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Decarbonisation Options for Transport Infrastructure

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CONFIDENTIAL

Waka Kotahi NZ Transport Agency

150 YEARS IN AOTEAROA

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Rev B	Incorporating responses to client feedback, addition of executive summary.
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Executive Summary

Introduction

Waka Kotahi NZ Transport Agency (Waka Kotahi) requested WSP NZ Ltd to deliver a project to uncover opportunities during construction, maintenance and operation that will contribute to reducing emissions and delivering low carbon infrastructure. The opportunities relate to reduction of embodied carbon through the project lifecycle. Emissions from vehicles using state highways and corporate emissions reductions are excluded from this study.

The project has involved desktop research and online conversations and workshops with a range of subject matter experts, researchers, and construction industry personnel. This consultation has aimed to create a comprehensive list of opportunities for design, construction, and maintenance of the transport network which should if implemented lead to measurable reductions in embodied carbon emissions (see *Summary Method* figure).

Figure - Summary Method

Opportunity Selection and Prioritisation

The drive for decarbonisation has led to the development of a substantial body of peer reviewed academic research, and information in the 'grey' literature (industry publications, consultant reports, conference proceedings etc.). Review of the literature and consultation with subject matter experts has culminated in a database of recommended decarbonisation opportunities. The opportunities were grouped into the following practice areas:

- Processes, including design, business case and standards.
- Pavement
- Structures, Earthworks and Slopes
- Water and Nature-Based Solutions

These opportunities were then prioritised by subject matter expert workshop, using assessments of:

- Likelihood to produce measurable and significant reductions in embodied carbon
- Cost implications (more expensive, neutral, or less expensive compared to standard approaches)
- Current feasibility for New Zealand, including availability or nearness to market.

The opportunities and the prioritisation outcomes in full are presented in an Excel workbook which accompanies the report. Prioritised opportunities are summarised in the recommendations below.

Recommendations

The journey of transforming the carbon intensity of infrastructure projects will require concentrated effort across all technical disciplines, and by asset owners, contractors, and consultants. There is a global focus on this work with organisations such as Waka Kotahi, National Highways (England) and Austroads all developing targets, processes, policy, and standards aiming for low carbon infrastructure development, operations, and maintenance.

Process Opportunities

During the project lifecycle the biggest carbon (or decarbonisation) impacts are made in the planning phases when macro decisions are made about project feasibility, funding, scale, and location. The following groups of opportunities were selected for prioritisation.

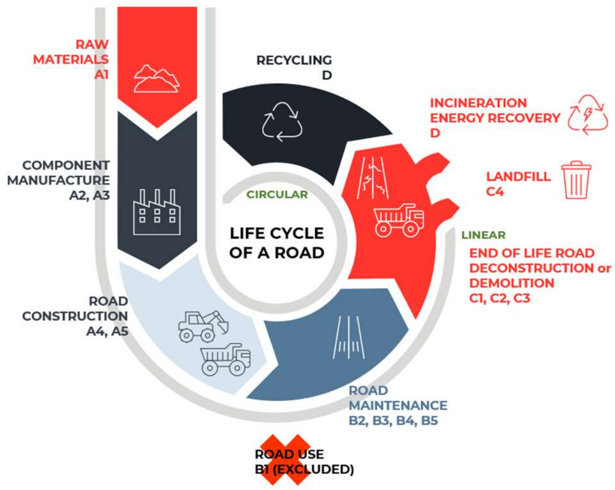

Figure - Circular and linear project life cycles, showing opportunities for materials reuse and recovery. Numbering of project stages reference the BS EN 15978 standard for infrastructure project carbon accounting

– To bring greater attention to options for reduction of life-cycle embodied carbon at the business case and concept design phases, including overarching investment decisions and major design decisions such as route selection, road geometry and structures requirements.

– To extend the design life and defer infrastructure replacement through planned maintenance and taking opportunities during maintenance to increase infrastructure resilience.

– Increase uptake of Nature-Based Solutions (NbS) through education and incentives.

– To implement procurement policies which incentivise embodied carbon reduction, leveraging the Waka Kotahi substantial market influence.

Other key opportunities that are process related were:

– To review standards to ensure that these aren't presenting institutional barriers to decarbonisation.

– To promote wherever possible the use of materials that are produced and processed locally leading to reduced transport emissions and co-benefits in support of Broader Outcomes. Barriers to local procurement discussed were cost sensitivity and availability of specialist products and skills.

Leveraging cross industry engagement and enthusiasm for decarbonisation is key and timely.

Pavement Opportunities

Ensuring that pavement design is resilient, and durable is a key decarbonisation step covered in process opportunities and to be pursued during design and through any standards review. Other pavement opportunities identified follow a hierarchy of.

1. Get quality right first time, avoiding rework and early failures.
2. Design for whole of life and long-life including use of technologies such as epoxy modified OGPA, and bitumen emulsion / warm mix application for sealing (emulsion mandated by Waka Kotahi after July 01, 2024).
3. Optimise design and programming, and,
4. Support and encourage innovation in materials and construction technology.

Availability and cost of aggregate for construction can be a significant issue in locations without a ready aggregate source. Market cost and availability has already led contractors to include recycled materials either those produced in-situ during pavement replacement or repair or imported materials for reuse. Waka Kotahi has an opportunity to influence greater reuse, and strengthen a circular economy approach through:

- Investigating setting up regional depots for the storing and reprocessing of construction waste materials / resources.
- Ensuring that standards are flexible to include for reused materials where appropriate.
- Continuing to research, trial and develop the use of other materials as aggregate substitutions such as glass, rubber crumb and plastics.

The current situation of no bitumen production in NZ has led to several research projects in the development of alternatives. Bio-bitumen processes have potential to make a positive contribution to a circular economy with waste products from the textile and forestry industry being investigated as feasible new materials to replace bitumen.

The Waka Kotahi mandated change to bitumen emulsion for sealing has been driven by health and safety improvements but research indicates this will also reduce pavement embodied carbon by around 50% compared to cut back bitumen, although certain additives and the transport large quantities of water may offset this saving (Bearsley and Rogers, n.d.). It is also key to ensure that additives used to enable bitumen emulsion do not have ecotoxic properties.

Energy for raw material production, materials transport and construction machinery energy is dominated diesel. Waka Kotahi should track projects for heavy vehicle energy transitions towards options such as lithium batteries and green hydrogen, working with and supporting suppliers and contractors. Where feasible grid connection or on-site solar should be considered for stationary plant.

Structures and Earthworks / Slopes Opportunities

The significant part that structural materials play in the overall carbon footprint of the transport network meant that less carbon intensive alternatives to concrete and steel and other alternative structural materials were a key focus of the structures SME team. Priority opportunities for concrete are summarised as:

- Expanding use of concrete mixtures with embodied carbon reducing additives, ensuring that life cycle carbon is accounted for as several supplementary cementitious materials (SCMs) are imported and / or mined, increasing their embodied carbon.

– Introduction of concrete using entrained / permanently sequestered CO_2

– Use of concrete from plants with lower embodied carbon due to alternative fuel uses[1].

The addition of fly ash into concrete, and other proprietary SCMs is already commonplace. Increasing this uptake, facilitating wider availability of the most effectives SCMs and continued research into low carbon alternatives is required.

Production of 'Green Steel' or steel production without coal is under development. Industrial scale production is planned for 2026 in Europe but is dependent on other investments in the hydrogen industry. Some research is underway in New Zealand ("Green Steel," n.d.) and would be dependent on significant structural investment in both hydrogen ("A vision for hydrogen in New Zealand | Ministry of Business, Innovation & Employment," n.d.) and steel technologies at scale to provide a long term alternative to current on-shore steel production and imports.

Waka Kotahi is already working on implementation of timber-based alternatives to steel such as Glulam. Further adoption of this technology is a key recommendation where appropriate.

Weathering steel is another technology which has been partially implemented and is commercially available now. These materials have improved weather and corrosion resistance and hence expected increased durability leading to lower lifecycle carbon.

Water and Nature Based Solutions Opportunities

Swales, raingardens, wetlands, and pond systems (also termed Water Sensitive Design, WSD) are NbS that have become relatively common practice in urban and rural transport infrastructure (opportunity 034, 059). As well as biodiversity, treatment and retention benefits, the systems (by mostly avoiding in ground pipes and reducing other hard infrastructure) also avoid adding embodied carbon. It is worth noting though that some nature-based stormwater solutions do require concrete or other man-made material elements for effective operation. Opportunities related to further adoption of nature-based water management solutions include:

– Guideline or policy revisions to encourage more widespread take up.

– Encourage replacement of piped stormwater systems with nature-based alternatives during maintenance and renewals.

– Eco-sourcing of plants for planted systems to support positive biodiversity and Broader Outcomes targets.

Decarbonisation opportunities for piped water management systems include:

– Use of lower embodied carbon materials and attention to whole of life cost.

– Installation practices that minimise the need to import or export materials and spoil, including trenchless technology.

The Structures SME group also discussed potential for research into NbS for slope stability, with research needed into the feasibility of establishing natural solutions for slope stability. Waka Kotahi is considering where implementation of NbS will lead to increased resilience in infrastructure recovery design following recent flooding and cyclone damage.

Any broad adoption of NbS that includes significant planting of native trees, shrubs or wetland plants has potential to provide Waka Kotahi with a carbon sequestration opportunity. Further investigation of sequestration and offsetting opportunities is underway by the Waka Kotahi environmental / landscape team.

[1] Currently only Golden Bay Cement are using wood waste and end of use tyres as kiln fuel (Source https://concretenz.org.nz/page/s_introduction)

Next Steps

WSP have developed an Excel based list of decarbonisation opportunities, that should be widely discussed and disseminated. This is an opportunity to develop a targeted decarbonisation opportunities and innovation programme that is designed to progress opportunities that will deliver the decarbonisation impact the transport system needs by certain timeframes, balancing scale of impact, timeliness, and likelihood of success.

Tracking decarbonisation projects and progress against targets also requires some focus. This project has made some recommendations on how to begin setting decarbonisation targets, and what potential quantum might be expected from different opportunities, based on subject matter expert workshop outputs. This work should be refined and further developed with the aim of quantifying the potential decarbonisation impacts of the most promising decarbonisation opportunities so that they can be specifically targeted to meet with any future Waka Kotahi or CNGP targets.

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Abbreviations

BAU	Business-As-Usual
BNV	Baseline Network Version
CERF	Climate Emergency Response Fund
CLMG	Contaminated Land Management Guidelines
CNGP	Carbon Neutral Government programme
EECA	Energy Efficiency and Conservation Authority
ERP	Emissions Reduction Plan
FTP	Fleet Transition Programme
GPS	Government Policy Statement on Land Transport
LETF	Low Emissions Transport Fund
LEVCF	Low Emissions Vehicles Contestable Fund
LTMA	Land Transport Management Act 2003
NESCS	Resource Management (National Environmental Standards for Assessing and Managing Contaminants in Soil to Protect Human Health) Regulations 2011
NLTF	National Land Transport Fund
NLTP	National Land Transport Plan
NPSFM	National Policy Statement on Freshwater Management
NPSIB	National Policy Statement on Indigenous Biodiversity (Draft)
NZUP	New Zealand Upgrade Programme
P46	P46 Stormwater Specification
P48	P48 Specification for Resource Efficiency for Infrastructure Delivery
R&D	Research and Development
RDPT	Research and Development Tax Incentive
REWMP	Resource Efficiency and Waste Minimisation Plan
SCM	Supplementary Cementitious Material
SCORS	Structural Carbon Rating Scheme
SSDF	State Sector Decarbonisation Fund
Waste Programme	Government Waste Work Programme
WMF	Waste Minimisation Fund
WSD	Water Sensitive Design
Zero Carbon Act	Climate Change Response (Zero Carbon) Amendment Act 2019

Disclaimers and Limitations

This report ('**Report**') has been prepared by WSP exclusively for Waka Kotahi ('**Client**') in relation to opportunities for decarbonisation of transport network infrastructure ('**Purpose**') and in accordance with the AoG Consultancy Services Order (CSO) dated 2022. The findings in this Report are based on and are subject to the assumptions specified in the Report. WSP accepts no liability whatsoever for any reliance on or use of this Report, in whole or in part, for any use or purpose other than the Purpose or any use or reliance on the Report by any third party.

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1 Introduction and Purpose

1.1 Background

Waka Kotahi requested WSP NZ Ltd to explore opportunities during construction, maintenance and operation of their transport network that will contribute to reducing emissions from land transport infrastructure. The project will inform responses to the Waka Kotahi Environmental and Social Responsibility Policy, Carbon Neutral Government Programme and the 2022 Emissions Reduction Plan. It is part of a large programme of work towards emissions reduction.

Analysis of New Zealand's carbon footprint shows that lifecycle carbon emissions from the built environment contribute approximately 13% of New Zealand's gross carbon footprint (thinkstep Ltd, 2018), see Figure 1-1.

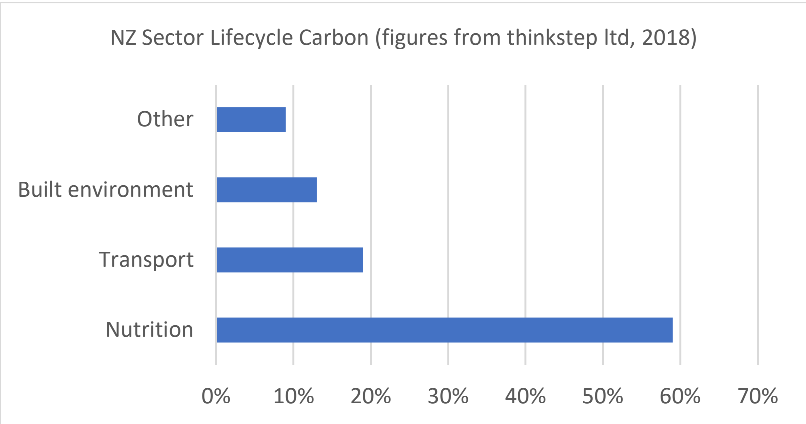

Figure 1-1 : NZ Sector Lifecycle Carbon, 2015 (adapted from thinkstep Ltd, 2018).

The scale of the embodied carbon added to the national carbon footprint through infrastructure construction is significant. The construction of transport infrastructure planned to start in 2021 in NZ was an anticipated $7.2 billion spend being 33% of total infrastructure projects (Statista, 2022).

A Waka Kotahi study (AECOM, 2022), assessed the embodied emissions associated with construction materials to be the biggest source of road construction emissions in NZ at 73% (inclusive of emissions from transport to site). This study included carbon emissions baseline for capital projects giving estimated per lane/km tCO2e for various classes of land transport construction projects with or without major structure or earthworks. Figure 1-2 inserted below is Table 6 from this report (addendum Nov '22).

CONTEXT FROM THE IPCC

In the sixth report of the International Panel on Climate Change (IPCC, 2022) it is noted that there is no single strategy to make a decarbonisation shift happen; it involves *"several factors, including technological innovations, shifts in markets, concerted efforts by scientists and civil society organisations to raise awareness of the costs of continued emissions, social movements, policies, and governance arrangements, and changes in belief systems and values"*.

	Number of Footprints	Mean average emissions per lane km (tCO_2e/ lane km)	Median average emissions per lane km* (tCO_2e/lane km)	Largest emissions per lane km (tCO_2e/lane km)	Smallest emissions per lane km (tCO_2e/lane km)
Road/Busway/Path	24	3082	2,964	5714	105
Shared path only	4	3621	2,053	10353	25
Intersection improvements – at grade	5	2340	1,206	7548	558
Intersection improvements – grade separated	2	4322	4,322	5570	3074
Railway	18	9194	9,388	9398	5889
Bridge	3	9029	5,717	18322	3047
Tunnel	2	9425	9,425	11099	7751
Safety and traffic flow improvements	2	1079	1,079	1699	459

Figure 1-2 Table 6 excerpt from Aecom 2022

The research outlined in this document is complementary to Waka Kotahi work completed on carbon baselining, providing insights into opportunities to materially reduce emissions. Emissions reduction will contribute to requirements under the Climate Change Response (Zero Carbon) Amendment Act 2019, and Waka Kotahi policies developed in response to this act and within the framework of the Carbon Neutral Government Programme.

The project has involved desktop research, online conversations, and workshops with a range of subject matter experts, researchers, and construction industry personnel. This consultation has aimed to create a comprehensive list of opportunities for design, construction, and maintenance of the transport network which should, if implemented, lead to measurable reductions in carbon emissions.

1.2 Scope

The scope of the decarbonisation opportunities assessed within this project are those within construction and operations/maintenance work on land transport infrastructure. This includes the whole project life cycle from business case process to asset disposal, and is focussed on life cycle embodied carbon, excluding emissions from users of the road.

Figure 1-3 illustrates the infrastructure life cycle addressed, differentiating between linear and circular lifecycle approaches. This figure references life cycle stages 'modules' A1, A2, ... D from the BS EN 15978 (2011) and BS EN 15804 standards, further information is included on Figure 3-1.

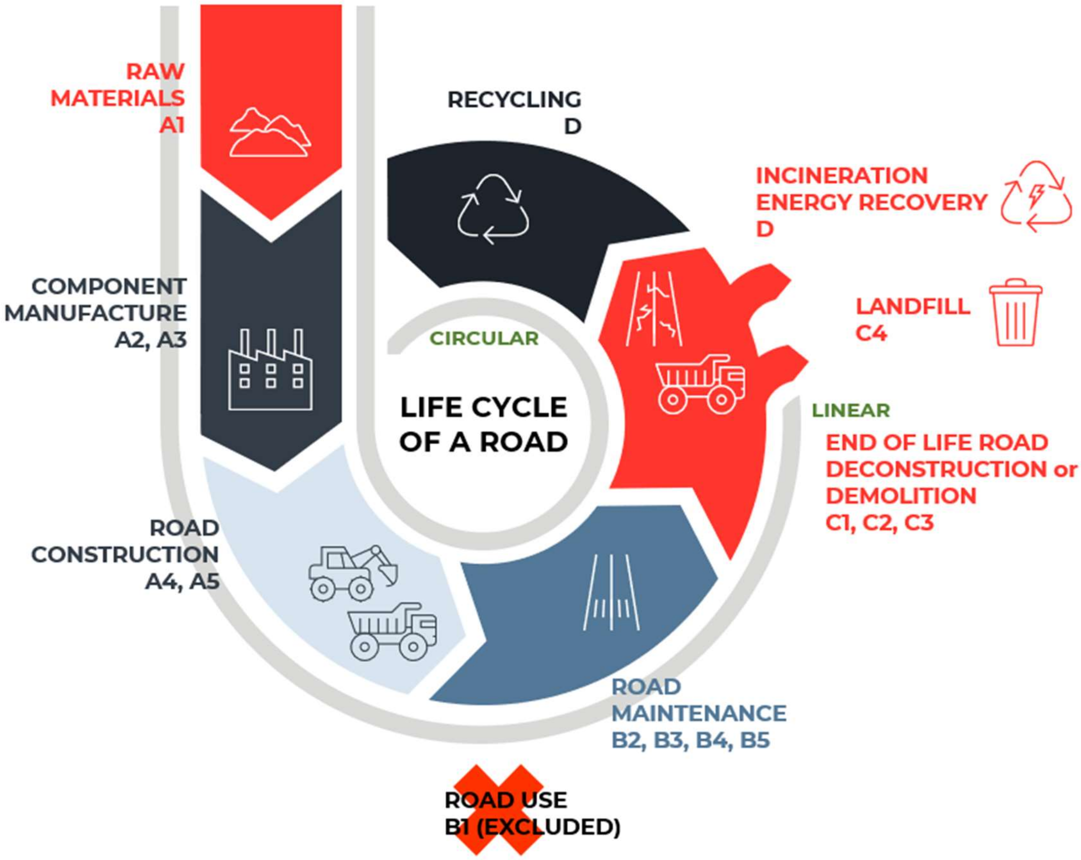

Figure 1-3 : Circular v. linear construction project lifecycles (adapted from Moins et al., 2022),

Known major contributors to transport infrastructure carbon emissions are the materials used (particularly concrete, asphalt, steel, aggregates) and the transport and heavy machinery fuel use for both transport of raw materials and placement and construction at site. Reduction of the total embodied carbon of these materials and processes carries major challenges. Opportunities to reduce these is the key scope area. It is acknowledged that commonly available alternatives are not always accessible, and that process and design related avoidance approaches are equally, if not more valid ways to address decarbonisation. As such the scope of this work includes opportunities outside of materials or fuels substitution for decarbonisation, such as design approaches, business case assessments and training. Figure 1-4 is an illustration of the potential for decarbonisation at various project stages, which highlights the impact of early decision making to minimise the building of new infrastructure.

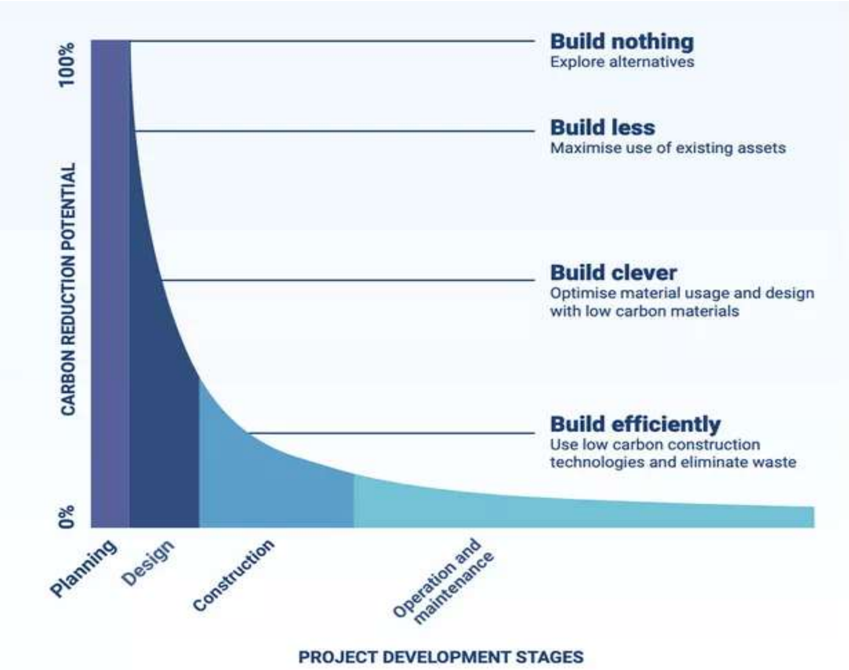

Figure 1-4: Illustration of the potential for decarbonisation through decision making and design during the project cycle (illustration adapted from 'Bringing Embodied Carbon Upfront', World Green Business Council 2019).

Excluded from the opportunities in this study, but covered by other major Waka Kotahi programmes of work, are enabled emissions reductions (e.g., mode shift, high occupancy vehicles and electrification projects) and emissions related to Waka Kotahi corporate emissions, (e.g., office energy use, corporate transport, and vehicle use).

1.3 Deliverables

The project deliverables are.

1. A list (in Excel) of decarbonisation opportunities. The list has undergone evaluation by subject matter experts as to the potential impact on carbon reduction, the relative cost compared to a business-as-usual approach and the feasibility of implementation.
2. This report, including literature and policy review and to provide some additional context and explanation of the evaluation process, potential barriers, and funding sources for opportunities.

It is anticipated that the opportunities list will be dynamic with both the opportunities being able to be added to and their evaluations revised as new technologies arise or become more established in the market.

This report is structured into:

- Methodology
- Literature Review
- Prioritised opportunities
- Policy Review
- Target Setting
- Funding Mechanisms
- Recommendations, and
- Next Steps

2 Methodology

2.1 Overarching Method

The project comprised the following steps (and see Figure 2-1).

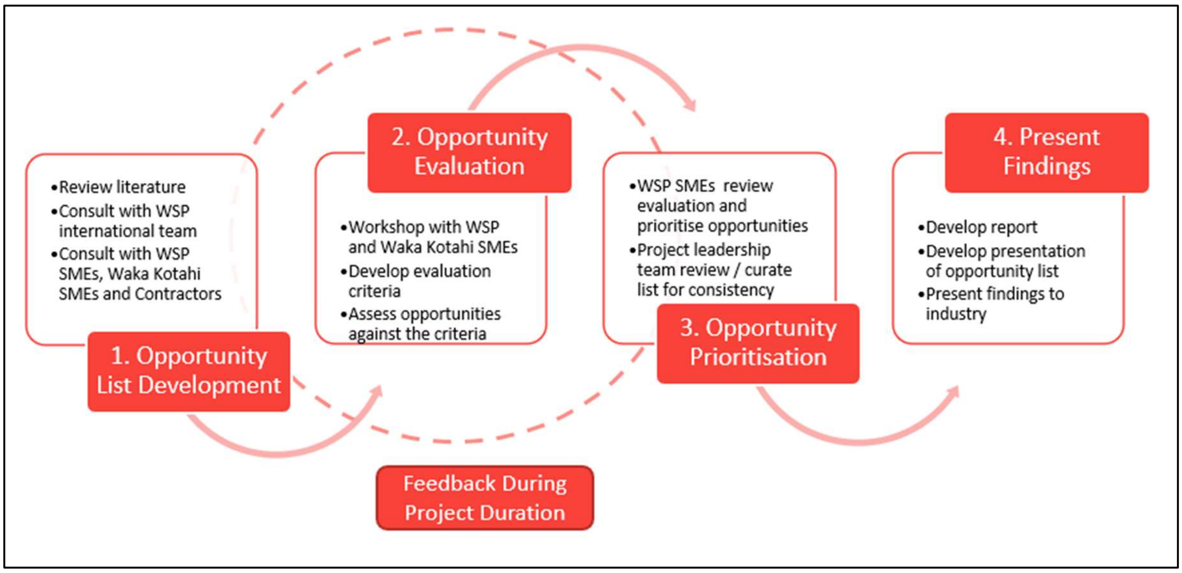

Figure 2-1 : Method flowchart.

1 Develop a long list of decarbonisation opportunities by consulting with in-house experts from WSP (national and international), Waka Kotahi experts, discussion with contractors (Downer, Fulton Hogan, Higgins), and a literature review, focussed on international literature (Section 3).

2 A longlist of opportunities was established (see Appendix A) from the literature and expert consultation meetings for further development during the project.

3 After initial development of the long list an online workshop was facilitated with WSP and Waka Kotahi subject matter experts (SMEs). During the workshop we split the experts into breakout groups to focus on opportunities from the following areas:

- Pavement
- Structures
- Water Sensitive Design and Nature Based Solutions

Each group first developed evaluation criteria for ranking opportunities as high, medium or low decarbonisation impact for three aspects, being:

- Potential carbon impact
- Cost of implementation
- Feasibility for implementation

It is important here to note the focus of these workshops was decarbonisation. The wider lifecycle impacts of opportunities (on biodiversity, cultural effects, water, or other emissions etc.) were not part of this assessment.

4 Following evaluation at the workshop the project leadership team, with assistance from WSP SMEs undertook some review and curation of the lists for cross over and comparability. Note that more opportunities were added at this point after additional consultation with SMEs in the geotechnical area and from the construction industry (Fulton Hogan, Downer and Higgins representatives).

5 Where gaps were discovered during the development of the report an iterative process was followed to add to the literature review and the opportunities list, WSP SMEs continued to be engaged with this process where new opportunities were introduced or additional areas for discussion were added to the report.

The summary of options is designed to be a 'live' document where new opportunities that arise can be recorded and evaluated. The list should also be regularly reviewed as opportunity evaluations are subject to change for a variety of reasons including additional research, technology development and market economics.

2.2 How the Options Were Evaluated

During the SME workshop expert groups first assessed how opportunities would be evaluated into high, medium, and low impacts based on three impact criteria: carbon impact, cost and feasibility of implementation (qualitative assessment against status quo options). These criteria would then be used to prioritise opportunities.

The results of those discussions are shown in Table 2-1. The water and nature-based solutions group decided on some higher targets for carbon reduction and expected cost neutrality for 'high' evaluations. This reflects both that the use of green infrastructure (wetlands, ponds, and swales) is already relatively common for stormwater and runoff treatment, and that replacing a concrete and pipe-based solution with a NbS has high decarbonisation potential.

Table 2-1 : Evaluation Criteria Detail, as developed at the SME Workshop.

		High - 3	Medium - 2	Low - 1
Pavement	Carbon Impact	>25% reduction	5-25% reduction	<5% reduction
	Cost	Cost neutral	10% increase	30% increase
	Feasibility	Proven now	~2 years away	Significant uncertainty & investment
Structures and Slopes	Carbon Impact	>30% reduction	10-30% reduction	<10% reduction
	Cost	Cost neutral	10% increase	30% increase
	Feasibility	Proven now	10 years away	Significant uncertainty & investment
Water Sensitive Design and Nature Based Solutions	Carbon Impact	>50% reduction	10-30% reduction	<10% reduction
	Cost	Cost Negative	Cost neutral	100-200% increase
	Feasibility	Happening now and enabled	Possible, not prevalent or consensus	Significant uncertainty & investment

The second part of the workshop required the groups to use these criteria to evaluate the opportunities, taking each opportunity and sorting it for its carbon impact, cost and feasibility in accordance with the criteria in Table 2-1. It is important to understand that these assessments are 'expert qualitative' and that no detailed assessment of carbon or costs were undertaken. An example of the output is shown below in Figure 2-2.

Changes and refinements to the cost feasibility and carbon impacts of any opportunities are very likely over time, and this is a key reason that the list of prioritised deliverables, which is the main project output, should be a live document which should be regularly revised and challenged.

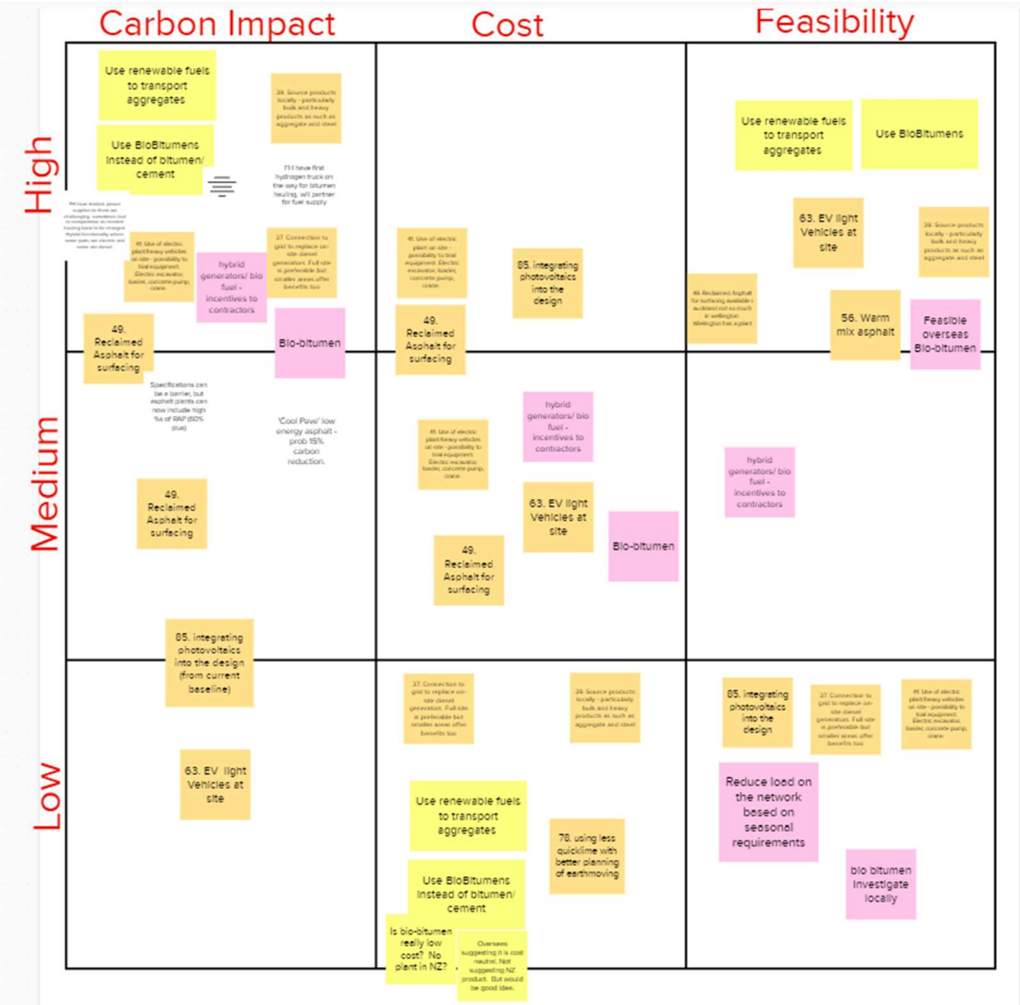

Figure 2-2 : Example Mural Output from Evaluation Workshop, Pavements Group.

Following the workshop, the evaluations were transferred into the spreadsheet of opportunities, and reviewed for consistency and presence of duplication by WSP. The low-medium-high evaluations were translated into scores of 3 (High), 2 and 1 (Low) to allow for easier sorting for prioritisation. The prioritised list was also reviewed by Waka Kotahi SMEs prior to finalisation, with review comments leading to several changes / refinements.

3 Literature Review

A review of literature related to reduction of embodied carbon in transport infrastructure has been undertaken, focussing, where available on life cycle carbon. We have utilised review articles where available, especially where there is a great depth of highly technical information available (for instance use of supplementary cementitious materials, and water sensitive design) and focussed on information released within the last decade. The review is organised into literature relating to the areas of:

- Policy making
- Carbon emissions and the project cycle
- Key sources of carbon in transportation projects
- Construction materials and their alternatives
- Water infrastructure and nature-based solutions

3.1 Policy making

Policy alignment with decarbonisation objectives is essential for success. The literature review identified the following success factors (Zhang et al., 2021a), (Zhang and Peng 2021)

- Policy grounded in robust research.
- Thorough understanding of local economic factors
- Multi-disciplinary decision making

Waka Kotahi can apply significant influence on the market through their procurement policies and ensuring that Standards support achievement of decarbonisation. Whilst Waka Kotahi may not be positioned to directly influence them other policy and economic levers such as implementation of subsidies, and tax reductions to reward companies investing and achieving in decarbonisation, are also recommended by a number of authors (Zhang et al., 2021a) (Zhang et al., 2021b) (Umar et al., 2020).

3.2 Carbon Emissions and Project Lifecycle

Measuring the success of policy direction and associated decarbonisation initiatives is a necessary part of any significant transition programme, providing beneficial feedback and understanding of any future needs to amend the programme. There are several international standards which have been developed for both carbon accounting and carbon reduction management covering both organisations and projects. The use of these standards allows for ready comparison between projects and brings transparency to the carbon accounting and reduction process.

Carbon accounting for projects is covered by ISO 14064:2 (2006), and the phases of infrastructure project life cycle for carbon management are commonly described as laid out in BS EN 15978 (2011) (see Figure 3-1). Note that this report and literature review includes all stages except B1 – 'Use' [2]which relates to carbon emitted by road users (sometimes referred to as tailpipe emissions).

The PAS 2080 (2023) standard published by the British Standards Institution (BSI) is a standard that has been adopted globally including by MBIE (MBIE, 2020). This standard covers the process

[2] Note that in PAS2080:2016 (now superseded) user / tailpipe emissions are referred to as 'B9'

for planning, managing and delivering projects to reduce 'whole-of-life embodied' carbon. Note that in this report we refer to this as 'life cycle' carbon.

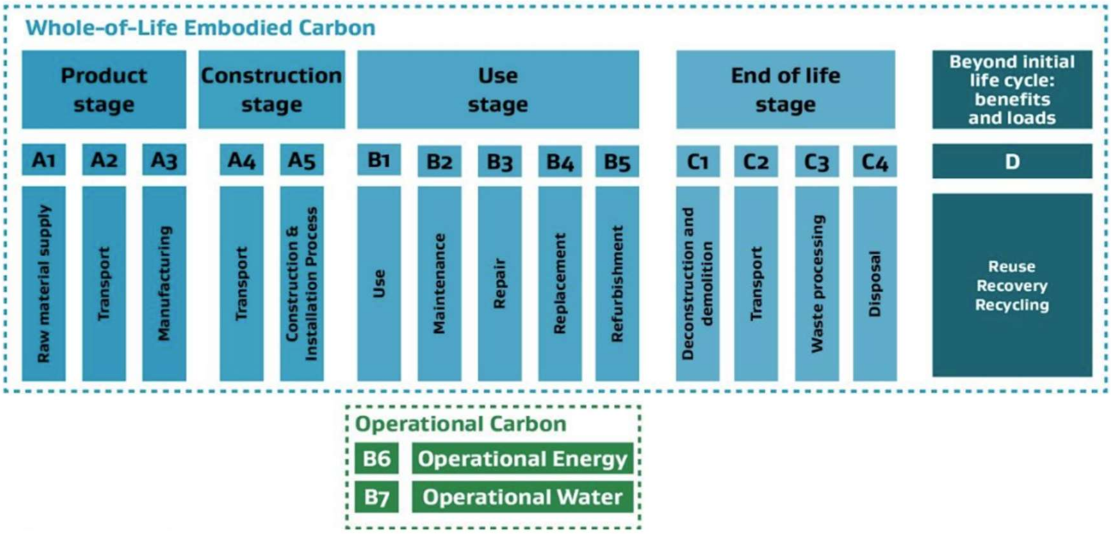

Figure 3-1 : Embodied Carbon in the lifecycle of construction projects (BS EN 15978 (2011).

Life cycle carbon assessment and circular economy approaches are fundamental to implementation of change in the transport sector (Smith, 2019). An example of a circular economy framework in the sector has been developed by National Highways, the agency which manages motorways and major roads in England, who are working towards adoption of circular economy with a five-point approach, being (summarised).

- Minimising demand on primary resources and maximising the reuse of resources.
- Being innovative and working with suppliers.
- Working to achieve stability of supply for high performance products.
- Supporting objectives in biodiversity.
- Adopt a natural capital approach to value of road land holdings.

The current road map is shown in Figure 3-2. This international example is presented for comparison. There are notable differences in the starting points for decarbonisation between different countries and their road controlling authorities which are important. For instance, the electricity grid in England is in a phase of rapid decarbonisation which is not available in NZ as renewable energy sources are already dominant. This difference means there is a major decarbonisation step opportunity in England for network operation (lighting and signage etc.) which facilitates a rapid percentage reduction in operational emissions.

Focussing on the construction and maintenance actions the National Highways plan has a very strong focus on.

- Influencing the supply chain.
- Appropriate standards.
- Development of a roadmap with targets.

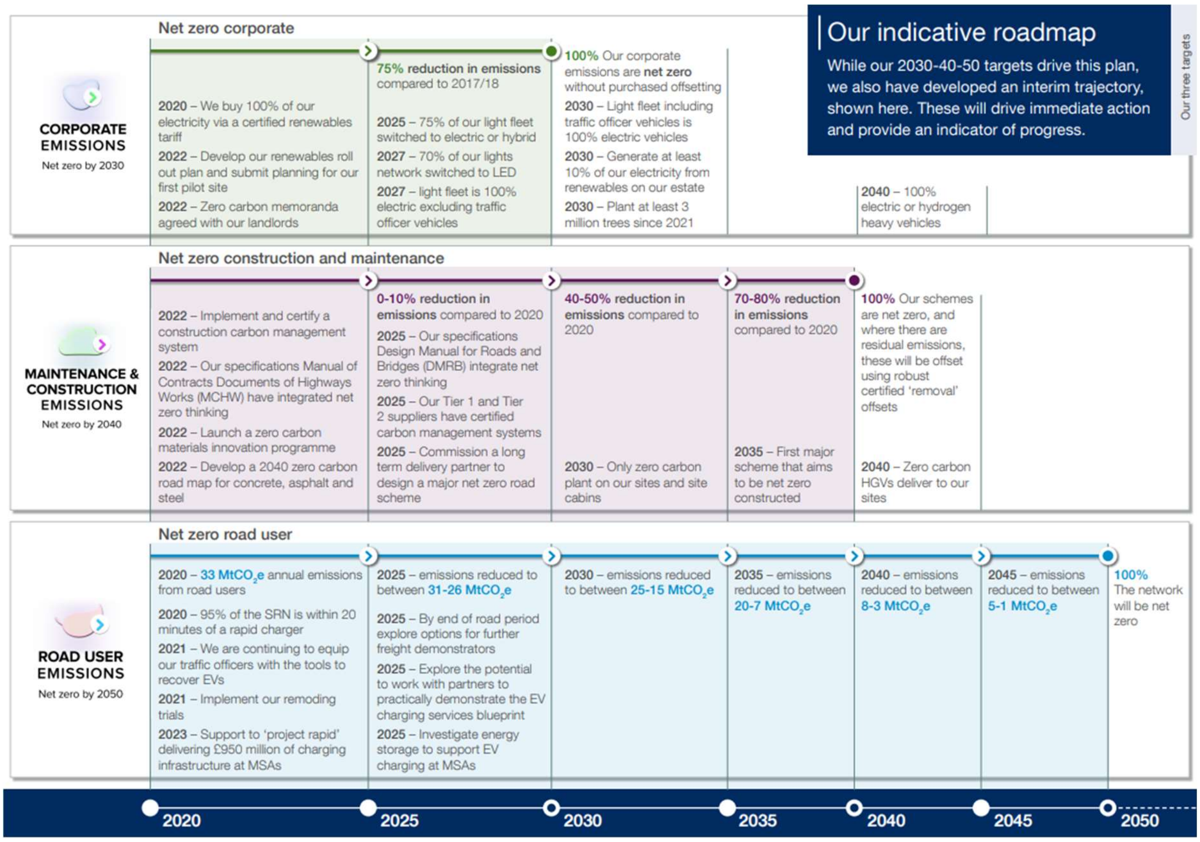

Figure 3-2 : National Highways Roadmap to Net Zero 2050 (Highways, 2021)

3.3 Key Sources of Carbon Emissions

This section of the literature review identifies research into material sources of carbon emissions in the transport sector.

A Waka Kotahi study, (AECOM, 2022), assessed the embodied emissions associated with construction raw materials, and their transport to site, to be the biggest source of road construction emissions in NZ at 73%. Sizirici et al., 2021 in their review of carbon footprint reduction in construction and Wang et al., 2015 both reach similar conclusions regarding the prominence of construction materials in the life-cycle embodied carbon of transport infrastructure. Wang et al studied four highway construction projects in China concluding 80% of the carbon embodied in road projects was accounted for within the materials of construction and their transport.

In the Waka Kotahi study, (AECOM 2022) onsite construction emissions were estimated at 20% with those emissions driven by the use of diesel-powered heavy construction machinery, this proportion can be significantly increased however if the project requires major earthmoving, or tunnelling. Sizirici et al., 2021., cite earthworks and reinforced concrete works as significant contributors for all construction projects and also assessed the impact of idling time. Whilst vehicles only emit approx. 20 – 30% of the carbon dioxide whilst idling compared to whilst working the amount of idling time can be significant. Their study described a USA construction project (18.8-mile highway) where across the combined machinery there was approximately 6 hrs of idle time per day over a 7-day work week, being significant over a 2.5-year construction timeframe. Waka Kotahi network outcomes contract (NOC) contractors are currently working in this space to assess the impact of idling and putting in place processes to reduce emissions from idling vehicles (pers. comm Dr P O'Shea, Downer).

The final percentage split of embodied carbon between materials and construction activity is highly dependent on the type of project, the project ground conditions, project setting with the presence or absence of major structural works (bridges, grade separation etc.). Major structures will skew carbon emissions towards materials whilst significant cut and fill requirements, or tunnelling, increase the percentage of carbon emissions from construction fuel / energy requirements.

3.4 Materials, alternatives, and methods to lower carbon emissions

Key areas of research to reduce embodied carbon in road transport infrastructure include assessment of potential new ways to manufacture, or alternatives to, core materials such as bitumen, concrete, and steel (Beca, 2021), the Beca report includes an estimate that more than 70% of the embodied carbon in Waka Kotahi infrastructure is attributable to concrete (cement), asphalt (bitumen) and steel. This section and those following discuss the literature related to the reduction of embodied carbon present in materials used.

3.4.1 Bitumen and Asphalt

Opportunities for reducing embodied carbon in asphalt include:

- lower energy application techniques.
- partial or full replacement of bitumen with lower embodied carbon materials, and
- use of recycled materials,

Warm mix asphalt (WMA) research and technology has developed over the past two decades (Tutu and Tuffour, 2016) as an industry response to the significant energy requirements of hot mix asphalt (HMA). Industry uptake of WMA is strong with a range of industry bodies and government agencies recommending rapid take up of the technology ("Development of Specifications and Technical Guidelines for Warm Mix Asphalt," n.d.), ("Warm mix asphalt offers green solution," n.d.). This technology is enabled by the introduction of agents which allow decreased binder viscosity at lower temperatures, including foaming and emulsifying agents and organic additives with the required melting point(Choi, 2007). As well as carbon reduction the use of lower temperature techniques have been assessed as having significant health and safety benefits ("#21-07 Move from hot cut-back bitumen to bitumen emulsion | Waka Kotahi NZ Transport Agency," n.d.) .The safety benefits have been the main driver behind the Waka Kotahi mandate that cut back bitumen will be replaced by bitumen emulsion from 01 July 2024.

It is estimated that WMA can reduce energy by 25-50%, although depending on the final mixture some of this may be offset by requirements to transport material with the additional weight of water (emulsions), or other possible environmental side effects of foaming or emulsifying agents including kerosene (WSP, 2021).

Mhatre et al., (2021) cite several alternatives to bitumen such as tyre rubber powder, palm oil fuel ash, recycled plastics as well as other materials for use in repair. As well as needing to prove the technical feasibility of these alternatives, other factors such as other environmental emissions, availability in the project locale and availability of suitable processing plant will need to be assessed to fully understand their potential.

New Zealand directly imports the 150-170,000 tonnes of virgin bitumen it uses annually. A locally produced alternative, with a lower carbon footprint would have multiple benefits including resilience of supply (WSP, 2021). Waka Kotahi have completed research into bitumen alternatives for New Zealand such as recycled material mixes, bitumen emulsions, foamed bitumen surfacing and recovered textile fibres (Beca, 2021). The Formary report to Waka Kotahi demonstrated the potential use of recovered textile fibre for roading surfaces, (WSP et al., 2021), and research commissioned through the Endeavour fund in 2022 seeks to develop a 100% natural, renewable bitumen alternative.

Recycled asphalt pavement (RAP) has been used widely and has many benefits, though there are still research areas to tackle, (Zhao and Liu, 2018). RAP can significantly contribute to cost-saving and emissions reduction and is very common in hot mixed asphalt as well as being suitable for warm mix applications. It can also be used as an aggregate in sublayers (Zhao et al., 2021) and studies continue to look at maximum / optimised RAP percentage mixes (Mattinzioli, 2022). Technological improvements in asphalt plants mean that some are now capable of handling 80-90% RAP (WSP, 2021).

3.4.2 Aggregate and Alternatives

According to the Aggregate and Quarry Association, NZ uses 9-10 tonnes of aggregate per capita, per annum, with the majority of this being used in either house or road building. 500 truck and trailer loads of aggregate provide 14,000 tonnes of construction aggregates for each kilometre of a two lane highway ("Fact Files | Aggregate & Quarry Association," n.d.). Alternatives to virgin quarried aggregates are required to preserve the source environments and lower embodied carbon.

Construction and Demolition (C&D) waste may represent up to 50% of all waste generated in NZ. 20% of this waste is estimated to go to landfill and 80% of it to cleanfill sites (source, BRANZ). The need to divert these wastes from landfill and the relative abundance of the materials means that use of suitable clean fill as aggregates and sublayers is relatively common, (Vieira et al., 2022). The use of recycled coarse aggregates (RCA) in asphalt was studied and modelled in Vega A. et al., 2022, the study showed the 15% and 25% recycled aggregate mixtures scored well in all aspects of the life cycle assessment including multiple environmental factors, greenhouse gas emissions and pavement performance. They also found that a higher percentage mixture with 45% recycled content was less preferable than 100% natural aggregate largely because of lower pavement performance leading to a necessity for use of a deeper surfacing layer or more regular maintenance and repair.

Austroads released an updated guide for the use of recycled materials in pavement in July 2022. It contains a framework to navigate the initial assessment, engineering performance, environmental performance, health and safety and project performance of recycled materials (Clark, 2022). The materials covered in the guide are.

- Recycled crushed glass.
- Recycled plastic waste.
- Industrial slag.
- Recycled tyres.
- RAP.
- Coal combustion products.
- Recycled crushed concrete and masonry.

The Austroads guide provides a detailed review of each of these classes of recyclate but does not comment specifically on potential carbon emissions reduction. The details in the guide highlight that understanding the full life cycle carbon emissions of the recovery, collection, processing technologies required, transport distances and application technologies employed is complex. Key decarbonisation specific areas for consideration would be:

- Material availability (including long term) and locale. Note some commonly used recyclate such as fly ash will become less available with a renewable energy transition.
- Energy requirements for processing.
- Energy requirements for application.
- Suitability and durability.
- Potential for end of use recycling, i.e., does the material further degrade during use leading to eventual necessity to landfill.

3.4.3 Structural Materials

Steel and concrete are the most common structural materials in the transport corridor. Recent Waka Kotahi research (Beca, 2021) assessed the potential for alternative materials, specifically for NZ. The study concentrated on the currently available, near term, and longer-term potential lower embodied carbon alternatives to address the majority carbon emissions from the materials production phase. An extract from a table in the report is shown as Figure 3-3, summarising available alternatives for concrete/cement and steel.

Material Type	Alternatives commercially available now (0-2 years)	Alternatives available mid-term (2-5 years)	Possible alternatives future (5+ years)
Concrete/Cement	Fly ash substitution - *import* Fly ash substitution – *Huntly Power Station* Steel fibre reinforcing Glass as sand substitute	Natural pozzolans Magnesium based cement - *repairs only currently*	N/A
Steel	Timber Weathering Steel Recycled Steel Plastic reinforcement Glass reinforcement FRP (Fibre reinforced polymer) Optimise beam design	Lower embodied carbon steel - *Biomass as a reducing agent to replace coking coal*	Lower embodied carbon - *Hydrogen as a reducing agent* Electrolysis - *reduced iron or using electricity*

Figure 3-3 : Assessment of alternative construction materials, partial table extract from (Beca, 2021).

The contribution of the materials production phase to the embodied carbon of bridge structures has led to an upsurge in the interest in and practical application of timber or timber-based products for bridge construction, particularly in countries where construction timber is commonly grown. There are a lack of detailed, comparable LCA studies that include timber bridges (Niu and Fink, 2018), but what is available, such as the Norwegian study on a 1,650m 4 lane highway bridge (O'Born, 2018) clearly shows the reduction in embodied carbon that can be achieved with these structures due to the low (or negative) embodied carbon of the timber materials.

The use of supplementary cementitious materials (SCMs) is an area of significant research activity over the past decade. A critical review (Samad and Shah, 2017) highlights the reasons for this; each tonne of cement produced using traditional methods produces about a tonne of CO_2, and, at the time of publication, they reported that concrete consumption worldwide is about one tonne per annum for each person alive. The cement industry accounts for approximately 5% of anthropogenic CO_2 emissions split between burning coal during manufacture and (40%) and calcination of limestone (60%). There are various SCMs available, including waste materials such as fly ash or products of recycled glass, and mined products such as pozzolans. The impact of SCMs on concrete performance and applications is included in Samad and Shah, and other reviews (Park et al., 2021) (Juenger et al., 2019). SCMs described in these articles have been shown to be applicable for many uses on the transport network. The use of fly ash is described as commonplace and there is ongoing research into long term durability and materials properties of concrete containing both fly ash and other SCMs.

Whilst the use of SCMs is promising due diligence is recommended for understanding the full life cycle carbon for concrete containing these materials (Tushar et al., 2022). SCMs may influence durability and hence possible need for more frequent repair or replacement, and some SCMs are from mined sources and hence include embodied carbon from mining activities. Fly ash, one of the most used SCMs, is a by-product of coal fired power and the CO_2 produced during that process is accounted for as part of energy production. With the anticipated decrease in coal fired power production globally this resource should become scarce. At the current time fly ash is imported from Asia to NZ as an SCM due to lack of material availability domestically.

LCA is demonstrating that paying close attention to the material used in construction and aiming for higher rates of recycled materials, particularly recycled steel reduces life cycle embodied carbon (Dequidt, 2012; García San Martín, 2011). In a review of application of the circular economy to Indian transportation projects (Mhatre et al., 2021) several methods to reduce embodied carbon are suggested, including using strength enhancers more efficiently, use of bio-based materials, cathodic protection repair, carbon fibre reinforced polymer sheets, or steel supports, can be used with corrosion inhibitors, and can be reused and recycled.

3.5 Maintenance Considerations

Several studies were found related to opportunities for emissions reduction associated with the maintenance and rehabilitation of pavements. Similar to capital works researchers have identified that materials reuse is an effective decarbonisation strategy (Freire et al., 2022).

Reduction of life cycle carbon in the maintenance phase is heavily influenced by design for durability, to minimise the maintenance and repair (Broomfield, 2013). Planned maintenance to increase durability and extend pavement or structure life for normal use, and to resist climate change and natural hazard risks, is highlighted as a life cycle decarbonisation opportunity by several studies (Wang et al., 2020), (Yu et al., 2015). A change from threshold based rules, where maintenance will happen when the deterioration of the system exceeds a certain threshold, to planned and preventative maintenance strategies based on smart decision making models with a life cycle approach is recommended (Chu and Chen, 2012). Additional benefits of this life cycle and durability approach are highlighted by Dhatrak et al 2020, as the failure of pavement often impacts the wastewater, stormwater, electricity and communication infrastructures underneath the system or along the corridors (Dhatrak et al., 2020).

Accounting for and optimising design for climate change will increase the resilience of infrastructure to extreme events and therefore reduce general maintenance and emergency maintenance requirements and embodied carbon. Some examples of cases where climate projections are heavily influential to minimise maintenance are the number of days above the high-temperature threshold for rail design or extreme rainfalls and floods for underpass design (Hayhoe et al., 2015).

Designing for extreme events considering the location and context is going to be a new normal such as urban flood loads, post-disaster functionality, storm surges, and land-use changes in building codes (Pritchard, 2013). Existing infrastructure is designed based on the previous historical data; however, the growing impact of natural disasters needs a change in the design and recovery of the system and actionable steps to make it easier for different agencies to take action (Daniels and MacArthur, 2022). Road access can be the first and main access route in times of extreme events. Therefore, post-event disruption analysis and estimating scenarios are required to design and restore transport infrastructure and provided resiliency which will lead to lower carbon impacts of rebuilding requirements following natural disasters (Williams et al., 2022).

Saleh and Hashemian undertook a review of major vulnerability issues and adaptation measures for pavements in a number of geographies, concluding that a suite of engineering-informed adaptation strategies (increasing the thickness of a pavement layers, the use of stiffer binders, the use of more steel reinforcement for concrete pavements, load allowances and/or restrictions, the use of geotextiles, and updates of worker safety and comfort requirements) were needed to adapt pavement to allow for increasing temperatures and precipitation, being the key climate related stressors they assessed. (Saleh and Hashemian, 2022).

A study by Banerjee discusses infrastructure maintenance deficiencies due to spending budget in the wrong place; that is, the required maintenance of existing roads and bridges is more important than building new infrastructure. When maintenance does not take place in a timely manner, the costs of repairing the infrastructure and vehicles increase, and this cost is not only financial as carbon emissions of the overhaul maintenance are more than preventive maintenance (Banerjee, 2016; Zhang et al., 2021b).

Smart monitoring of networks for maintenance needs is a rapidly evolving area of research, a systematic review (Amândio et al., 2021) concludes that smart technology can contribute to more efficient, less costly, safer, and environmentally friendly outcomes. The review states that combining easily applicable smart technologies, such as smart phones apps, drones for external analysis, and embedded sensors for internal analysis, could lead to optimised maintenance decision making.

3.6 Water Infrastructure and Nature Based Solutions

The stormwater drainage system is a significant element of transport construction projects. The design of these systems and the potential for the use of water sensitive design (WSD)[3]

NATURE-BASED, GREEN, BLUE, AND GREY ENGINEERING DEFINITIONS

Te Mana o te Taiao – Aotearoa New Zealand Biodiversity Strategy 2020 defines nature-based solutions as "solutions that are inspired and supported by nature, cost-effective and simultaneously provide, environmental, social and economic benefits and help build resilience".

Within NbS design elements may be referred to as green, blue, or grey. Green refers to plants or terrestrial ecosystems and Blue to aquatic, freshwater, wetland, or coastal systems. Grey are elements of a design that use traditional engineering materials like concrete, steel, or plastics.

Often, as is the case with water sensitive design (such as swales, raingardens and constructed wetlands), the design incorporates green, blue, and grey elements (such as concrete or steel)

[3] Referred to in this paper as water sensitive design (WSD), these techniques refer to more naturalised solutions to stormwater and runoff management. These techniques may also be known as water sensitive urban design (WSUD), sustainable urban drainage systems (SUDS) and as elements of LIUDD (low impact urban design and development).

methods with less 'grey' infrastructure and more 'green' elements are highly dependent on both location and the rainfall intensities to be designed for. Traditional civil engineering systems of kerb and channel, concrete pipes or PVC/PE pipes and infiltration basins or connections to stormwater pipe systems tend to use more carbon intensive materials and require more transportation energy than a number of WSD alternatives (Fathollahi and Coupe, 2021), (Moore and Hunt, 2013).

Where full scale application of WSD with limited hard engineering is not feasible similar principles to the construction of other structures apply for stormwater system design. Lower embodied carbon alternatives to concrete pipes are available, with life cycle carbon assessments advising that PVC pipe has the lowest embodied carbon (Alsadi, 2019). Design of the stormwater system to lower likely maintenance requirements and in particular taking account for climate change is described by several authors as being beneficial for lifecycle carbon reduction, (Yang et al., 2020), (Popovska et al., 2019), (Kalyviotis et al., 2017).

Nature based solutions (NbS) "*leverage nature and the power of healthy ecosystems to protect people, optimise infrastructure and safeguard a stable and biodiverse future'* (IUCN). From a built environment perspective this describes a variety of approaches to infrastructure design which aim to incorporate or entirely use natural 'green' (plant based) or 'blue' (water-based) systems to replace functions that might typically be played by structures which are built with 'grey' materials (hard / concrete / steel materials). Common examples of NbS applied in transport infrastructure design are.

- Wetlands, ponds, raingardens, and swales in WSD for stormwater runoff attenuation and treatment.
- Planting and bio-based mulches / coir mats to stabilise slopes and batters.
- Tree plantings for shading and amenity.

Interest in NbS for increased climate resilience is increasing, particularly relating to coastal zone protection for infrastructure and property, but also for inland flooding protection. This encompasses systems such as:

- Dune restoration.
- Floodplain restoration.
- Beach nourishment.
- Dynamic revetments.

A study by Małecka-Ziembińska provided a list of solutions which are applicable to transport infrastructure design and at a smaller scale than the landscape scale interventions listed above, they include native plantings, green stops, shelters and roofs, biophilic design style, use of vegetation resistant to road pollution, and permeable road surfaces (Małecka-Ziembińska and Janicka, 2022).

There are a number of guidance documents that have been produced for NbS ("Nature-Based Solutions for Coastal and Riverine Flood and Erosion Risk Management," n.d.), (Małecka-Ziembińska and Janicka, 2022), ("Nature-Based Solutions for Coastal Highway Resilience," n.d.) which focus on design principles and practical application. However, these do not make specific consideration of embodied carbon of these infrastructure elements, or their potential carbon sequestration. Kavehei et al., 2018 reviewed several WSD devices and concluded that rain gardens have potential to sequester over their lifetime all or more of the carbon embodied in their construction, with bioretention basins, green roofs and vegetated swales also potentially sequestering proportions of their construction footprint. The soil within roadside wetland and swale systems sequesters carbon along with plantings, with damp and wetland spoils sequestering at a higher rate (Bouchard et al., 2013). Additional targeted research based on NbS for carbon sequestration, and the embodied carbon in NbS as practically applied, would be required for confidence in applying this as a factor in life cycle carbon assessments. In the absence of specific research, standard factors for earthmoving, transport, concrete and aggregate or other planting medium use in design can be applied to develop embodied carbon calculations for such systems. Note that Waka Kotahi is not currently able to include carbon offsets in their carbon reporting.

The role of urban trees and green areas has been the topic of many studies for both carbon sequestration and encouraging active transport. The importance of natural adaptive potential and creating urban design solutions adjusted to the natural conditions is presented in Rędzińska & Piotrkowska, 2020. Kiel studied the harmony between greenways and public transportation and found that greenways can improve social cohesion, promote physical activities, landscape aesthetic, economic development and ecological restoration; also, they encourage emission-free transportation and sequester carbon (Kiel, 2017). Iligan proposed to use green walls in major transport infrastructures to reduce temperature and pollution. A lack of knowledge, standards, regulations and support for NbS has been identified as a barrier (Iligan and Irga, 2021). Additional knowledge on the maintenance and management is these systems is also required to build confidence in their long term cost and maintenance needs, variability in information currently available is highlighted in the National Science Challenge report on costs and maintenance of WSD solutions (Moores, n.d.).

NbS and other 'green' infrastructure can link the urban environ to nature and green areas and many co-benefits can accrue from greening infrastructure for carbon management. Quality of life, health and social cohesion and another point of view, soil imperviousness, stormwater management/quality, water infiltration, and reducing urban heat islands would be improved. Trapani describes this green-grey-blue infrastructure connection as a feasible answer to the previous failures in urban planning (Trapani et al., 2021).

3.7 Conclusion

Findings from the literature review reveal several critical elements from international studies which are equally applicable in New Zealand.

Themes in governance and change management include the importance of multidisciplinary approaches and development and application of policies and regulation, and development of programmes of work and guidelines to turn targets into on-ground outcomes. As all jurisdictions are only just beginning on significant, targeted decarbonisation programmes there are no mid- or long-term quantitative studies on the effectiveness of road transport decarbonisation programmes yet.

The largest proportion of embodied carbon in road transport infrastructure life cycle is from the main material elements used in construction (and maintenance). This encompasses extraction and transportation of raw materials, and manufacturing of construction materials and products. The following areas / themes from the literature review which are either proven or promising for decarbonisation are considered most relevant in the New Zealand context.

- *Considering whole of life carbon, including durability to minimise the addition of embodied and operational carbon during maintenance works*. Resilience and understanding impacts such as natural hazards and increasing risks due to climate change are key elements of this durability planning. Use of long life pavement treatments and shifting to planned maintenance for resilience and durability.

- *Reuse and recycling of elements*, where possible, including decision making at a macro scale (keeping road layouts for instance) and on individual construction elements such as reuse of onsite materials as backfill.
- *Use of renewable energy sources for transport / construction*. This encompasses both changing from a diesel dominated vehicle fleet and ensuring that transport and construction processes are efficient to reduce transport and construction energy wastage.
- *Working towards replacement of key materials with lower embodied carbon options* . This is an area of significant investment by both research bodies and manufacturers. Lower carbon, 'green' and zero carbon options for steel, bitumen and concrete are all coming to market for either immediate application or are in development or testing phases. Several promising alternatives are highlighted in this review and discussed in other areas of this report.
- *A shift in thinking away from predominantly 'grey' infrastructure into more 'green' and 'blue' alternatives*. Research into application of these approaches is mature for stormwater runoff and Waka Kotahi advocate and provide guidance for these approaches, but other elements such as slope stabilisation and coastal protection are less well published and trialled.

Some areas are light of published research, particularly review articles comparing approaches, challenges, and achievements in decarbonisation for transport infrastructure. As more of this work is undertaken it is likely that these studies will begin to appear and following this is a recommendation from the study.

4 Prioritised Opportunities

4.1 Overview

This section contains summary information on the opportunities prioritised during SME workshops. The opportunities are presented in four sections ('Element Types'), three being the groups within which opportunities were brainstormed and evaluated, and an additional 'Process' section to cover the high number of opportunities that cut across all construction output types, such as changes to standards, carbon-focussed design workshops and training to support a carbon neutral transition. The summary tables are presented in the following order.

1. Process,
2. Pavement,
3. Structures and Earthworks / Slopes, and,
4. Water and Nature-Based Solutions

As the opportunities list grew, they fell naturally into the following groups/categories which also reflect areas which Waka Kotahi can focus on to drive progress towards decarbonisation. These categories are described in Table 4-1.

Table 4-1 : Opportunity categories.

Category	Description
Approach or Processes	Approaches to design, construction and operations that can lead to lower carbon outcomes. It includes adoption of decarbonisation targets, design and delivery approaches which are optimised for carbon reduction. These opportunities tend to be applicable across different project types, and their impacts can be around the whole project life cycle.
Local Procurement	In the absence of full electrification of the fleet, transport of materials to site is a major contributor to project embodied carbon. Where possible local procurement is preferred to minimise the carbon cost of transport. In addition to carbon cost this approach assists in achieving additional aspects under the government wide "Broader Outcomes" initiative by supporting local businesses.
Lower Carbon Materials	Existing or proposed materials that have lower embodied carbon than the traditional alternative. Included are several concrete additives and alternatives, and low carbon steel.[4]
Digital Solutions	Digital techniques such as digital twins and the use of remote sensing or alternative digital approaches to site assessments for gathering of design data and design optimisation.
Water Sensitive Design	Solutions which are man-made but employ green engineering to mimic the water cycle, such as increasing permeable areas and construction of raingardens.
Nature Based Solutions	Solutions that replace man-made materials with natural or nature mimicking systems, e.g., wetlands for stormwater systems, use of planting for slope stability and redevelopment of mangroves or dune systems for coastal protection.
Reuse/ Repurpose/ Recycle	Opportunities which are related to reuse of materials from site or other construction projects
Energy sources / electrification	Opportunities where carbon reduction relies on a change in energy source, for instance fleet electrification or hybrid generators.

[4] Steel has one of the highest tCO_2e of any material used on the network. There are some steels available which claim to be low carbon or carbon zero. Some of these materials may achieve carbon neutrality by their manufacturers offsetting the embodied carbon through carbon offsetting schemes, which is not currently allowable in Waka Kotahi carbon reporting.

4.2 Opportunity Tables

The tables below are extracted from the opportunity spreadsheets in MS Excel. These opportunities presented are those ones rated as having potential for adoption or development by the SME teams. Additional opportunities are in the spreadsheets as a record of their evaluation. Materials availability, energy sources available, affordability or other changes may mean other opportunities in the spreadsheets should be re-evaluated.

Table 4-2 contains some explanatory notes to assist in interpretation of the opportunities.

Table 4-2: Explanatory Notes for the Opportunity Tables columns

Column Name	Descriptor	Options (where applicable)
UID	A unique identifying number for each opportunity	
Element Type	Opportunities classified by transport infrastructure element, or as a process which cuts across elements	– Process – Pavement – Stormwater – Structures and Earthworks/slopes
Key decision / management phase of influence	Stage in lifecycle where decision making will make most carbon impact. Additional stages of influence are shown by dots in the following four columns	– Design – Construction – Operations – Maintenance
Opportunity Description	Succinct description of the opportunity to address carbon impact	
Opportunity Category	Category for type of opportunity by overarching mechanism to reduce carbon	– Reuse/Repurpose/Recycle – Lower carbon materials – Approach or process – Local procurement – Energy sources / electrification – Standards – Nature based solutions – Digital solutions
Business-as-usual approach / assumptions	Succinct description of the business as usual (BaU) approach against which the lower carbon opportunity is evaluated	
Decarbonisation potential	A qualitative assessment of the potential to decarbonise from the BaU approach	3 - High, large carbon reduction, 2 - Medium 1 - Low impact, small carbon reduction
Cost Impact	A qualitative assessment of the financial cost of the opportunity vs BaU approach	3 - Small cost difference 2 - Medium 1 - Large cost difference
Feasibility Impact	A qualitative assessment of the feasibility of the opportunity	3 - High, very feasible 2 - Medium 1 - Low, needs more action to become feasible

Underneath each opportunity table is a summary / bullet points of the most promising opportunities.

4.3 Process Opportunities

Table 4-3 : Prioritised opportunities (process).

UID	Element Type	Key decision / management phase of influence	Design	Construct	Operate	Maintain	Opportunity Description	Opportunity Category	Business-as-usual approach / assumptions	Carbon Impact 3=High, 2=Medium, 1=Low	Cost Impact 3=Low, 2=Medium, 1=High	Feasibility Impact 3=High, 2=Medium, 1=Low
021	Process	Scoping	•				Ensure project business case analysis and project scoping account for, and place an increased value on, carbon impact/externalities/sustainability outcomes.	Approach or process	Carbon impact not assessed during business case processes[5]	3	3	3
022	Process	Maintenance/ Operations	•	•	•	•	Risk-based delivery and maintenance approach - optimise outcome needs, avoid-reduce-replace + 4Rs - right treatment, right time, right place, right risk.	Approach or process	Precautionary approach, following standards.	3	3	3
097	Process	Investigation	•				Greater, multidisciplinary, focus (and where necessary expenditure) on investigations to reduce embodied carbon associated with design and construction, including road geometry and geometrics.	Approach or process	Often not done due to narrow focus on transport planning issues alone.	3	3	3
098	Process	Design/Specification	•				Early focus on sustainability and resilience can substantially reduce embodied carbon by all disciplines collaborating from an early stage.	Approach or process		3	3	3
099	Process	Design/Specification	•				Resilience based design can reduce the embodied carbon by a focus on functionality and recovery rather than use standard factors of safety.	Approach or process	Often simply follow standards.	3	3	3
096	Process	Design/Specification	•				Challenge revisions to standards and specifications that support low carbon options	Standards	Carbon reduction is not a focus of the standard	3	3	2
017	Process	Maintenance/ Operations	•	•	•	•	Prioritise maintaining and optimising existing network over new builds. Design for lower maintenance and durability.	Reuse/Repurpose/Recycle		3	3	2
006	Process	Design/Specification	•				Creating urban design solutions adjusted to the natural conditions, soil imperviousness, stormwater management, water infiltration, and reducing urban heat islands would be improved	Nature based solutions		3	2	3
134	Process	Design/Specification	•				Planting native plants, green stops, shelters, and roofs, biophilic design style, use of vegetation resistant to road pollution, and permeable road surface	Nature based solutions		3	2	3
039	Process	Maintenance/ Operations			•	•	Strengthening to extend life of existing assets that may be nearing end of life or deficient in resilience.	Approach or process	Replacement by default	3	2	2

[5] It is noted that the Waka Kotahi Resource Efficiency Policy requires assessment of carbon baseline, and the Land Transport Benefits Framework measures manual requires incorporation of embodied carbon assessments into project benefits assessments. The BaU in this report / potential impact assessment has been left as no assessment undertaken due to the recency of these policies and guidelines, and the importance of this change to effect decarbonisation.

UID	Element Type	Key decision / management phase of influence	Design	Construct	Operate	Maintain	Opportunity Description	Opportunity Category	Business-as-usual approach / assumptions	Carbon Impact 3=High, 2=Medium, 1=Low	Cost Impact 3=Low, 2=Medium, 1=High	Feasibility Impact 3=High, 2=Medium, 1=Low
095	Process	Construction		•			Using construction products that are made from locally available raw materials, through energy efficient and low emission processes and by manufacturers local to the construction site	Local procurement	Depends on site and available suppliers, would require designers to think about the type of materials available near site	3	2	2
092	Process	Scoping	•				Investment in enhancing resilience of transport networks can reduce life cycle carbon emissions by reducing natural hazards damage and reconstruction costs, especially with climate change increasing frequency and severity of climatic events.	Approach or process	Reactive approach often chosen because of funding frameworks.	3	2	2
093	Process	Scoping	•	•			Review procurement methods to minimise construction embodied carbon, with balance to reduce "construction content"	Approach or process		3	2	2
139	Process	Construction		•			Create incentives for contractors to develop and apply decarbonisation opportunities. Consider how to include in addition / alongside price based tender assessment.	Approach or process		3	2	2
122	Process	Construction		•			Reduce the use of high embodied carbon materials and request Environmental Product Declarations (EPDs) from all suppliers.	Lower carbon materials		3	2	2
152	Process	Design/Specification	•			•	Increase standard design life to 40 or 100 years (from 25) to improve resilience and reduce maintenance requirements.	Approach or process	25-year design life	3	1	2
153	Process	Construction		•		•	Minimise machinery idling time to reduce fossil fuel use. Find incentives to encourage this behaviour.	Energy sources / electrification	Idling not monitored and managed actively.	2	3	3
031	Process	Maintenance/ Operations				•	Holistic approach in maintenance planning to consider all other interdependent infrastructures maintenance	Approach or process		2	3	2
082	Process	Maintenance/ Operations				•	Preventative maintenance is less carbon-intensive than overhaul maintenance	Approach or process		2	2	3
148	Process	Investigation	•				Remote sensing - use of satellite images to UAVs for desk studies, geological inspection and engineering geological mapping can reduce carbon emissions by reducing site work periods.	Digital solutions	Investigations by site visit by default	2	2	2
050	Process	Construction		•			Observational methods during construction to minimise embodied carbon by making changes to design and construction based on observations.	Approach or process	Team not specifically assessing carbon efficiency during construction observations	2	2	2

4.4 Process Opportunities Summary

During the project lifecycle the biggest carbon (or decarbonisation) impacts are made in the planning phases when macro decisions are made about project feasibility, funding, scale, and location. The following groups of opportunities were selected for prioritisation.

- To bring greater attention to options for reduction of life-cycle embodied carbon at the business case and concept design phases, including overarching investment decisions and major design decisions such as route selection, road geometry and structures requirements (UIDs 021, 022, 096).
- To extend the design life and defer infrastructure replacement through planned maintenance (UIDs 017, 031, 039, 152).
- Increase uptake of NbS through education and incentives (UIDs 006, 134).
- To fully implement procurement and other policies which incentivise and provide guidance for embodied carbon reduction (UID 139)

Other key opportunities that are process related were:

- To review standards to ensure that these aren't presenting institutional barriers to decarbonisation (UID 096).
- To promote wherever possible the use of materials that are produced and processed locally leading to reduced transport emissions and co-benefits in support of Broader Outcomes. Barriers to local procurement discussed were cost sensitivity and availability of specialist products and skills.

An opportunity that has recently been taken up by some contractors is related to reduction of idling time and fuel use when machinery is not at work (UID 153). Organisations are actively encouraging this fuel and cost saving by setting up small smartphone based apps / competitions to reduce idling time.

4.5 Pavement Opportunities

Table 4-4 : Prioritised opportunities (pavement).

UID	Element Type	Key decision / management phase of influence	Design	Construct	Operate	Maintain	Opportunity Description	Opportunity Category	Business-as-usual approach / assumptions	Carbon Impact 3=High, 2=Medium, 1=Low	Cost Impact 3=Low, 2=Medium, 1=High	Feasibility Impact 3=High, 2=Medium, 1=Low
152	Pavement	Construction		•		•	Focus on quality to avoid rework.	Approach or process		3	3	3
077	Pavement	Design/Specification		•			Change material thickness and composition to reduce total material used.	Lower carbon materials	Efficient use of materials	3	3	2
052	Pavement	Construction		•		•	Plan for on selling/ donating unused new materials	Reuse/Repurpose/Recycle	Stockpiled on network or stored at depot for later use or on sold	3	3	2
056	Pavement	Construction		•			Warm mix asphalt, including emulsion applications	Approach or process	Hot mix	3	2	3
135	Pavement	Construction	•	•		•	Use of recycled concrete in low spec aggregate (as per M4 specification for basecourse)	Reuse/Repurpose/Recycle	Recycled materials generally used where available and fit within specification	3	2	3
151	Pavement	Construction	•	•		•	Waka Kotahi transition from cut back to emulsion sealing	Lower carbon materials	Transition planned with a confirmed timeframe.	3	2	3
141	Pavement	Construction		•		•	Develop regional materials storage and processing facilities for greater uptake of reuse, recycled and reprocessed aggregates.	Reuse/Repurpose/Recycle	Individual organisations manage locally, or waste goes to landfill	3	2	2
066	Pavement	Construction		•			Site based batching concrete plant	Approach or process	Concrete delivered to site	3	1	2
150	Pavement	Construction		•		•	Alternative fuels for heavy vehicles (biofuels, electrification, hydrogen)	Energy sources / electrification		3	1	1
076	Pavement	Construction	•	•			Recycled aggregates in Pavements	Reuse/Repurpose/Recycle	Recycled materials generally used where available and fit within specification	2	3	3
061	Pavement	Construction	•	•			Reduce occurrences of over-ordering, e.g., concrete	Approach or process		2	3	3
064	Pavement	Construction		•			Just in time deliveries to reduce damage or waste	Approach or process		2	3	3

UID	Element Type	Key decision / management phase of influence	Design	Construct	Operate	Maintain	Opportunity Description	Opportunity Category	Business-as-usual approach / assumptions	Carbon Impact 3=High, 2=Medium, 1=Low	Cost Impact 3=Low, 2=Medium, 1=High	Feasibility Impact 3=High, 2=Medium, 1=Low
068	Pavement	Construction		•			Minimise packaging brought to site by working with supply chain	Approach or process	Packaging accepted as normally delivered	2	3	3
075	Pavement	Construction		•		•	Reuse soil throughout project landscaping	Reuse/Repurpose/Recycle	Maintenance operations do the following: Soil from berm excavations is donated to farmers for fill/levelling. Otherwise transported to agreed dumpsites on network and then removed to quarry sites to fill	2	3	3
055	Pavement	Design/Specification	•	•		•	Crush and reuse existing road materials from other areas of project, or other projects	Reuse/Repurpose/Recycle	Recycled materials generally used where available and fit within specification	2	3	2
012	Pavement	Design/Specification	•	•		•	Use of high recycled content materials	Reuse/Repurpose/Recycle	Recycled materials generally used where available and fit within specification	2	3	2
045	Pavement	Construction		•		•	Direct excess or spoil to other developments or charity goods where it can't be used on site.	Reuse/Repurpose/Recycle	Contractors are reusing materials within specifications.	2	3	2
038	Pavement	Construction		•			Energy consumption reduction measures in site accommodation	Energy sources / electrification	Very dependent on project scale and also on mix of renewables in national grid	2	2	3
018	Pavement	Construction	•	•	•	•	EV Vehicles at site	Energy sources / electrification	Small percentage uptake of EVs for light vehicles	2	2	3
057	Pavement	Construction	•	•			Increasing percentages of reclaimed asphalt (RAP) in surface pavement mixes.	Reuse/Repurpose/Recycle	Recycled materials generally used where available and fit within specification	2	2	2
041	Pavement	Construction		•			Use of electric plant on site - possibility to trial equipment. Electric excavator, loader, concrete pump, crane.	Energy sources / electrification	Majority diesel for large plant. Mixed diesel and petrol for smaller and handheld plant.	2	2	2

4.6 Pavement Opportunities Summary

The greatest carbon reduction potential for pavement is found in the business case and design phases covered in process opportunities (section 4.3). This includes ensuring business cases are aligned with carbon reduction targets, designs are resilient, and standards are flexible to allow for implementation of low carbon initiatives.

Key opportunities in pavement materials and construction are:

- To assure a focus on quality and avoid rework in capital and maintenance projects.
- To adopt warm mix asphalt and emulsion technologies (UID 056, UID 151) including the planned mandated transition from cut back to emulsion sealing from the end of July 2024.
- To investigate setting up regional depots for the storing and reprocessing of construction waste materials / resources (UID 141)
- To allow for flexibility in standards so site based decisions which could save materials but maintain resilience / long design life can be made (UID 077)
- To encourage and track fuel transition projects including for light vehicle use in construction and maintenance teams (UID 018), and for more challenging heavy vehicle transitions in biodiesel (especially waste product related) and towards hydrogen fuel for heavy machinery (UID 150).

This section is focussed on pavement materials and construction methods. Many of the opportunities for pavement changes to decarbonise, are related to materials reuse. There are a variety of materials suggested for reuse in either pavement or basecourse which can be reused directly or processed for reuse (opportunities 012, 043, 052, 055, 057, 076, 135). Cost efficiencies (cost of purchase of virgin materials and cost of disposal of waste materials) have already driven contractors to include the reuse of materials as business as usual (BAU) where:

a) cost effective materials are available,

b) standards and specifications allow, and,

c) availability, and location, of plant for any materials reprocessing materials allow.

For this reason, the carbon impact of use of these recycled materials is assessed as 'medium' (2) in the table above because the baseline already includes for use of recycled materials. If the baseline was all virgin materials used this impact would be raised to 'high' (3).

Other opportunities prioritised within pavement included:

- Using procurement pressures and efficiencies to impact supply chain carbon, packaging, and waste management (UIDs 061, 064, 068).
- Using lower impact but very visible site-based initiatives around zero waste or other environmental initiatives to help embed a sustainability culture across the workforce (UID 001)

4.7 Structures and Earthworks / Slopes Opportunities

Table 4-5 : Prioritised opportunities (structures, earthworks / slopes)

UID	Element Type	Key decision / management phase of influence	Design	Construct	Operate	Maintain	Opportunity Description	Opportunity Category	Business-as-usual approach / assumptions	Carbon Impact 3=High, 2=Medium, 1=Low	Cost Impact 3=Low, 2=Medium, 1=High	Feasibility Impact 3=High, 2=Medium, 1=Low
103	Earthworks / Slopes	Design/Specification	•				Naturally stable slopes can reduce embodied carbon by eliminating / reducing the need for stabilisation with shotcrete / anchors / soil nails etc.	Approach or process	Variable - some focus on reducing earthworks and end up with a lot of stabilisation that is carbon intensive.	3	3	3
112	Structures	Design/Specification	•		•	•	Retaining walls with natural earth materials and reinforcements can reduce embodied carbon e.g., concrete walls v reinforced soil walls.	Nature based solutions	Retaining walls often used without sustainability consideration.	3	3	3
116	Structures	Design/Specification					Use of post-grouting of anchors to reduce embodied carbon by maximising capacity and reducing the number of anchors.	Approach or process	Used only by some specialists.	3	3	3
083	Structures	Design/Specification	•				Use structural materials as finished surfaces (e.g., no facing panels).	Lower carbon materials	Aesthetically pleasing designs for finished surfaces	3	3	2
120	Structures	Design/Specification	•			•	Review of codes/standards for over-conservatism. i.e., Bridge Manual. Within this is to review guardrail design guidance in standards (criteria for TL4, TL5)	Standards		3	3	2
113	Structures	Design/Specification	•				Collate information on embodied carbon associated with retaining wall / foundation / anchors etc., so that prudent choices can be made to minimise embodied carbon associated with retaining wall options.	Lower carbon materials	There is no current information.	3	3	2
118	Structures	Design/Specification	•	•			Enhanced use of pile capacity testing to reduce the number / size / depth of piles and reduced embodied carbon.	Approach or process	Used selectively as testing costly.	3	3	2
005	Structures	End of Life	•			•	Reuse of existing steel girder stock around the country. Based on Kiwirail initiative.	Reuse/Repurpose/Recycle	Small steel girder stock currently sitting in various paddocks around country.	3	2	3
104	Earthworks / Slopes	Design/Specification	•				Nature based solutions (vegetation based, natural materials for protection and reinforcement) for stabilisation of slopes using selected vegetation that enhances stability.	Nature based solutions	Knowledge in industry very limited.	3	3	2
025	Structures	Construction	•	•			Use of composite timber as a material in bridges, e.g., Glulam.	Lower carbon materials	Already being implemented. Main materials used at the moment are virgin steel, recycled steel, concrete. Commercially available now (Beca, 2021)	3	2	3
119	Structures	Construction	•	•			Use supplementary cementitious materials (e.g., fly ash, silica fume, ground granulated blast furnace slag, pozzolans) to reduce portland cement content in concrete	Lower carbon materials	Partially implemented at the moment. Fly ash Commercially available now (Beca, 2021)	3	2	3

UID	Element Type	Key decision / management phase of influence	Design	Construct	Operate	Maintain	Opportunity Description	Opportunity Category	Business-as-usual approach / assumptions	Carbon Impact 3=High, 2=Medium, 1=Low	Cost Impact 3=Low, 2=Medium, 1=High	Feasibility Impact 3=High, 2=Medium, 1=Low
142	Structures	Construction	•	•			Use recycled aggregates (aggregate comprising crushed and graded demolition concrete, or aggregate recovered or manufactured from waste fresh concrete)	Lower carbon materials		3	2	3
080	Structures	Design/Specification	•	•			Use of modular/standardised design which can be applied across different projects. Specifically, develop substructure standardised design. Will require further code guidance on component connections and the benefits of adopting this approach.	Approach or process	Standardised beams, barriers, capping beams, abutments can already be standardised.	3	2	2
036	Earthworks / Slopes	Investigation	•				Savings in carbon emissions can be made by incorporating a mix of less carbon intensive investigations e.g., CPTs and geophysics v boreholes, and ensuring all previous investigation results are located to avoid duplication.	Approach or process	Standard investigation suite applied to all sites	2	3	3
035	Structures	Construction	•	•			Use proprietary additives, admixtures, and systems to reduce cement content, e.g., Neocrete, CarbonCure.	Lower carbon materials	Cement or flyash used at the moment.	2	3	3
123	Earthworks / Slopes	Maintenance/ Operations			•	•	Focussed maintenance on drainage, to avoid failures during storms and then avoid embodied carbon associated with repair and reconstruction.	Approach or process	Continue with BaU maintenance practices	2	3	3
136	Structures	Construction		•			Coatings on concrete can improve design life for lower quality concretes	Lower carbon materials	Standard concrete design / life	2	3	3
143	Structures	Construction		•			Use of concrete from plants with lower embodied carbon due to alternative fuel uses	Lower carbon materials	Technology in use now.	2	3	3
137	Structures	Construction	•	•			Optimise use of waste streams - i.e., use of tyres as a fuel source.	Reuse/Repurpose/Recycle	Waste to landfill	2	3	2
060	Structures	End of life	•			•	Recover foundations for reuse if in good condition or with rehabilitation to reduce embodied carbon associated with new foundations.	Reuse/Repurpose/Recycle	Use virgin materials	2	3	2
063	Structures	Construction	•	•			Use of weathering steel, a "structural steel with improved atmospheric corrosion resistance". Requires less maintenance and corrosion painting.	Lower carbon materials	Partially implemented at the moment. Commercially available now (Beca, 2021)	2	2	3

4.8 Structure and Earthworks / Slopes Summary

The significant part that structural materials play in the overall carbon footprint of the transport network meant that less carbon intensive alternatives to concrete and steel and other alternative structural materials were a key focus of the structures SME team. Priority opportunities for concrete are summarised as:

- Expanding use of concrete mixtures with embodied carbon reducing additives (UIDs 035, 119, 142).
- Exploration and potential adoption of concrete using permanently sequestered CO_2 (UID 044).
- Use of concrete from plants with lower embodied carbon due to alternative fuel uses (e.g., EcoSure (TM) produced by Golden Bay Cement). UID 143.

The addition of fly ash into concrete, and the use of some other proprietary SCMs is already commonplace. Increasing this uptake, facilitating wider availability of the most effectives SCMs and continued research into low carbon alternatives is required. The feasibility of the above are dependent on the availability of materials at a reasonable cost or distance from construction site.

Production of 'Green Steel' or steel production without coal is under development, with pilot scale production of steel using hydrogen and renewable energy. Industrial scale production is planned for 2026 but is dependent on numerous other investments in the hydrogen industry in Europe. In May 2023 NZ Steel and the NZ Government announced a partnership to replace 50% of the coal fired furnace at Glenbrook Steel with electric arc technology for recycling of steel ("Government announces emissions reduction partnership with New Zealand Steel | Ministry of Business, Innovation & Employment," n.d.).

Waka Kotahi is already working on implementation of timber-based material alternatives to steel such as Glulam (opportunity 025). Further adoption of this technology is a key recommendation where appropriate. Weathering steel is another technology which has been partially implemented and is commercially available now (opportunity 063) these materials have improved weather and corrosion resistance and hence expected increased durability leading to lower lifecycle carbon.

SMEs agreed that there are significant knowledge gaps in the industry related to embodied carbon for options available for commonly used structural components (opportunity 113) and collating and sharing of this knowledge is a key opportunity to improve awareness and lower carbon solution adoption across the industry.

4.9 Water and Nature Based Solutions (NbS) Opportunities

Table 4-6 : Prioritised opportunities (stormwater / NbS)

UID	Element Type	Key decision / management phase of influence	Design	Construct	Operate	Maintain	Opportunity Description	Opportunity Category	Business-as-usual approach / assumptions	Carbon Impact 3=High, 2=Medium, 1=Low	Cost Impact 3=Low, 2=Medium, 1=High	Feasibility Impact 3=High, 2=Medium, 1=Low
059	Stormwater	Design/Specification	•				Water sensitive design (WSD) to manage surface water runoff within the urban environment to mimic the natural drainage processes, while supporting broader biodiversity and amenity aims. Common alternatives include swales, detention ponds/basin, retention ponds, soakaway, and raingardens. Some options include significant 'grey' engineered elements which increase embodied carbon of the solution.	Nature based solutions	WSD typically employed in many construction projects, note importance to incorporate accounting for 'grey' engineered elements in any life cycle analysis.	3	3	3
131	Stormwater	Design/Specification	•				More focus in Principals Requirements, and "behaviours" across design and construction of water sensitive design (nature based) solutions over pipes in policy/guidance.	Approach or process	Lots of pipes in the ground but moving towards water sensitive design for new projects	3	2	3
007	Stormwater	Maintenance/ Operations	•		•	•	Convert existing treatment devices to lower carbon devices as part of asset renewal: Existing ponds to wetlands as part of renewals. Sand filters to biofiltration (where practicable) Pipes to vegetated swales	Lower carbon materials	Ponds provide water quality treatment function aligned with guidelines 10-20 years old. Ponds don't provide temperature control.	3	2	3
020	Stormwater	Design/Specification	•	•	•	•	Highway planting - Implementation of emerging tree policy (linked to green infrastructure)	Nature based solutions	Planting for visual amenity and stormwater treatment	3	2	2
034	Stormwater	Construction		•		•	Convert table drains, unformed and eroding drains into vegetated swales as carbon sinks, also providing treatment	Nature based solutions	table drains/"ditches" that convey runoff and groundwater, taking sediment and pollutants into receiving environment	3	2	2
051	Stormwater	Construction	•	•	•		Source plant and planting material locally also selection of plants (landscape guidelines).	Local procurement	Source based on price or landscape architect knowledge	2	3	3
058	Stormwater	Construction		•			Trenchless construction method for pipe installation	Approach or process	Open cut/installation within the road corridor while road is being constructed.	2	3	3
133	Stormwater	Design/Specification	•	•			Asset material selection for whole of life in mind - right material for right location (e.g., RCRRJ vs metal vs recycled plastic) piping for stormwater. Consider all assets (e.g., Manholes), and asset location so loading requirements aren't such an issue.	Approach or process	Apply default practice - NZTA guidelines/standards, low-cost option	2	2	3
026	Stormwater	Design/Specification	•				Pipes manufactured from lower carbon materials (compared to standard concrete pipes)	Lower carbon materials	Concrete and steel a significant component of stormwater carbon impact	2	2	3
062	Stormwater	Maintenance/ Operations			•	•	Waste minimisation / circular economy - e.g., Utilise sediment from wetlands and other treatment devices	Reuse/Repurpose/Recycle	Sediment build up is deteriorating wetland quality and/or it needs to be removed and transported to landfill	2	3	2

UID	Element Type	Key decision / management phase of influence	Design	Construct	Operate	Maintain	Opportunity Description	Opportunity Category	Business-as-usual approach / assumptions	Carbon Impact 3=High, 2=Medium, 1=Low	Cost Impact 3=Low, 2=Medium, 1=High	Feasibility Impact 3=High, 2=Medium, 1=Low
130	Stormwater	Construction		●			Minimise earthworks, reduce machinery use and also to reduce amount of sediment and erosion control (ESC) required. Apply trenchless technology.	Approach or process	Large earthworks and trenching cause great disruption to the natural environment	1	3	3
028	Stormwater	Maintenance/ Operations		●	●	●	Inventory management - store spare parts from construction for use on next project, or for regional maintenance/renewal activities	Approach or process	Spare materials to landfill	1	3	3

4.10 Water and Nature Based Solutions (NbS) Summary

Swales, raingardens, wetlands, and pond systems (also termed Water Sensitive Urban Design WSUD) are NbS that have become relatively common practice in urban and rural transport infrastructure (opportunity 034, 059). As well as biodiversity, treatment and retention benefits, the systems (by mostly avoiding in ground pipes and reducing other hard infrastructure) also avoid adding embodied carbon. It is worth noting though that some nature-based stormwater solutions do require grey infrastructure for effective operation. Opportunities related to further adoption of nature-based water management solutions include:

- Guideline or policy revisions to encourage more widespread take up (UID 131).
- Encourage replacement of piped stormwater systems with nature-based alternatives during maintenance and renewals (opportunity 007, 034).
- Eco-sourcing of plants for planted systems to support positive biodiversity and Broader Outcomes targets.

Decarbonisation opportunities for pipe water management systems include:

- Use of lower embodied carbon materials and attention to whole of life cost (opportunities 133, 026).
- Installation practices that minimise the need to import or export materials and spoil, including trenchless technology (opportunities 130, 058).

The Structures SME group also discussed potential for research into nature-based solutions for slope stability, with research needed into the feasibility of establishing natural solutions for slope stability (UID 104).

An associated outcome from broader adoption of NbS with significant planting of native trees, shrubs or wetland plants that have high carbon sequestration potential is the potential to provide Waka Kotahi with a carbon sequestration opportunity. Further investigation of sequestration opportunities is outside the scope of this report, and it is known that this is a programme of work being pursued by the Waka Kotahi environmental / landscape team.

5 Policy Review

5.1 Introduction

This section provides a high-level overview of the legislative context through which the construction and maintenance of land transport networks may be decarbonised and the potential policy gaps and barriers for carbon reducing initiatives. More detail of the policies reviewed and their potential impacts in decarbonisation is contained in Appendix A.

5.2 Policy Context

The reduction of embodied and operational carbon emissions associated with the construction and operation of the roading network is largely controlled or influenced by the following statutes:

- The Land Transport Management Act 2003
- Climate Change Response (Zero Carbon) Amendment Act 2019, and consequently the.
  - National Emissions Reduction Plan (ERP)
  - National Adaptation Plan (NAP)
  - Carbon Neutral Government Programme (CNGP)
- Waste Minimisation Act 2008

These statutes provide a range of policy and implementation tools for enabled carbon emissions, but limited direction for the reduction of embodied carbon in land transport infrastructure.

The legislative context for decarbonisation is continuously evolving, and although not assessed within this study, we note that through the Resource Management Act (RMA) Reforms there is an intention to create legislation which supports a low emissions economy. It is unknown how this legislation will be formed and the extent to which it may affect the delivery of the prioritised initiatives.

Waka Kotahi operates under policies, programmes and plans which are guided by these statues and regulations. Review of these provides additional context for the implementation of identified decarbonisation initiatives and enables identification of any existing barriers which may directly conflict with the outcomes of the prioritised initiatives. Table 5-1 contains an overview of key relevant Waka Kotahi policies.

Table 5-1: Policy Overview

Title	Summary
Toitū Te Taiao – 'Our Sustainability Action Plan'	Sets out the commitment of Waka Kotahi to environmental sustainability and describes how Waka Kotahi will use levers to deliver this. Improving resource efficiency and waste management is one action identified to act upon reduction of environmental harm. Focus of GHG emission reduction lies mainly on enabled carbon.
Z/19 Taumata Taiao – Environment and Sustainability Standard	This minimum standard sets out the process and requirements to give effect to the organisations environmental and sustainability policies. The standard includes requirements for the integration of environmental and sustainability considerations throughout business case development.

Title	Summary
Environment and Social Responsibility (ESR) Policy	This policy describes how Waka Kotahi commits to operating in a socially and environmentally responsible way. It sets out how Waka Kotahi commits to operating in a socially and environmentally responsible and sustainable way across all its activities, including corporate activities and statutory functions and activities. Sustainable and efficient use of resources and a transition to low carbon infrastructure are specifically committed to.
Te Hiringa o Te Taiao – Resource Efficiency Strategy	Sets out how Waka Kotahi will achieve their vision for resource efficiency of 'We use resources sustainably and with minimal environmental impact'.
Resource Efficiency Policy for Infrastructure Delivery and Maintenance	Policy (P48) contains requirements for projects to consider resource efficiency throughout the project lifecycle, from early business case to construction and maintenance.
Sustainability Rating Scheme Policy	The policy requires Waka Kotahi to: - Consider merits of Infrastructure Sustainability Council (ISC) certification for projects over $15m capital value - Complete ISC certification for projects over $100m
Broader Outcomes Procurement Strategy	Key objective of the environment and sustainability target outcome is to improve resource and energy efficiency across activities, projects, and programmes and throughout the supply chain.

5.3 Summary

Embodied carbon emissions are explicitly excluded from the Transport chapter (10) of the ERP, but the chapter refers to chapter 12, Buildings and Construction. Chapter 12, whilst primarily focussed on buildings, strongly emphasises low carbon infrastructure and the necessity to reduce embodied carbon in the construction sector, with an emphasis on life cycle emissions reduction.

NbS are referred to in the ERP Transport chapter, action 10.1.5, primarily for climate adaptation and biodiversity outcomes but their contribution to other socio-environmental challenges is also referred to. These approaches are already found in the Waka Kotahi Landscape Guidelines (2014) and a transition to low carbon infrastructure is committed to in the ESR Policy and Resource Efficiency Policy. NbS are also facilitated by the National Policy Statement on Freshwater Management and the National Policy Statement on Indigenous Biodiversity (draft). Mandatory adoption of these approaches can be implemented via planning rules. Resource Management reform does present opportunities to legislate decarbonisation and push for more nature-based solutions via the NPS for Indigenous Biodiversity.

The Resource Efficiency Policy and Strategy both strongly support the practical implementation of the transition to low carbon infrastructure providing guidance and framework for designers and contractors on both capital and maintenance contracts.

This review has found limited examples of policies that would act as barriers, whether they are intentional or not. It highlights the opportunity to work to front-foot a change in policy direction to enable the uptake and implementation of low-carbon initiatives in transport infrastructure. The enabling policies, both recently released and under development, should be backed up with training and capacity building to support full implementation.

There is an opportunity to amend existing, or create new, standards that provide for and incentivise the uptake of low-carbon alternatives that do not compromise on the safety and practicality of existing requirements, focussing on embodied carbon aspects of the specifications and standards.

5.4 Recommendations

Based on this policy review, we recommend the following:

- P46 – Review of design life requirements as a potential limitation to initiatives where alternative materials and nature-based methods will be implemented, durability may be reduced, and design life might not yet be known.
- Review of Waka Kotahi policies, specifications, and manuals to support the uptake of initiatives to remove real or perceived impediments and ensure its policies give mandate to the decarbonisation of constructing and maintaining transport infrastructure.
- Input to new Waka Kotahi policy, standards or specification should specifically reference decarbonisation of embodied carbon.
- Waka Kotahi to champion the development and implementation of enabling or mandatory policies and specifications such as the ESR Policy and Resource Efficiency Policy that provide for the uptake of initiatives and behaviours vital to reaching the target of a net-zero emissions transport sector by 2050.
- Waka Kotahi to consider how their influence on Resource Management reform could be an enabler for more uptake of low carbon infrastructure nationally.

6 Target Setting

6.1 National Emissions Reduction Plan

The first National Emissions Reduction Plan (ERP) was released in May 2022 and includes National emissions budgets for three periods, 2022-2025, 2026-30 and 2031-25. The ERP calls for a 41% reduction from transport sector emissions in 2019 by 2035. These targets are anticipated to be largely met by reducing emissions from burning of fossil fuels for transport and require the success of a range of initiatives aimed at reducing reliance on cars, adopting low emissions vehicles and decarbonising heavy transport and freight.

The emission reduction plan also contains targets for the building and construction industry. The focus is on buildings, but the opportunities identified in this report are consistent with the ERP, such as reducing embodied carbon of building materials, sharing of best practice, transitioning away from fossil fuel use in the supply chain and working with the industry to improve emissions data and pathways to low carbon design. Whilst targets are not specified, estimates in the ERP are that these low carbon building and construction initiatives, if realised, could reduce the sector emissions by 10-20%.

Infrastructure building targets are not specified in the ERP, but Chapter 7, Planning and Infrastructure includes discussion of approaches and initiatives which are aligned with those in this report, and particularly with process and design-based initiatives, including adoption of nature-based systems, climate resilience in design, and circular economy approaches.

6.2 Embodied Carbon Reduction Targets, Transport Infrastructure

There is no specified embodied carbon reduction for the transport infrastructure in the ERP. However, Waka Kotahi in its leadership role and within the intention of the CNGP is pursuing low carbon infrastructure outcomes through implementation of Toitū Te Taiao, its ESR Policy and Resource Efficiency and Waste Minimisation Policy and Guidelines.

Other organisations in the transport infrastructure delivery pipeline have set specific emissions reduction targets, for instance.

- Downer made a commitment to reduce Scope 1 and 2 GHG emissions by 45-50 per cent by 2035 from a FY18 base year and are expected to have a scope 3 emissions target in their FY2022 annual report. They are working with the Science-Based Target Initiative (SBTI) which will require a detailed set of targets for Scope 3 emissions reduction which are likely to be based around bitumen and asphalt production.
- Fulton Hogan has committed to reducing carbon emissions 30% by 2030 and has adopted a net carbon zero target by 2050 from its 2021 baseline, this includes scope 3 emissions and Fulton Hogan have several initiatives related to embodied carbon reduction in materials and construction processes (focus on quarried products and bitumen / asphalt).
- Whilst not strictly a target, Golden Bay Cement (Fletcher Concrete and Infrastructure Ltd) have worked with independent assessors to verify carbon reduction for their EverSure™ GP cement and EverFast™ HE cement products.
- WSP NZ made a commitment to halving the carbon footprint of its advisory and design services by 2030.

There are many other similar commitments across the industry and there is a good opportunity to leverage this momentum through procurement practices and industry knowledge sharing.

For Waka Kotahi, target setting for reduction of embodied carbon could be developed based on an increased understanding of the carbon baseline of the infrastructure network (work on which is ongoing) and gaining a more detailed understanding of the potential quantitative impacts of the key recommended opportunities in this report. These two pieces of information can be brought together to set a ‘drawdown’ pathway with targets for lower carbon infrastructure.

Quantifying potential reductions to set targets will be simpler for some opportunities than others. For instance, work on replacing cutback with emulsion chip sealing has already undergone some analysis, the reduction opportunities from certain SCMs are published and some work has been done on replacement of engineered stormwater treatment with NBS. Other products used in roading construction may also have EPDs that can be compared and used in target setting.

The impact of high potential reduction opportunities such as change to business case assessment, extension of design life and the impact of the resource efficiency and waste management policy and changes may be harder to create targets for. However, projects that are required to work towards an Infrastructure Sustainability Council rating, or to have created a carbon base case during design, will begin to build up an invaluable database of information for future target setting.

7 Funding Mechanisms

There are number of funding mechanisms available both directly to Waka Kotahi and suppliers which may be utilised to support the development and implementation of the decarbonisation initiatives. The funds, which include research and development of low-carbon alternatives, and waste minimisation initiatives are summarised in Table 7-1.

Table 7-1 : Possible Funding Mechanisms for Decarbonisation Initiatives

Fund	General Description	Open To	Potential Impact
LETF Low Emission Transport Fund https://www.eeca.govt.nz/co-funding/transport-emission-reduction/low-emission-transport-fund/	To support demonstration of high potential and replicable solutions to help accelerate the decarbonisation of the New Zealand transport sector. The fund will stimulate the uptake of low emission solutions.	Public Service Departments, Non-Public Service Departments or Statutory Crown Entities are excluded	Dependent on the focus of the current round, possible opportunities for Waka Kotahi Suppliers related to low emission heavy vehicles.
CERF Climate Emergency Response Fund https://www.treasury.govt.nz/information-and-services/nz-economy/climate-change/climate-emergency-response-fund	The CERF is an initial $4.5 billion proceeds of the Emissions Trading Scheme. It is a dedicated funding source for public investment (not a contestable fund) on climate-related initiatives distinct from the main Budget 2022 allowances.	State Sector	Current focus is on low emission vehicles and mode shift, but future focus could have greater alignment with embodied carbon reduction.
SSDF - State Sector Decarbonisation Fund	The SSDF has a core focus on replacement of fossil fuel burners in state owned institutions, but also supports government departments to transition to low emission vehicles.	State Sector	Support Waka Kotahi to transition light fleet to EVs, reducing embodied carbon where these vehicles are involved in construction and maintenance project support.
Jobs for Nature	The Jobs for Nature programme was developed in response to the COVID-19 pandemic as a four-year programme to support a green recovery for New Zealand and support thousands of jobs for people in nature-based employment.	Local Government, Iwi, Charitable Trusts, Community Catchment Groups, community groups, and private companies	Possible support for decarb projects with a significant natural environment / biodiversity focus.
Waste Minimisation Fund	The Waste Minimisation Fund (WMF) provides funding for projects that increase the reuse, recovery and recycling of materials. The WMF is identified to consider and align with strategic waste outcomes as described in the ERP and new Aotearoa New Zealand Waste Strategy.	Any NZ based legal entity.	The current rounds of funding ($120 million over two years from October 2022) are for reduction of organic waste to landfill, and as such are unlikely to be of significant interest to Waka Kotahi or contractors. Opportunity may exist to influence future funding rounds towards more applicable areas such as construction waste and supply chain impacts.

Fund	General Description	Open To	Potential Impact
Government Investment in Decarbonising Industry (GIDI), part of CERF	GIDI supports energy efficiency, and the switch from fossil fuels to cleaner renewable energy sources across the industrial and commercial sectors. Funded via proceeds from the Emissions Trading Scheme. A total of $650m ($1b over 7 years) was allocated as part of Budget 2022. The partnership approach helps by getting decarbonisation projects across the line and happening faster than they otherwise would, delivering larger and earlier emissions reductions. It helps by investing in businesses instead of buying offsets overseas – and by supporting a just transition.	All New Zealand-based and NZBN registered private sector businesses. State sector agencies eligible for State sector decarbonisation funding are excluded.	Whilst Waka Kotahi is excluded from accessing this funding organisations in the supply chain responsible for production of some of the most carbon intensive infrastructure components are eligible (e.g., steel and cement manufacture). An example of this fund influencing the supply chain is the partnership with Glenbrook steel to replace half of the coal used in steel production at the Glenbrook site.

7.1 Summary

This funding review has identified a range of different funding mechanisms that may be available to be utilised by Waka Kotahi, its contractors, suppliers, and other agencies working on decarbonisation projects or initiatives. The list of funding mechanisms provided in this review does not constitute a comprehensive list of all funding potentially available to support the transition to a net-zero carbon transport sector.

8 Summary Opportunities

Review of the literature and consultation with subject matter experts have led to a series of potential decarbonisation opportunities for Waka Kotahi to progress or investigate further, these are described in Section 4 above and summarised below. Opportunities are referred to below by reference to their unique identifier in the tables in Section 4 and the MS Excel workbook associated with this project.

8.1 Process Opportunities

There are several opportunities which are likely to have high potential for decarbonisation due to their impact across the whole lifecycle. These include policy initiatives responding to the Carbon Neutral Government programme, such as the Waka Kotahi Resource Efficiency Policy. Impacts of these programmes and policies are already being seen in supply chain responses, and many suppliers are also driven by their own policy direction to investigate and implement decarbonising activities.

8.1.1 Leverage Cross Industry Engagement and Enthusiasm

All three construction companies (Downer, Fulton Hogan, and Higgins) involved in our consultation have work programmes underway to lower operational and embodied carbon. Design and advisory based consultant organisations such as WSP, Beca, Stantec and Aurecon also each have decarbonisation programmes underway. A significant opportunity is to leverage and combine efforts on these commitments towards design and construction of lower embodied carbon infrastructure.

These industry commitments have been developed in parallel to the implementation of the Waka Kotahi Resource Efficiency Policy and updating of the Land Transport Benefits Framework Manual. Full implementation of these Waka Kotahi instruments should lead to formalisation and focussing of industry engagement into lower carbon outcomes on projects. Monitoring the success of these instruments in producing lower carbon solutions is important. Engagement of Waka Kotahi project sponsors and project managers as well as design and construction teams is required.

The Resource Efficiency and Waste Minimisation Policy should influence the uptake of Opportunities 021, & 022 ensuring that design teams include carbon (and other Broader Outcome) measures in project investment decisions, and multi criteria assessments and use risk-based approaches that optimise outcomes for each project element for capital investment and maintenance needs.

Land Transport Benefits Framework Manual should influence the uptake of opportunities 021, 086 and 088 which are focussed on Waka Kotahi project business case development and assessments and implementing lifecycle carbon assessments into those processes as a requirement.

8.1.2 Leverage Procurement Power for Change

Waka Kotahi procurement power is already influencing change, and this is clear from large projects, particularly where ISC accreditation is being pursued. This will presumably lead to lower carbon solutions and additional Broader Outcomes. Full implementation of the Resource Efficiency and Waste Minimisation Policy will accelerate these outcomes.

Waka Kotahi holds substantial power to enforce change through policy and procurement decisions but also 'nudge'[6] the market towards more sustainable carbon and Broader Outcomes through placing Sustainability values central to decision making and influencing behaviour of policy and project decision makers. As stated in 8.1.1 the Waka Kotahi project sponsors and project managers are at the interface with design and construction managers. Their engagement with decarbonisation targets and motivation to communicate and influence is essential.

8.1.3 Consider Life Cycle Carbon and Resilience in Macro Decision Making

Exploring longer design life and / or increased durability, and in particular design for climate change resilience, was recommended across subject matter experts' groups. This is particularly important early in investment and project decision making. Longer life or increased durability may (but doesn't always) increase the carbon designed in at the capital stage but reduces inputs in the operations, maintenance stages and delays planned renewal leading to low life cycle carbon. Opportunities 024, 092, 099, 100. Investigating the macro placement, road geometry and challenging the scale of earthmoving / structures required through a carbon lens can lead to paired carbon and cost savings, (opportunity 097).

8.1.4 Undertake Carbon Lens Standards Reviews

Opportunities related to standards and specifications are also impactful across the project lifecycle. A general review of whether standards are enabling or creating barriers to embodied carbon reduction could be undertaken. Requiring a carbon impact assessment as part of any planned standards or specifications reviews or development is recommended.

8.1.5 Continue to Track and Support Alignment with Energy Transition

There are numerous opportunities across the project lifecycle that are related to energy use. As NZ continues towards its aim of a transition towards a 100% renewable electricity grid ("100% renewable electricity generation by 2030," n.d.) preferential use of electricity as a construction site power source where practicable and transition to light electric vehicles are recommended.

8.1.6 Local procurement

Use of locally available materials and services both reduces transport carbon and supports Broader Outcomes.

8.1.7 Funding opportunities

A review of funding opportunities was undertaken that had highlighted some funds which are suitable for Waka Kotahi or it's suppliers to apply to for project support, and for suppliers to use to accelerate the transition lower carbon materials production. For transport related projects these funds are mostly focussed on electric vehicles and mode shift rather than low carbon infrastructure. However, there is potential to influence future rounds of larger funds, for instance the Waste Minimisation Fund, to allow for applications for development of best practice or innovations in delivering low carbon construction.

[6] Nudge theory is a concept in behavioural economics, decision making, behavioural policy, social psychology, consumer behaviour, and related behavioural sciences. Nudging contrasts with other ways to achieve compliance, such as education, legislation, or enforcement. (https://en.wikipedia.org/wiki/Nudge_theory). The nudge if human centred rather than economically incentivised.

8.2 Pavements and Structures / Slopes Opportunities

8.2.1 Embed and Further Explore Materials Reuse

Carbon reductions are available where materials are reused, recycled, and repurposed. Numerous opportunities recorded during this project fall under this category. Many major material components (steel, concrete, asphalt, aggregates, spoil, existing vegetation, and soils) can be reused directly on site, on other construction sites or processed to ensure that they meet standards before being reused. The Waka Kotahi resource efficiency policy has a strong focus on encouraging these behaviours and there are likely cost effectiveness benefits for construction too.

8.2.2 Facilitation of Materials Reuse

Opportunity exists to further facilitate reuse of construction materials by creation of dedicated facilities in areas of high construction activity where clean reusable materials can be stored and processed. Such facilities could be shared between construction organisations assisting smaller companies as well as ensuring materials are stored appropriately, kept dry if needed, etc.

8.2.3 Use and development of lower embodied carbon materials.

The carbon intensity of key materials in transport infrastructure means that Waka Kotahi and key suppliers are already implementing several initiatives such as use of fly ash as an SCM, trials of other SCMs and replacement of steel in suitable structures with Glulam, weathered steel or other alternatives. Replacement of bitumen with a lower embodied carbon material is challenging, but research into bio-bitumen is promising and underway.

8.2.4 Warm Mix Asphalt

Implementation of warm mix asphalt technology has been reported to lead to 10 – 25% carbon savings and improvements in setting time. Further implementation should be encouraged.

8.2.5 Slopes and use of planting for slope stability

Working towards more natural slope angles can reduce the need for grey geoengineering lowering or eliminating the concrete and steel requirements. Ensuring these options are assessed at an early project stage is a good decarbonisation opportunity alongside the use of native plantings and other organic materials to help bind soil and stabilise slopes / prevent erosion through runoff.

8.2.6 Construction and materials transport energy transition

Materials transport and heavy plant use during the construction phase and during maintenance and renewal works are a major user of fossil fuels (diesel) so opportunities to explore and implement use of plant with alternative fuel sources are recommended. Feasibility barriers exist in this area which will require cross sectoral collaboration. The two key alternatives are hydrogen and electrification. Fulton Hogan have already invested in hydrogen powered heavy fleet as a pilot project and there are significant NZ based research programmes and implementation projects under development ("NZ Hydrogen Projects," n.d.). Use of hydrogen to power the majority of heavy vehicle fleet will require substantial investment in infrastructure which would take decades to complete.

Several manufacturers have begun to manufacture heavy plant which run on lithium batteries (Volvo, Bobcat, JCB, Caterpillar etc.), including excavators, loaders, and rammers. Lithium battery technology does not suffer from the same production energy losses as hydrogen fuel cells. A key recommendation from this study is that construction teams should seek opportunities to use electricity to power construction activities on site where possible, and track developments in other low carbon emission options for powering plant such as lithium batteries or the potential for hydrogen fuel cell technology.

8.3 Water and Nature Based Solution Opportunities

Waka Kotahi has taken up the use of WSUD and replacing traditional pipe-based systems where the space and ground conditions allow, the opportunities highlighted here are intended to support and enhance this progress and encourage deeper connection with nature-based solutions.

8.3.1 Review / revise guidelines and policies

Opportunity to require and / or encourage more widespread uptake of WSUD and other green / blue or green / blue / grey mix engineering techniques.

8.3.2 Encourage uptake of opportunities to replace grey with green / blue solutions during replacements and maintenance

Opportunity for network outcome contracts and other replacement / renewal contracts to consider NbS alternatives to like for like replacements.

8.3.3 Undertake research and development

Implementation of NbS and mixed green / green / blue engineered solutions is an emerging field, Waka Kotahi could support targeted research for the New Zealand environment.

9 Recommendations

The key area identified by all SMEs, and through literature search in this project is that designing and constructing for durability and long-term resilience has the greatest potential impact on embodied carbon across the infrastructure life cycle. Ensuring this approach is taken by design teams and hurdles to implementation (e.g., standards, minimum requirements, design life) are addressed is an overarching recommendation.

Achieving this goal will require several lines of work.

Ensure implementation of the newly developed Waka Kotahi policy framework and guidelines in relation to ESR and Resource Efficiency and Waste Minimisation.

- Monitor implementation and address any barriers, facilitate knowledge sharing between major projects.
- For waste minimisation consider how construction waste management could be supported working with contractors and TLAs on resource recovery.

Further disseminate report findings.

- Use existing forums such as the Waka Kotahi environmental industry meeting for targeted knowledge sharing. Several contractors and design consultants are pursuing low carbon opportunities and setting their own targets, there is a significant cross industry opportunity to accelerate low carbon design.
- Knowledge building is underway due to the recent implementation of the resource efficiency and waste minimisation policy. Formally tracking successes and lessons learnt from projects would be beneficial and inform target setting.

Continue to support the implementation of, and research and development into.

- Nature based solutions, including coastal protection and geotechnical / slope stability applications as well as the more well developed WSD applications.
- Biobased bitumen (including NZ based research projects underway).
- SCMs for lower carbon concrete.
- Track development of the NZ green steel initiative.
- Alternative materials such as structural timber and recycled / green steel.
- Energy transition particularly in relation to heavy vehicles and earthmoving equipment.
- Smart monitoring for maintenance, and the use of digital technology for site selection and materials efficiency.

Consider development of quantitative targets

- Combine findings of this report with outcomes from the infrastructure carbon baselining underway to quantify the benefit of developing and refining targets for infrastructure carbon and define these targets and the responsibilities to achieve them.

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Appendix A

POLICY IMPACT SUMMARIES

Statutory context	
The Land Transport Management Act 2003	The Land Transport Management Act 2003 (LTMA) is the predominant legislation which sets out the requirements for management of New Zealand's land transport network and provides a legal framework for managing and funding land transport activities. One of the key objectives of the LTMA is to ensure options and alternatives are considered early in the development of programmes and environmental responsibility is improved through land transport funding, planning and management. The LTMA provides for the Government Policy Statement on Land Transport 2021/22 – 2030/31 (GPS), which sets out priority investments for land transport over the next 10-years. The GPS identifies decarbonisation as one of four big challenges, and the development of a "*low carbon transport system that supports emissions reductions, while improving safety and inclusive access*" is identified as one of four strategic priorities which will guide investment from 2021/22 to 2030/31 (New Zealand Government, 2020). The GPS further states that in order to deliver the identified outcomes, alignment from Waka Kotahi with internally developed initiatives, such as the Sustainability Strategy and Action Plan, and national guidance such as the National Adaptation Plan are essential.
Climate Change Response (Zero Carbon) Amendment Act 2019	The Climate Change Response (Zero Carbon) Amendment Act 2019 (Zero Carbon Act) established a framework for effective mitigation across New Zealand. This national framework includes a domestic greenhouse gas (GHG) reduction target of net zero by 2050 (for the long-lived gases, including carbon-dioxide), establishment of a system of emissions budgets and the first Emissions Reduction Plan (ERP) was released on 16 May 2022. Both the ERP and the NAP provide direction and actions on the prioritisation of nature-based infrastructure solutions.
Waste Minimisation Act 2008	The Waste Minimisation Act 2008 encourages a reduction in the amount of waste generated and disposed of in New Zealand, with the aim of reducing environmental harm. Reducing waste contributes to reducing GHG emissions, and new waste legislation is currently under development by Central Government aimed at creating a low carbon circular economy. Development of the new waste legislation is part of the Government Waste Work Programme (Waste Programme). The objective of the Waste Programme is to transition to a low-emissions circular economy involving "*keeping resources in use for as long as possible, extracting the maximum value from them while in use, and then recovering and regenerating them*" (Ministry for the Environment, 2022). This supports identified initiatives which look to increase the longevity of assets through preventative rather than overhaul maintenance, and the prevention, reuse, recycling, recovery and waste management of material to build circular flow into projects.

Carbon Neutral Government Programme	The Carbon Neutral Government Programme was launched by the Ministry for Environment December 2022 to accelerate the reduction of emissions within the public sector. It includes requirements for government departments and agencies (including Waka Kotahi) to measure, monitor and report their emissions annually and set target reductions and plan for carbon neutrality.
Emissions Reduction Plan	The ERP sets out how New Zealand will meet the first emissions budget for 2022 – 2025 including through reducing transport-related carbon emissions (as one of the largest sources of GHG emissions in New Zealand) and the efficient use of and investment in infrastructure. The focus of Chapter 10 Transport of the ERP is heavily on infrastructure planning to promote transport modal shifts, reducing car reliance and the electrification of vehicles with the CNGP identified as the vehicle through which transport infrastructure agencies will be expected to measure, verify, report and reduce operational emissions. Chapter 12 Building and construction sector of the ERP identifies actions for reducing the embodied carbon of construction materials, reduction in waste and more energy efficient built forms.
National Adaptation Plan	The National Adaptation Plan (NAP) responds to the risks identified in the National Climate Change Risk Assessment 2020 and contains the Government-led strategies, policies and proposals to enabled adaptation. Chapter 8 Infrastructure assigns actions to Waka Kotahi which will ensure resilience in the infrastructure Waka Kotahi owns and operates.
Waka Kotahi Policy Context	
30-year Plan	Waka Kotahi is currently developing its 30-Year Plan, looking at how it will deliver for the future including meeting Government's long-term priorities for the transport system. The 30-Year Plan is due for release March 2023 and will incorporate 'Arataki: Our Plan for the Land Transport System 2021-31' and the 'Baseline Network Version' (BNV) which identifies all major work planned on the land transport system over the next 30 years. Under the Arataki National Summary, key mitigation activities include embedding GHG emissions reduction in all decision-making, investment in low-carbon infrastructure, and partnering to increase the purchase and use of electric vehicles (Waka Kotahi NZ Transport Agency, 2020), 2022a) . The 30-Year Plan and supporting resources are assessed to provide key policy support for decarbonising transport infrastructure through long-term maintenance and construction works.
Arataki 10-year Plan	Arataki was developed by Waka Kotahi as a 10-year plan recognising what is required in order to deliver on current government priorities and long-term objectives with regard to the land transport system. Addressing the impact that the land transport sector has on the New Zealand's total emissions is a focus of Arataki, largely through consideration of the impacts of urban form, and the opportunities of addressing current and future climate impacts arising through the land transport sector. Opportunities to positively influence the climate emissions of land transport through Arataki are largely centred

	around infrastructural, behavioural, and physical mode shifts to improve urban form across New Zealand. The ambition of Arataki to achieve carbon reductions through efficiencies with the current and future urban form will be directly influenced through external aspects such as spatial planning and will require close co-ordination / partnership with local government, specifically in major centres. As with the other initiatives discussed within section 2.3 of this report, alignment with the various Government and Waka Kotahi initiatives and plans and strategies to ensure consistency of approaches where priorities overlap and to ensure best outcomes are produced.
Toitū Te Taiao - Our Sustainability Action Plan	Toitū Te Taiao (TTT) sets out Waka Kotahi's commitment to environmental sustainability and public health within the land transport sector, with the specific vision for a 'low carbon, safe and healthy land transport system'. The vision is underpinned by four long term (2050) outcomes which include achieving net zero land transport GHG emissions, reducing air and noise emissions to eliminate harm using resources and energy sustainably. Also included is achieving a neutrality for Waka Kotahi corporate emissions all by 2050. An ambition unpinning Toitū Te Taiao is the 'opportunity to shape transport sector-wide sustainable management practice', this is based on developing and implementing sound environmental practices while also meeting the requirements of the RMA. It will be important to review the alignment of Toitū Te Taiao, and other similar policies guiding carbon neutrality in the transport sector through the RMA reform as the Natural and Built Environments Act (NBA), Strategic Planning Act (SPA) and Climate Adaptation Act (CAA) enforce new requirements and plans are enacted.
Z/19 Taumata Taiao - Environment and Sustainability Standard	The ESR standard is an enabler for positive environmental and social outcomes to assess project plans against during business case assessment. It requires projects to be screened for environmental impacts as well as multiple other social and cultural impacts. Decarbonisation is addressed by objectives under the resource efficiency and waste minimisation and climate change Focus Areas.
Te Hiringa o Te Taiao – Resource Efficiency Strategy	'Te Hiringa o Te Taiao; Our Resource Efficiency Strategy' sets out what Waka Kotahi will do to achieve its 'low carbon, safe and healthy land transport system' vision in relation to resource efficiency and waste minimisation. The strategy sets long-term outcomes for the transport system including achieving net zero by 2050 and one of the strategy's key focus areas is reducing carbon. Headline actions which support the prioritised initiatives include the increased uptake of recycled and alternative materials, empowerment of contractors to deliver low carbon projects, initiating behaviour change across the industry, and championing innovation. Long-term goals include using low embodied carbon options in infrastructure design, use of recycled and alternative materials, and renewable energy sources for transport, plant and machinery use (Waka Kotahi NZ Transport Agency, 2021). The Strategy has led to the development of the Resource Efficiency Policy and the Specification for Resource Efficiency for Infrastructure Delivery (P48) which outlines requirements for the design and delivery of infrastructure improvement projects. The Policy applies to all new infrastructure projects and new maintenance contracts. Any

	project that includes design is required to prepare a Resource Efficiency and Waste Minimisation Plan (REWMP), and all projects with a capital value exceeding $2 million must have a project carbon footprint. Contractors need to report annually or more frequently on materials by source including recycled material content, total embodied carbon in materials, total carbon from energy use, and total amount of waste generated, diverted from landfill or cleanfill and sent to landfill or cleanfill. P48 is assessed as an enabler for priority initiatives relating to the reuse, reclamation and recycling of materials, and the requirement to decarbonisation construction (Waka Kotahi NZ Transport Agency, 2022). The Resource Efficiency Strategy and supporting policy and specification could be leveraged as a key starting point for implementation of reuse, reclamation and recycling initiatives.
Sustainability Rating Scheme Policy	Waka Kotahi has developed the Sustainability Rating Scheme Policy which proffers a number of requirements for medium to large capital projects under the scope of sustainability, to enable an independent verification of the sustainability achievements of high value projects. The SRSP applies to the following capital projects and programmes, in the following ways. All capital projects and programmes over $15 million capital value – must consider the merits of ISC certification. All projects over $100 million are required to complete ISC certification, unless the following qualifiers apply; Alignment with the objectives, non-monetised and monetised benefits and a strong value for money case demonstrates that it is not practical; and The sustainability objectives of Waka Kotahi, such as reducing GHG emissions, reducing the environmental harm and improving public health can be implemented in an agreed alternative way.
Broader Outcomes Procurement Strategy	The Broader Outcomes Procurement Strategy (BOPS) is a government wide initiative that seeks to achieve positive wider social, economic, cultural and environmental outcomes through procurement strategies. One of the BOPS targets relates specifically to the reduction of emissions and waste to support the transition to the goal of a net zero emissions economy by 2050. To guide alignment with the government led 'Broader Outcomes' Waka Kotahi has developed the BOPS as recognition of the critical role in contributing to positive wider social, economic, cultural and environmental outcomes with regard to procurement. The BOPS has been created with specific alignment to complimentary Government and Waka Kotahi Strategies and plans such as Toitū Te Taiao, Enterprise and Infrastructure Procurement Strategies, the Government Policy Statement on Land Transport, among others. The BOPS sets targeted priority objectives for the procurement activities of Waka Kotahi which includes the 'Environment and Sustainability' targeting the reduction of emissions and waste through the procurement process. Toitū Te Taiao is a foundational plan for the BOPS where success is directly measured against its visions and principles, as such the success of the BOPS depends on the uptake

	and rollout of this plan. Further, under the BOPS emphasis is placed on the development of new initiatives for resource and energy efficiency and positive sustainable outcomes across activities, projects and programmes through the scope of the land transport sector. The successful implementation of the BOPS requires close coordination with approved organisations, suppliers and third-party providers and partners, emphasising the importance of inter-agency buy-in of the BOPS and its guiding strategies and plans, such as Toitū Te Taiao.
Other Relevant Standards / Programmes	
Engineering New Zealand Standards •	The reuse or reclamation of material will be controlled through Engineering New Zealand Standards. For example, in addition to generic standards for asphalt testing AS/NZS 2891, reclaimed asphalt for surfacing would also be required to meet standard BS EN 13108-8:2016. Material selected for reuse or reclamation will need to be suitable for its intended reuse and will be managed and controlled through these standards to ensure that it is fit for purpose.
The Building Code	The Building Code is contained in Schedule 1 of the Building Regulations 1992 and all building work in New Zealand must meet the performance standards of the Building Code even if it does not require building consent. Under Clause 'B2: Durability', a minimum durability period (design life) of 50-years is required for all buildings. This includes structures located within the transport network such as bridges and retaining walls. As noted in Section 1.3.2.4, these requirements should be considered a potential limitation where initiatives changing the composition of materials used may risk a decrease in durability and may be unable to meet the design life requirements.
MBIE Building for Climate Change	MBIE have implemented a Building for Climate Change Programme (Ministry of Business, Innovation and Employment, n.d.) to lead the construction sector approach (focussed on vertical infrastructure) to emissions reduction and adaptation to climate change. The programme provides a framework for whole-of-life embodied carbon emissions reduction (MBIE, 2020) and a methodology for whole-of-life carbon assessment. Whilst these have buildings focus the methods are closely based on PAS 2080 and have applicability to all infrastructure projects.

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