Appendix B: Carbon Hierarchy and Life Cycle Assessment

1. Purpose

This guidance provides a high-level summary of application of the “avoid, switch, and improve model” in the carbon hierarchy, and the requirements for undertaking a life cycle assessment (LCA) for carbon, energy, materials and water on transport infrastructure investments.

For infrastructure investments valued at $5M and over, the guidance outlines when a LCA should be considered where GHG emissions from energy, material and water impacts are significant. For example, if large volumes of concrete, steel, aggregates and asphalt are required or user enabled emissions from vehicles or operational emissions are high. An LCA should be applied in a way appropriate to the scope and scale of a contract. For lower value contracts this maybe a very high level assessment based on cost estimates for energy and materials for example.

It is not intended to provide detailed guidance on how to undertake an LCA. For this, there are many resources that can be used in conjunction with this guidance including:

- PAS 2080:2023 Carbon management in buildings and infrastructure.
- RICS, 2023, Whole life carbon assessment for the built environment global, 2nd edition.
- BS EN 17472:2022, Sustainability of construction works. Sustainability assessment of civil engineering works.
- Infrastructure and Transport Ministers Meeting, 2024, Embodied Carbon Measurement for Infrastructure
- Infrastructure Australia, 2024, Guide to assessing greenhouse gas emissions.
- Infrastructure WA, 2024, Decarbonisation Guide.
- ISO 59004:2024 Circular economy, 2024 — Vocabulary, principles and guidance for implementation
- ISO 59010/20 Circular economy, 2024 — Measuring and assessing circularity performance

There is no specified tool for undertaking an LCA that is recommended, recognising that many industry partners have developed their own tools in addition to some government, research and peak bodies. The NSW government is currently developing an open-source database for embodied emissions intensities, and work through the Infrastructure and Transport Ministers Meeting (ITMM) has developed some national carbon intensity values based on the NSW guidance in the measurement of embodied emissions guidance.

Ideally, nationally consistent metrics will be used particularly at business case and strategic planning where detailed information is not available. As detailed design is reached and known materials are specified, environmental product declarations (EPDs) where available can be used that provide more granular LCA emissions factors.

This document should be read in conjunction with:

- The Transport Portfolio Sustainable Infrastructure Policy;
- Appendix A: Sustainable Procurement and Contracts Guidance; and
- Appendix C: Sustainability Reporting Requirements.

There is significant benefit to be gained from avoided and reduced energy, water and material use from a cost perspective, and also from a biodiversity and land perspective if the footprint can be avoided or reduced. To realise the full potential of benefits, a life cycle approach should be taken so that any trade-offs can be weighed against different life cycle stages. For example, a product may have a higher upfront carbon impact but has a longer lifespan meaning less maintenance and replacement. These considerations need to be assessed on a case-by-case basis with best available information. Box 1 illustrates that using recycled materials is often a low carbon option also.[1]

2. Carbon Hierarchy

Box 1. Low Carbon Vs Recycled Materials

As research by the National Transport Research Organisation (NTRO) indicates, significant environmental benefits can be expected for the majority of recycled material applications in road and rail infrastructure.

Greenhouse gas (GHG) emission reductions range from 47% to as high as 98%. On the environmental impact measures, the best-performing recycled materials were:

- the use of RAP in surface and base layers as a replacement for asphalt made with virgin aggregates and binders (98% fewer GHG emissions)
- the use of fly ash as a replacement for hydrated lime and cement in stabilised asphalts and concrete pavements (98% fewer GHG emissions).

The greatest potential from reducing carbon and material impacts is in the early business case and planning stages for projects. Build nothing and build less options in business cases should provide a reference assessment for lower carbon and reduced material impacts. Figure 1 provides an overview of the carbon reduction potential at different life cycle stages.

The PAS2080 guidance offers an avoid, switch, and improve model to carbon abatement similar to the carbon reduction potential. As detailed in the PAS2080 standard: *in applying the carbon reduction hierarchy, the assessment must demonstrate the following:*

avoid: align the outcomes of the project and/or program of work with the net zero transition at the system level and evaluate the basic need at the asset and/or network level. This may include exploring alternative means for satisfying the need for whole life performance while not constructing a new asset/network or reusing/ retrofitting/ repurposing existing ones.

switch: assess alternative solutions and then adopt one that reduces whole life emissions through alternative scope, design approach, materials, technologies for operational carbon reduction, among others, while satisfying the whole life performance requirements. This may also include employing innovative models that optimize the balance between capital, resource use, operational and user efficiency of an asset/network.

[1] ARRB, 2022, Best Practice Expert Advice on the Use of Recycled Materials in Road and Rail Infrastructure: Part B Sustainability Impacts Report.

improve: identify and adopt solutions and techniques that improve the use of resources and design life of an asset/network, including applying circular economy principles to assess materials/products in terms of their potential for reuse or recycling after end of life.

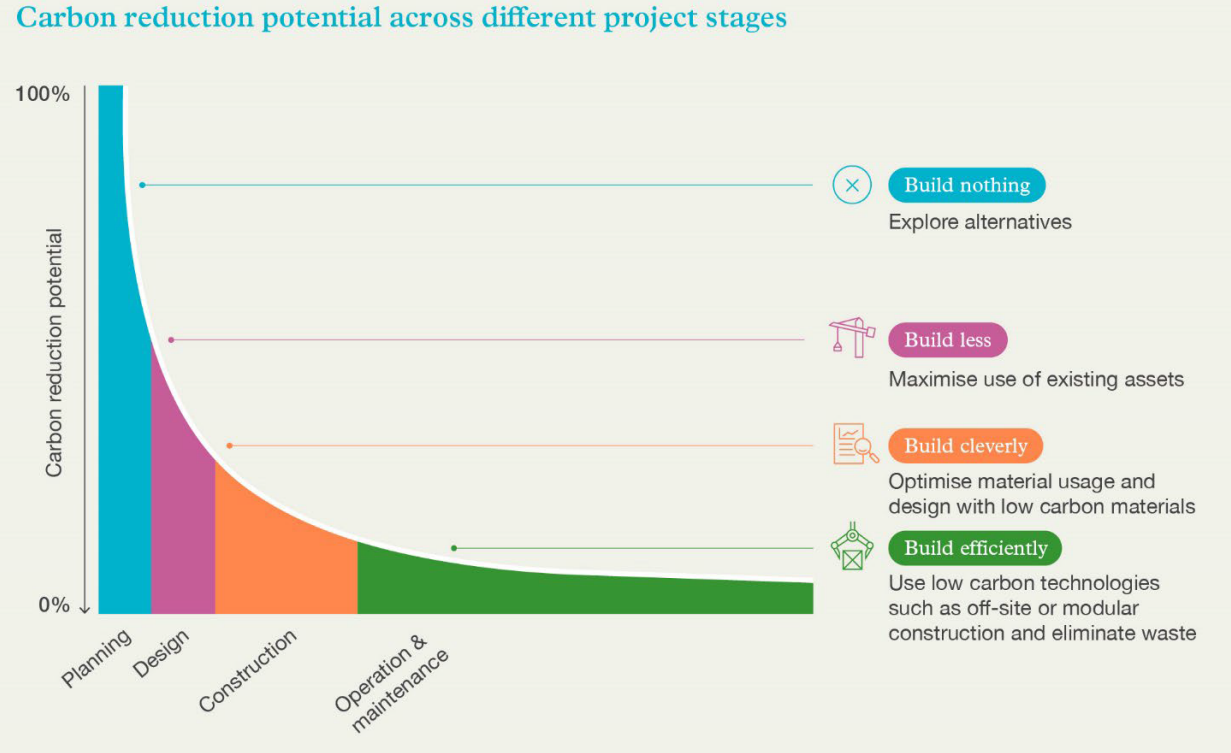


Figure 1: Carbon Reduction Potential, Infrastructure Victoria[2]

3. Life Cycle Assessment (LCA)

The purpose of a life cycle assessment is to assess the GHG emission impacts of energy, water and materials across the infrastructure's asset life, and to identify where the opportunities are to avoid or reduce impacts. The next sections provide an overview of the steps that should be incorporated into an LCA on transport infrastructure projects. A high-level overview of the process is shown in Table 1 below.[3]

These steps should be repeated at key project phases including business case and options analysis where the assessment will be high-level based on cost estimates for key materials, water and energy requirements. As the project/program moves through concept and detailed design further granularity can be added to the assessment as detailed information becomes available.

[2] Infrastructure Victoria, *Opportunities to reduce greenhouse gas emissions of infrastructure Advice to the Victorian Government, 2023*
[3] RICS, 2024, *Whole life carbon assessment for the built environment global*.

Step 1 **Initiate Assessment**	**Step 2** **Collate project information**	**Step 3** **Assess Materiality**	**Step 4** **Assess GHG LCA Baseline**	**Step 5** **Develop Carbon Management Strategy and Plan**	**Step 6** **Measure Performance and Reporting**
Define project scope and identify assessment boundary	Project BIM model, BoQ/cost plan, consultants drawings	List and quantify all construction elements and energy sources	Apply LCA modules A1-C4 to create base case	Targets, risks and opportunities, actions, KPIs	Design gate reporting and construction reporting against LCA base case
Review, reduce, re-evaluate at key project phases					

Table 1: Adapted from RICS, 2024, Whole Life Carbon Assessment for the Built Environment, Recommended steps for LCA repeated at various project phases.

3.1 Define Scope and Boundary

The first step in undertaking an LCA is to define the scope and boundary of the project/program of works. This will include the actual footprint of the infrastructure to be built and supply chain impacts from transport, construction, operation, and user enabled emissions. Figure 2 provides an overview of the whole life carbon system boundary.

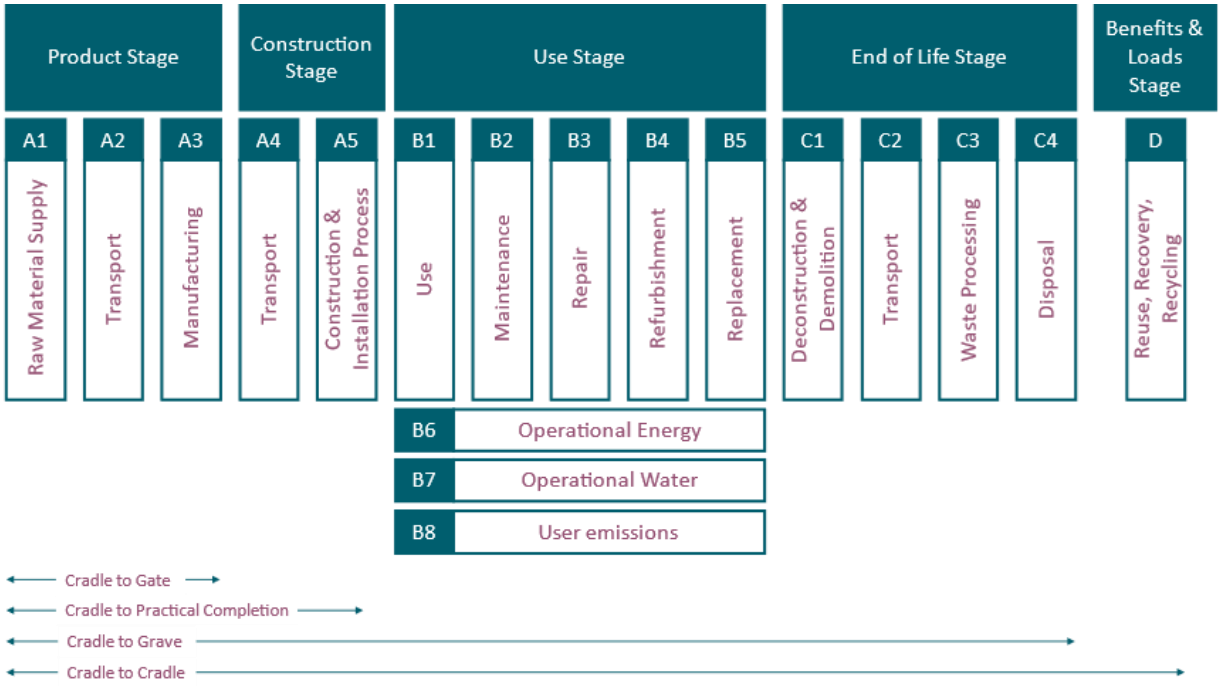


Figure 2: Infrastructure lifecycle stages (EN15978)

3.2 Collate Project information

At business case and options analysis the data and information available is likely to be at high-level using high level bill of quantities (BoQ) cost used to estimate the project or program budget. This is expected to be further developed as it progresses to concept and detailed design when products are specified and Environmental Product Declarations (EPDs) where available with actual life cycle data.

At concept design the selected option should be refined from the business case as a 'base case' or 'reference design', and at detailed design the assessment will become more granular as actual emissions factors for specified materials is available. Figure 5 outlines how the decision making and information available changes as the project life phases develop.

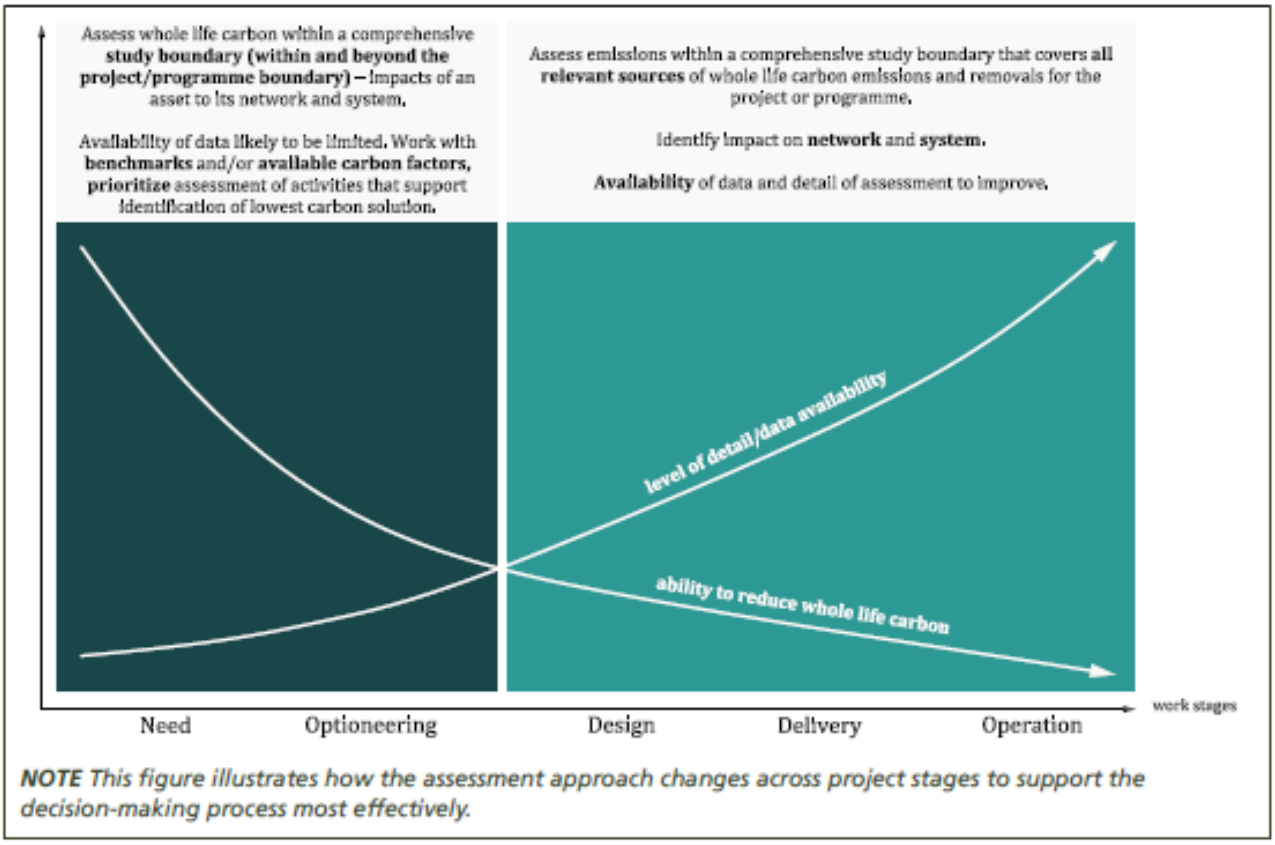


Figure 3: PAS2080, 2023, Degree of accuracy and data availability in whole life carbon assessments across work stages.

3.3 Assess Materiality

Identify the sustainability outcomes and the materiality impact of the product/material/ asset across the life cycle according to the table below for spend $5M and over. The impacts should cover upfront emissions from materials, construction activity and transport of materials, operational and user enabled emissions, maintenance and end-of life emissions using the *PAS2080 carbon standard*[4] and *RICS Global harmonisation of whole life carbon assessments*[5] as guidance.

For projects/programs contracts with spend over $5M, materiality of carbon impacts across energy, materials and water can be defined as:

[4] PAS 2080:2023 Carbon Management in Infrastructure | BSI (bsigroup.com)
[5] WLCA-harmonisation-guide.pdf (rics.org)

an emissions source that constitutes one per cent or more of the total carbon emissions (capital and operational) is considered 'material'. In applying the one per cent materiality threshold across all emissions sources, the total amount of emissions excluded must not exceed five per cent of the total footprint.[6]

Materiality threshold for spend $5M and over	
Resource Consumption	
What is the project construction material cost as a percentage of capital value?	Low <10% Medium 10-50% High >50%
Does the project require significant material resource use?	More than 1% of total GHG life cycle emissions
Is resource efficiency a significant focus for the project and key stakeholders?	Yes/No
Energy consumption	
Does construction require the use of diesel plant and equipment?	Yes/No
Is the diesel consumption during construction expected to be high?	More than 1% of total GHG life cycle emissions
Are the operational annual energy requirements from fuel and electricity expected to be high?	More than 1% of total GHG life cycle emissions
Water consumption	
Does the project have high water requirements during construction and operations?	Yes/No
Is water efficiency a significant focus for the project and key stakeholders?	Yes/No

Table 2: Materiality threshold for spend over $5M

3.4 Assess GHG Baseline

The next step after assessing materiality is to undertake a GHG emissions baseline for energy, material and water consumption across the asset life. At business case stage, this will be done at a high-level for the preferred option using best available information following the lifecycle stages below.

The summary below of the lifecycle stages A1 to C4 indicates which parts to include for Transport Portfolio infrastructure LCA, taken from RICS *Whole Life Carbon Assessment for the Built Environment*:

[6] IS v2.1 TECHNICAL MANUAL PLANNING RATING, 2023 IS v2.1 Planning Technical Manual Document_FINAL.pdf (iscouncil.org)

Life cycle stage A: covers all carbon emissions and removals from any activities necessary to complete the construction of the asset.

- **Modules A1–A3 (product stage)** cover the extraction, transportation and manufacturing processes necessary to produce any construction products.
- **Modules A4–A5 (construction stage)** cover transportation of construction products to the site and all construction processes, including wastage, up to project completion. Module A5 also includes any on-site demolition or strip-out works required at the beginning of the project.

Life cycle stage B: covers all carbon emissions and removals that occur over the in-use stage of the asset.

- **Module B1** covers direct emissions and removals from construction products.
- **Modules B2–B4** cover material-related emissions that occur from maintenance, repair and replacement of any construction products, components, or elements of the asset over the reference study period.
- **Module B5** covers any refurbishment or change in performance of the asset (e.g. retrofit/refurbishment or extension) planned at the outset of the project to occur at some point after construction is completed.
- **Module B6** covers the energy use of the asset over the in-use stage.
- **Module B7** covers water use over the in-use stage.
- **Module B8** covers user activities not included elsewhere and could include, for example, emissions from vehicles using a road or the impact of commuting to an office building over the in-use stage.

Life cycle stage C: covers all 'end-of-life' impacts.

- **Modules C1–C4** cover impacts during the end-of-life stage of an asset. This includes deconstruction or demolition, waste processing, recovery or disposal and associated transport.

3.5 Develop Sustainability Management Plan

For contracts valued at over $100M, once the reference design has been developed, a sustainability management plan should be developed which includes:

- Project description, scope and boundary
- The project's most important sustainability topics aligned to the Transport Porotlfio ESG Framework or IS rating where applicable.
- LCA Baseline and GHG emissions reduction targets for energy materials and water.
- Sustainability goals or objectives and targets and actions plans relevant to the project
- Roles and responsibilities for overall sustainability management and all sustainability targets
- Reporting and review requirements across the project life cycle.

Targets should be set within contract requirements to reduce GHG emissions across water, energy and materials with associated action plans. Where infrastructure is expected to operate beyond 2050 this must be net zero aligned, with a focus on absolute emissions reductions. Interim WA climate targets should also be aligned with.

An example template structure and contents list are provided below in Box 2, adapted from the NSW, 2024 *Decarbonising Infrastructure Delivery Policy*. Box 3 illustrates some best practice examples of net zero aligned plans on UK infrastructure, and Box 4 summarises the Westport Net Zero Strategy at business case phase.

BOX 2: Example Carbon Management Strategy/Plan Template

Introduction

1.1 Scope of the Carbon Management Plan

2 Policy context and guidance

- 2.1 Organisation-specific policies and commitments
- 2.2 Industry standards and guidance documents

3 Objectives and targets

- 3.1 Project objectives and targets
- 3.2 LCA baseline and target
- 3.3 Work package-specific targets

4 Roles and responsibilities

- 4.1 Scope of control and influence

5 Approach to carbon management

- 5.1 Business case/options analysis
- 5.2 Procurement
- 5.3 Design
- 5.4 Construction

6 Carbon assessment

- 6.1 Monitoring and reporting schedule
- 6.2 LCA tool and calculations

7 Key actions and opportunities

BOX 3: Examples of Net Zero Strategies in UK Transport Infrastructure

National Highways, England

THREE STRONG COMMITMENTS - BACKED BY IMMEDIATE AND SUSTAINED ACTION

CORPORATE EMISSIONS

Net zero by 2030

Net zero for our own operations by 2030

Covering our own energy and travel. Actions include:

- We have bought certified, renewable electricity for our network lighting and operations since 2020
- We will replace 70% of our road lighting with LEDs by 2027
- Our non-traffic officer vehicles will be 100% electric by 2027, with traffic officer vehicles to be 100% electric by 2030
- We will plant at least 3 million trees by 2030
- We will reduce our corporate emissions by 75% by 2025 when compared to a 2017/18 baseline

MAINTENANCE & CONSTRUCTION EMISSIONS

Net zero by 2040

Net zero for maintenance and construction by 2040

Covering emissions from making and transporting the materials used to maintain our network. Actions include:

- Launch a zero carbon construction innovation programme
- Develop a near-zero plan for each of our procurement categories by the end of 2022
- Design and build the first net-zero major road enhancement scheme, open by 2035
- Increase capacity on existing roads by roll out of our digital roads vision
- We will follow a trajectory of 0-10% reduction by 2025, 40-50% by 2030, 70-80% by 2035 and net zero by 2040 against a 2020 baseline

ROAD USER EMISSIONS

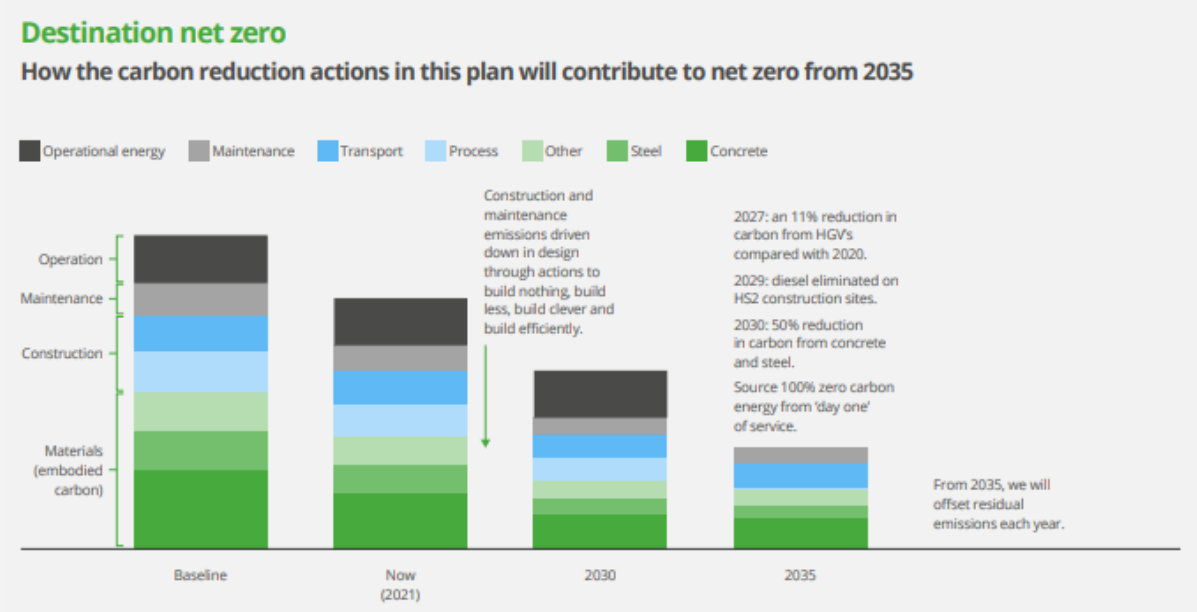
Net zero by 2050

Net zero carbon travel on our roads by 2050

Covering emissions from users of our network. Actions include:

- We will publish our proposed approach to zero carbon HGV trials by the end of 2022
- We will publish a blueprint for EV charging services on our roads by 2023
- Integrate a strong modal shift programme in Road Period 3 (RP3) building on our work to date
- We are planning for a trajectory of 31-26 $MtCO_2e$ by 2025, 25-15 $MtCO_2e$ by 2030, 20-7 $MtCO_2e$ by 2035, 8-3 $MtCO_2e$ by 2040, 5-1 $MtCO_2e$ by 2045 and net zero by 2050 against a 33 $MtCO_2e$ 2020 baseline

High Speed 2, UK



Westport: Net Zero Strategy

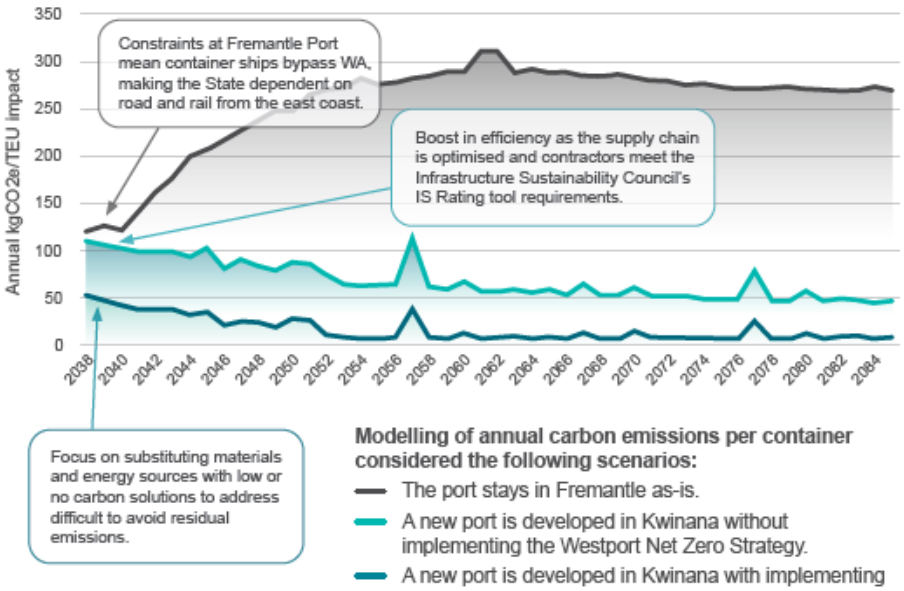
Westport is the State Government's major infrastructure program to move container trade from Fremantle to Kwinana. Guided by the vision is plan, build and operate Australia's most sustainable port, Westport is committed to designing and catalysing a net zero port and local container supply chain by 2050.

Development of Net Zero Strategy

The Westport Net Zero Strategy focuses on whole-of-life carbon management, collaboration across the entire supply chain, adherence to the carbon hierarchy, and early intervention to maximise decarbonisation.

A comprehensive whole-of-life carbon assessment guided the identification of initiatives targeting Westport's most significant emissions sources. This modelling informed engagement with government and industry stakeholders on net zero targets to identify barriers to adoption.

Annual carbon per container (whole of supply chain)



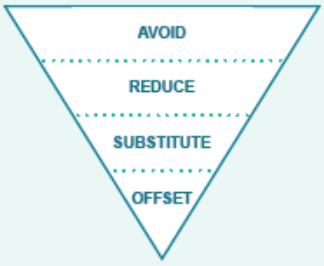
Modelling of annual carbon emissions per container considered the following scenarios:

- The port stays in Fremantle as-is.
- A new port is developed in Kwinana without implementing the Westport Net Zero Strategy.
- A new port is developed in Kwinana with implementing the Westport Net Zero Strategy.

Methodology for identifying focus areas:

- The carbon hierarchy, prioritising reductions over the use of carbon offsets.
- Through the carbon assessment, identified the materials, processes and operations that will have the greatest impact on Westport's carbon footprint.
- Evaluated the ease of implementation and barriers to adoption through consultation.
- Developed a preliminary cost estimate based on consultation, industry experts and benchmarking.
- Considered feasibility of application within WA and previous implementation of similar initiatives in Australia.

Westport Carbon Hierarchy



Westport's Net Zero Focus Areas

Stage	Potential Initiatives	
Definition and Delivery Stage	• Lower Carbon Steel • Lower Carbon Concrete • Lower Carbon Asphalt • Low Carbon Terminal Equipment	• Construction Machinery Decarbonisation • Dredging Decarbonisation • Insetting Projects • Construction Offsetting
Port Operations	• 100% Renewable Electricity • Greener Port Fleet	• Operational Offsetting
Operations – Users	• Container Shipping Decarbonisation • Container Truck Decarbonisation	• Container Train Decarbonisation

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3.6 Measure Performance and Reporting

During detailed design and construction procurement phases the LCA base case should be submitted to agency/project sustainability specialists with the sustainability, carbon management and resource efficiency plans with the updated design LCA assessment and performance against targets set in contract requirements.

A sustainability opportunities and risk register, incorporating carbon and materials, should be submitted and discussed at quarterly sustainability leadership meetings with action plans and tracking.

The carbon and material reporting requirements are detailed in the Sustainability Reporting Requirements document.