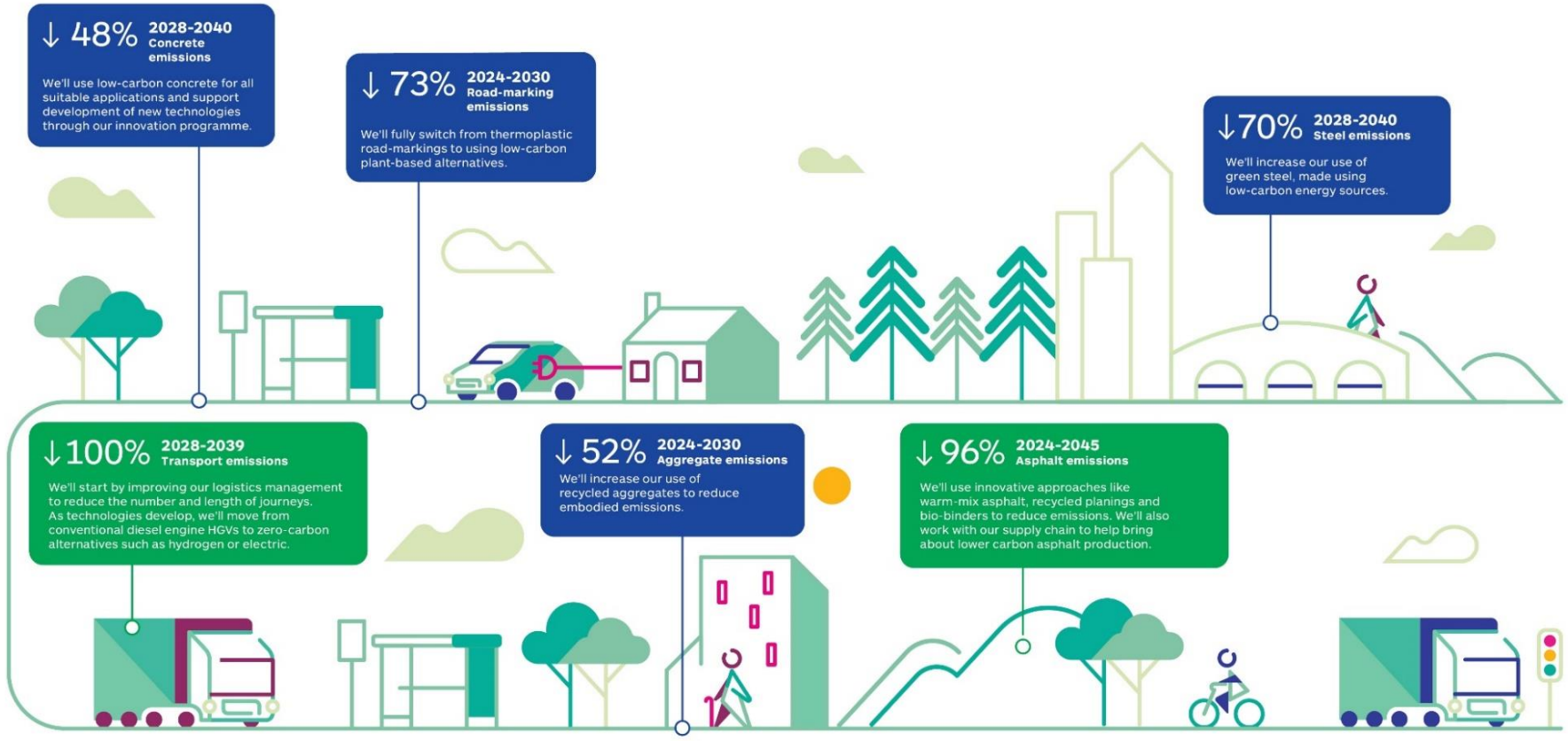
Collaboration & Innovation

As a national infrastructure organisation, Transport Scotland is well placed to work with industry bodies, manufacturers, and delivery partners to support innovation and accelerate the development of low carbon solutions. Closer collaboration will help provide confidence to the market that there is sustained demand for Net Zero products and services.

Within the supply chain, opportunities will be explored to support and incubate innovative ideas, including consideration of how promising concepts might be supported through pilot projects or targeted funding. The Route Map has identified key emissions “hotspots” that will inform priorities for research and development.

Through improved processes, stronger collaboration and a sustained focus on innovation, these enablers will support delivery of the Route Map and help achieve Net Zero emissions by 2045, with the responsible use of offsetting where required.

Appendix 1 – Decarbonisation of Maintenance and Improvement Activities



Appendix 1 shows that significant emissions reductions will be delivered across materials, transport, and improvement activities through targeted interventions between 2025 and 2045.

Materials transport (2028–2039)
Transport related emissions reduce by **100%** through improved logistics management, reducing journey numbers and distances, and the transition from diesel HGVs to zero-carbon alternatives such as electric and hydrogen vehicles as technologies mature.

Aggregates (2025–2030)
Aggregate-related emissions reduce by **52%** through increased use of recycled aggregates, reducing the need for extraction and processing of virgin materials.

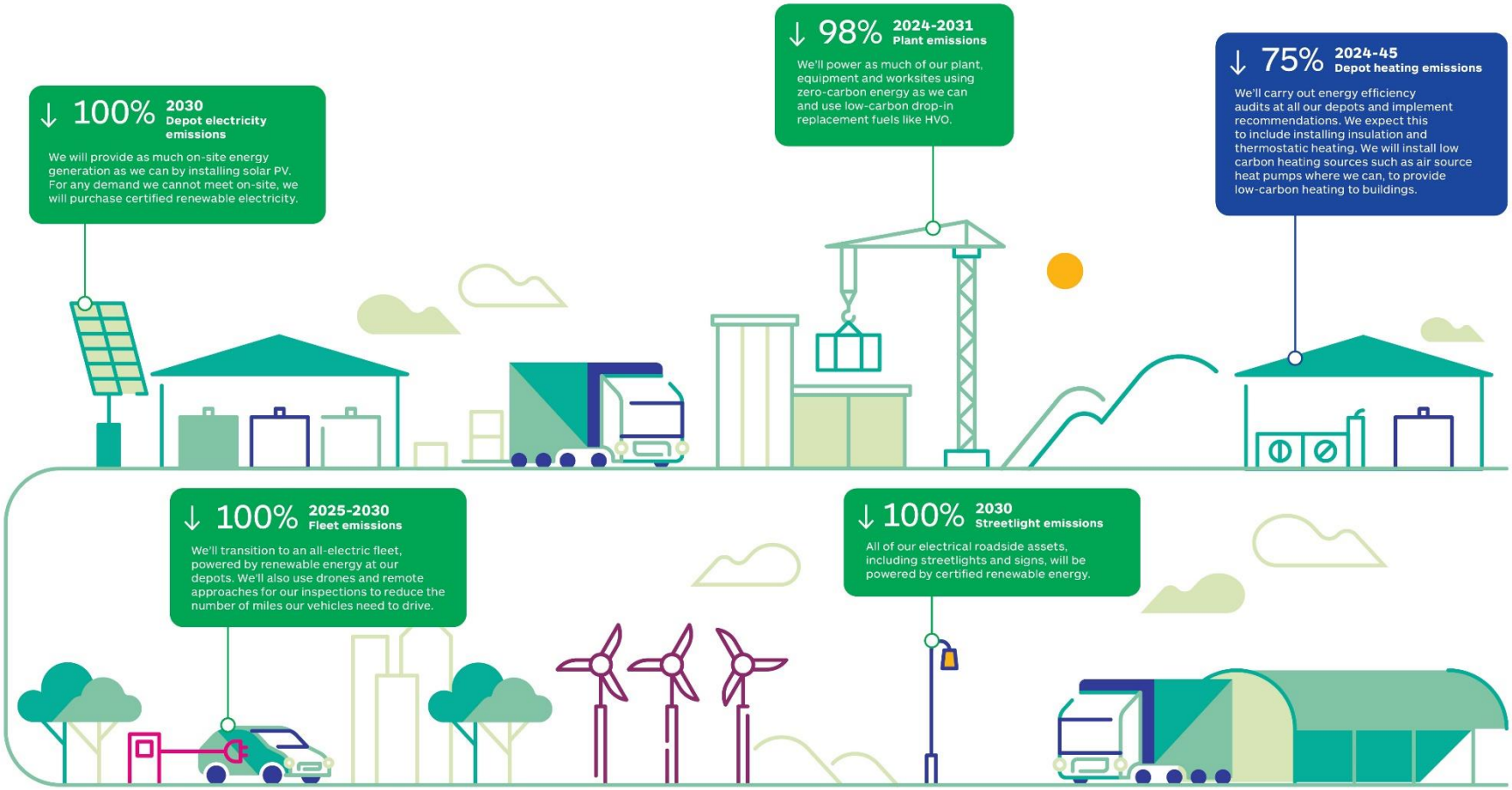
Road markings (2025–2030)
Road marking emissions reduce by **73%** through the replacement of thermoplastic products with low carbon, plant-based alternatives.

Asphalt (2025–2045)
Asphalt related emissions reduce by **96%** through the use of warm mix asphalt, increased recycled asphalt planings and the adoption of biobased binders, supported by collaboration with the supply chain to lower production emissions.

Concrete (2028–2040)
Concrete related emissions reduce by **48%** through the use of low carbon concrete in all suitable applications and support for the development of emerging low carbon concrete technologies.

Steel (2028–2040)
Steel related emissions reduce by **70%** through increased use of green steel produced using low carbon energy sources.

Appendix 2 – Decarbonisation of Operational Activities



Appendix 2 shows significant emissions reductions will be delivered across operation emissions through targeted interventions between 2025 and 2045.

Depot electricity (by 2030)
Depot electricity related emissions reduce by **100%** through onsite renewable energy generation, such as solar PV. Any remaining electricity demand is met through the purchase of certified renewable electricity.

Fleet (2025–2030)
Fleet related emissions reduce by **100%** through the transition to an all-electric fleet, powered by renewable energy at depots. Increased use of drones and remote inspection methods reduces vehicle mileage.

Plant (2025–2031)
Plant related emissions reduce by **98%** by powering plant, equipment, and worksites with zero carbon energy where possible, alongside the use of low carbon drop in replacement fuels such as hydrotreated vegetable oil (HVO).

Streetlighting and roadside assets (by 2030)
Streetlighting and other electrical roadside assets achieve a **100% reduction in emissions** through the use of certified renewable electricity.

Depot heating (2025–2045)
Depot heating emissions reduce by **75%** through energy efficiency audits and improvements, including insulation and thermostatic controls, and the installation of low carbon heating systems such as air source heat pumps where feasible.

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