CEDR Transnational Road Research Programme
Call 2020: Resource Efficiency and the Circular Economy

Funded by: Denmark, Ireland, Netherlands, Norway, Sweden, Switzerland and the United Kingdom

CERCOM
Circular Economy in Road COnstruction and Maintenance

Good practice inventory of current systems and procurement methods

Deliverable No. 2.1
May 2022

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CEDR Call 2021: Transnational Road Research Programme

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Due date of deliverable: 31/05/2022
Actual submission date: 31/05/2022

Start date of project: 01/09/2021 End date of project: 31/08/2023

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Version: draft, V1-R01

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Executive summary

This report forms deliverable D2.1 of the CERCOM project, funded under the CEDR 2020 Transnational Research Programme on Resource Efficiency and Circular Economy. The CERCOM project aims to deliver tools and supporting resources to assist National Road Administrations (NRAs) transition to a more resource efficient (RE) approach to highway maintenance, consistent with the principles of a circular economy (CE) where greater emphasis is placed on reusing, repairing, repurposing and recycling materials, preserving their value through multiple lifecycles. This change forms the basis of the EC's plan for addressing climate change challenges and building a "greener, more digital and more resilient Europe".

This document (D2.1) provides an inventory of good practice and makes recommendations for approaches that can be adopted by NRAs to accelerate their transition to circularity. It is based on the results of an extensive review of academic and industry literature, a questionnaire survey with follow up interviews of selected NRAs in Europe and workshop discussions with industry experts. The report is divided in two parts:

Part A presents a working definition of circularity in the context of highway maintenance and assesses the progress that is being made towards it by NRAs:

Circular Economy and Resource Efficiency for Road Maintenance means, by design:

- ***Minimising consumption of natural resources***
- ***Designing out waste and keeping resources in use and at their highest level of utility***
- ***Optimising the value obtained within each lifecycle***
- ***Improving environmental performance and contributing to societal development***

The definition provides an input to other technical work packages and will be further refined during the project. It is accompanied by a framework that was developed to show how, at a strategic and operational level, material requirements can be assessed, and available resources considered to meet the structural and functional requirements that are set.

To assess the current practices of NRAs, a maturity model was developed to characterise stages on the journey to embedding CE principles, ranging from starting to engage with the transition to RE and CE, through early stages of practicing RE and CE, to active deployment. The strategies being implemented by NRAs in Denmark, Ireland, Norway, Switzerland, the Netherlands and United Kingdom were assessed against the model. The rubric that has been developed is provided to enable these and other NRAs to assess their progress and identify areas for development. It will also be useful to inform the resource pack and training that will be developed in Work Package 5.

Part B of the report provides an inventory of good practice, providing the detail NRAs will need to shape the policies, objectives and strategies for managing highway maintenance to achieve RE and CE objectives.

The maturity model in Part A and the inventory of practice in Part B are structured around similar themes, which were identified during this review as being critical to progress:

- **CE ambition** – the stated aims of the organisation and the internal and external visibility of this commitment.

- **Embedding CE** – the actions being taken to embed CE in the organisation's thinking and activities. This includes staff roles, knowledge and behaviours, accountability, and openness to innovation.
- **Performance monitoring and KPIs** – the use of metrics to understand the use of resources by maintenance activities and to monitor progress towards more efficient use of resources, particularly scarce resources, and limiting other impacts of maintenance.
- **Standards** – the degree to which standards adopted by an NRA support progress to RE & CE while providing effective management of the risks of innovative approaches.
- **Supply chain** – how relationships with the supply chain promote improvements in resource efficiency.
- **Business Models** – how value is ascribed to improvements in resource efficiency in decision making.
- **Circular Procurement** – how the supply chain is incentivised to offer more circular and resource efficient products.

Each section of the inventory of practice in part B contains a summary of good practice a horizon scan to identify trends that could impact on the relevance of current practices and experience, as NRAs progressively move from linear to circular practices. This means the findings can be future-proofed and remain 'fit-for-purpose' in the short- and longer-terms. The horizon scan will also contribute to the development of a long-term perspective and to establish the content of the resource pack and training that will be delivered by work package 5, aimed at allowing NRAs to close the circularity gap.

Finally, section A.4 presents our observations on the current state of progress (including any opportunities and barriers noted) under each of the headings above, together with recommendations. The key recommendations are:

- Define CE and RE in the context of national targets and organisational priorities.
- Set CE & RE targets at an organisational level.
- Define the organisation's current point in the various categories of the maturity matrix.
- Communicate CE and RE ambition throughout organisations with CERE champions.
- Enter into long term agreements with contractors, considering end of first life at outset.
- Undertake pathfinder projects to bring elements of CE into road schemes and take learning to other schemes.
- Share data with contractors to understand where resources are being deployed and improve resource efficiency.
- Develop performance-based standards and specifications to allow high levels of recycled contact and enable resources to be used over multiple lifecycles.
- Develop business models that account for overall value, including the degree of circularity, within decisions in addition to the initial capital cost.

The recommendations are further presented in section III of the report along with 5 examples of good practice observed in various NRAs that could be adopted elsewhere to improve and embed circular thinking within NRAs. These are:

- Defining CE to meet national requirements and organisational objectives (UK)
- Use of pathfinder projects to test ideas (UK)
- Adoption of long-term contracts to optimise material reuse (the Netherlands)
- Set targets to minimise waste and maximise resources (Norway / Switzerland)
- Changing standards to remove barrier to circular practices (Denmark)

I. Introduction

Many governments around the world have declared a climate emergency, with urgent action required to mitigate the worst impacts of climate change. As such, organisations across all sectors have a responsibility to reduce their climate impact. Transportation is responsible for around one fifth of global CO_2 emissions, of which around 75% comes from road transport (Richie, 2020). Whilst most of these emissions derive from the vehicles using the road, the construction and maintenance of road infrastructure is also responsible for significant material consumption and associated CO_2 emissions. As such, national road administrations need to play their part in reducing the environmental impact of their activities.

To date, efforts to tackle the climate emergency have focused on a transition to renewable energy, complemented by energy efficiency. The Ellen McArthur Foundation (EMF, 2021) recognises that though crucial and wholly consistent with a circular economy, these measures only address around 55% of emissions (Figure 1). The remaining 45% comes from the production of goods, food and land management. CE therefore has the potential to make a significant contribution to completing the decarbonisation picture by transforming the way in which products are manufactured and used. Adoption of resource efficiency (RE) and the circular economy (CE) has the potential to preserve natural resources, whilst producing fewer emissions compared to linear economy 'take-make-waste' practices.

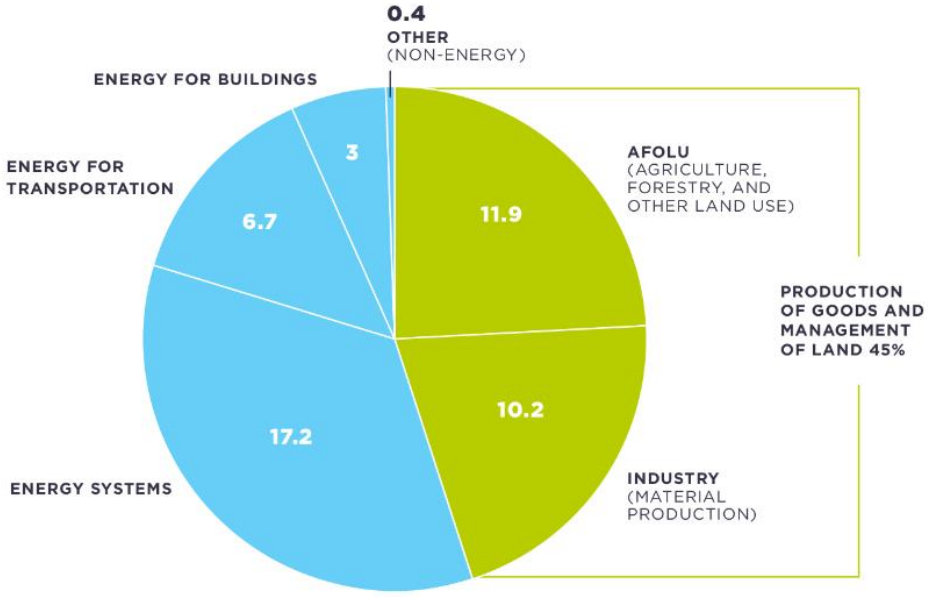

Figure 1 Global GHG emissions, 2010 (billion tonnes of C02e per year), reproduced from Ellen McArthur Foundation, 2021

The Circularity Gap Report (CGR, 2022) measures the extraction of natural resources and the proportion which can be replenished. Between 2018 and 2020, circularity in the global economy reduced by 0.5% from 9.1% to 8.6% and has continued to get worse with consumption of virgin materials continuing to increase. Another way of expressing this is that over 90% of the resources extracted and used, are wasted. Most business models remain linear, with 'take-make-waste' practices, which at the extreme level deliberately builds in obsolescence to fuel consumption. The same report states that through smart strategies and reduced material consumption, transition to the circular economy could shrink global GHG emissions by 39% and cut virgin resource use by 28% compared to 2019 levels.

It has been suggested (EDIE, 2021) that CE is misconstrued with recycling. The two are in fact quite different as CE relates to reuse, repair and refurbishment which requires a fundamental rethink of how products are designed, produced, assessed, and used.

The CERCOM project investigates how the circular economy could work in the context of highway construction and maintenance and what barriers and opportunities exist for its adoption. It will deliver an innovative risk-based framework and management tool to facilitate a step change in the adoption of RE & CE principles in procurement and multi-lifecycle management by NRAs across Europe.

II. This document

This report is an output of work package 2 that provides information on current good practice, opportunities and barriers, compiled from the results of an extensive review of academic and industry literature, a questionnaire survey with follow up interviews of selected NRAs in Europe and workshop discussions with industry experts. It provides NRAs with recommendations on good practice and will inform the work packages that follow, as illustrated by Figure 2.

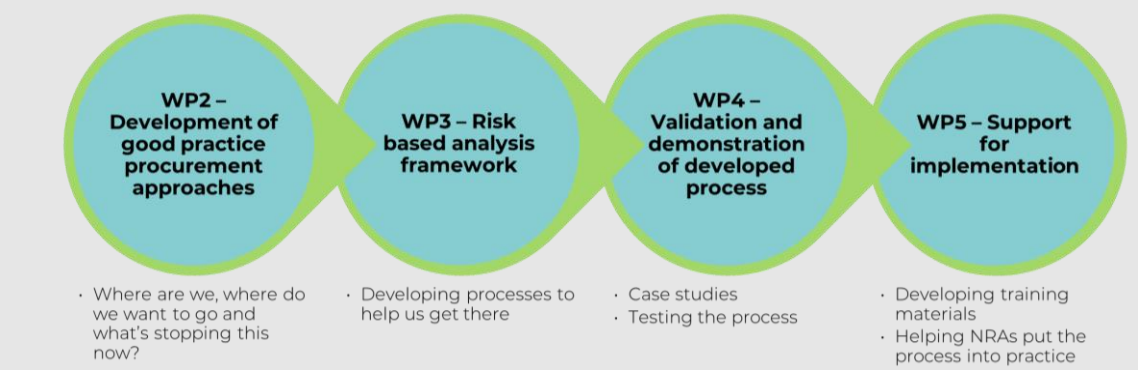

Figure 2 Structure of CERCOM project

The report is divided into two parts. Part A covers a definition of circularity in the context of highway maintenance and assesses progress that is being made towards it by NRAs. For this assessment, a maturity model is developed which presents an inventory of good practice at different stages of implementation (from starting to engage with the transition to RECE, through early stages of practising RECE to active deployment). The implementation strategies adopted by a number of NRAs are assessed against this maturity model before presenting our assessment of the current situation, including barriers to transition to RECE that were observed, and our recommendations.

Underpinning the maturity model was a questionnaire which was deployed specifically to NRAs. This was followed up by 'ideas exploration' sessions and other discussions with NRA personnel (e.g., policy makers, technical leaders, procurement) and relevant stakeholders (e.g., contractors, suppliers, experts in CE, data managers, innovative thinkers) to shape the development of the maturity model and reach consensus on a common definition of RE & CE for road maintenance. A maturity rubric has been developed to allow NRAs to assess their progress and identify areas for development.

Part B of the report provides an inventory of good practices, resulting from an extensive literature review, to assist NRAs shape the policies, strategies and supporting tools for managing maintenance to achieve RE and CE objectives. The output of work package 3, a risk-based analysis framework for comparing maintenance options, will also be central to this. The structure of the review aligns to the aspects of good practice identified through discussion with NRAs and forms the basis of the maturity model. It addresses organisational and supply chain competence. Performance measurement and key performance indicators (KPIs) are discussed, as are the barriers and enablers to CE in current NRA procurement practices and the innovative approaches which can be employed to encourage and embed CE. Work package 4 will provide insights on the steps taken to overcome barriers related to metrics for performance quantification, and the availability and uniformity of data, to assist NRAs establish robust performance monitoring processes. Standards and specifications are known to support and incentivise new methods and approaches, those relating to the uptake of CE are therefore

reviewed as they are a key to overcoming barriers, reducing perceived risk and increasing flexibility (from the outset of projects, at the design stage).

Each section of the literature review includes a summary of good practice and a horizon scan to identify trends that could impact on the relevance of current practices and experience, as NRAs progressively move from linear to circular practices. This means the findings can be future-proofed and remain 'fit-for-purpose' in the short- and longer-terms. The horizon scan will also contribute to the development of a long-term perspective and to establish the content of the resource pack and training that will be delivered by work package 5.

PART A: Definition, current status and recommendations

A.1 Definition of circularity in the context of highway maintenance

There are many definitions of the circular economy, primarily focussed on improving resource use and efficiency. The Ellen McArthur Foundation describes the circular economy as:

"A circular economy is one that is restorative by design, and which keeps products, components and materials at their highest utility and value, at all times"

Over the last decade, the highway sector, as part of their commitment to sustainability, has focussed on increasing recycling rates of asphalt and reducing energy consumption by using asphalt materials that can be mixed and laid at lower temperatures.

Circularity is much more than recycling and entails a fundamental re-evaluation of how valuable resources can be used at their highest value, i.e., efficiently used, reused, repaired, and repurposed, not just recycled. A key aspect is about designing out waste and pollution rather than addressing these downstream after they are produced or designing for reuse and repair. The overarching objective is not necessarily to minimise the cradle-to-grave flow of materials, but to generate cyclical, cradle-to-cradle metabolisms that enable materials to maintain their status as high-value resources. Reflecting this, the familiar '3Rs' concept (reduce, reuse, recycle) for sustainable maintenance has been extended to the '9Rs' (refuse, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, recover energy), as shown in Figure 3.

In the context of existing road infrastructures that were generally not designed with future recyclability or disassembly in mind, R0 refuse and R1 rethink are not relevant. Given the nature of the work involved in road maintenance in particular, the operations can span several of the levels in Figure 3. As such, the figure cannot easily be used to assess the current levels and requirements to reach a higher level at an organisational scale but could be useful at a process scale. The Rs that play a major part in current maintenance practices are recycling of materials (R8) and the inclusion of secondary materials (R7).

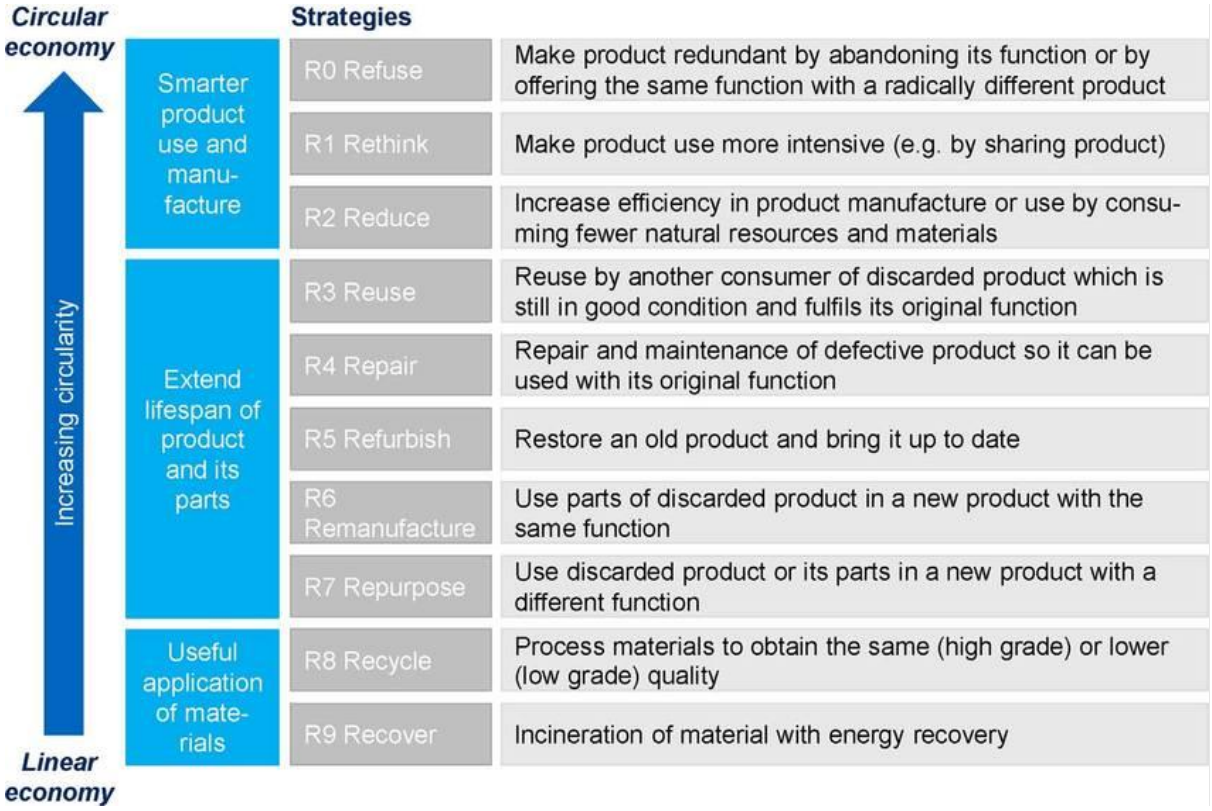

Figure 3 9 'Rs of the Circular Economy (Kirchherr et al)

Other examples of how circularity has been interpreted in construction are given in Table 1.

Table 1 Examples of the interpretation of circularity

Source	Interpretation
CRGi (2022)	• Extract no virgin construction materials and maximise the cycling of construction and demolition waste in new buildings
CIRCuIT (2021) – Wiki supported by a Horizon 2020 project	• Material does not deplete non-renewable (natural) resources • Has no adverse impact on the environment when used
Platform CB'23 (2019) – Method for assessing circularity in buildings and civil engineering in the Netherlands	• Protecting existing material stocks • Protecting the environment • Protecting existing value
Mi-ROG (2018) – White paper by the UK Major Infrastructure Resource Optimisation Group	• Keep resources in use for as long as possible • Extract the maximum value from resources while in use • Recover and regenerate products and materials at the end of life • Keep products, components and materials at their highest utility and value at all times

The overall system must limit its impacts to those which can be sustained over long time periods, and so a definition of circularity can also take a broad range of environmental and social impacts into consideration. This inherently generates a synergistic relationship between ecological and economic systems, a positive recoupling of the relationship between economy and ecology.

For environmental impacts, carbon footprint methodologies are now well-established and subject to standardised approaches although detail is generally lacking about the end-of-life phase (see Part B). Nevertheless, National Road Administrations are starting to demand this information from their supply chains as well as assessing their own operational footprints. Progress has also been made in reporting on other environmental impacts (e.g., quantifying emissions to air, water and land).

There is also a social dimension to circularity. This is important because, to be fully sustainable, it is necessary to consider that the activities undertaken may impact on the prosperity, health and wellbeing of workers (including the global supply chain), the local population and users (in this case, road users). The concept of social impact is not fully defined, but can include aspects such as avoidance of child labour, fair remuneration and opportunities for work/life balance, accessibility, inclusivity and engaging with affected communities.

In practice, attempts to address a scope that is too broad are unlikely to be successful since the data to support measurement of performance or assessment of the circularity of different maintenance options is unlikely to be available. Furthermore, National Road Administrations will differ in the extent to which they have already implemented circularity principles and in their rate of development. For these reasons, the following definition is proposed, which can form a flexible approach that can be extended and developed over time:

Circular Economy and Resource Efficiency for Road Maintenance means, by design:

- ***Minimising consumption of natural resources***
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- ***Optimising the value obtained within each lifecycle***
- ***Improving environmental performance and contributing to societal development***

Whilst the definition of circularity is an important guiding principle, it needs to be translated into practical actions for organisations to embed circular economy principles into their operations. The Framework shown in Figure 4 shows how, at an operational level, material requirements can be assessed, and available resources considered to meet the functional and structural requirements set. The available resources are evaluated against a risk framework with associated metrics. Finally, overall performance is measured, and improvement opportunities identified.

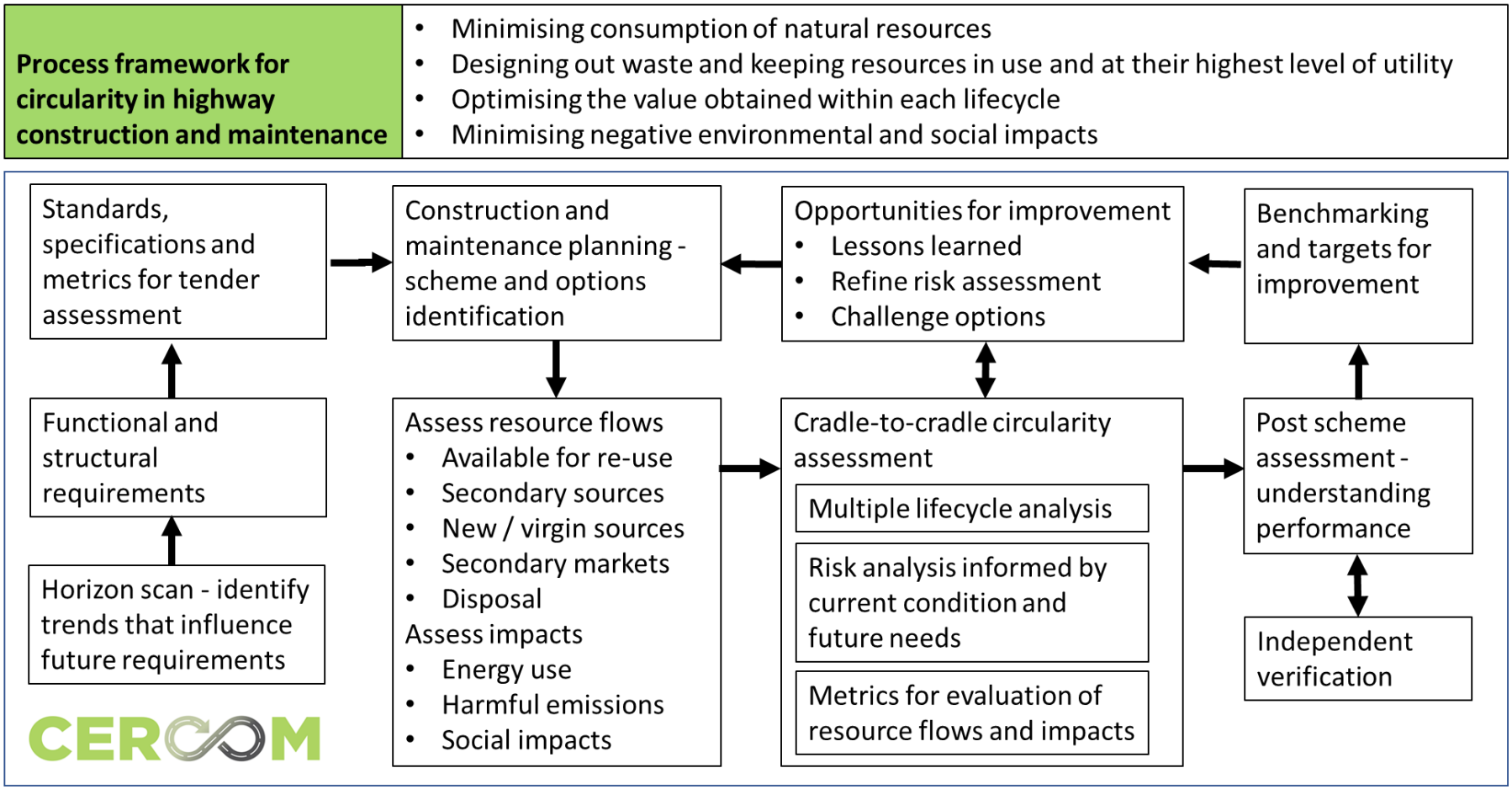


Figure 4 Flow Chart for RECE Framework

A.2 Assessing progress towards circular economy

To determine what aspects of good practice can be most useful to NRAs we have assessed NRAs' current activities on their journey towards implementation of circular principles. Based on the findings of the literature review presented in Part B of this document, it is clear that multiple attributes are important in embedding principles of resource efficiency and transitioning towards a circular economy. We identified the following aspects:

- **CE ambition** – the stated aims of the organisation and the internal and external visibility of this commitment.
- **Embedding CE** – the actions being taken to embed CE in the organisation's thinking and activities. This includes staff roles, knowledge and behaviours, accountability, and openness to innovation.
- **Performance monitoring and KPIs** – the use of metrics to understand the use of resources by maintenance activities and to monitor progress towards more efficient use of resources, particularly scarce resources, and limiting other impacts of maintenance.
- **Standards** – the degree to which standards adopted by an NRA support progress to RE & CE while providing effective management of the risks of innovative approaches.
- **Supply chain** – how relationships with the supply chain promote improvements in resource efficiency.
- **Business Models** – how value is ascribed to improvements in resource efficiency in decision making.
- **Circular Procurement** – how the supply chain is incentivised to offer more circular and resource efficient products.

Each of these areas is developed to outline the characteristics of an NRA at a given level of maturity, which are broadly described as follows:

- Engaging in transition to RECE (stages 1 to 3 inclusive)
- Early stages of practising RECE (stages 4 to 6 inclusive)
- Active deployment of RECE (stages 7 to 9 inclusive)

The complete maturity model is provided in the form of a rubric (see Annex A:) to assist in evaluating performance and providing a pathway to achieving full embedment of resource efficiency and circularity. An extract from the rubric can be found in Table 2 which highlights the step change in maturity from initial engagement in RECE to active deployment.

The maturity model serves two useful functions; firstly, with the guidance on different levels, it enables relatively consistent assessment of 'as is' status for a road administration, whether being assessed by different members of the project team, or through self-assessment. This could be further developed into a more formal procedure in the future. Secondly, when moving towards the training element of the project and for ongoing deployment, it will be useful for NRAs to determine the planning and actions required to enable them to move along the maturity levels of the model.

This has been applied by the project team as shown in the following section. The results were used to inform the recommendations presented in section A.4 and will be used in the definition of the resource pack and training that are to be delivered in Work Package 5.

For NRAs that wish to make use of the maturity model to assess their own progress, it is recommended that it is applied in the following steps. However, the model was designed primarily to guide thinking within the project and as such is not standardised or necessarily

suitable for providing auditable records of organisational performance. As with any such assessment, the results are subjective and dependent on the information available to the assessor. Other approaches to assessing organisational maturity are presented in the literature review in Part B of this document.

Guidance for application of the CERCOM maturity model:

- Determine the scope of the assessment. For this project, the scope was in relation to highway maintenance activities. NRAs wishing to apply the model more broadly, either for the organisation as a whole or for a part of its structure or activities, should first define this scope.
- Based on a rounded knowledge of the relevant scope, list the main activities which are taking place and the milestones that have been achieved, under each of the model's headings.
- Allocate a score for each heading. These are presented individually and are not combined into an overall score. The start point is a score of one and the maximum is nine. Under each heading, determine whether there has been any progress to merit a score above one. If so, progress to assess:
    - Which of the Stages (1-3, 4-6, 7-9) the activities that have been listed are most consistent with, when taken as a whole.
    - Within the Stage identified, whether the activities listed represent initial progress being made in some areas (in which case, select the lower score within the range applicable), represent progress being achieved in most areas (select the higher score within the range applicable), or mid-way (select the middle score).
- Obtain input from a relevant cross section of personnel to validate the activities and scores allocated.
- Considering organisational priorities, agree the most important areas for improvement and develop an action plan to address them.

Table 2 NRA Maturity Levels

Maturity level	Engaging in transition to RECE (Stage 3 extract)	Early stages of practising RECE (Stage 6 extract)	Active deployment of RECE (Stage 9 extract)
CE ambition	NRA has committed to a transition to CE and a definition for what CE means in practice is in place	Policy to transition to CE has been published. Targets for RE and CE elements, some developed & others under development	Strategic plan for transition & route map with timeline in place and embedded in the NRA. Targets for RE and CE, monitoring systems to track progress are developed.
Embedding CE	Moderate staff awareness of CE and how it affects their roles. Ad-hoc initiatives to support innovation to deliver CE.	Clear communication, internally & externally, on commitment to CE. Corporate commitment to innovation initiatives to deliver CE. Champions in project teams are beginning to drive through change. Supporting instruments, tools and staff training are being developed and implemented.	Staff are fully engaged with CE. Significant investment in innovation in RE and CE with forward plan to continue commitment. Visible leadership at senior level, with accountability assigned to key leadership roles, supported by champions. Supporting instruments, tools and staff training are fully developed, implemented, and embedded. Business and personal objectives are set for delivery of RE and CE. CE principles are embedded in process as 'business as usual', and subject to continuous improvement.

Performance monitoring (KPIs)	A partial inventory is available of the resources in use. Tracking occurs of selected and isolated aspects, e.g., RAP or CO_2.	RE & CE are routinely monitored internally, the supply chain is required to provide data to support. Increasing detailed inventories that track resource inputs and outputs. Increasing visibility of performance and awareness of areas for development. KPIs (internal & external) are in place, and additional ones being developed.	A common data standard exists and robust, up to date data are available (for NRA and supply chain). A detailed understanding of materials, input, and output (waste) streams throughout the supply chain has been achieved and routinely monitored and updated as necessary. Metrics in place for quantification of resources and impacts, with third party verification are reported upon. Internal & external transparency in performance achieved with reports on progress being made towards targets.
Standards	Standards and methods for treatment of risk allow greater reuse of materials, e.g., recycled asphalt, within traditional methods.	Standards accommodate opportunities for high-value use of existing materials (accommodating Repair, Reuse, Repurpose, etc., in addition to Recycle). Novel approaches are actively sought through a streamlined process for derogation.	Standards support and help to embed innovation in high-value use of resources whilst providing effective management of risk. Effective (audited) methods in place for verifying the provenance and quality of materials in a secondary market.
Supply chain	Engagement is occurring between internal & external stakeholder communities (e.g., developing guidelines, good practice). Suppliers deliver projects as mandated by existing standards.	Collaborative mechanisms, e.g. Early Contractor Involvement at design stage, and positive attitude to innovation are used more widely, enabling progress to circularity. Supply chain demonstrating continued commitment to monitor and improve performance.	A Systems approach is established, with collaborative partnerships and alignment of incentives throughout the supply chain. NRA & Supply chain on track to deliver NRA targets.
Business models	Linear business models (WLC, with environmental	NRA business model thinking is influenced by RE and circularity	Circular Economy Business Model based on delivering maximum value of

	aspects such as recycling in line with legislative requirements)	principles e.g.: reducing overall resource consumption, keeping materials in use, minimising ecological and social costs, designing out waste, and consideration of the residual value of resources, products as services.	resources and maintaining continuous relationship with supply chain in active use in the NRA. Circularity is inherent in the business models, drives decision making and procurement towards improving longevity, repairability and resource efficiency.
Circular procurement	Procurement is on a transactional basis. Elements of CE are accommodated although are not specifically designed to influence internal and supply chain behaviours on circularity. Tendering is based on specified technical requirements and suppliers deliver on value elements as mandated by standards	Systems and tools to include CE & RE principles within the procurement process are being developed. Circularity (e.g., plans for reuse of materials, development of secondary value chain) is rewarded in tender assessment.	Systems and tools that recognise and reward CE & RE are embedded in the procurement process. Procurement based on collaborative relationship with supply chain is embedded in the NRA. Tendering process includes functional specifications with circularity metrics embedded into the decision process. Monitoring system in place to report on progress, track and demonstrate improvements.

A.3 Implementation strategies adopted by National Road Administrations

A review of NRA practice was undertaken through a literature search, an online survey of NRAs and follow up discussions with selected NRAs.

An online questionnaire was sent out to members of the Project Executive Board and other members of CEDR, eliciting 13 responses from 11 countries. The questionnaire asked basic questions regarding the environmental targets of the road administrations, what environmental reporting they requested from their supply chain, how they assessed risk in asset management, particularly regarding materials over multiple lifecycles, and their willingness for follow up discussions. A summary of the results is presented in Annex B:. The greatest value from the questionnaire was to identify engaged parties and getting the opportunity to discuss the results in greater detail and understanding what initiatives regarding the circular economy are in place. The discussions were undertaken around the answers given in the questionnaire and were used to beta test the maturity matrix.

The findings are summarised for each country in the following tables. Based on this information each country was scored against the maturity model presented in the previous section. The scores have been fed back to individual NRAs and are not published here. The scoring was subjective and based on a limited number of interviews with NRA staff. As a result, the project team were not satisfied that the scores allow for robust comparisons to be made between NRAs. The value comes rather in the identification of good practice and in tailoring the recommendations and development of resources to NRAs' current situation. Reflecting in their own scores will also allow individual NRAs to prioritise areas for development.

The range of scores obtained through this process is shown in Figure 5, indicating a considerable range between NRAs that are relatively advanced, particularly in their ambition for a more circular approach to road maintenance and in monitoring their progress to this goal, and those that are at the early stages. In these areas, there are opportunities to disseminate the good practice that has already been established. It is also clear that no NRAs are particularly advanced in managing their supply chain, business models and approaches to procurement. In these areas, there is scope for new thinking.

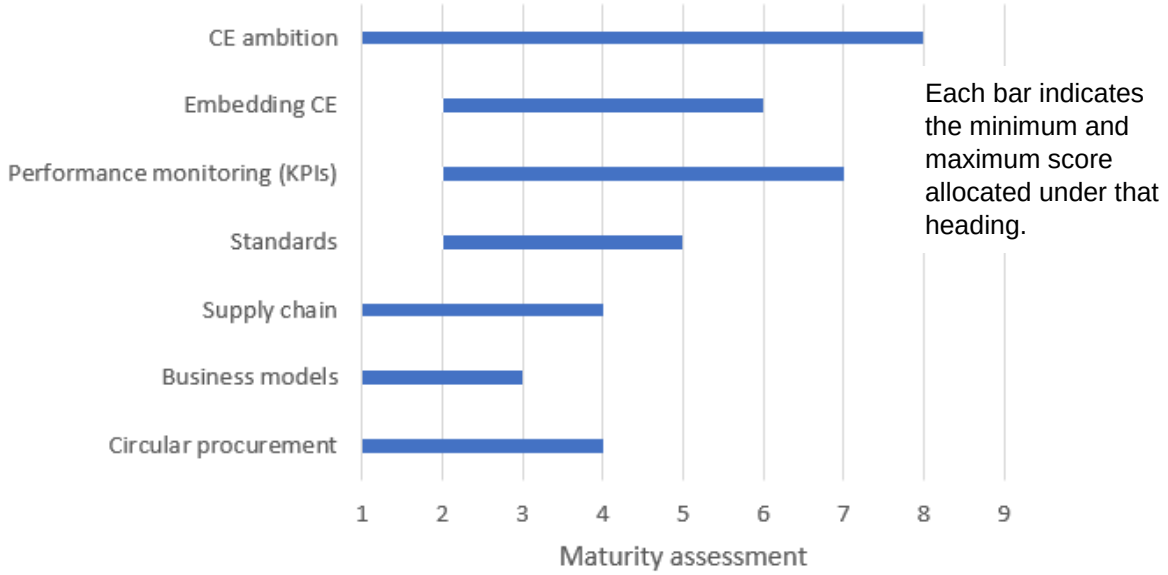


Figure 5 Range of maturity scores from the six NRAs participating in this study

A.3.1 Denmark

Maturity level	Vejdirektoratet
CE ambition	• No direct goals or plans for CE implementation. • Ambition for implementation of "Sustainable solutions", more focus on CO_2-emissions. • Future strategies include sustainability as a central theme. • Strategies are still in test-phase and not yet fully implemented.
Embedding CE	• Awareness of CE, but as of yet not a primary driver. • Importance- and reduction of carbon emissions play a larger role in future strategies than CE. • Transition to more green solutions is an ambition and follows the policy changes in Denmark and the Danish building sector. • No direct changes implemented for the fostering of CE, but existing practices are adjusted to no longer hinder CE as much. Such as allowing for more recycled content in asphalt. • CE may be applied when an overlap exists with ambitions for reduction of CO_2-emissions
Performance monitoring (KPIs)	• Implementation of LCA-tool for the calculation of environmental impacts of construction projects. No benchmarking values established yet. • Delivery of LCA-calculation now included in tenders for all large-scale construction projects, as test-phase for full rollout. • Information gathered from submitted LCAs will be analysed internally and used to establish a baseline for future benchmarking values.

	• Indirect inclusion of CE in KPIs, from well-performing CE solutions in terms of other indicators – primarily CO_2
Standards	• Current standards allow for recycled asphalt content in all layers, previously not. • Adopted new highway standard to allow for the implementation of BSM (Bitumen Stabilised Material) based on recycled asphalt. • Challenging to update/adopt new standards due to existing construction product regulations. • Standards are sometimes a barrier for implementing CE solutions.
Supply chain	• New requirement for Environmental Product Declarations (EPD's) for materials used in the supply chain. • Requirement to supply EPD's will be extended to be part of procurement, and requirements to the contents/results of EPD's will follow. Product-specific EPD's seen as future requirement.
Business models	• Economic considerations are still a primary driving factor and cannot yet be compromised to facilitate CE. • New project focused on establishing performance-based requirements is initialized, aimed at facilitating more freedom in road construction and potential inclusion of CE.
Circular procurement	• No direct inclusion of CE & RE in procurement, either in current practice or test-phase. • People in charge of purchasing are now weighing sustainable products and products with higher reuse-potentials more highly. • Future procurement practices may include clause to allow for higher project costs if corresponding CO_2-emission reductions can be documented. Still internal test-phase. • Still searching for the win-win solution for both economic- and environmental considerations.

A.3.2 Ireland

Maturity level	Transport Infrastructure Ireland
CE ambition	• Commitment to transition to CE has been made in line with the EU CE Action Plan. • Definition of CE adopted from Ellen McArthur Foundation. • Policy for CE under development but not yet published.
Embedding CE	• Most technical staff are aware of the growing interest in CE. • Carbon counting tools developed for road construction in Ireland (innovation incentives) • CE mostly adopted by pavement experts. Not yet realised for Structures but there is a growing interest in sustainability in this area.

Performance monitoring (KPIs)	• Carbon counting adopted through new carbon counting tool for embodied and operational carbon. • Systems to monitor improvements in RE & CE are not yet developed.
Standards	• Standards do not prohibit circular and sustainable / recycled materials, but do not actively reward these principles.
Supply chain	• Currently engaging consultants to assist in implementing CE approaches and deliver CE demonstration projects. • These are at an early stage and implemented on an ad hoc basis.
Business models	• Linear business models are still adopted but with consideration of circularity in the process.
Circular procurement	• Green Procurement and CE adoption in procurement identified in the Programme for Government as key area to lead to transition but this has not yet been implemented. • Use of an evidence-based approach (e.g., through the use of environmental product declarations). • Sustainability has been built into scoring for tenders (e.g., 5-10% of marks available).

A.3.3 Norway

Maturity level	Statens Vegvesen / Norwegian Public Transport Administration
CE ambition	• No clear definition of term in Norwegian Public Transport Administration (NPRA). • There is a lot of discussion around CE in terms of innovation, but not specifically discussed in organisation. • Aspiration to consider design for disassembly, with digital twins starting to be progressed.
Embedding CE	• No champion yet, but recognised need to have someone in management team to move it forward. Groundwork is needed first to establish this, learn from projects to enable effective implementation across the organisation • Emissions from construction, operations and maintenance and own activities should be cut by 50% by 2030. • Construction sites: 50% cut in emissions by 2030 - zero emissions by 2050.
Performance monitoring (KPIs)	• Emissions budgets and greenhouse gas accounting for all projects above NOK 51 million (requirements and criteria for sustainability in all procurements). • All projects over NOK 200 million must have CEEQUAL certification

	• CO_2 budget is agreed for all new projects, covering multiple phases (pre stages, during planning and prebuild etc). • Targets in terms of pavements. Often, reduction of waste • Targets for 100% reuse from maintenance.
Standards	• Inclusion of secondary materials and recycling and reuse of materials is permitted.
Supply chain	• Meeting with suppliers planned to see how to progress RECE procurement.
Business models	• Lowest price remains the dominant factor. • Bonus system applied in relation to achieving targets, penalties for not reaching targets – applied to CO_2e emissions so far for the larger contracts. Still collecting insights to refine the process.
Circular procurement	• Climate and environmental performance criteria become much more important, often now up to 30% weighting. Incentives etc dealt with separately. Standardised contracts used. • Reduction of waste set out on contract basis usually. • Often have targets based on climate or greenhouse gas emissions rather than volume or weight of material because there are set targets to achieve

A.3.4 Switzerland

In Switzerland, much of the work on construction and maintenance is undertaken by the Cantons. This is the response from the Federal office, who are responsible for the motorway infrastructure.

Maturity level	Swiss Federal Roads Office
CE ambition	• The concept of CE is not widely used, but the extension of life-cycles is an important part of the culture of the organisation • Asphalt specialists with good knowledge of the market and recycling, VSS financed almost exclusively by NRA to update norms and keep up with innovation.
Embedding CE	• CE is not embedded at an organisational level • Waste management plans have to be submitted for each project, where any material that is not reused must be justified, providing project managers with tools as to how strategies can be incorporated. • Different specialised technical groups (bridges, tunnels etc), each group elaborate and determine the materials used for construction and maintenance. For example, if using asphalt, they can take recycling above the norm, optimising wherever possible.

Performance monitoring (KPIs)	• Ideas for monitoring in place, but not clear on return on investment from effort to analyse data. No legal requirement to report CO_2 • Do not know precise number of materials due to 26 cantons and federal systems which are responsible for waste collection. • Motorway network built by cantons with at least 20 different ways of planning and building.
Standards	• Systematically 30 – 40% secondary materials for binder and base course. • In technical sheets, only a maximum amount of recycled content is listed. One canton gives a minimum and assesses amount of recycling and transport distance.
Supply chain	• Generally, much cheaper to buy material with more recycled content so it is price driven. • Often specified what they want contractor to incorporate, so difficult to make big changes.
Business models	• Strategic alignment and Cost Benefit Analysis (CBA) internalises the external costs – choose what to build or not. CO_2 and environmental aspects. Swiss rail can structure the market more than roads.
Circular procurement	• Procure planning and building separately. They use tunnels as a source for materials. Undertake life cycle carbon (LCC) for lighting and electrics projects. • Now asking contractors for a page on sustainability 'hotspots' within assessment procedure for work (worth 3-5% of the points). Qualitative analysis only. Ideas around this area very dynamic

A.3.5 The Netherlands

Maturity level	Rijkswaterstaat
CE ambition	• RWS has a definition of CE, that complies with most of the principles of the CERCOM definition. • Government-wide Circular Economy program 'The Netherlands circular in 2050' that sets policies and targets for the development and realization of a circular economy before 2050. The focus is on the reduction of resource consumption and energy, and on net zero carbon. • For road infrastructure and civil engineering works, there is also the programme 'CE in GWW' with a Roadmap that focuses on developing knowledge about circular infrastructure and its translation into practice at Rijkswaterstaat. It works closely with the 'Climate Neutral and Circular Infrastructure Strategy' and the 'Sustainable Construction and Maintenance Program' in the field of circular procurement and measuring circularity.

Embedding CE	• Awareness in the organization has increased significantly; Adoption of CE principles is no longer under discussion for a large part of the organization and for cooperation partners. Current definition of circular working is used at strategic level and is a good benchmark for a roadmap. At a tactical management level (adapting working methods and approaches) and operational level (implementation in construction and maintenance projects), circular working can sometimes be an abstract concept. • Initiatives for sharing knowledge: Since 2018, a 'Learning Approach' was developed, but has not yet been consciously applied to knowledge development. In 2020, a 'Knowledge Plan' was drawn up for knowledge management. • There are specific CE-focused roles such as the 'Director of Sustainable Living Environment and Circular Economy', 'CE advisor', 'CE international advisor' that are leading developments in circular design, monitoring and procurement, and demonstration projects.
Performance monitoring (KPIs)	• Methods (Most Economically Advantageous Tender methodology (MEAT)) and tools (LCA software DuboCalc, CO_2 performance ladder, Environmental Cost Indicator (ECI) and Product Category Rules (PCR)) have been developed for sustainable and circular procurement. • Targets are in place for resource efficiency (i.e., to achieve 50% less use of primary raw materials (mineral, fossil and metals) by 2030 and to use 100% renewable (recycled and biobased) materials by 2050) and for CO_2 reduction (i.e., 55% reduction compared to 1990 levels by 2030 and climate neutrality by 2050). • A monitoring system has been set up to measure progress towards CE, using a set of indicators for monitoring the transition process (i.e., transition dynamics and monitoring and actions) and the effects of the transition process on the use of raw materials, environmental pressure and socio-economic development. • Data related to environmental footprint (11 impact categories) and ECI are stored in the National Environmental Database (Nationale Milieu Database) for reference materials.
Standards	• Main driver for adopting circular economy approaches is the solid framework of legislation that bans the landfilling of construction and demolition waste (C&DW) streams. • Current standards (RAW) specify in detail which percentages can be reused and in which mixtures are allowed. Overall, the reuse percentage is limited to 30%, while in mixtures such as stone mastic asphalt (SMA) and very open asphalt concrete (zeer open asfaltbeton ZOAB) reuse is not allowed. Developments towards functional-based specifications standards are on-going. • Market parties with innovative (circular) products that are not (yet) legally permitted under current regulations, they can follow an

	accreditation procedure through the Rijkswaterstaat Innovation Test Centre (ITC).
Supply chain	• There is engagement with stakeholders & supply chain on CE related issues. Example is 'Platform CB'23' that brings together stakeholders in the construction domain with the aim to achieve working agreements (terminology and definitions, review of existing frameworks, methodology for measuring circularity, material passports, data sharing) to support transition to circular economy. • Innovation is promoted through procedures (e.g., Rijkswaterstaat Innovation Test Centre) that allow for products/processes not covered by existing standards, to be benchmarked and approved.
Business models	• Linear business models that include sustainability & environmental aspects. • Pilot projects for circular business models (Infra-as-service contracts).
Circular Procurement	• Circular procurement is part of the Sustainable Public Procurement. Several pilot projects are ongoing and aim to increase experience and expertise in the practical implementation of circular procurement. • Dutch Public Procurement Expertise Centre (PIANOo) has put in place guidelines for circular procurement. • Knowledge platform ikwilcirculairinkopen.nl provides information about the Circular Procurement Acceleration Network, the completed Circular Procurement Green Deals and several circular procurement projects.

A.3.6 United Kingdom (England)

In the United Kingdom, road transport is a devolved area, with the Scottish and Welsh Governments and Northern Ireland Assembly holding responsibility for road transport strategy, construction and maintenance. This response is from National Highways, the company responsible for strategic highways in England.

Maturity level	National Highways
CE ambition	• High levels of ambition to transition to CE • Have adopted a definition of CE, which complies with the principles of the CERCOM definition • Have a policy and targets for some elements of CE; still under development; more focussed on decarbonisation targets • Strategic plan for long-term delivery and timeline for net zero carbon. Not yet for reduction in resource consumption

Embedding CE	• High staff awareness in pockets but knowledge of CE is patchy across the organisation • CE message only at high level in strategy and design standards • Some champions are leading development and Implementation of CE principles in live projects • Some innovation initiatives directed at RE & CE: Pathfinder projects to identify and explore new solutions with the supply chain and investigation of a Resource Exchange Mechanism. However, these are work –in-progress and yet to be embedded across the organisation.
Performance monitoring (KPIs)	• Asset databases allow resources in use to be estimated. Limited information on the quantity and type of materials available for use. The development of the 'Resource exchange Mechanism' can potentially enable availability of up-to-date information on resources • A target is in place for CO_2 reduction (a major component of impact and RE but not specifically CE). This is supported by assessment tools and requirements for suppliers to report data. This information is collated and reported on internally.
Standards	• Standards permit a limited amount of reclaimed asphalt planing and certified preservation treatments. The Departures from Standards mechanism would allow suppliers to put forward RE & CE options, for authorisation • Standards are under review to assess how CE can be facilitated.
Supply chain	• Working with supply chain on transition to CE: Definition of CE was developed in consultation with stakeholders and there is on-going engagement with some stakeholders & supply chain on CE related issues • Pathfinder projects demonstrate active collaboration with supply chain to identify issues and determine solutions • Some examples taking place of RE practice e.g. A590 design for in-situ recycling.
Business models	• Linear business models • Selected projects - Early Contractor involvement to facilitate CE in pilot projects, design stage discussions enable identification of opportunities for reuse, waste minimisation etc • Whole life cost considerations, including some sustainability/environmental factors
Circular Procurement	• Work is commencing to look at procurement but is at an early stage.

A.4 Recommendations on good practice

A general summary of findings from the maturity assessment is provided below, under the headings of the maturity matrix. Considering these findings, a number of recommendations are made, which have been developed from the review of current practice (Part B of this report) as well as discussions with NRAs and industry. These are subject to revision as practical

experience is gathered during Work Package 4 and will inform the content of the resource pack and training provided under Work Package 5.

CE Ambition

Many NRAs have goals that are focused on sustainability objectives (generally carbon reduction) rather than circular resource inputs, decreasing resource dependence and increasing resource efficiency. The ambitions, specifically for CE and RE need to be defined. Recommendations are for NRAs to:

- Assess the relevance of CE and RE within their national context (and ultimately within a global context), including their organisational goals (e.g., greater circularity can contribute to reduced carbon emissions.
- Adopt a definition of CE and RE that addresses factors such as consumption of natural resources, keeping resources in use at their highest level of utility, optimising the value obtained in each lifecycle and minimising negative impacts.
- Develop specific objectives and a strategy for achieving them.

Embedding CE

Even without a stated CE ambition, some NRAs are moving to adopt a more RE approach during highway maintenance (by removing barriers on recycled content in asphalt, material reuse, life extension, whole life resource consideration etc). Furthermore, design maintenance regimes are increasingly being influenced by RE, with greater emphasis on long life and reduction of waste and / or of carbon. NRAs more advanced in RE and CE also consider what happens to resources at the end of life considering disposal during sourcing. Recommendations are to:

- Select a suitable maturity model (e.g., the approach developed under this project, or one of the formal certification schemes presented in Part B) and use it to assess current organisational performance.
- Appoint champions in key areas of the organisation to drive progress and develop competency profiles for the skills needed.
- Develop a communication strategy to raise awareness and understanding of the benefits of CE and RE throughout the organisation.
- Set corporate and personal objectives to drive innovation and change.

Performance and monitoring/KPIs

There is currently little quantification of resource flows associated with highway maintenance although some targets exist for reduction of waste and progress is also being made in tracking carbon emissions. An important barrier is the current lack of transparency of the degree of RE achieved which commonly exists between NRAs and the supply chain. Recommendations are to:

- Collaborate with the supply chain on the provision of data, leading to requirements to record and report on the production, consumption, recovery and disposal of material resources.
- Develop, monitor and report on suitable KPIs. Detailed recommendations are given in Part B.
- Make available the data that can help the supply chain find solutions to improve the efficiency of material circulation. This can include materials inventories and, in future, material passports.

Standards

Rigid standards, with slow modification, remains a barrier to innovation. Where development is occurring, it is generally limited to increasing the permitted content of reclaimed asphalt. Recommendations are to:

- Move towards functional performance / performance-based specifications to provide more flexibility to adopt innovative solutions for use, reuse and repurposing of materials, or waste minimization.
- Identify strategies for analysing and mitigating the risk associated with new maintenance approaches. The framework under development in Work Package 3 will assist with this.

Supply chain

Higher scoring NRAs have established an active engagement with the supply chain. Early engagement with contractors on construction projects has been shown to result in additional, novel options being proposed. Dialogue can also facilitate progress on topics such as agreement of terminology, approach to measuring circularity, materials passports and data sharing. Recommendations are to:

- Establish communication channels with the supply chain.
- Collaborate to foster innovation through collaborative designs, circular inputs, product as a service, life extension, recovery and reuse, close material and product loops.
- Share data on the nature, location and availability of resources to facilitate efficient use of materials, close to source.

Business models

Almost all NRAs operate with primarily linear business models in which economic considerations remain the main driver of decisions. However, wider environmental performance (particularly carbon) is beginning to have an impact. As the initial cost of RE and CE solutions may be higher than traditional approaches, NRAs will need business models capable of reflecting the value of increasing resource productivity and reducing resource dependence. Recommendations are to:

- Link business models to organisational, national, and global targets.
- Incorporate CE and RE considerations into decision making, valuing circular design, longer life and the recovery, reuse, and repurposing of materials.
- Adopt multi-life cycle models in which circular use and residual value at the end of each lifecycle are taken into account.

Circular procurement

The majority of NRAs are at an early stage of including RE in their procurement processes. However, good practice exists in the form of circular procurement guidelines and the use of environmental impact criteria in the assessment of the most economically advantageous tenders allows cost to be balanced with environmental impact. Recommendations are to:

- Redesign procurement rules to move from a traditional, lowest-first-cost system to performance-based procurement.
- Develop tender scoring criteria based on RE aspects (such as extended / optimised lifespans, intensity of material use and waste minimisation) and shadow trial to allow refinement prior to incorporating into all tender assessment.

PART B: Inventory of current practice

The following review has been organised around the following themes, which closely relate to the pillars in the maturity model presented in A.2:

- Organisational culture
- Performance measurement / KPIs
- Standards
- Procurement and supply chain
- Business models

In each case, relevant documents are summarised prior to a short synthesis of the concepts of particular relevance to NRAs and a horizon scan that considers how future trends could impact on the relevance of these ideas.

B.1 Organisational culture

In part A, the link between a definition of circular economy and a framework to put this into practice was presented (Figure 4). However, the effectiveness of the implementation of a strategy is, to a large extent driven by strong leadership and organisational culture. The Harvard Business Review (Groysberg et al., 2018) gives a quote of "culture eats strategy for breakfast". The Society for Human Resource Management states the following:

The key to a successful organization is to have a culture based on a strongly held and widely shared set of beliefs that are supported by strategy and structure. When an organization has a strong culture, three things happen: Employees know how top management wants them to respond to any situation, employees believe that the expected response is the proper one, and employees know that they will be rewarded for demonstrating the organization's values.

This is true too, for the implementation of the circular economy within an organisation as it requires clear leadership, enabling various levels of the organisation to work collaboratively and embed the principles in their day-to-day practices, for example, operational teams specifying different products or services working with the procurement team changing and adapting processes to make this happen. This collaborative culture extends to the supply chain too, to develop products, services, and new business models to enable this transition.

The purpose of this section of the report is not to go into detail on organisational practices, but rather, to provide context on the literature detailing the implementation of the circular economy, which are presented in the following sub-sections.

B.1.1 BS 8001:2017 Framework for implementing the principles of the circular economy in organisations – guide

This British Standard document is intended to help organisations implement more circular practices whether through improved ways of working, providing more circular products and services or redesigning their complete business model and value proposition. The document is not aimed specifically at the highways or civil engineering sector, but is designed as a framework, which has informed the framework presented in Part 1 of this report. Whilst British Standards are voluntary, they often become the basis for operations and can form the basis for European or ISO standards. It is aimed at organisations with different levels of knowledge and has a stated principle:

"To take full advantage of the reusability of products, components and materials, the restorative and regenerative capacity of natural resources and to optimize value creation (both directly and indirectly)"

The concept is illustrated through a diagram of nested loops, indicating that the smaller the loop (which can indicate both activity and geography) and lower the linear input/waste generation, the more profitable and resource efficient it is likely to be (Figure 6).

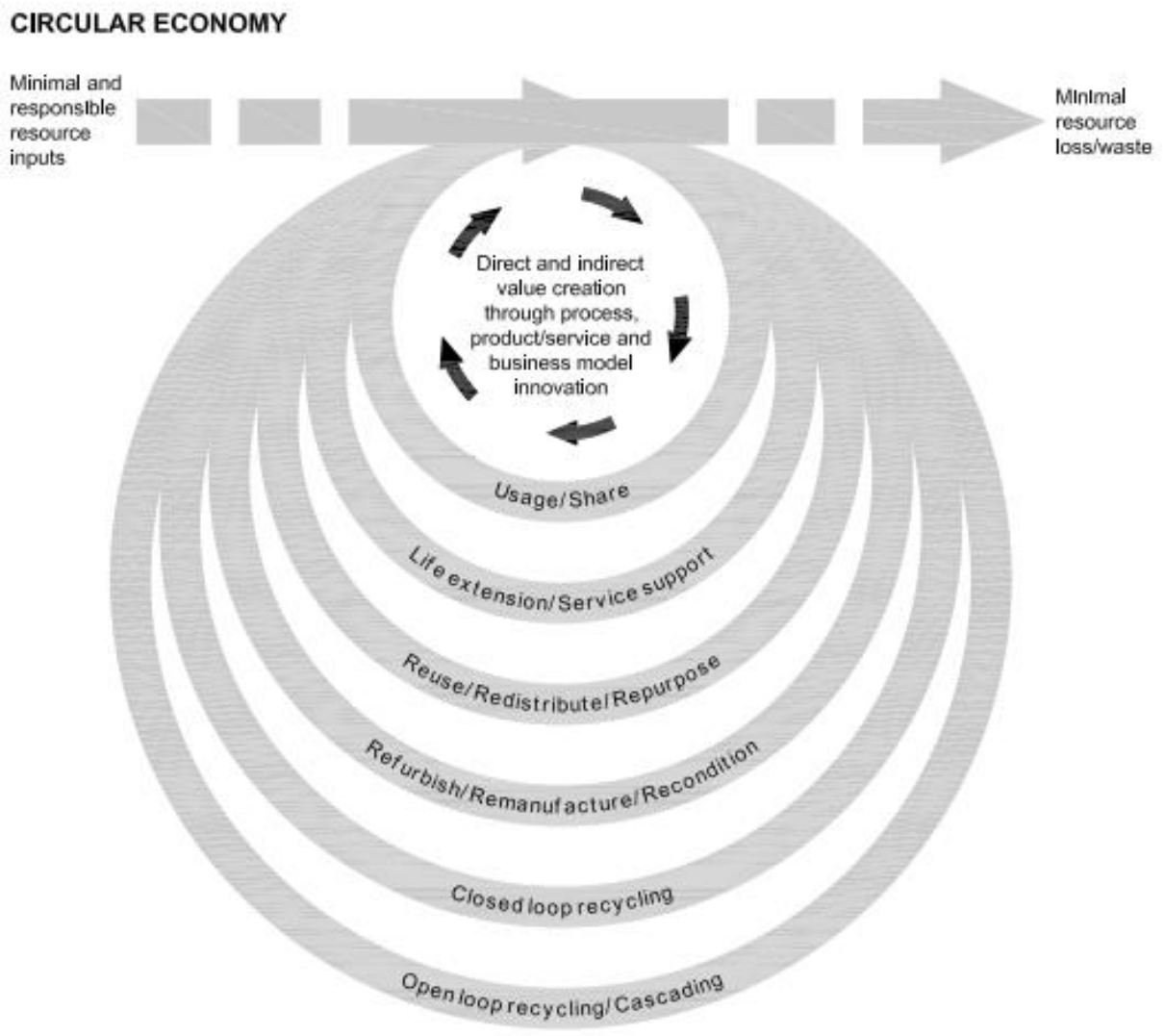


Figure 6 Circular economy model, from BS 8001:2017

Six principles are introduced which can be used by organisations as a frame of reference for their decision making and behaviour:

- **Systems thinking** – adopting a holistic approach to understand how individual decisions and activities interact with the wider systems they are part of
- **Innovation** – recognising the critical role of continuous innovation in processes, products/services, and business models
- **Stewardship** – acknowledging accountability for the direct and indirect impacts of decisions and activities

- **Collaboration** – embracing collaboration, internally and externally, developing trust and delivering a shared vision and purpose
- **Value optimisation** – keeping all products, components and materials at their highest value and utility
- **Transparency** – clear, accurate, timely and complete communication about decisions and activities

The standard defines a flexible framework for achieving organisational change, which consists of a maturity model, through which organisations will develop an 8-stage improvement process (see Figure 7).

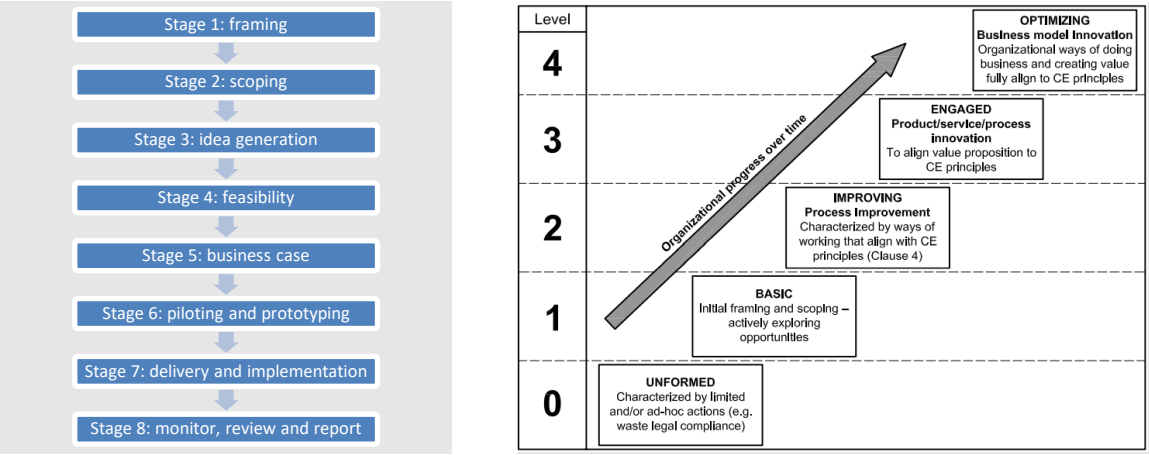


Figure 7 Stages in improvement process (left) and assessment of organisational maturity (right), from BS 8001:2017

B.1.2 Platform CB'23

Platform CB'23 brings together stakeholders in the construction domain with the aim to achieve working agreements (not formal standards) that will support transition to circular economy. The agreements include a Lexicon with clear terminology and definitions in the circular construction sector (Platform CB'23, 2020a), a summary of existing frameworks in the circular construction sector (Platform CB'23, 2019a), a methodology for measuring circularity in the construction sector (Platform CB'23, 2020b) and a guide for passports where guidelines are given with regard to information storage and data exchange in the circular construction sector (Platform CB'23, 2020c). This guidance document for measuring circularity in buildings and civil engineering works was produced following a working group of 85 organisations supported by Rijkswaterstaat in the Netherlands (Platform CB'23, 2020). The intention was to produce a core, harmonised measurement method to complement the environmental performance reporting requirements by reflecting three goals of circular construction:

- Protecting existing material stocks
- Protecting the environment
- Protecting existing value

The document anticipates a progression towards a circular economy and lists the important factors that need to be in place for each of the stages (Figure 8).

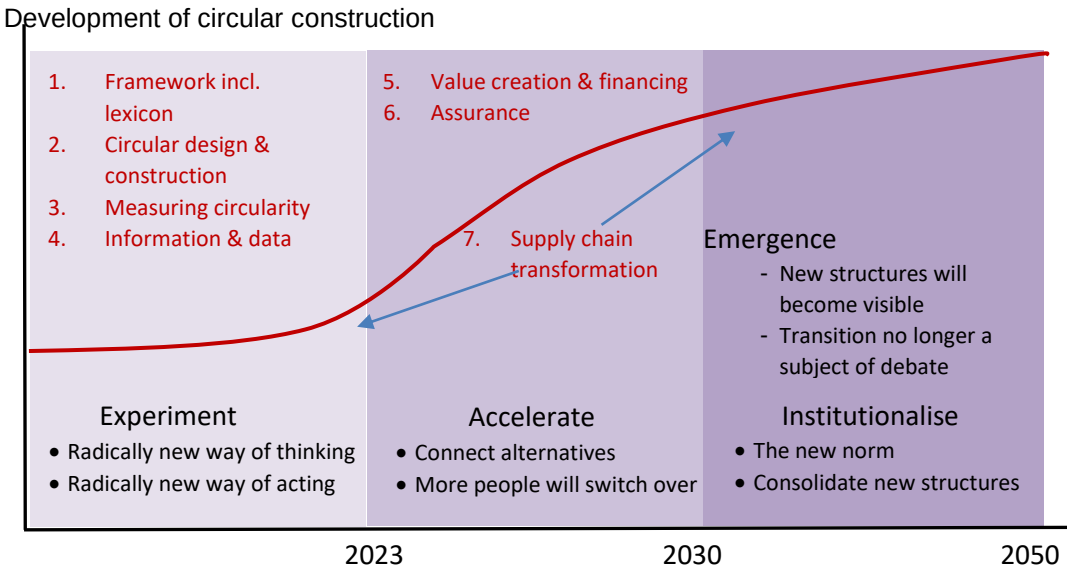


Figure 8 Four phases of development, reproduced from Platform CB'23 (2019)

B.1.3 Initiatives requiring a commitment to action

While the following two initiatives relate to carbon emissions rather than the wider circular economy, they are relevant both because the principles are similar (they require organisations to commit to a change programme) and because the objectives are linked (circular economy is pivotal in achieving next zero).

B.1.3.1 Science based targets for corporate net-zero

The Science Based Targets initiative (SBTi) is a collaboration between non-profit charity CDP (Carbon Disclosure Project), the United Nations Global Compact, World Resources Institute and World-Wide Fund for Nature. It was established to provide a standardized and robust approach for business to demonstrate their journeys towards net zero carbon emissions.

The framework requires companies to commit to near term (5-10 years) and long-term (2050) targets for emissions reduction, combined with additional mitigation measures to neutralise residual carbon emissions. At the time of writing, over 2300 companies were registered as taking action, with over 1000 science-based targets established by these organisations. Each organisation develops its own targets, in line with SBTi criteria, which are submitted to SBTi for validation. The process for this is to:

- Select a base year, that is typical of the company's greenhouse gas profile and where scope 1, 2 and 3 emissions data are accurate and verifiable
- Develop a full emissions inventory, following a defined method
- Set targets and choose a target year. This must be within 5-10 years of submission for near-term targets and by 2050 or sooner for long-term targets
- Implement a strategy to achieve the targets
- Disclose progress towards targets annually

With some exceptions, near term targets must cover at least 95% of company-wide scope 1 and 2 emissions (i.e., relating directly to the company's activities) and long-term targets

additionally cover at least 90% of company-wide scope 3 emissions (i.e., including bought-in products and services, and the use of the company's products by its customers). The guidance shows the trajectories for emissions reduction that are required to stay within the remaining carbon budget for a 50% likelihood of limiting warming by 1.5°C.

In the highways sector, National Highways and Autostrada per l'Italia are signatories, along with over 20 rail companies in Europe including Network Rail, Deutsche Bahn, SNCF, ProRail, Thalys, Alstom and Eurostar.

Many of civil engineering companies in the highways supply chain have also signed up to the scheme, which should help bring alignment; Amey, Colas, Costain, Royal BAM, Acciona, Fugro, Vinci and Ferrovial are just some examples of major contractors who have signed up.

B.1.3.2 CO_2 performance ladder

Th CO_2 performance ladder is a carbon management system that is used in the procurement of construction projects in the Netherlands. This new procurement scheme is currently used by several Dutch public authorities. It is a certification programme for energy and CO_2 management that gives companies a competitive advantage in the contract awarding process. It has 5 levels of certification (SKAO, 2022) with requirements for insight (measurement of footprint), reduction targets, transparency (both internal and external to the company) and participation, for example collaborative development of carbon innovations. Up to level 3, an organisation addresses carbon reduction within the company (scope 1 and 2 emissions), whereas levels 4 and 5 require carbon emissions embedded within purchased goods and services to be addressed (scope 3 emissions).

Almost 1000 certificates have been issued, collectively incorporating the results of many thousands of companies and SKAO quote research that suggests certified organisations reduce their emissions at twice the rate of uncertified organisations. According to Verstegg (2019) almost all the organisations working in infrastructure have implemented a carbon management system, assessed their carbon footprint, and established carbon reduction targets, presumably as a result of the direct influence of the certification on tender assessment.

A short video explaining the CO_2 ladder is available at https://youtu.be/yM0I4winCPQ.

B.1.4 Summary of good practice

Good practice in the context of organisational culture could be summarised along six key themes, namely:

- Clear direction set at director level and communication to all levels of staff.
- Establish baseline in terms of organisational maturity
- Collect data
- Commit to action
- Set targets and monitor progress
- Involve the supply chain on the journey
- Consider bonus schemes / incentives for achieving environmental targets

B.1.5 Horizon Scanning

Challenging targets were set at the COP26 conference[1] in Glasgow in 2021. Relatively few countries have legally binding targets for achieving net zero. The EU has set a long-term strategy of becoming carbon neutral by 2050, whilst Sweden and Germany have set legally binding targets for 2045 and France, Denmark, Spain, Hungary, Luxembourg, the Netherlands and the UK for 2050 (Carver 2021). Ireland has proposed legislation. The UK also has an interim target of 78% reduction in carbon by 2035.

There remains some ambiguity about the enforcement of targets, but it is clear that national governments will require all sectors to play their part in achieving them, with the transport sector being a key emitter. How this will be enforced at a company level also remains to be seen, but national road administrations will likely be expected to collect more data from their supply chain to demonstrate reductions in emissions. Whilst many of the companies in the supply chain will have their own net zero targets, agreed measures for certification will be required.

At a more geopolitical level, the events in Ukraine and restrictions on the imports of oil and gas from Russia will hasten the requirement for energy security. This in turn could accelerate the generation of power from renewable sources, and electrification and/or hydrogen power of vehicles. Technical advances have also resulted in less bitumen being produced from the distillation of crude oil, with a further reduction in oil use resulting in a shortage or the requirement to develop new alternatives.

B.2 Performance measurement / KPIs

To assess progress in improving circularity, particularly if products and services are to be selected based on these credentials, methods are needed to compare options and assess progress. This section reviews various published approaches.

Indicators such as the National Circularity Indicator and Circulytics are applicable at an organisational or even at a national level. Others, including the Material Circularity Index and Platform CB'23 indicators are more suited for evaluating options at the project level. As well as circularity, it is noted below, it is important to monitor additional impacts to avoid the possibility of perverse outcomes in a complex system. Other indicators, particularly of environmental impact are consequently included as they may have a role within a comprehensive suite of KPIs.

Finally, two examples of data format are presented: producing KPIs requires appropriate data and, with complex processes and supply chains, obtaining and validating this data is not straightforward. Systems to manage the organisation of this data and its sharing across the supply chain can be useful to limit the cost of maintaining these additional data.

B.2.1 National Circularity Index (NCI)

Circle Economy produce an annual report analysing the circularity of global or national activities, attempting to map material throughput across global value chains to a final use by society to meet their functional needs. Their analysis (Circle Economy, 2020) is based on a series of accounts for supply and use of resources (mass of goods, terajoules of energy and millions of Euro for intangible services). The national, rather than global level, analysis is more

[1] https://ukcop26.org/

relevant to NRAs, since it includes considerations of import and exports, whereas the global analysis considers the planet as a whole. The National Circularity Index (*NCI*) represents the share of cycled materials in the total raw material consumption (including cycled materials), defined as:

$$NCI = \left(\frac{sm^{reg} + sm_{ntb}^{reg}}{RMC^{reg} + sm^{reg} + sm_{ntb}^{reg}}\right) * 100$$

Where RMC^{reg} is raw material consumption within the region, sm^{reg} are secondary materials (waste recovered) by the region and sm^{reg}_{ntb} represents the net trade balance (difference between imports and exports) in secondary materials. The complexity multiplies when considering how some of these components are calculated:

$$sm_{ntb}^{reg} = (imp^{reg} * GCI) - \left(\exp^{reg} * \left(\frac{w_{rec}^{reg}}{r^{reg} + w_{rec}^{reg}}\right)\right)$$

That is, the trade balance of secondary materials can be determined by the quantity of regional imports (imp^{reg}) multiplied by GCI, which represents the circularity indicator for those imports, minus the quantity of regional exports ($\exp^{reg}$) multiplied by a ratio reflecting the proportion of recovered waste within the overall resources used to produce the export. Calculated at a national level, published data sources are used to estimate individual resource groups. For example, considering resource extraction, data were available for biomass, fossil fuels, metals, ores and non-metallic minerals. The indicators are thus calculated at a macro level for each region (rather than as a sum of relevant activities).

It is noted (Circle Economy 2022) that organisations tend to lack data on material flows, which are a complex combination of extraction, energy use, procurement and production activities. In many cases, this information is needed from the supply chain, which is not always readily available. To incentivise partners to collect and share data it recommends leveraging key moments such as contract renewals, participation in ambitious projects and joining forces with other organisations to create a new industry norm.

Circle Economy also define a scale of “Methodologies Readiness Levels”, recognising that indicators for circularity are still under development. Being complex, even the relatively thoroughly tested indicators can produce odd results in some circumstances. They also vary in the level of expertise that is needed to implement them. The scale of MRL has 6 levels:

1. Theoretical test
2. Tested within a limited set of applications
3. Tested by a wider community of practitioners
4. Metric published
5. Metric widely available and easily accessible
6. Metric standardised

B.2.2 Circulytics

Circulytics is a framework developed by the Ellen MacArthur Foundation (EMF) to measure a company’s circular economy performance (Ellen McArthur Foundation, 2022). It is applicable to organisations of any size and is free of charge. At the time of writing, over 200 companies had assessed their activities using this method.

Companies register on the EMF website and provide data and supporting information to score against 37 indicators in 11 themes:

- Enablers: Five themes that encompass activities to facilitate change and which are applicable to all companies: strategy and planning; innovation; people and skills; operations; external engagement.
- Outcomes: Six themes that measure actual circular economy results, at a company level: products and materials; services; plant, property, and equipment assets; water; energy; finance. Each theme is weighted according to whether it is core to company activities, relevant, or not applicable.

The individual indicators within each theme are scored based on the data submitted; these are then aggregated within the themes and combined to produce the overall score. Details of the individual indicators and their weighting are provided in the resources available on the Circularity website (https://ellenmacarthurfoundation.org/resources/circulytics/overview).

The company receives back a confidential scorecard showing the overall performance, a breakdown of the score by theme and, for industries where there have been sufficient submissions to guarantee anonymity, a comparison with the industry benchmark. Data are updated annually, allowing progress to be monitored.

B.2.3 Material Circularity Indicator (MCI)

The assessment of company-level performance, using Circulytics, can be complemented by the Material Circularity Indicator, MCI, to assess the circularity of a company's flows of products and materials. The method was published in 2015 and updated in 2019 (Ellen McArthur Foundation and Granta Design, 2022). The MCI can be used to compare products for internal reporting, or as the basis for procurement decisions, for example by defining a minimum threshold for products that are purchased. It can be applied at either a product level or at a company level and has been piloted by a range of companies, although these were not specifically related to transportation or infrastructure.

The MCI is a mass-based indicator that considers the flow of materials throughout the use of a product. However, to assess circularity it is important to consider multiple lifecycles, since the effect of choices made in the design of the original product may not be felt until the second and subsequent lifecycles are accounted for. This leads to significant additional complexity and a potential loss of precision. To address this, the reliability and relevance of the input data should be assessed, and sensitivity studies can be valuable to assess reliability of the MCI result.

It is also necessary to assess whether the materials described can, in practice, be captured and reused as is being predicted. For example, a product may be 100% recyclable, but it is the mass of the units that are actually recycled that should be used in the calculations. Providing clear statements of the assumptions behind the MCI value, monitoring the actual resource flows in subsequent lifecycles, and taking corrective action where needed, are necessary parts of this process.

The MCI is formed from two underlying indices:

- The **linear flow index** (LFI) – this takes a value between 0 and 1, reflecting the proportion of materials that are extracted as virgin materials or discarded as unrecoverable waste:

$$LFI = \frac{Mass\ not\ from\ reuse\ or\ recycling + Mass\ of\ unrecoverable\ waste}{2\ x\ Product\ mass + factor\ for\ waste\ generated\ during\ recycling}$$

- The **utility index** (X) – this accounts for the length of the product's use and the intensity of use, made by comparison with the industry average for products of a similar type:

$$X = \left(\frac{Length\ of\ use}{Industry\ average\ length\ of\ use}\right).\left(\frac{Functional\ use\ achieved}{Industry\ average\ functional\ use}\right)$$

- The **MCI** combines these indices. For a product with average utility (i.e., X=1), the MCI value will range from 0.1 for a fully linear product (LFI=1) to 1.0 for a fully circular product (LFI=0). Products with a greater or lower utility than the industry average are rewarded or penalised through the variation of X.

$$MCI = Maximum\left(0,\quad 1 - LFI\left(\frac{0.9}{X}\right)\right)$$

The approach can be adapted to account for products with multiple components and across whole supply chains, although it is noted this approach is often constrained by lack of data. It can also be applied to companies, where a company-level MCI is obtained as an average of product-level MCIs, weighted by mass or sales volume.

The paper notes that improving the MCI of individual products or companies does not necessarily lead to an improvement in the circularity of a whole system. This suggests the possibility of 'perverse outcomes' unless the system boundaries are defined carefully. However, widespread adoption of the approach can form part of the improvement needed. It is also recommended to adopt additional indicators to track relevant risks and impacts that are not covered within the MCI methodology. For example, risks such as the scarcity and toxicity of materials or impacts such as of water or energy use, or biodiversity loss.

B.2.4 Value-based Resource Efficiency (VRE) indicator

Di Maio et al. (2017) note that the choice between minimising the mass or maximising the value of resources that are used in producing some service or product will produce different outcomes, as will minimising the environmental impact of resource use. They propose that value is the appropriate metric to select, on the grounds that economic value is widely understood in decision making and will be more effective in policy making. It also has the advantage that different aspects can be translated into value, including the quality of resources (as opposed to simply their mass), and the cost of environmental impacts.

The authors distinguish between abundant resources, which are available for everybody and likely to remain so in future, and stressed resources, the use of which makes them unavailable in future. Their definition of resource efficiency is specifically in relation to these stressed resources, which can include societal stresses.

A **Value-based Resource Efficiency** (VRE) indicator is proposed, which consists of the value added, divided by the amount of all inputs:

$$VRE = \frac{Y}{\sum_i w_i X_i}$$

Where Y is the value of the output, X_i are the quantities of resources used and w_i are the weights applied to each resource type. With no weighting applied, i.e., $w_i = 1$, the VRE reduces to a mass indicator.

Values of w_i would ideally represent the environmental and social impacts of the use of each resource X_i. However, this information is often not available, and the authors propose that market price can be used as proxy since the price of materials and energy represents the quality and scarcity of resources. In the case of highway maintenance, it is not clear that an appropriate system of weighting could readily be developed, and use of market prices would not, in this author's opinion, adequately reflect the environmental and social impacts associated with its procurement.

The output assessed in VRE is the value added, the gross output (GO), minus intermediate inputs: Energy ($E = w_e X_e$), Materials ($M = w_m X_m$) and Services, S, giving:

$$VRE = \frac{GO - E - M - S}{E + M} = \frac{GO - S}{E + M} - 1$$

Measurement can either be applied to specific parts of a supply chain or globally to an entire product. Figure 9 illustrates the cumulative value added, compared with the value of the resources consumed, during the different stages of a process. VRE is represented by the slope of each stage or, for the complete process, the slope between the origin and the final point. A high slope indicates a larger addition of value compared to the resources consumed. The approach is attractive in that the same indicator allows focus on individual parts of the process, where it is easier to effect local change, and can also give a view of the performance of the process as a whole.

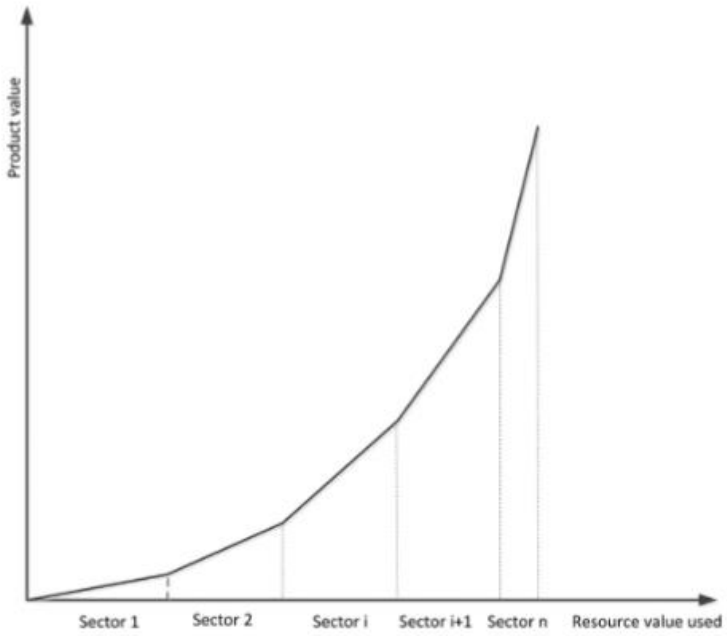


Figure 9 Value-based resource efficiency curve, from Di Maio et al (2017), illustrating value created vs value of the resources consumed during each part of a process

Di Maio et al. calculated the VRE indicator for 40 sectors of Dutch industry, using published economic data. The results showed that the ranking of many sectors differs considerably compared with those obtained from the previous, mass-based approach.

B.2.5 Platform CB'23

The core indicators from CB'23 (a guidance document for buildings and civil engineering works in the Netherlands) are summarised in Table 3 and these can be supplemented by additional indicators that are relevant for specific projects. By addressing the principles of reducing use (column 1) and limiting loss (column 2), this framework assesses the extent to which the value of resources is preserved for future use. The guide recommends that the indicators should not be aggregated, both because it is currently too early for a consensus to have emerged over the weightings to be used and because aggregation hides the granular information from view, reducing the visibility of the factors that have influenced the overall score.

Table 3 Indicators of circular construction, from Platform CB'23 (2019)

<table>
<tr><th>Quantity of materials used (input)</th><th>Quantity of materials available for the next cycle (output)</th><th>Influence on the quality of the environment</th></tr>
<tr><td>Quantity of primary materials</td><td>Quantity of material for reuse</td><td>Depletion of abiotic raw materials, excl. fossil energy carriers</td></tr>
<tr><td rowspan="2">Quantity of secondary materials
• From reuse
• From recycling</td><td rowspan="2">Quantity of material for recycling</td><td>Depletion of fossil energy carriers</td></tr>
<tr><td>Climate change</td></tr>
<tr><td rowspan="6">Quantity of materials that are susceptible to depletion
• Sustainably produced renewable materials
• Non-renewable or unsustainably produced
• Scarce materials
• Generally available materials</td><td rowspan="2">Quantity of materials lost (output)</td><td>Ozone layer depletion</td></tr>
<tr><td>Photochemical oxidation (smog)</td></tr>
<tr><td rowspan="2">Quantity of materials for energy generation</td><td>Acidification</td></tr>
<tr><td>Eutrophication</td></tr>
<tr><td rowspan="2">Quantity of materials sent to landfill</td><td>Human-toxicological effects</td></tr>
<tr><td>Ecotoxicological effects, aquatic (freshwater)</td></tr>
<tr><td></td><td>Ecotoxicological effects, aquatic (seawater)</td></tr>
<tr><td></td><td>Ecotoxicological effects, terrestrial</td></tr>
</table>

B.2.6 Major Infrastructure – Resource Optimisation Group (MI-ROG)

White paper No 2 (MI-ROG, 2018) considers appropriate measures that could be used to assess the success of an infrastructure operator or maintainer in applying their circular economy approach. The approach is founded on the Ellen MacArthur "Growth Within" (EMF 2017) report and applied in a context of transport infrastructure (road, rail, airports, and ports), utilities (energy, water and telecommunications) and flood protection.

The paper focusses on indicators of organisational performance rather than specific materials or components, although many of the metrics could also be applied to individual construction or maintenance schemes (Table 4). A maturity model is also suggested as a way for organisations to track their progress in improvement. The paper does not make recommendations for the form of this, although BS 8001 provides a possible approach.

Finally, since the value achieved by implementing circular approaches may only be realised many years in the future, the approach proposed is to monitor both outcomes and enablers.

Table 4 Metrics of circular economy proposed by MI-ROG

Impact-based metrics – retrospective outcomes should be compared to forecasts	i. Energy use and/or energy-related carbon emissions ii. Water use iii. Waste generation iv. Landfill diversion v. Material use and/or material-related carbon emissions vi. Proportion of recycled content (caution needed since use of recycled material can increase impact in some cases) vii. Natural capital accounts
Productivity metrics – these provide context to the quantity of resources employed	• Organisational output per unit of net virgin finite material input • Total value created / total resource inputs
Attribute metrics – indicators of product utilisation and depreciation / lifetime	• Product utilisation (*in a highway environment one interpretation could be the traffic supported by a given embodied resource*) • Product depreciation / lifetime (average lifetime of products) • Residual value: material value retention ratio (value of recovered materials such as energy recovery, recycling and remanufacturing / value of net virgin materials, as a 5-year rolling average)
Enabler based metrics – monitoring aspects of activity that can encourage adoption of circular principles	• Proportion of procurement activities which incorporated circular economy requirements • Number of circular economy innovation initiatives implemented • Number / proportion of procurements / projects that incorporated whole life carbon foot-printing • Number / proportion of assets / asset components that have end-of-life adaptability plans • Number / proportion of assets / asset components that are using condition-based monitoring and maintenance • Number / proportion of assets / asset components that have climate change adaptation plans

B.2.7 SCREEN guidelines for the assessment of projects' circularity

Braccini et al (2018) report the assessment criteria for comparing circularity initiatives that were developed during the SCREEN project. These are reproduced from SCREEN Deliverable D3.3 in Table 5. For each initiative (i.e., "project"), the appropriate category is selected from rows 1-6, covering production, consumption, and disposal. Data are provided in the selected row and in the environmental and social impact criteria in rows 7-9. Applying the listed metrics and weights allows an overall score to be produced for the initiative, allowing comparisons of different approaches.

An earlier version of the approach received good feedback in a questionnaire, with 75% of 165 participants ranking it as 7 or above on a scale from 0 (poor) to 9 (very good). The current version (rev 3.0) was also positively received by the European Commission Director General for Environment (DG ENV), which generated suggestions for further improvement, including:

- Inclusion of waste reduction as an indicator. The metric for criterion 6 should also refer to collected waste not produced waste.
- A definition of "circular procurement" is needed, since selecting the final two rows of the table results in a substantial alteration of the result.

Table 5 Assessment criteria for circular economy projects (Rev 3.0) reproduced from Deliverable D3.3 of the SCREEN project

These criteria are based on the explanation given in the circular economy action plan [COM(2015) 614], where circular economy is explained as an economy ***'where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised'***. The cost (€/year) as an intermediate indicator is a mean to harmonize the different metrics and to easily arrive at a coherent and transparent ranking list.

		A	B	C	D	E	F
	N.	**CRITERION**	**Explanation**	***Metrics***	***Additional parameters***	***Assessment indicator***	***Weight***
PRODUCTION	1	**ECO- Design**	Re-shaping the first stage of an industrial process (Product design) in order to reduce the waste generated AND/OR increase the life of the final product	Kg/year of virgin material avoided through the new process AND/OR by the prolongation of the product's life	Economic value of the virgin material (€/Kg)	Metrics x additional parameter (€/year)	10
	2	**New production process accepting "secondary raw material"**	Replacement , total or partial, of virgin material with "secondary raw material"	Kg/year of virgin material avoided through the new process	Economic value of the virgin material (€/Kg)	Metrics x additional parameter (€/year)	8
CONSUMPTION	3	**RE-Use, Re-Manufacturing, Refurbishment,**	Prolongation of the life of a certain product that otherwise will be disposed	Kg/year of virgin material avoided by the prolongation of the product's life	Economic value of the virgin material (€/Kg)	Metrics x additional parameter (€/year)	8
DISPOSAL	5	**Mass of waste resources recovered and re-introduced in a production cycle as secondary raw material**	The new process generates waste that can be re-used in the same process or in another production process	Kg/year	Economic value of the secondary raw material(€/Kg) **minus** Cost of its transport to the production site (€/Kg) (*)	Metrics x additional parameter (€/year)	8
	6	**Project promoting waste recycling**	Promotional campaign with a specific target producing a specific waste	Waste produced by the target Kg/year	Cost of disposal (€/Kg)	Metrics x additional parameter (€/year)	6
ENVIRONMENTAL CRITERIA	7	**"Net Energy balance respect to the previous system" or "Amount of energy recovered"**	Energy (KWh) used in the old process per unit of product divided by energy used in the new process for the same unit of product	Number that can be lower or higher than 1		Metrics (the number in column C)	1 (*the assessment indicator is "per se" a weight*)
	8	**Reduction of emissions**	Emissions of CO2 (**) generated by the old process per unit of product divided by emissions used in the new process for the same unit of product	Number that can be lower or higher than 1		Metrics (the number in column C)	
SOCIAL CRITERION	9	**Net balance of jobs**	Number of new jobs created by the circular economy project, minus the number of jobs lost in the previous linear process	N = Number of full time working units (can be positive or negative)	P = Number of full time woking units in the old process	$1 + \frac{(N)}{P}$	
Applicants may select only one of these two boxes		**Implementation of "CIRCULAR PROCUREMENT" in the project** *(tick the box if relevant)*		The wheigt of the related project is increased by 50%			
		Educational projects targeted to relevant stakeholders *(tick the box if relevant)*		The wheigt of the related project is increased by 20%			

(*) In case the secondary raw material does not have a final destination but is just "put on the market", the weight is reduced from 8 to 7

(**) In case of other pollutans, a table of equivalence should be used to convert them into CO2 equivalent emissions - https://climatechangeconnection.org/emissions/co2-equivalents/

B.2.8 Environmental Cost Indicator (ECI)

The ECI (Dutch acronym MKI) provides a method for combining a widely accepted range of environmental impacts into a single score that is expressed in Euros. It is already used for tender assessment in the Netherlands at Rijkswaterstaat, ProRail and some large municipalities for contracting large civil engineering works, through the DuboCalc tool, and could form a useful metric for assessing environmental criteria in the context of improving circularity.

The ECI is based on a lifecycle assessment that follows the requirements of EN 15804 (A1+A2) (BSI, 2020) in relation to:

- Environmental impact categories: global warming potential, ozone depletion, acidification, eutrophication, photochemical ozone formation, depletion of abiotic resources, water use and further indicators of toxicity
- Resource use indicators: use of renewable / non-renewable energy, use of secondary materials and secondary fuels, use of fresh water
- Hazardous waste produced
- Outputs available for future cycles: components for re-use, materials for recycling or energy recovery, energy production

Emissions are tabulated within each impact category and are reduced to a single score of environmental costs using weighting factors, for example as shown in Table 6. The ECI is reported in Euros to represent the environmental cost of a product or project. The weighting factors represent the cost of preventing the emissions from arising (Van Geldermansen, 2013).

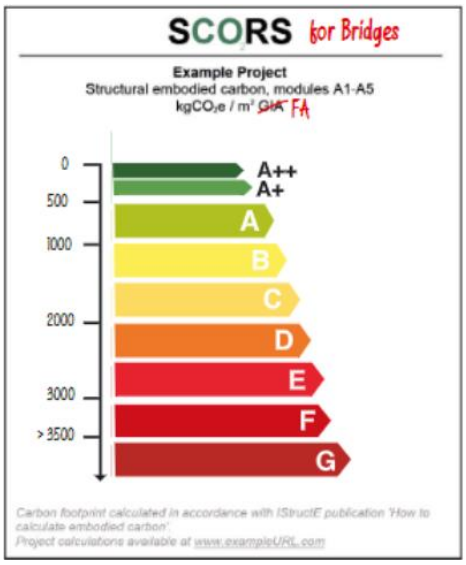
Table 6 Example of the weights applied in shadow pricing, reproduced from Ecochain (2022)

Impact category	Unit	Weighting Factor (€/ unit)
Global warming	kg CO_2-eq	0,05 €
Ozone depletion	kg CFC-11-eq	30,00 €
Acidification of soil and water	kg SO_2-eq	4,00 €
Eutrophication	kg PO_4^{3-}-eq	9,00 €
Depletion of abiotic resources – elements	kg Sb-eq	0,16 €
Depletion of abiotic resources – fossil fuels	kg Sb-eq	0,16 €
Human toxicity	kg 1,4 DB-eq	0,09 €
Freshwater ecotoxicity	kg 1,4 DB-eq	0,03 €
Marine water ecotoxicity	kg 1,4 DB-eq	0,0001 €
Terrestrial ecotoxicity	1,4 DB-eq	0,06 €
Photochemical oxidant creation (Smog)	kg C_2H_4	2,00 €

Ecochain provides a case study (Ecochain, 2022c) of a major asphalt producer in the Netherlands, showing how the production of ECI values can focus suppliers on the areas that can lead to the greatest improvement. In the case study, the largest contribution to the average environmental footprint was from extracting the raw materials, showing the alignment with circular objectives.

B.2.9 Development of a carbon indicator for bridges

Archer-Jones and Green (2021) report on applying a carbon footprint calculation method (SCORS) to produce a rating system in which the carbon footprint is normalised using the functional area, FA, of the bridge deck ($kgCO_2e/m^2$ FA). This normalisation is consistent with the idea of expressing resource use in relation to the utility or value of a product in the Material Circularity and Value-based Resource Efficiency indicators discussed above.



The authors note that explicit calculations should be made, for example including activities that require significant temporary works. Also, given the challenges in obtaining such data, that the focus should be on the most energy-intensive processes. Anticipating whole-life carbon targets, they recommend developing a structural carbon target, so that the design team can focus on parameters within their control (as opposed to user carbon).

Considering the imperative to achieve substantial carbon reductions in the next decade, the authors recommend calibrating the ratings such that current practice delivers a D/E rating. This allows room to differentiate between the worst performing current projects (G) and set targets for improvement in future projects. The aim is for a rating of B to be achievable by 2030, and A++ by 2050, at which point the remaining low levels of emissions can be feasibly offset.

B.2.10 Carbon footprint calculation methodology

Whilst it is not the intention to provide a detailed assessment of carbon accounting methods within this review, carbon-intensity is relevant within the assessment of circularity and is directly linked to the aims of circular economy with regard to improving environmental performance. Furthermore, as carbon neutrality is a priority for many NRAs, it may be the starting point from which a wider concept of circularity is established.

A recent review by PIARC (2019) assessed the strengths and weaknesses of eleven tools for calculating the carbon footprint of road pavements. It notes that international standards ISO 14040 and ISO 14044 provide a proven, transparent, and accepted approach. However, these standards allow flexibility in the selection of system boundaries and the allocation of impacts. For use in a procurement context, the methods need to be applied in a way that is sufficiently consistent for a meaningful comparison between options.

Of the eleven tools reviewed, only two considered the end-of-life impacts and, of these, the UK's Transport Research Laboratory's (TRL) asPECT (aspect Asphalt Pavement Embodied Carbon Tool (aspect, TRL 2020) provided more detailed analysis at end of life and beyond

system boundaries, enabling the benefit of recyclable materials to be included. Consequently, asPECT is the best match for circular economy considerations. The values produced by this tool per tonne of asphalt were close to the centre of the results from all the models studied, suggesting the calculations to be reasonable.

DuBoCalc (www.dubocalc.nl) is also noteworthy as already being in use in procurement. The calculator was developed by Rijkswaterstaat to evaluate the material and energy affects from cradle to grave, or from extraction to demolition and recycling. It applies lifecycle analysis according to ISO 14040 and allows users to create a project using items from a standard library. The resulting impacts are assessed using the framework of the Environmental Cost Indicator (Versteeg, 2019).

National Highways supplies a carbon accounting tool that is used by its supply chain to report quarterly or monthly carbon emissions (Highways England, 2020). Although not a LCA tool, this uses some of the same base data as asPECT. Reeves et al (2020) reviewed the tools used in Norway, Sweden, and the Netherlands, noting that none include emissions associated with end-of-life.

B.2.11 Format for transfer of data (EN 15942:2011)

The standard EN 15942:2011 (Sustainability of construction works – Environmental product declarations – communication format business-to-business) specifies the communication format for the information defined by FprEN 15804. It takes the form of a template (called an Information Transfer Matrix) which is mandatory as part of an EPD. The template includes:

1. General information, including the validity and applicability of the information contained and the basis on which it was derived.
2. Declaration of the environmental parameters derived from LCA. The different environmental impacts and resource impacts are tabulated, using specified units, within each of the stages (product, construction and process, use, end of life and beyond system boundaries). Additional information is required on the quantities of waste in different categories and the quantities of other resource outputs: mass of components available for reuse, mass of materials available for recycling or energy recovery and quantity of exported energy.
3. Scenarios and technical information.
4. Additional information on emissions to indoor air, soil, and water during the use stage.

B.2.12 Material Passports and Building as Material Banks (BAMB)

Material passports (or circularity passports) are an emerging area of work within the building industry, used to provide the methodology and data structure needed for collecting and handling the information relevant for a transition to CE. These digital data sets aim to catalogue and disseminate the CE characteristics of building materials, components, and products, helping to exchange information between the various actors within the supply chain. They also provide traceability of materials used throughout multiple lifecycles. Standardised information exchange is thought (Matthias and Werner, 2019) to be one of the key ways in which to transition to CE successfully. For a solid data source for circularity to exit it must contain holistic information from different fields. Furthermore, the digitalisation of material information can then

be linked to building information modelling (BIM), reversible design tools, and business models.

A recent European project (Matthias and Werner, 2019) defines material passports as digital sets of data describing defined characteristics of materials and components in products and systems that give them value for present use, recovery, and reuse. The passports are an information and education tool that address questions often not covered by other documents or certification, especially in relation to circularity. Material passports do not assess the data output and are not an evaluator of data. Instead, they provide information that supports the assessment and certification by other parties and allows existing assessments and certifications to be entered into the passport as uploaded documents. Key elements of data required include:

- Physical, chemical, and biological properties (not all aspects will apply to all products)
- Material health (impact on air quality, hazardous material)
- Unique product and system identifiers (traceability throughout lifespan)
- Design and production (focus on circularity at all stages and responsible sourcing)
- Transportation and logistics (at every stage of handling, including waste)
- Construction (identifying material and product location)
- Use and operate phase (warranties, guarantees, availability)
- Disassembly and reversibility (circular design and deconstruction strategy)
- Reuse and recycling (improved connection between supply and demand to encourage)

Through the use of material passports, the relevant products can be rated prior to demolition to allow planning and reclamation of materials for reuse. In addition, the use of material flow analysis (MFA) can be used to provide information about the pattern of resource use, production steps, material losses and waste collection, help balance the inputs and outputs of the overall system and support life cycle assessment.

B.2.13 Summary of good practice

Good practice in relation to performance measurement and KPIs can be summarised as:

- Measurement should be undertaken both at organisation-level performance and for specific resource flows. These are considered in more detail individually below.
- Data collection should be undertaken by NRAs and their supply chain to support robust measurement of performance, with a requirement for third party verification to give confidence in the results. Material passports can be a very useful tool in this regard. Events such as contract renewals or participating in flagship projects can be leveraged to increase the flow of information.
- The most critical aspects of circularity performance should be identified for highway construction and maintenance since it may not be practical or cost effective to implement global indicators that encompass the entire supply chain for a product. Indicators of specific parts of an overall process can, in any case, be more helpful to effect local change.

Organisational performance

- Various options are available for NRAs to assess their organisational performance. These range from the CERCOM maturity model presented in Part A of this report, as a straightforward approach, to comprehensive assessment tools capable of providing

benchmarking and external audit, e.g., the Circulytics framework. Other approaches include, monitoring the number or proportion of the value, of procurement activities in which circularity and resource efficiency is monitored.

Resource flows

- Performance should be measured across multiple lifecycles since the effect of choices in design or production may not be felt until second or subsequent lifecycles.
- Claims made for the value obtained through reuse of materials in future lifecycles should be critically assessed, with monitoring in place to see if these are achieved in practice, particularly where they have a significant effect on the value of the KPIs.
- Indicators should distinguish between scarce resources, whereby their use will deplete the supply and ultimately prevent their future use, and resources that are abundantly available and likely to remain so. In the former case the primary objective is to reduce resource use; in the latter it is to develop circular processes in which waste and negative impacts are minimised.
- Indicators for circularity can be used to assess the production and consumption of materials (or other resources) during construction, the materials that become available for subsequent lifecycles at the end of life, and the quantity of materials that are lost in each cycle. They are usefully expressed as 'productivity' metrics, where the use of resources and the adverse impacts generated are compared with the functional use or value delivered by a product or service. The MCI is a useful approach that combines these concepts into a single indicator that directly reflects the ambition for circularity. Alternative indicators for specific aspects of resource use are used in CB'23 and proposed by MI-ROG and SCREEN.
- Relevant risks and impacts should be included within the system for performance monitoring to protect against the possibility of perverse outcomes. This can be through additional supporting indicators such as in the MCI and CB'23 approaches, or by incorporating weights that take these risks and impacts into account, as suggested in the VRE approach. The ECI is an established methodology for combining an accepted range of environmental impacts as a monetary value expressed in Euros. Some specific aspects of resource use are included in the ECI, overlapping with the resource efficiency indicators described above. Considering major infrastructure, the indicators proposed by MI-ROG include energy use / energy-related carbon emissions, water use and natural capital.

Managing data

- Trusted systems for validating data and transferring it between organisations will be a fundamental component of measurement, and necessary to avoid inflated claims of performance. Material passports could be a useful approach from the buildings industry.

B.2.14 Horizon scan

While sources pointed to lack of data as a barrier to reporting circularity there are several trends (that could be encouraged) to improve the situation in future:

- Increasing scrutiny of environmental performance, and carbon emissions in particular, will lead to carbon reporting becoming embedded throughout industry. Reporting methods will also continue to develop (Zampori and Pant, 2019). EN 15942 already contains requirements for the format of data for environmental product declarations, and these data overlap with those needed to support KPIs on resource efficiency and circular economy.

- Development towards full 'digital twins' and material passports for transport infrastructure will improve the accuracy and detail of data held on infrastructure assets and their components.
- Third-party certification programmes are becoming established and are being used to set targets and monitor progress. This will drive an increase in data collection as companies look for opportunities to reduce their environmental impact and demonstrate their progress in doing so.

The increase in data will support more comprehensive reporting of circularity, leading to better identification of the areas where highway maintenance can be made more resource efficient and circular.

B.3 Standards

Performance based standards and specifications have incentivised the uptake of various products, processes, and systems for many years. Often the main driver for the use of standards is economic and allows products to be made more cheaply, accurately, and efficiently, with a consistent quality, safety, and performance. Maintenance, repair, reuse and managing end of life and recycling are becoming increasingly important facets of standardisation. Within the scope of CERCOM Task 2.3, this section reviews standards currently available for the adoption of circular practice and related principles within the context of construction and maintenance of highways to support NRA's in setting up their approach to a circular economy.

B.3.1 Responsible sourcing and circularity

The world's first standard relating directly to circularity (BSI, 2017), 'Framework for implementing the principles of the circular economy in organizations – Guide (BS 8001)' was introduced in 2017 and is built on six guiding principles, as discussed in section B.1.1. The British Standard aims to give guidance to organisations around the globe of all types and sizes, on the steps they can take to transition to a more circular and sustainable mode of operation. Specifically, it aims to provide organisations with an understanding of (BSI, 2017):

- what the circular economy is and how it might be relevant both now and in the future; and
- how to implement the principles of the circular economy in order to create direct and indirect value as a result of process, product or service or business model innovation.

Annex A provides details to facilitate evaluation of implementation of CE principles of CE to be undertaken. Furthermore, the standard aims to provide guidance on the enabling mechanisms and potential business models to achieve progress towards CE and CE maturity.

Prior to the publication of BS 8001, in 2016 the Building Research Establishment (BRE) published BES 6001, a Framework Standard for Responsible Sourcing (environment and sustainability standard). It was first published to enable construction product manufacturers to ensure and prove that their products were made with constituent materials that had been responsibly sourced. The updated version of the standard (BRE, 2021) describes a framework for the organisational governance, supply chain management and environmental and social aspects that must be addressed to ensure the responsible sourcing of construction products, specifically including resource use and product circularity. This version of the document mandates that the organisation shall establish a policy, supported by a documented management system for the efficient use of constituent materials and development of products for a circular economy, as appropriate to the product(s) under assessment. The organisation

can be expected to achieve the highest performance rating of 1 by demonstrating at least two of the following:

1) Actions taken to improve future resource use at end-of-life of the assessed product(s)
2) Actions to extend the lifespan of the assessed product(s)
3) Declaration of recycled content in accordance with ISO 14021 or recognised sector standard of the assessed product(s)
4) A product development approach to design products for a circular economy
5) The assessed product(s) have independent certification against established product circularity standards

BES 6001 is one of the BES (BRE Environmental and Sustainability) Standards published by BRE (an independent research-based consultancy organisation in the UK). It specifies requirements for organisational management, supply chain management and management of sustainability issues. In addition to satisfying the mandatory elements, organisations can achieve additional performance scores by demonstrating additional benefit. For example, considering the aspect "material traceability through the supply chain":

- Score 1 (compulsory) – achieved if a minimum of 60% of constituent materials is traceable to suppliers with a certified quality management system or equivalent
- Score 2 – a minimum of 75% of constituent materials is traceable to suppliers with a certified quality management system
- Score 3 – a minimum of 90% of constituent materials is traceable to suppliers with a certified quality management system

The elements assessed under this standard are summarised in Table 7. Certification of products is undertaken through life cycle assessment methods and include product labels and declarations; these are discussed further in section B.3.2.

Table 7 Elements assessed within BES 6001

<table>
<tr><th>Organisational management</th><th>Supply chain management</th><th colspan="2">Sustainable development</th></tr>
<tr><td rowspan="2">A written policy that addresses responsible sourcing</td><td rowspan="3">Traceability of constituent materials to the suppliers responsible for extraction of raw materials, recovery of recycled materials, production of by-products and processing of traded materials</td><td colspan="2">Quantification of the direct and indirect emissions and removals of GHG</td></tr>
<tr><td colspan="2">Hazard assessment of the ecotoxicity of chemicals used</td></tr>
<tr><td rowspan="5">Policy / documentation / management system for</td><td>Monitoring and reduction of energy intensity</td></tr>
<tr><td>Efficient use of constituent materials</td></tr>
<tr><td>Procedures to identify and adhere to relevant local and international laws and regulations</td><td>Traceability of constituent materials to suppliers having in place an environmental management system</td><td>Waste prevention and waste management</td></tr>
<tr><td>Reduction in the intensity of water abstraction or use</td></tr>
<tr><td>Continuous improvement in lifecycle environmental performance</td></tr>
<tr><td>A documented quality management system</td><td>Traceability of constituent materials to suppliers having</td><td>Continuous reduction of the impacts of transport</td></tr>
</table>

to implement responsible sourcing procedures	in place and health and safety management system		of materials, goods and people
			Employee learning and development
A supplier management system that references the responsible sourcing policy			Consultation with local community stakeholders affected by its operations and recording of complaints
			Business ethics, avoidance of bribery and corruption and mechanism for confidential reporting

This complements BES 6002: Ethical labour sourcing complements BES 6001 and, specifies the requirements for organisational management to demonstrate an on-going commitment to the principles of ethical labour sourcing and provides a framework for assessing organisational maturity under 12 criteria.

Early standards relating to responsible sourcing include BS 8902 (BSI, 2009). The standard gives requirements for the management, development, content and operation of sector certification schemes for responsible sourcing and supply of construction products. Table A.1 in the standard provides a sustainable development maturity matrix for continual improvement of organisations seeking certification of their products. The organisation is required to determine its current position in its maturity matrix, by identifying the most applicable criteria; this process allows the production of a maturity profile. Particular attention should be given to areas that the organisation has identified as weaknesses or potential growth areas. The position of the organisation depicted by the matrix is then used in the review process and/or used to demonstrate its sustainability progress to relevant stakeholders.

B.3.2 Lifecycle assessment, Product labels, and declarations

B.3.2.1 Lifecycle Assessments

Life cycle assessment (LCA) is a standardised technique, formalised in international standards (for example ISO 14040:2006:+A1:2020 (ISO, 2020a) and 14044:2006+A2:2020 (ISO, 2020b)) and used to provide information for assessing the environmental impacts of products over their lifecycle. LCA's are used to assist and support specifiers, purchasers, and users to make informed decisions between products and to encourage improvement of environmental impacts.

ISO 14040:2006:+A1:2020 provides the principles and framework for LCA whilst 14044:2006+A2:2020 specifies the requirements and provides guidelines. These international standards focus mainly on the process of performing an LCA and provide requirements and guidelines for:

- Definition of the goal and scope of the LCA
- Life cycle inventory analysis (LCI) phase
- Life cycle impact assessment (LCIA) phase
- Interpretation phase
- Reporting and critical review of the LCA

Neither standard provides the technique in detail nor methodologies for individual phases.

The ISO 14040 series of standards is used in the development of environmental labels and declarations, more specifically ISO 14025 Type III environmental declarations. Furthermore, it establishes principles for the use of environmental information, in addition to those given in ISO 14020:2000 (ISO, 2021b). Further details regarding environment labels and declarations are provided in section B.3.2.2.

B.3.2.2 Environmental labels and declarations — General principles

Environmental labels and declarations are known to provide information about a product or service in terms of its overall environmental character, a specific environmental aspect, or any number of aspects (ISO, 2021a). Purchasers and potential purchasers can use this information in choosing the products or services they desire based on environmental, as well as other, considerations. Typically, the provider of the product or service hopes that the environmental label or declaration will be effective in influencing the purchasing decision in favour of its product or service to support an increase in market share. With an increase in uptake from providers, this approach should result in reduced environmental stress from that product or service category.

The certification methods employed by various schemes which utilise life cycle assessment can vary and be broadly split into the following (GMB, 2022):

- ISO 14024 (ISO, 2018) Eco labels, and an environmental label of type I. The eco-labels are granted by an independent third party, which acts as certifying entity.
- ISO 14021 Self declaration, and environmental label of type II. A voluntary environmental qualification system that officially identifies and certifies (ISO 14021, 2021b) that certain products or services have a minor impact on the environment, considering their entire life cycle. Although the eco-labelled products and services meet strict environmental criteria, self-declaration is increasingly used by suppliers in response to trends towards achieving CE.
- ISO 14025 (ISO, 2010) Product Environmental Declaration and an environmental label of type III. An environmental product declaration (EPD) is a certified environmental statement made in accordance with the international standard ISO 14025 (Environmental Statements Type III). It is an environmental product / service information based on life cycle analysis (LCA) and other relevant information, in compliance with the standard. (ISO 14025 enables comparisons to be made between products which are fulfilling the same function). ISO 14025 specifically establishes the use of the ISO 14040 (ISO, 2020a) series of standards in the development of Type III environmental declaration programmes (a voluntary programme for the development and use of Type III environmental declarations are based on a set of operating rules, the programme operator for which can be a company or a group of companies, industrial sector or trade association, public authorities or agencies, or an independent scientific body or other organisation), and Type III environmental declarations. Type III environmental declarations provide quantified environmental data using predetermined parameters (based on the ISO 14040 series of standards, which is made up of ISO 14040 and ISO 14044) and, where relevant, additional environmental information. Where ISO 14025 provides more specific requirements than ISO 14020 (ISO, 2021a), such specific requirements shall apply (in addition to those given in ISO 14020:2000).

The standard EN 15804 (Sustainability of construction works – Environmental product declarations – core rules for the product category of construction products) provides the basis for many other lifecycle assessment methodologies. It sets out the basis of an Environmental Product Declaration (EPD) to provide quantified environmental information for a construction product or service on a harmonized and scientific basis, such that the results are verifiable and

provide a sound basis for assessing the options that provide the least stress to the environment. The standard defines the scope of each module within the lifecycle:

- Product (A1-A3),
- Construction and process (A4-A5),
- Use (B1-B5) - covering application, maintenance, repair, replacement, and refurbishment,
- Operational use (B6-B7),
- End of life (C1-C4) - covering de-construction / demolition, transport, waste processing for reuse / recovery / recycling, and disposal, and
- Benefits and loads beyond system boundaries (D) - including reuse, recovery, and recycling potential.

The minimum assessment required in most circumstances includes cradle to gate impacts (modules A1-A3) plus end of life (modules C1-C4) and benefits and loads beyond the system boundary (D).

In parallel to the development of EPDs, the European Commission has also been developing a new approach and guidance to quantify the environmental performance of products, known as the Product Environmental Footprint (PEF) (Manfredi et al, 2012). PEF, a new term in the field of LCA is a new methodology and standard, initiated by the EU, that is intended to steer organisations to perform more reliable environmental measurements and create a level playing field and improved communication with a wider target audience (i.e., in house and external). The PEF takes a life cycle perspective but follows product environmental footprint category rules (PEFCR) with further specific requirements and standardised specifications. To align the environmental reporting approaches, the European Commission issued an amendment mandate to require the revision of EN 15804 to align with the PEF methodology, however unlike EPDs, the PEF methodology has not taken off in the marketplace. Researchers recognise (Durao et al, 2020 and Bach et al 2018) that further work is required to address shortcomings related to the (1) definition of product performance; (2) definition of the product category; (3) definition and determination of the representative product; (4) modelling of electricity; (5) requirements for the use of secondary data; (6) circular footprint formula; (7) life cycle impact assessment methods; and (8) approach to prioritise impact categories. As such there continues to be a great effort on the harmonisation of coexisting LCA calculation and reporting methods, including PEF, EN 15804, and of the several EPD schemes currently operating.

The most recent amendments to EN 15804 in 2019 highlight the improved alignment with the European Commission's 'Product Environmental Footprint (PEF)'. The EN15804+A2 results in six main changes in EPD's for construction companies, these are (Ecochain, 2022a):

I. Accounting for the benefits of end-of-life recycling – this means that circularity and recycling will play a larger role in defining environmental impact and new opportunities for biobased materials will be available.
II. EPD's will be required to include more life stages – leading to more extensive calculations but also improved understanding.
III. More attention is placed on biogenic carbon (including carbon offsetting) - this means that the biogenic carbon mass in the product and packaging will need to be declared and biogenic carbon in construction products will need to be included in EPD's.
IV. The initial revision, EN15804 + A1, required reporting on 7 impact categories as well as 17 reporting categories (resource use, output flow data or waste generation). However, the EN15804 + A2 now requires reporting on 13 impact categories with 6

additional environmental impact categories that are in line with the new PEF methodology from the EU. One noticeable change is that the impact category 'resource depletion' (metals + fossil fuels) weighs more heavily in the EN15804+A2. A change that will most certainly have a positive effect on the development of a circular economy.

V. Datasets need to be converted into the International Reference Life Cycle Data System (ILCD) format.

VI. Detailed descriptions of functional and declared units – this allows for more comparison with other product systems that fulfil the same functional unit. (EPD's were not initially intended for product comparison).

The revisions of EN15804 + A2 allow for more product comparison which is leading to the development of a standard that will contain the horizontal rules for business-to-consumer construction EPD benchmark systems in the future (rather than purely business to business). These horizontal rules are called the Product Category Rules (PCRs) and are currently being developed (Ecochain, 2022b). One of the first completed PCRs are for the Dutch asphalt sector (discussed further in section B.3.2.3).

In the United States ISO 21930:2007 is used for environmental product declarations (ISO, 2017). The standard (ISO 21930) Sustainability in Buildings and Civil Engineering Works provides the principles, specifications, and requirements to develop an environmental product declaration (EPD) for construction products and services, construction elements and integrated technical systems used in any type of construction works. The document mirrors the most important revisions of EN 15804+A1 but fails to consider more recent updates (EN 15804+A2) and therefore no longer complies with the impact categories creating a potential barrier to trade unless harmonised (Oneclicklca, 2022). The prevalence and quality of EPDs complying with EN 15804 has not gone unnoticed, public procurement bodies in the EU and European Economic Area (EEA) typically use EPDs complying with this standard, furthermore, they are also recognised by market-based systems such as LEED and BREEAM.

B.3.2.3 Product category rules for Dutch Asphalt Producers

The Determination Method Environmental Performance of Buildings ('Determination Method') is a uniform measurement to calculate the environmental performance. As it measures performance, it does not impose constraints on the technical solutions adopted, leaving freedom to innovate. The method is based on EN 15804 and contains product category rules, reference to protocols for assessing environmental data for inclusion in national databases and rules for the calculation of environmental performance (National Environmental Database 2022)

A project 'Demonstrably sustainable asphalt' managed by CROW, a not-for-profit organisation and technology platform for transport, infrastructure, and public space in the Netherlands in which the government and businesses work together in pursuit of their common interests through the design, construction and management of roads and other traffic and transport facilities, is under way and is applying this method to asphalt pavements. Product category rules (PCR) have been developed for asphalt and came into force during 2022 (BouwendNederland, 2022a). Environmental profiles have also been developed for the maintenance phase that include (BouwendNederland, 2022b).

- LCA background report on crushed stone from quarry in Europe,
- LCA background report on modified bitumen.

From 1st January 2021, LCA practitioners have to report on both the old impact categories as well as the 19 new impact categories until the transition period to the new EN15804 + A2 is complete (July 2022). In addition, the Dutch PCR asks for data about the lifespan and intensity of use of the product which was not the case for the PCR at European level. In the Netherlands

specifically, the revised norm will have a larger effect due to the sustainability norms already present. Due to EN15804+A2, the SBK Bepalingsmethode now requires dual reporting: reporting according to EN15804+A1 as well as EN15804+A2. This means that capabilities of existing LCA's will need to be expanded and will eventually also have implications for the calculations of the Dutch MKI (Milieukostenindicator), (Ecochain, 2022a).

B.3.2.4 PAS 2080

Publicly Available Specification or PAS are open standards. PAS 2080 is a global standard for managing infrastructure carbon and has been authored to meet World Trade Organisation requirements. The framework looks at the whole value chain, aiming to reduce carbon and reduce cost through more intelligent design, construction, and use. PAS 2080 also ensures carbon is consistently and transparently quantified at key points in infrastructure delivery which promotes sharing of data along the value chain (Carbon Trust, 2021).

PAS 2080 is applicable to anyone involved in the delivery of infrastructure, including asset owners/managers, designers, constructors, and product/material suppliers (BSI, 2016). The standard examines:

- Carbon management (as part of wider climate change mitigation),
- Consistency in the use of data, reporting, quantification, benchmarking, target setting, continuous improvement, leadership, inclusion in BIM, etc.
- Management of capital and operational carbon under direct control of the value chain, and user carbon over which the value chain has influence.
- Promoting whole life cost reductions through whole life carbon reduction.

Circular economy targets, including amount of waste generated and treated, percentage of recycled content used versus virgin material and percentage of biological material used, drive carbon emissions reduction and support net zero ambitions. It is recognised (Bonfait, 2021) that this is being endorsed by the standard for managing infrastructure carbon (PAS 2080), which presents a hierarchy of options for carbon reduction from building nothing to building less, followed by building smart and, finally, by building efficiently.

B.3.2.5 CEN/TC 350/SC1/WG1

CEN has a committee on circular economy in the construction sector, outputs will include a framework, principles and definitions. It is currently at a preliminary stage with no published standards but will seek to specific circular principles and guidelines including design for deconstruction and end of life scenarios for new and existing construction works, including buildings and civil engineering works. There is an anticipated date to vote on this in September 2025.

B.3.3 Sustainable Procurement and Collaborative Business

BSI has packaged together the following standards to enable organisations wanting to implement sustainable procurement practices and collaborate successfully with their chosen partners:

- BS ISO 20400: 2017, Sustainable procurement — Guidance
- BS ISO 44001: 2017, Collaborative business relationship management systems — Requirements and framework
- BS ISO 44002: 2019 Collaborative business relationship management systems — Guide to implementing BS ISO 44001

The integration of sustainability into procurement policies and practices allows organisations to manage risk and optimise opportunities whilst also influencing their supply chains to act in a responsible and sustainable manner. This approach helps to build stability and trust that can open markets, improve operational efficiency, and optimise the benefits of collaboration between organisations.

B.3.4 UK Design Manual for Roads and Bridges

Standard GG103 in the UK Design Manual for Roads and Bridges (DMRB) sets out the goals for sustainable development that are to be delivered throughout the design lifecycle. With respect to circular economy, it requires that:

> *"the design be resource efficient and reflect a circular approach to the use of materials"*

Specific requirements are set out for each of the devolved transport administrations in the UK, summarised in Table 8. The requirements are high level, where they are present.

Table 8 Specific requirements established by each devolved administration in the UK

England	Minimise consumption of materials and generation of waste Take opportunities to reuse site-won materials Take opportunities for deconstruction (etc.) to facilitate future high-value recycling, re-manufacture, or re-use at end of first life
Northern Ireland	Design decisions to be informed by achieving whole life value Take measures to reduce need for maintenance, repair, refurbishment, and replacement, to increase design life
Scotland	None
Wales	None

The DMRB also contains a suite of sustainability and environment Standards setting out the requirements for Environmental Impact Assessment (EIA) in compliance with Directive 2014/52/EU. Of these, the most directly relevant to circular economy is LA 110, which requires that an EIA be carried out for significant proposed construction projects, to assess the likely effect of on the consumption of materials and products and the production and disposal of waste. Significant projects (these are defined by LA 102) include construction of motorways and express roads, roads with four or more lanes, or widening of existing roads, as well as those that could give rise to significant environmental effects according to the Directive. EIAs are therefore likely to be mainly confined to major construction projects rather than maintenance renewals.

LA 110 adopts the waste hierarchy established by the Waste Directive, i.e., in descending order of preference: prevention > re-use > recycling > recovery > disposal. The requirements are summarised in Table 9. Although specific, they are again high level, with no detailed requirements, for example, in relation to the format of the data to be produced. Thus, while the data from EIAs could support monitoring of circularity, the data may not be produced in a consistent format.

Table 9 Stages in the management of materials and waste in UK Standard LA 110

Stage	Purpose
Scoping	To document an initial baseline of material assets likely to be used and the waste likely to be produced by the scheme.
Further assessment	To establish the study areas, baseline scenarios and data needed in relation to waste and material assets, prior to rating the significance of the scheme in one of 5 categories, from neutral to very large.
Design, mitigation, and enhancement	To evidence the adoption of design and mitigation measures for material assets and for waste and to identify opportunities for environmental enhancement.
Reporting and monitoring	To require a report on the construction phase and first year of operation within the EIA, including a comparison of actual with forecast waste generation and documentation of the correct disposal route for relevant waste streams.

The other areas covered by this suite of Standards may also provide data to assess other environmental impacts:

- Air quality (LA 105)
- Cultural heritage (LA 106, LA 116)
- Landscape and visual effects (LA 107, LA 117, LA 119)
- Biodiversity (LA 108, LA 115, LA 118)
- Geology and soils (LA 109)
- Noise and vibration (LA 111, LA 119)
- Population and human health (LA 112)
- Road drainage and the water environment (LA 113)
- Climate (impacts and vulnerability, LA 114)

B.3.5 Summary of good practice

Good practice in relation to standards can be summarised as a set of guidelines, ethics, ideas that provide the most efficient course of action. To date international standards of this nature directly related to circular economy are very much a work in progress. Many of the available standards provide guidance and frameworks in which to work to achieve improved sustainable outcomes which often require companies to make voluntary commitments to take account of wider social and environmental considerations.

The increased uptake of EPD's can improve the availability of quantified environmental information whilst providing the basis for many lifecycle assessment methodologies. This approach, if aligned and harmonised more broadly, has the potential for circularity to play a larger role in defining environmental impact and improved comparison with other products and systems. Furthermore, this approach has the potential to find application in renewals and major construction projects.

B.3.6 Horizon scan

As outlined in section B.3.2.2. the Product Environmental Footprint (PEF), is a new approach that measures the environmental performance of any service or good throughout its Life Cycle (considering all supply chain activities). The mission is (Ecochain, 2022b) to strengthen the (European) market for green alternatives and ensure that environmental impacts are transparently assessed and, in the end, of course; reduced. The PEF methodology is in a 'transition phase'. The European Commission is still developing the details for the PEF Product

Category Rules (also the PEF-PCR's) to finalise the methodology developments. It also means, that using the PEF isn't mandatory for all sectors. However, for the European construction sector, the PEF resulted in some mandatory changes in LCA's. This is due to the PEF norm EN15804+A, as detailed in section B.3.2. These revisions allow for more comparison and future development of a standard that will contain the horizontal rules for business-to-consumer construction EPD benchmark systems. This will help many consumers select construction products based on their environmental impact and performance.

It is acknowledged (Totaro, 2021) that there is an abundance of standards and initiatives that most often examine just a few components of circularity, such as recycling, for example, and there what is missing is a shared global vision of how a company can really close the circle, which any organisation can benefit from. To address this shortcoming, the International Standards Organisation (ISO) created a technical committee in 2018 dedicated to the circular economy. The Technical Committee in question, ISO/TC 323; the scope of which is the standardisation in the field of Circular Economy to develop frameworks, guidance, supporting tools and requirements for the implementation of activities of all involved organisations, to maximise the contribution to sustainable development (ISO, 2022), aims to cover all individual aspects of the circular economy, including public procurement, production, distribution, and end-of-life, as well as wider-scope issues like behavioural change in society and the evaluation - and, indeed, the creation - of a circular footprint or a circularity index.

This work is still ongoing (Totaro, 2021), with the standard fully in the development phase. The draft for one section - Performance-based approach – Analysis of case studies (ISO/CD TR 59031) - has been presented to the Technical Committee, while the other three parts - Framework and Principles for Implementation (ISO/WD 59004), Guidelines on business models and value chains (SO/WD 59010) and Measuring circularity framework (ISO/WD 59020.2) - are still under development.

In addition, Italy's National Standardisation Agency (UNI) has, in parallel with the ISO, created a relevant Technical Committee (UNI/CT 057) which includes companies, institutions, universities, and NGOs. The UNI/CT 057 Circular Economy Committee, in turn, has four workgroups dedicated to:

- Definitions,
- Frameworks and principles,
- Implementation guidelines and sectoral applications, and
- Circularity measuring and best practices.

B.4 Procurement and supply chain

Procurement is a powerful strategic tool in enabling organisations to bring together technical and functional requirements in the acquisition and delivery of goods and services. NRAs, as public bodies with substantial purchasing power have recognised that they can and have to play a significant role in ensuring environmental sustainability by embedding appropriate measures and assessment techniques within their procurement processes.

When carried out properly, sustainable procurement not only delivers value for money, but it also offers added benefits of planning to manage demand, effective ongoing contract management and dealing with supply chain risks and impacts. Over the last decade, increasing numbers of NRAs have placed sustainability high on their agenda and have made significant progress with several tools and specification approaches being developed.

Sustainable procurement continues to be 'work in progress', with major differences in maturity, at organisational and national levels. However, the underlying environmental and social criteria are also being reviewed and updated so that they remain appropriate to meet the evolving national and global challenges. For example, in addition to initiatives such as Sustainable Public Procurement and Green Public Procurement that have been gaining momentum, Circular Public Procurement is now being recognised as the extension needed to support the transition from the current linear practices to circularity.

B.4.1 Sustainable Public Procurement (SPP)

Sustainable procurement was the first response following growing recognition of the need to protect the environment and minimise carbon emissions to mitigate climate change.

Sustainable public procurement is defined as *"a process whereby public organisations meet their needs for goods and services, works and utilities in a way that achieves value for money on a whole life cost basis in terms of generating benefits not only to the organisation but also to society and the economy while significantly reducing negative impacts on the environment*" (UNEP, 2011)

The first international Standard, ISO 20400, published in 2017 sets out guidelines, aimed at senior managers and directors of the purchasing function, for integrating sustainability into the organisation's procurement processes. It defines the principles of sustainable procurement, including:

1. Accountability
2. Transparency
3. Respect for human rights
4. Ethical behaviour

It covers various stages of the procurement process, highlighting risk management and priority setting and detailing the steps to integrate social responsibility into the purchasing function.

Over the years the EU and other national governments have developed a range of legal and policy instruments to enable environmental and social criteria to be considered in public procurement and set ambitious targets and implement strategies to achieve environmental goals and social benefits through their public procurement practices.

B.4.2 Green Public Procurement (GPP)

Green Public procurement is defined (EC, 2017) as *"a process, whereby public authorities seek to procure goods, services and works with a reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that would otherwise be produced".*

Since 2008, the Commission has developed more than 20 common GPP criteria covering various product and service groups. The priority sectors for implementing GPP were selected through a multi-criteria analysis including scope for environmental improvement; public expenditure; potential impact on suppliers; potential for setting an example to private or corporate consumers; political sensitivity; existence of relevant and easy-to-use criteria; market availability and economic efficiency.

GPP is still a voluntary instrument, and the aim is to encourage governments to develop clear and verifiable environmental criteria for products, goods and services and use their purchasing power to move towards those with reduced environmental impacts. Regarding road construction and maintenance, the EU has published the Technical Background Report (Garbarino et al 2016) and GPP criteria (EC, 201. For example, the proposed GPP criteria cover the following stages in the procurement process for the construction of new roads and the maintenance of existing roads:

- Selection of the design team and contractors;
- Detailed design and performance requirements;
- Construction or major extensions;
- Use of the road;
- Maintenance and operation;
- End of life

There is clearly a growing interest in adopting GPP and the OECD (2015). As such, GPP provides an intermediate stage in the transition to Circular Economy.

B.4.3 Circular Public Procurement (CPP)

Circular public procurement is an outcome of the growing recognition that global resources are not infinite and exploitation of natural resources has to reduce significantly to save the planet. It is an extension of the aspects that are already part of sustainable green procurement and a means to support the transition to Circular Economy,

Circular procurement is defined as (EC, 2017) an approach to green public procurement which pays special attention to *"the purchase of works, goods or services that seek to contribute to the closed energy and material loops within supply chains, whilst minimising, and in the best case avoiding, negative environmental impacts and waste creation across the whole life-cycle".*

Traditionally, procurement has been about the acquisition of products, goods and services with no (or limited) consideration of 'end of life' options. The key aspect of circular procurement is the move to consider, ***at the design stage***, how the resources or materials required to create products can be optimally reused or recycled for the same purpose or alternative applications and also minimise waste creation across the whole life-cycle of the product. Developing an understanding of what options are potentially available at 'end of current phase of use' for products at the very start of the product cycle will help to structure specifications that can take account of ***total*** life cycle costs. Circular procurement therefore provides a framework for more holistic consideration of environmental impacts and waste creation across the whole life-cycle of goods and services and thereby contributes to using resources more efficiently and effectively.

Another important aspect is that circularity cannot be achieved by NRAs (or any public body) acting alone but requires collaboration and the forming of partnerships with the supply chain. One of the drawbacks in the current linear model for procurement in the roads sector is that assets tend to be long-life. For long life construction projects everything is financed, with the exception of demolition and recycling. Structures, for example, are built to last significant periods of time and when the time comes to replace them, the community or the new investor will typically pay the price. A long-term relationship therefore is crucial in design for high-value reuse, for materials exchange and to boost innovation.

The model that is appropriate to formulate circular demand and circular solutions for road construction and maintenance schemes will be influenced by the maturity levels of the NRA and its supply chain in the transition to Circular Economy. Circular procurement is still in its nascent stage, a novel concept and the transition to an entirely circular model for all products and materials is probably sometime away. The task of NRA procurement teams is therefore to identify, through early involvement with their contractors and consultants, the most appropriate materials and services that best meet circularity principles.

Figure 10, reproduced from Jones et al. (2017a), illustrates different methods or models that can help making procurement more circular – either by using one of the models or a combination of them – depending on the options available in the market and the product/service in question.

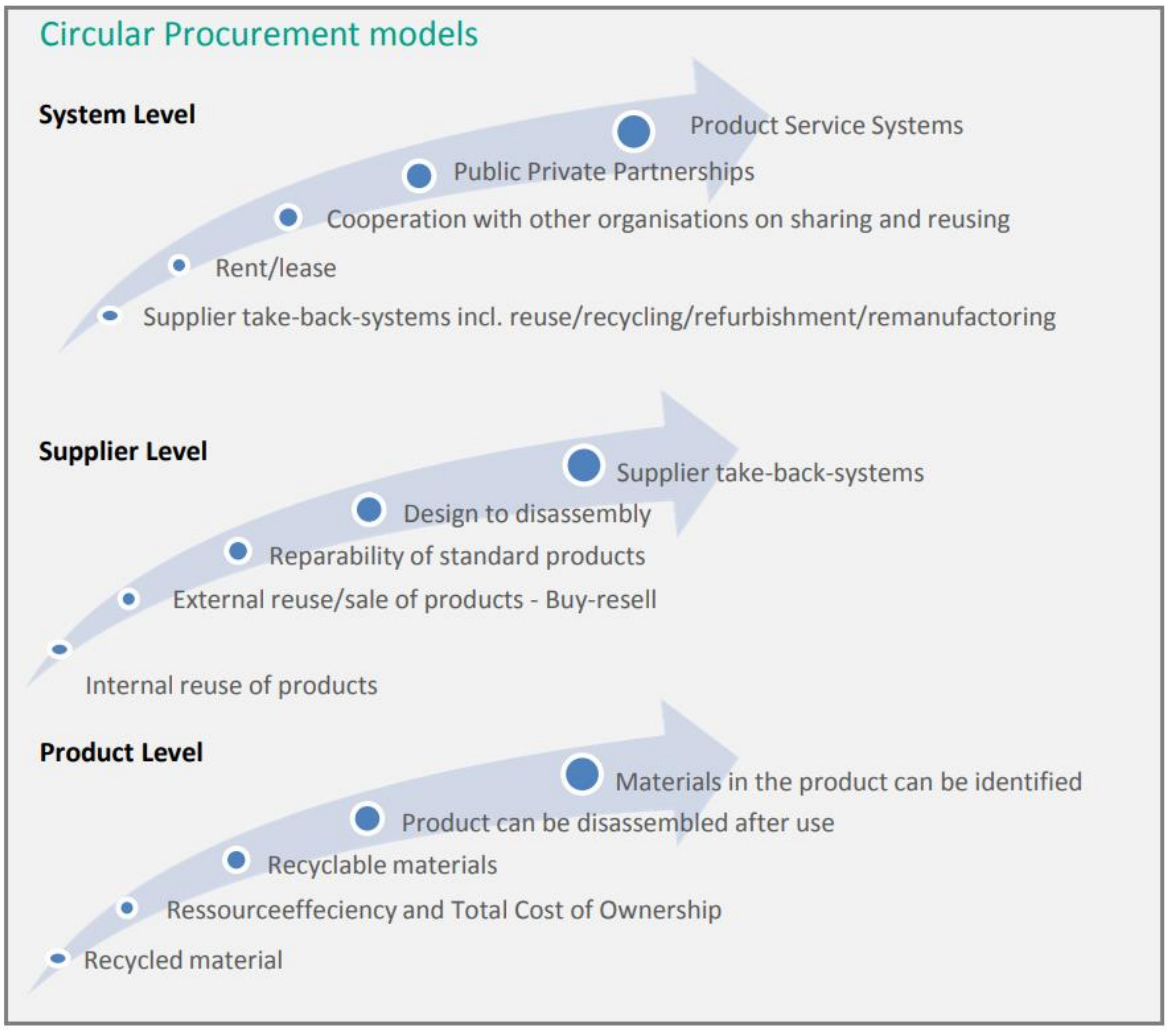


Figure 10 Options for making procurement more circular, reproduced from Jones et al. (2017)

In summary, circular procurement starts with the initial formulation of project needs and ends when the goods or products in question, after repeated reuse within the same application at similar value level are transferred for use in a new application.

B.4.4 National examples

B.4.4.1 Netherlands

The Netherlands was the first European country to formalise the process for sustainable procurement, with the Dutch Government establishing clear goals as early as 2005 and embedded this further into their procurement processes in 2010 when the Dutch House of Commons ruled that all public authorities must implement 100% sustainable procurement as of 2015.

In response to this, Rijkswaterstaat (the Department of Public Works of the Ministry of Infrastructure and the Environment) developed a methodology for infrastructure projects whereby the functional specification of the tender together with the quality input from the client ensure an innovative and high-quality solution.

The criteria that formed the basis of assessing the sustainability attributes of tenders were CO_2 emissions and environmental impact. The following two tools were developed to measure CO_2 emissions and environmental impacts, and are now mandated to be used by all tenderers:

i. The CO_2 performance ladder - a certification system with which a tenderer can show the measures to be taken to limit CO_2 emissions within the company and in projects, as well as elsewhere in the supply chain,
ii. "DuboCalc" - a life-cycle analysis (LCA) based tool which calculates the sustainability value of a specific design based on the materials to be used. Bidders use DuboCalc to compare different design options for their submissions. The DuboCalc score of the preferred design is submitted with the tender price.

Rijkswaterstaat (RWS) has identified the role that procurement can play in focussing delivery on the core objectives, creating a scale for suppliers and achieving a consistent and long-term commitment to sustainability goals (Versteeg, 2019). The scale and long-term approach are beneficial to suppliers and enable investment in improved technologies and approaches.

An example of sustainable procurement is the A12 Reconstruction of 19 km of the A12 motorway between Ede and Grijsoord junction in Netherlands (Jones et al., 2017b).

The size and complexity of the A12 meant that the project had ample scope for circular procurement principles to be considered. Rijkswaterstaat used the Most Economically Advantageous Tender (MEAT) approach which enabled the selection of the bid that offered the best ratio of price to quality including assessment of CO_2 mitigation and reduction of environmental impacts. In addition, the consideration of 'use and disposal' at the planning and procurement stage of the major infrastructure projects represented an explicit move by Rijkswaterstaat towards circular procurement.

Outcomes and Lessons learnt from A12

- CO_2 emission reductions were achieved through design and materials choices, e.g., road surfacing materials that extended the standard expected product lifetime;
- Optimising product lifetime created greater circular resource consumption leading to greater whole embodied carbon benefits when compared with standard practices;
- Setting a target for environmental performance was shown to be one way of embedding circularity in the early stages of the procurement phases, particularly when considering long term contracts that included maintenance, in-use management and disposal of assets and infrastructure;

- The procuring client needs to have a well-thought-out reference design and an understanding of where there is scope for improvement when considering circular procurement options;
- Collaboration is an important principle in circular procurement thinking e.g., through early market engagement and competitive dialogue. This gives the tenderers the flexibility to innovate and provide solutions based on performance specifications in the tender;
- In the case of long-life infrastructure assets, whether procured on initial costs or standard approach to whole life costs, end of life costs are not factored in. As a result, these costs fall on the asset owner at the time, the community or the new investor. As an alternative to this model, considering whole life impacts using circular procurement principles mitigates the environmental, economic and social costs of any waste management activities.

Key circular procurement elements included in the A12 reconstruction scheme:

- Requirement for waste prevention and recyclability in the tender specifications and ensuring inclusion in the early design stage;
- Inclusion of recycled content in targets and specifications to create demand for recyclable materials and components;
- Specification for refurbishment and reuse of materials and components, where applicable, to extend product life (lifetime optimisation);
- Specification for reuse of demolition materials at end of life

B.4.4.2 United Kingdom (England)

Following the initial strategy set out in 1999, the UK Government's Sustainable Development Strategy in 2005 set out ambitious goals to make the UK a leader in the EU in sustainable procurement by 2009. The strategy recognised that this was important in moving towards a more sustainable economy, firstly because the scale of the public sector spend on goods, services, works, and utilities can stimulate the market for more sustainable goods and services. Secondly, because only with government leadership can the consumption patterns of business and consumers be shifted onto a more sustainable path.

National Highways (or Highway England as it was) started the move to Circular Economy in 2015 by commissioning the development of a corporate circular economy plan to help build a culture of resource efficiency and effectiveness across the organisation.

National Highways (NH) definition of Circular Economy

After initially adopting a working definition of Circular Economy based on Ellen MacArthur Foundation advice, National Highways engaged with stakeholders to define what circular economy actually represents in practice for the organisation (Highways England, 2016):

- Minimising demand for primary resources extracted from the ground; and maximising the reuse of resources already in use on the network and ultimately in the wider economy. Reutilising resources at end of life in as high a value application as is possible;
- Being innovative; working with suppliers to find new ways to deliver a more resilient and adaptable network – seeking efficiency and value for money;
- Working to achieve security of supply; working with others to improve the stability and predictability of demand for high-performance products and services. Enabling suppliers to invest in innovative approaches and secure long-term partnerships with wider supply networks, their staff and wider communities;

- Supporting the objectives of Biodiversity 2020, seeking to reverse biodiversity loss and, in the longer term, delivering biodiversity gains; and
- Consideration of the potential for a natural capital approach to capture the value of Highways England's land holding

Circular economy approach to procurement

The A303 Amesbury to Berwick Down scheme commission, undertaken between September 2017 and June 2018, was the first scheme in the UK that adopted Circular Economy approaches from the preliminary design phase with the aim of raising awareness of, identifying, and promoting circular economy approaches in the organisation (Highways England, 2018). The approach built upon the lessons learnt from an earlier A14 Circular Economy Pathfinder Project:

- Early design stages have the greatest potential to improve resource efficiency and contribute to circular economy
- Identifying and implementing opportunities at this stage can enable significant reductions in cost, waste and greenhouse gas emissions and other sustainability benefits.

The specific objectives of the project with regard to the NH transition to circular economy were to:

- Integrate circular economy thinking into the preliminary design phase of the A303 Amesbury to Berwick Down scheme
- Raise awareness of and support the identification and documentation of resource efficiency and circular economy opportunities during the preliminary design phase of the scheme
- Adopt circular economy at later stages of the project, beginning overtly at the detailed design phase and continuing through construction preparation.

The activities that were relevant to supporting and enabling circular economy elements to become embedded in the scheme delivery included:

- Creation of a list of generic RE initiatives identified in the earlier A14 Pathfinder project and Benefits Realisation management for the opportunities that could be used in A303
- Collaborative approach from the start, working with contractors, consultants, technical specialists to identify, realise, record and then raise awareness of potential opportunities to apply circular economy approaches
- Resource efficiency workshops to provide a mechanism to collate and record information, facilitate the identification and realisation of additional benefits at subsequent stages of project delivery
- Collation and documentation of identified opportunities and activities to help build organisation's circular economy case study library and support transfer of best practice to subsequent stages of this scheme and also future projects
- Bringing complex schemes under single leadership to increase the capability of the organisation to manage and deliver these and to create efficiencies in delivery by sharing learning and resources between schemes
- Discussions & workshops with a wide network of stakeholders, internal groups, technical specialists and potential suppliers

Circular economy related outputs from the project:

- Over 100 opportunities for material, processes and environment / biodiversity gains were identified for the A303, and approximately one quarter of them were incorporated within the Preliminary Design.
- Communication materials to raise awareness of significant sustainability benefits including, reductions in cost, waste and greenhouse gas emissions that CE initiatives

can generate and also provide guidance to progress CE approaches, both during procurement and delivery of the project.

In addition to aligning with NH's Circular Economy RouteMap, benefits from the CE approach adopted included:

- It helped to develop and document approach to the practical application of circular economy approaches and will inform future project and help to build a corporate culture of resource efficiency and effectiveness
- Provided evidence of the project level application of circular economy thinking which demonstrated realisation of commitments made in the organisation's Sustainable Development Strategy.

Circular economy pathfinder projects, such as the A14 and A303, are providing National Highways with valuable insights into how circular economy can achieve demonstrable efficiencies in road projects. The lessons learned will be used to inform future practice.

B.4.4.3 Nordic countries

Nordic countries, Denmark, Finland, Norway, and Sweden, with resource efficiency and circular economy as key focus areas, set up the Nordic Working Group for Circular Economy in 2019 (NCE, 2019). Priority areas for the 2019-24 period were:

- non-toxic and resource-efficient cycles
- cutting resource consumption
- cutting the volume of waste and using more of it as a resource
- working together on policy instruments for green transition
- incorporating plastics into a circular economy as far as possible rather than dumping it into the environment.

Circular economy was defined as: "*The procurement of competitively priced products, services or systems that lead to extended lifespan, value retention and/or remarkably improved and non-risky cycling of biological or technical materials, compared to other solutions for a similar purpose on the market. Circular procurement is part of green and/or sustainable procurement aiming at value creation, social well-being and environmental improvements through closed and safe material loops" (Nordic Council of Ministers, 2020).* For the infrastructure construction industry, waste and recycling, building and demolition were identified as having key roles in enabling circular economy.

Each of the four countries identified areas of focus in the transition to CE:

- Denmark: Key drivers of the Strategy for CE (2018-2022) launched in 2018 were reducing use of virgin resources and increasing competitiveness and productivity of Danish businesses.
- Finland: It was the first country to launch a national strategy for CE (2016-2025) in 2016, with a road map. The focus is on material efficiency, recycling and waste
- Norway: White Paper on move to CE was published in 2016, with the aim of launching their strategy in 2021. A key aim was to not only increase recycling and reduce/prevent waste but see waste as resources for future use.
- Sweden: Work on transition to a CE started in 2018 and a national strategy was adopted in 2020. The strategy highlighted key areas, sustainable production and product design, sustainable ways of consuming and using materials, products and services, toxin-free and circular ecocycles, measures to promote innovation and circular business models.

Circular Economy approach to procurement
Pilot study, Denmark *(Nordic Council of Ministers, 2020)*
An early precursor of circular thinking was the 'reuse' of old bricks from demolition sites as a value solution with environmental benefits and a way to combat the increasing costs of landfill. A company, Gamle Mursten, 7 demonstrated the life cycle cost benefits of cleaning and using old bricks from demolition sites as resources in construction projects, bricks that would normally be treated as waste. Two pilot cases were carried out in Copenhagen. Old hospital buildings, due for demolition, were demolished with care to save as many whole bricks as possible. The recovered bricks were cleaned and reused in the extension and renovation of schools.

- The tender document specified that the bricks for the outer walls of the schools being renovated should be from recovered bricks from demolition.
- The outcome established the feasibility, not only of requiring the reuse of materials, but also that it was possible to move away from the traditional 'lowest cost' option.
- While reused bricks were more expensive than new bricks at that stage, it was expected that the reused bricks would last longer. It was also estimated that the reuse of one brick reduced GHG emissions by 0.5 kg CO_2 equivalent on average and with a potential for reusing 30 million bricks in Denmark annually, there would be a significant reduction of 15,000 tonnes of CO_2 emission per year. A life cycle approach to the evaluation of alternatives could well support the move to more environmentally friendly alternatives.
- The lessons learnt from the pilot studies helped the development of more general rules for procurement within building and construction covering environmental criteria, promoting recycling and reuse, requiring life cycle assessment (LCA) of alternative materials. Procedures for the recycling of tarmac for road construction and road renovation, including storage options for these materials, became standard.

Example of circular procurement on road infrastructure, Finland: City of Lahti, Waste materials in road construction *(Nordic Council of Ministers, 2020)*
The driver in this case was to enable CE through an innovative solution, developed by a local company Tarpaper, of using of waste materials from another sector. The aim was to use roofing felt waste in road construction and make this part of a normal procedure for the future. Pilot areas were provided by the procurer, the City of Lahti, for testing and to also develop guidance for circular procurement.

Roofing felt waste from demolition or refurbishing was processed and added as a bitumen source in the production of new asphalt. This exercise resulted in the production of quality asphalt and also the availability of roof felt waste for use in the road sector.

Outcomes and lessons learnt:
- The innovator, Tarpaper Recycling Finland was able to register a patent for the method to recycle roofing felt waste and thereby introduce a new environmentally friendly option for road maintenance.
- The joint working between the City of Lahti and Tarpaper that resulted in accelerating the successful use of roofing felt waste as a material for asphalt highlighted the need for a collaborative approach between procurers and suppliers.
- Th success of the approach catalysed the search and use for other materials to similarly deliver environmentally friendly outcomes and reduction in carbon emissions.

Another example of alternative materials used in road construction projects is soil (extracted from construction sites) and ash resulting reduced costs due to shorter transportation distances and the reduced need to purchase soil.

B.4.5 Summary of good practice

Summary of good practice in circular procurement

1. Since the concept of Circular Economy gained traction, more than hundred definitions have been developed. For any organisation, to successfully progress the transition to circular economy, an early step is defining Circular Economy such that it meets National requirements &resonates with the organisation's Goals & objectives.

   For example: National Highways (UK) started with the Ellen Macarthur definition of CE as:
   "A circular economy is one that is restorative by design, which aims to keep products, components and materials at their highest utility and value at all times". NH has since gone on to work with a wide range of its stakeholders to define their own approach to Circular Economy, such that it fits within the context of its own goals, objectives and long-term plans. NH definition of CE is:
   - Minimising demand for primary resources and maximising the reuse of resources already in use on the network in as high a value application as is possible;
   - Working with suppliers to find new ways to deliver a more resilient and adaptable network
   - Achieving security of supply through collaborative working with stakeholders, enabling investment in innovative approaches, securing long-term partnerships
   - Supporting the objectives of Biodiversity 2020 seeking to ultimately deliver biodiversity gains; and
   - Considering the potential for a natural capital approach to capture the value of land holding

2. Transition to CE is a complex process and involves progress in the different aspects of infrastructure asset management, each of which may be at different levels of maturity. One good example of enabling the transition CE is a step-wise incorporation of principles in highway construction and maintenance schemes, through trials, feasibility studies, lessons learnt & knowledge transfer.
   For example: National Highways (UK) used 'Pathfinder' projects to:
   - To support project level thinking to inform path to implementation
   - The A14 Cambridge to Huntingdon was NH's first Pathfinder project
   - CE opportunities for A14, but even more importantly, for future projects are identified and collated
   - Lessons learned from the A14 informed CE thinking on the second circular economy pathfinder project at the A303.

3. A circular approach to the use of materials is where products are kept in use for as long as possible, and after they reach the end of their useful life they are recovered or regenerated and reused to retain as much value as possible. However, common practice in the procurement of construction and maintenance works on the road infrastructure is to focus on the acquisition of the required services and goods, to prescribed technical and possibly functional requirements and there is usually no (or

occasionally limited) consideration 'end of life' options. The cost of repurposing for reuse or disposal are not factored in the initial costs so that the community or a new investor has to bear these costs when the time comes. To enable the ***total*** life-cycle costs to be considered, an understanding of the options at 'end of current phase of use' for products at the start of the life cycle as well as other actions such as contractual clauses are necessary, i.e., embedding 'end of life' options at bidding stage of schemes
For example: Rijkswaterstat (Netherlands) procurement of A12 scheme:

- Tenders had to include proposals for use/reuse of materials at the ends of first life and tender evaluation was designed to value the options
- Rijkswaterstat had a 17-year contract with the supplier to ensure delivery of achieving planned, high-value use of resources.

4. CE cannot be delivered by NRAs on their own but collaboration between NRA and their stakeholder community is a necessity. Working in collaboration with suppliers can align new goals, unlock innovation, spread costs and risks, commit to a shared vision etc.
   For example, joint working between procurer and supplier in the road infrastructure project in Lahti, Finland:
   - Providing pilot areas to supplier for redesigning 'waste' products and testing for reuse in pavement maintenance enabled new materials and development of guidance for circular procurement
   - Accelerated the successful use of roofing felt waste as a bitumen source in the production of new asphalt for pavement maintenance and catalyses interest in identifying other alternative materials

B.4.6 Horizon scan

B.4.6.1 G20 (Finance ministers and Central Bank Governors) road map

Circular Economy in increasingly being accepted globally as the route to achieving sustainable infrastructure and meeting the Net Zero Carbon targets. However, the transition from a linear to circular economy is very much in its infancy. Most of the forward-looking Action Plans and strategies to enable this transition trend to be at the international and national levels with limited examples at the NRA level

International - G20 Roadmap for Circular Economy (2021)
The G20 Infrastructure Working Group (IWG) identified circular economy as a priority to deliver sustainable infrastructure and designed the road map to as an enabler of the transition to circular economy. Different countries are expected to adopt their different approaches to CE depending on their individual circumstances and the roadmap has been developed for use by national authorities as a basis to design their own road map.
This roadmap consists of transition pathways designed around 4 knowledge enablers

1. Data-based evidence: Circular economy requires collaboration between organisations and collection and sharing of data is a critical requirement. The aim is to encourage public and private sector partners to share datasets and data insights on circularity and build a better understanding of definitions, impacts and achieving the desired outcomes.

2. Innovative policies: The aim is to raise awareness of innovations around policy that could help governments and organisations to develop strategies to suit their circumstances.
3. Models for technological innovation: Technological innovation is critical to the circular economy transition and governments can incentivise the incubation stage through, for example direct fiscal support, grants, funds etc.
4. International collaboration: The aim is to raise awareness of the cost of inaction and the benefits of circular economy approaches

The report also has also provided examples of short-, medium- and long-term strategies for the transition to circular economy based around each of the four transition pathways. A selection of examples centred around the transition pathway, Innovative policies, are included below.

- **Short term strategies:**

Example: The Netherlands has made a commitment to achieve a Circular Dutch Economy by 2050, with an intermediate goal of reducing the use of primary materials by 50% by 2030. This is expected to be achieved through collaboration between industry, civil-society organisations and knowledge institutions. The Netherlands transition to a circular economy is centred around consuming less, using sustainably produced renewable materials and technological improvements by designing circular products and developing new production methods
Example: Singapore has committed to becoming a zero-waste nation with intermediate commitment to reduce by 30% the amount of waste sent to landfill per capita by 2030. The plan is based on adopting a circular economy approach with government taking the lead on the transition and progress being achieved through investments into research and infrastructure.

- **Medium-term: Models for policy innovation sandboxes**

Example: In the EU, Horizon 2020 includes research and innovation programme to develop innovative solutions to address circularity, reduce barriers to innovation and facilitate collaboration between the public and private sectors to get new ideas get off the ground and achieve results. To date, Horizon 2020 has funded circular approaches to the construction, electronics, waste management, and plastic packaging sectors.

- **Long-term: Reform around policy and regulation**

Example: Since 2013 the Green Deal for Circular Procurement in the Netherlands has been stimulating circular economy initiatives that encourage collaboration between public and private sector organisations to facilitate a procurement regime inspired by circular principles. In just three years, 80 circular economy pilot projects were undertaken with the key lessons learned shared to encourage further uptake.

B.4.6.2 EU road map

The European Commission produced its Circular Economy Action Plan in 2020 (EU, 2020) with the aim of reducing pressure on natural resources, creating sustainable growth and jobs, halting biodiversity loss and achieving the EU's 2050 climate neutrality target.
The key attributes of the Action Plan to enable the transition are:

- Scaling up circular economy from front-runners to the mainstream economic players to enable the EU to achieve climate neutrality by 2050 and also to decouple economic growth from resource use, while ensuring the long-term competitiveness of the EU.
- Accelerating the transformational change required by the European Green Deal, while building on circular economy actions implemented since 2015. This plan will ensure that the regulatory framework is streamlined, and new opportunities are maximised.
- Establishing a strong and coherent product policy framework that will make sustainable products, services and business models the norm and transform consumption patterns so that no waste is produced in the first place the EU has a well-functioning internal market for high quality secondary raw materials.

The transition to circular economy, while disruptive, is expected to be systemic, deep and transformative.

B.4.6.3 National – National Highways, UK

National Highways (or Highways England as it was then) developed a corporate circular economy plan (Highways England, 2016) to embed resource efficiency and effectiveness across the organisation. The specific objectives of were to:

- Develop a corporate circular economy strategy within the context of its Sustainable Development strategy
- Define what circularity means for the organisation
- Develop a Routemap to achieve fully optimised resource use on all its projects and operations, with intermediate targets and realistic timetables for achievement
- Deliver a plan to embed a culture of resource efficiency across the organisation and its supply chain.

B.5 Business Models

Business models underlying the management of highway networks are fundamentally based on a linear approach, ‘Take, Make, Waste’ or Cradle to Grave. Over the last decades as sustainability and the need to reduce carbon emissions have grown in importance, NRAs, to varying degrees, have adapted their approaches to take on board aspects such:

- Indirect costs associated with the management of road networks, e.g. emissions
- Carbon footprint of activities
- Use of recycled and secondary materials
- Life Cycle Analysis inherent in decision making

The transition to circular economy requires a fundamental change in approach to value chains, and for new Business Models that address the key principles of CE, a cyclical Cradle to Cradle approach, i.e., not just minimising resource consumption but designing out waste and pollution, keeping products and materials in use for as long as possible. One of the aims would be to enable an increase in resource efficiency to be underpinned by a reduction in the use of raw materials.

The move to circular economy is in the very early stages and while some NRAs have made progress with regards to some of the attributes related to circularity, there are no examples of the adoption of a circular business model by any NRA. Essentially, as shown in Section A3, Figure 4, NRAs still function with linear business models, with a greater bias towards economic considerations.

Circular business models contribute to circular economy by reflecting the fundamental principles underlying circular economy and key attributes are expected to include:

- Designing out waste and pollution at the design stage
- Materials management approach that supports value retention rather than a waste management approach
- Innovative ownership models, including for example provision of infrastructure as a service
- Early contractor involvement
- Extended contractor/supplier responsibility, with responsibility extending to end-of-life-options for products, materials etc
- Incentivising innovations and enabling risk and benefit sharing
- Focus shifting from outputs to outcomes
- Mitigate climate change impacts and resource scarcity

B.5.1 Summary of good practice

While the transition from a linear to a circular business model is yet to make a mark with respect to the construction and maintenance of roads, there are good practice examples from NRAs testing options within individual projects that are precursors to the transition. For example, pilot projects have been used to test the feasibility and learn lessons from introducing aspects relevant to CE based Business Model:

- Infrastructure as a service contract – pilot project in Netherlands
- Early contractor involvement to identify and collate opportunities for circular approach – major projects in the UK
- Innovative solutions for reuse of ‘waste’ materials in road maintenance – project in Finland
- Resource Exchange Mechanism – development in the UK contributing to mitigating resource scarcity

III. Findings, Examples of Good Practice and Recommendations

In parts A and B, key findings were made, and examples of good practice identified. Distilled below, are the main findings, five examples of good practice and a selection of recommendations for NRAs to consider and help support the transition towards becoming more resource efficient and to embed circular economy principles within their organisations.

Key Findings

CE Ambition

Many NRAs have goals that are focused on sustainability, not yet CE&RE. Recommendations for NRAs are:

1. Define ambitions for CE and RE.
2. Assess the relevance of CE and RE within their national context, including organisational goals (e.g., greater circularity can contribute to reduced carbon emissions).
3. Adopt definitions for CE and RE that fits into the context.
4. Develop specific objectives and a strategy for achieving them.

Embedding CE

Some NRAs are moving to adopt a more RE approach during highway maintenance and in designing maintenance regimes. Recommendations are to:

1. Select a suitable maturity model and use it to assess current organisational performance.
2. Appoint champions in key areas of the organisation to drive progress and develop competency profiles for the skills needed.
3. Communication strategy throughout the organisation.
4. Set corporate and personal objectives to drive innovation and change.

Performance Monitoring / KPIs

There is little quantification of highway maintenance resource flows and lack of transparency of the degree of RE achieved between NRAs and the supply chain. Recommendations are to:

1. Collaborate with the supply chain - provide data, enable recording and reporting material resource flows from production to recovery or disposal.
2. Develop, monitor and report on suitable KPIs.
3. Make available the data that can help the supply chain find solutions to improve the efficiency of material circulation

Standards

Rigid standards, with slow modification, remain a barrier to innovation. Recommendations are to:

1. Move towards performance-based specifications.
2. Identify strategies for analysing and mitigating the risk associated with new maintenance approaches. Risk based framework will assist with this.

Supply Chain
Some NRAs actively engaged with the supply chain. Early engagement on construction projects shown to result in novel options being proposed. Recommendations are to:

1. Establish communication channels with the supply chain.
2. Collaborate to foster innovation through collaborative designs, circular inputs, product as a service, life extension, recovery and reuse, close material and product loops.
3. Share data on the nature, location and availability of resources to help optimize material use close to source.

Business Models
Most NRAs have linear business models. Price main consideration with some environmental performance considered. Recommendations:

1. Business models accounting for overall value and improved resource efficiency needed.
2. Link business models to organisational, national, and global targets.
3. Incorporate CE and RE into decision making, valuing circular design, longer life and the recovery, reuse, and repurposing of materials.
4. Adopt multi-life cycle models in which circular use and residual value at the end of each lifecycle are taken into account.

Circular Procurement
Some NRAs are starting to include CE and RE in their procurement processes. Good practice exists in the form of circular procurement guidelines and the use of environmental impact criteria to balance cost with environmental impact. Recommendations are to:

1. Redesign procurement rules to move from a traditional, lowest-first-cost system to performance-based procurement.
2. Develop tender scoring criteria based on RE aspects (such as extended / optimised lifespans, intensity of material use and waste minimisation) and shadow trial to allow refinement prior to incorporating into all tender assessment.

Good Practice

Define CE
Defining CE to meet National requirements & resonates with the organisation's Goals & objectives, e.g. NH (UK) experience.

- Minimising demand for primary resources and maximising the reuse of resources already in use on the network in as high a value application as is possible;
- Working with suppliers to find new ways to deliver a more resilient and adaptable network
- Achieving security of supply through collaborative working with stakeholders, enabling investment in innovative approaches, securing long-term partnerships; and
- Considering the potential for a natural capital approach to capture the value of land holding

Trial approaches
Enabling transition to CE in maintenance schemes, through trials, feasibility studies, lessons learnt & knowledge transfer, e.g.: National Highways (UK) **'Pathfinder'** projects:

- To support project level CE thinking
- A14 Cambridge to Huntingdon was NH's 1st Pathfinder project
- CE opportunities for A14, but more importantly, for future projects were identified and collated

- Lessons learnt from A14 provided significant input and support success factors to integrate CE thinking into A303 scheme

Start with the end in mind
Embed 'end of life' options at bidding stage of schemes, e.g., RWS A12 scheme:

- Tenders had to include proposals for use/reuse of materials at end of first life and tender evaluation was designed to value the options
- 17-year contract with the supplier to ensure delivery of high-value reuse of resources

Set strict environmental targets
There are examples of environmental targets being set in schemes at the outset. For example, Statens Vegvesen in Norway has stringent emissions targets:

- They mandate that emissions from construction, operations and maintenance and own activities should be cut by 50% by 2030, there should be a 50% cut in emissions on construction sites by 2030 and zero emissions by 2050.
- There are emissions budgets and greenhouse gas accounting for all projects above NOK 51 million and all projects over NOK 200 million must have CEEQUAL certification. A CO_2 budget is agreed for all new projects, covering multiple phases (pre stages, during planning and prebuild etc). There is a bonus / penalty system around reaching targets for CO_2e emissions.
- There are waste reduction targets on a scheme basis and targets for 100% reuse from maintenance activities.

In Switzerland, there is a requirement to justify any material that is not reused, providing project managers with tools as to how strategies can be incorporated. Whilst most Cantons specify the maximum amount of recycled content, one canton gives a minimum percentage and assesses the amount of recycling and transport distance.

Change standards to allow innovative and circular approaches
A compendium of regulations is published by the Danish Road Directorate, covering most materials, and dictates, what requirements the individual materials must meet during construction. This results in the compendium's requirements for circularity being what is mostly followed.

In 2012, the general work specification for hot-mix asphalt was updated regarding recycled asphalt. Previously the work specification allowed 30% recycled asphalt in wearing course, which was limited to 15% for open-graded and kept at 30% for closed-graded. This was a setback for circular usage of materials. Besides the option of being used in limited amount in wearing courses, asphalt could be used as an unbound material in a lower part of the road structure. Using asphalt in a lower part of the structure would generally result in a downcycling of the material.

In 2020, the Construction Product Regulation changed the regulations from prescriptive based to performance based, completely removing the limitations on the extent of recycling in hot-mixed asphalt. This was confirmed in the most recent publication, in December 2021.

Performance based specifications in general are likely to be a requirement to enabling greater CE and RE, especially considering the requirement for materials to be used over multiple lifecycles. Moreover, performance-based standards give freedom to innovation in material production and use.

Recommendations

Based on the above, the following key recommendations are made:

1. Define CE and RE for your organisation in the context of national targets and organisational priorities.
2. Communicate CE and RE ambition throughout organisations with CERE champions
3. Set CE & RE targets and communicate them throughout the organisation.
4. Define where you are on maturity matrix to enable strategies to be developed to make progress in each of the areas, and to monitor progress being made against targets.
5. Enter into long term agreements with contractors, considering end of first life at outset (e.g., A12 NL)
6. Develop pathfinder projects on various schemes to see how embedding CE and RE works in practice and to bring lessons learned to future projects.
7. Share data with contractors to improve resource use and to develop innovative solutions.
8. Develop performance-based standards and specifications to remove barriers to greater resource efficiency.
9. Consider business models that account for overall value rather than solely, initial cost.

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Annex A: Maturity model rubric

CERCOM Maturity level	Engaging in transition to RECE (Stage 1)	Engaging in transition to RECE (Stage 2)	Engaging in transition to RECE (Stage 3)
CE ambition	NRA has not committed to a transition to CE.	NRA has committed to a transition to CE but is yet to define CE within the context of its operations	NRA has committed to a transition to CE and a definition for what CE means in practice is in place
Embedding CE	No staff awareness of CE.	Low staff awareness of CE and how it affects their roles. No innovation in RE and CE	Moderate staff awareness of CE and how it affects their roles. Ad-hoc initiatives to support innovation to deliver CE.
Performance monitoring (KPIs)	Inventory of the resources in use is incomplete, not up to date. No tracking occurs of selected and isolated aspects, e.g., RAP (Recycled Asphalt Pavement) or CO_2.	Work on creating an up-to-date inventory is underway Partial tracking occurs of selected and isolated aspects, e.g., RAP or CO_2.	A partial inventory is available of the resources in use. Tracking occurs of selected and isolated aspects, e.g., RAP or CO_2.
Standards	Standards and methods for treatment of risk are at status-quo, allowing only traditional methods for use of materials, e.g., recycled asphalt.	Standards and methods for treatment of risk allow limited reuse of materials, e.g., recycled asphalt, within traditional methods.	Standards and methods for treatment of risk allow greater reuse of materials, e.g., recycled asphalt, within traditional methods.
Supply chain	No engagement between internal & external stakeholder communities regarding CE & RE.	Recognition of need for engagement between internal & external stakeholder communities to progress to CE	Engagement is occurring between internal & external stakeholder communities (e.g., developing guidelines, good practice).

	Suppliers deliver projects as mandated by existing standards.	Suppliers deliver projects as mandated by existing standards.	Suppliers deliver projects as mandated by existing standards.
Business models	Linear business models (with environmental aspects such as recycling in line with legislative requirements). No whole life costing applied.	Linear business models, (with environmental aspects such as recycling in line with legislative requirements), whole life costing considered but not mandatory	Linear business models (with environmental aspects such as recycling in line with legislative requirements), whole life costing part of decision-making process
Circular procurement	Procurement is on a transactional basis, not on value maximisation Tendering is based on specified technical requirements and suppliers deliver as mandated by existing standards only. No circularity considered within procurement.	Procurement is still on a transactional basis, not value maximisation but some value elements included (e.g., recycling) Tendering is based on specified technical requirements and suppliers deliver on some value elements as mandated by standards	Procurement is on a transactional basis Elements of CE are accommodated although are not specifically designed to influence internal and supply chain behaviours on circularity. Tendering is based on specified technical requirements and suppliers deliver on value elements as mandated by standards

CERCOM Maturity level	Early stages of practicing RECE (Stage 4)	Early stages of practicing RECE (Stage 5)	Early stages of practicing RECE (Stage 6)
CE ambition	Policy to transition to CE and improve RE are under development.	Policy to transition to CE has been published. Targets for transition yet to be identified and developed.	Policy to transition to CE has been published. Targets for RE and CE elements, some developed & others under development

Embedding CE	Growing staff awareness of CE and how it affects their roles. Initiatives are starting to occur that support innovation to deliver CE. Ad-hoc champions in some project teams, but not widely spread across projects	Corporate communication for internal & external audience, beginning to be shared Initiatives to support innovation to deliver CE increasing. Champions in some project teams to enable CE thinking. Supporting instruments, tools and staff training are being developed	Clear communication, internally & externally, on commitment to CE. Corporate commitment to innovation initiatives to deliver CE. Champions in project teams are beginning to drive through change. Supporting instruments, tools and staff training are being developed and implemented.
Performance monitoring (KPIs)	Systems to monitor improvements in RE & CE are being developed. Recognition of need and plan to work with supply chain. On-going work on improving inventories that track resource inputs and outputs. Tracking occurs across multiple aspects and there is awareness of areas for development.	RE & CE are monitored internally, Supply chain involvement increasing. Increasing detailed inventories that track resource inputs and outputs. Greater visibility of performance and awareness of areas for development. KPIs (internal & external) are under development.	RE & CE are routinely monitored internally, the supply chain is required to provide data to support. Increasing detailed inventories that track resource inputs and outputs. Increasing visibility of performance and awareness of areas for development. KPIs (internal & external) are in place, and additional ones being developed.
Standards	Recognition of need for new/revised Standards to accommodate opportunities for high-value use of existing materials (accommodating Repair, Reuse, Repurpose, etc., in addition to Recycle) Novel approaches are not yet accommodated through a	New/revised Standards to accommodate opportunities for high-value use of existing materials (accommodating Repair, Reuse, Repurpose, etc., in addition to Recycle) under development. Progress on accommodating novel approaches through a streamlined process for derogation.	Standards accommodate opportunities for high-value use of existing materials (accommodating Repair, Reuse, Repurpose, etc., in addition to Recycle). Novel approaches are actively sought through a streamlined process for derogation.

	streamlined process for derogation.		
Supply chain	Collaborative mechanisms, e.g. Early Contractor Involvement at design stage, are being explored. Supply chain contributing to ideas to improve performance and move beyond existing standards	Collaborative mechanisms being tried out in some projects, e.g. Early Contractor Involvement at design stage, and positive attitude to innovation are allowing options for enabling circularity to be explored. Supply chain demonstrating actions to monitor and improve performance.	Collaborative mechanisms, e.g. Early Contractor Involvement at design stage, and positive attitude to innovation are used more widely, enabling progress to circularity. Supply chain demonstrating continued commitment to monitor and improve performance.
Business models	Exploratory work on changes to NRA business models to align with the new CE Policy, e.g., closing the loop and involvement in product life cycles for longer than linear model	New framework for business model, defining NRA value proposition and processes for capturing value being developed.	NRA business model thinking is influenced by RE and circularity principles e.g.: reducing resource consumption, keeping materials in use, minimising ecological and social costs, designing out waste, and consideration of the residual value of resources, products as services.
Circular procurement	Exploratory work on systems and tools to include CE & RE principles within the procurement process. Tendering is based on specified technical requirements and suppliers are encouraged to propose options supporting circularity (e.g., plans for reuse of materials, development of secondary value chain is encouraged within tendering).	Designs for systems and tools to recognise CE & RE within the procurement process; this includes collaborative relationships with supply chains. Tendering starting to include functional requirements and circularity (e.g., plans for reuse of materials, development of secondary value chain is encouraged and partly rewarded in procurement process).	Systems and tools to include CE & RE principles within the procurement process are being developed. Circularity (e.g., plans for reuse of materials, development of secondary value chain) is rewarded in tender assessment.

CERCOM Maturity level	Active deployment of RECE (Stage 7)	Active deployment of RECE (Stage 8)	Active deployment of RECE (Stage 9)
CE ambition	Strategy for transition and route map under development. Targets for RE and CE elements are in place	Corporate strategic plan and route map for the transition are published.	Strategic plan for transition & route map with timeline in place and embedded in the NRA. Targets for RE and CE, monitoring systems to track progress are developed.
Embedding CE	Staff are fully engaged with CE. Commitment and investment in innovation in RE & CE. Champions in project teams are beginning to drive through change, are recognised, and supported by senior management. Supporting instruments, tools and staff training are fully developed and implemented. Business and personal objectives beginning to be developed CE principles are defined and understood.	Staff are fully engaged with CE. Investment in innovation in RE & CE. Visible leadership at senior level, with accountability assigned to key leadership roles, supported by champions. Supporting instruments, tools and staff training are fully developed and implemented. Progress in development of business and personal objectives for delivery of RE and CE. CE principles are embedded in process as 'business as usual'	Staff are fully engaged with CE. Significant investment in innovation in RE and CE with forward plan to continue commitment. Visible leadership at senior level, with accountability assigned to key leadership roles, supported by champions. Supporting instruments, tools and staff training are fully developed, implemented, and embedded. Business and personal objectives are set for delivery of RE and CE. CE principles are embedded in process as 'business as usual', and subject to continuous improvement.

Performance monitoring (KPIs)	A common data standard has been developed. Understanding of materials, input, and output (waste) streams throughout the supply chain is being gathered. Metrics, not yet verified, have been developed for quantification of resources and impacts. Progress is being made on internal & external transparency in performance achieved	A common data standard exists, and databases are being populated with robust data. A detailed understanding of materials, input, and output (waste) streams throughout the supply chain has been achieved. Metrics are in place for quantification of resources and impacts, with third party verification. Internal & external transparency in performance and progress being made to achieve targets.	A common data standard exists and robust, up to date data are available (for NRA and supply chain). A detailed understanding of materials, input, and output (waste) streams throughout the supply chain has been achieved and is routinely monitored and updated as necessary. Metrics in place for quantification of resources and impacts, with third party verification reported upon. Internal & external transparency in performance achieved with reports on progress being made towards targets.
Standards	Standards encourage innovation in high-value use of resources; more work needed to manage risk. Methods for verifying the provenance and quality of materials in a secondary market being developed.	Standards support innovation in high-value use of resources, progress on management of risk. Some methods in place for verifying the provenance and quality of materials in a secondary market.	Standards support and help to embed innovation in high-value use of resources whilst providing effective management of risk. Effective (audited) methods in place for verifying the provenance and quality of materials in a secondary market.
Supply chain	Jointly exploring approaches to move beyond ECI and establish collaborative partnerships and alignment of incentives throughout the supply chain. Supply chain buy-in to move to Circular Economy	A Systems approach to partnerships and alignment of incentives throughout the supply chain starting to be used. Supply chain working with the NRA to deliver targets.	A Systems approach is established, with collaborative partnerships and alignment of incentives throughout the supply chain. NRA & Supply chain on track to deliver NRA targets.

Business models	Transition to Circular Economy Business Model based on maintaining value of resources underway Systems approach, external factors, supply chain role is being taken into consideration.	Business plans and procurement decisions increasingly driven by Circularity principles, minimising new resource use, improving longevity, repairability and efficiency of current resources.	Circular Economy Business Model based on delivering maximum value of resources and maintaining continuous relationship with supply chain in active use in the NRA. Circularity is inherent in the business models, drives decision making and procurement towards improving longevity, repairability and resource efficiency.
Circular procurement	Systems and tools that include CE & RE are developed and available in procurement. Training on new procurement processes underway. Tendering process includes functional specifications with circularity metrics to assess options.	Systems and tools that recognise and reward CE & RE are embedded in the procurement process. Training is on-going. Procurement process is based on collaborative relationship with supply chain. Tendering process includes functional specifications with circularity metrics embedded into the decision process. Monitoring system to report on progress being developed.	Systems and tools that recognise and reward CE & RE are embedded in the procurement process. Procurement based on collaborative relationship with supply chain is embedded in the NRA. Tendering process includes functional specifications with circularity metrics embedded into the decision process. Monitoring system in place to report on progress, track and demonstrate improvements.

Annex B: Questionnaire to NRAs

A total of 13 responses were obtained from 11 countries as shown in Figure 11. Two responses were received from both Portugal and the Netherlands.

Figure 11 Map of responses by country

The questionnaire asked a series of 'yes/no' questions on what environmental targets had been set by the road administration for various categories. 11 of the 13 responders reported that their organisation had targets for both inclusion of secondary materials and reuse/recycling of existing material. 9 of 13 had targets for extending the duration of the service life of the assets whilst 8 of 13 had targets for the reduction of construction waste and synergy with the next life cycle. The results are perhaps unsurprising given that much of the emphasis in recent years has been on recycling and use of recycled content and general operational requirements to extend the service life of existing assets. Less emphasis has been placed until recently on reuse of materials, consideration of design with a whole life basis including end of life and general reductions of materials use.

The results indicate that there will need to be a change in the mindset around the hierarchy of solutions, with more focus on reuse, repair and repurposing, before recycling is considered.

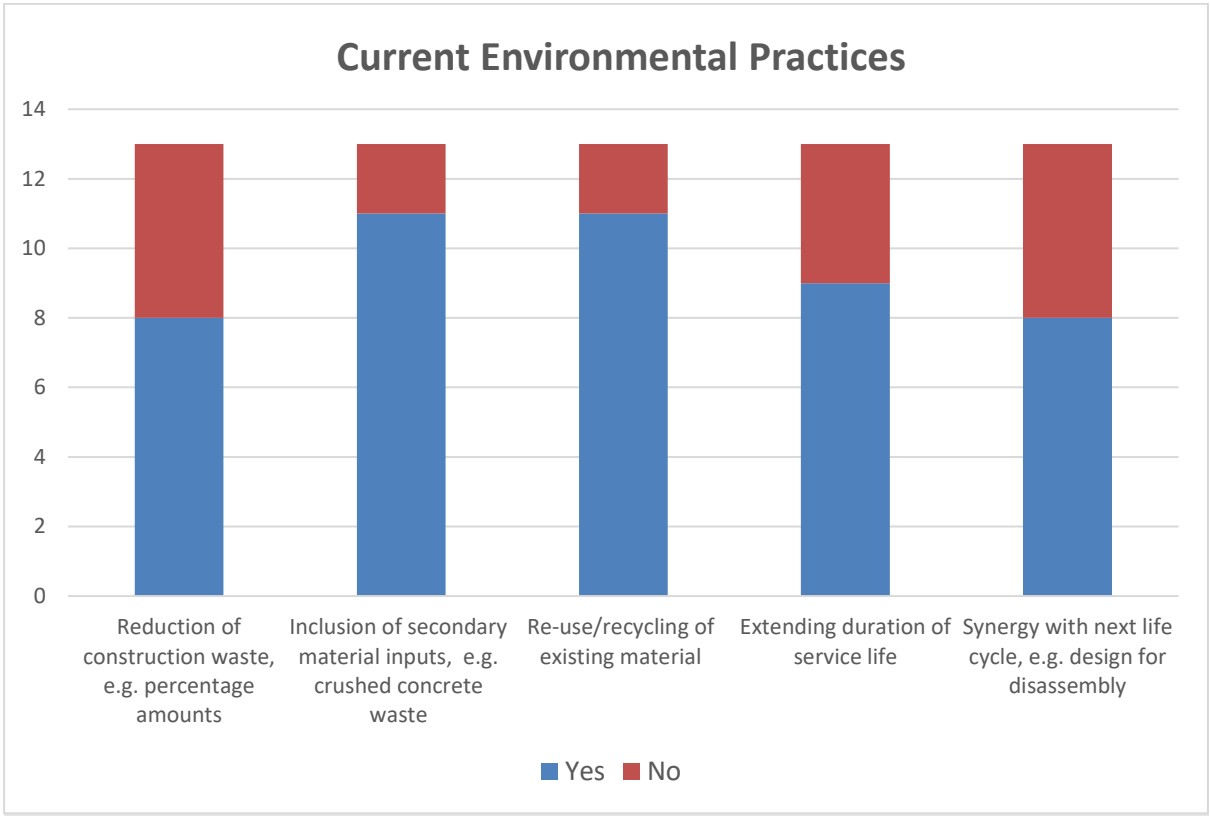

Figure 12 Current Environmental Practices

The questionnaire asked what environmental reporting was required from their suppliers with the options of carbon, waste, emissions, circularity or other. None reported that they are asking for circularity reporting. Of the 8 responses received, waste was the most common thing asked for, followed by emissions and carbon.

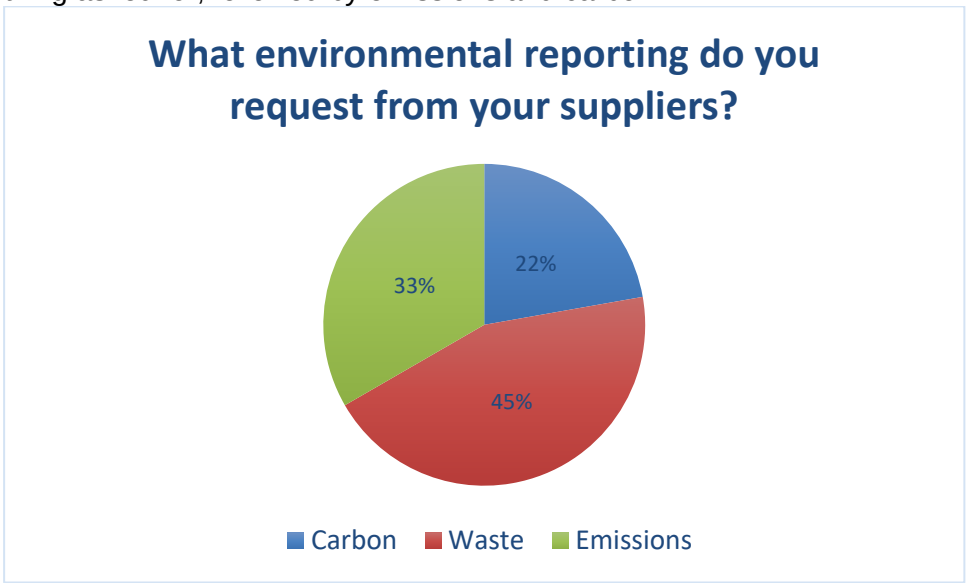

Figure 13 Environmental Reporting Requested by NRAs

Finally, NRAs were asked about their procurement practices, what metrics they use and what risk assessment tools they used in relation to CE and RE in highway maintenance, as shown in Figure 14. Most NRAs had partially (10 responses) or fully (1 response) adopted

procurement policies relevant to CE or RE. Moving to KPIs, the picture was more even, with 5 organisations reporting that they have partially developed metrics, with 3 unsure and 4 reporting that they don't have metrics; none reported they have fully developed metrics. Regarding risk assessment tools and frameworks to consider CE and RE, 4 reported that they did not have these, whilst 6 were unsure. This shows the value to be gained from the risk assessment framework being developed in the CERCOM project.

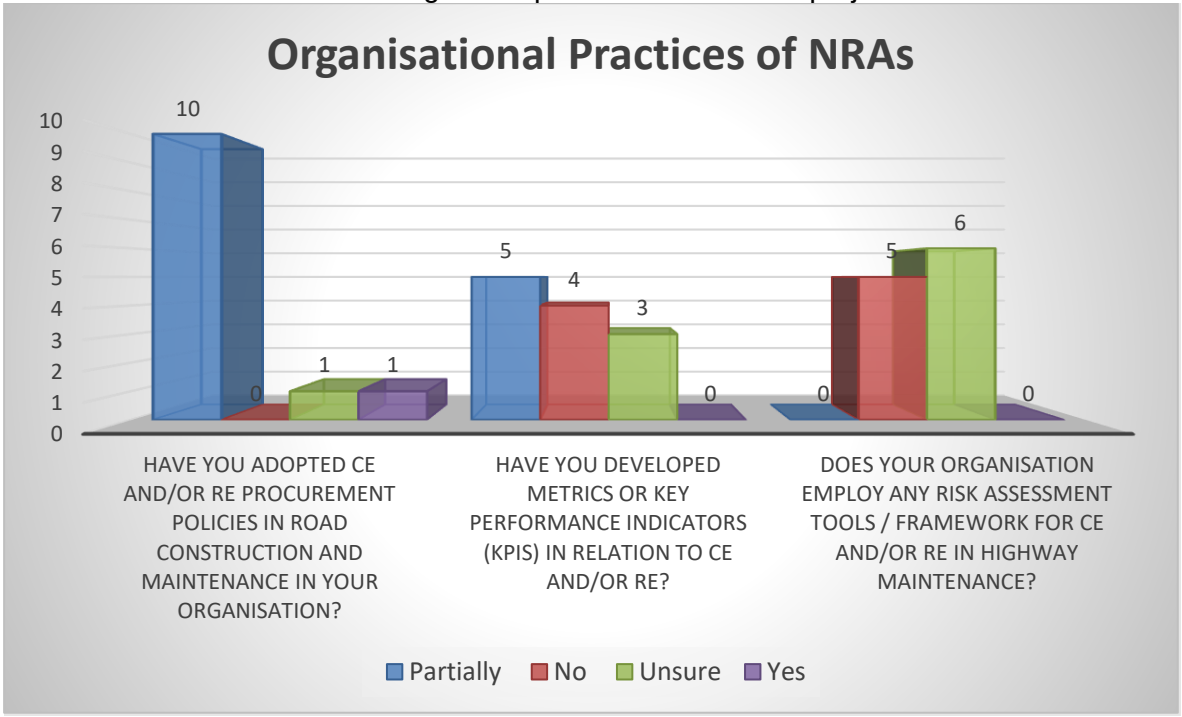

Figure 14 Organisational Practices of NRAs

Annex C: Industry workshops

Two industry workshops were held on November 30th and December 1st with five companies in total representing a mix of engineering / contracting companies, steel products manufacturer and asphalt contractors.

General thoughts on circularity

It was noted that more requests were being received from the supply chain for longevity of design. Many clients show interest but don't necessarily know what they want and there is no clear way to implement it, so need guidance. They are interested and are open to solutions/innovations.

It was pointed out that circularity is still relatively new, and there is a need to change mindsets internally and externally, to define commercially what it means to the organisation. When that is achieved, the supply chain will be able to offer more robust solutions to the clients.

Recycling vs circularity

It was felt that it is currently difficult for clients to understand what is circular, so there tends to be a focus on recycling, but it is just a small part of CE. It was commented that there is a lot of 'downcycling' going on, which although not ideal is better than taking raw materials and is a starting point.

There remains a large demand for building materials, which cannot be met, even with 100% reuse, so there is a need to change mentality and include RECE targets explicitly, particularly with regard to raw material use. There is a sense that procurement focusses on a small amount of sustainability, making the goals very hard to reach. Targets including biodiversity are important as well, so circularity shouldn't be the only focus.

It was pointed out that the most sustainable building is one that already exists, and so there is a need to adapt existing infrastructure.

There is already a lot of recycling in asphalt and a large demand in the Netherlands. There is a need for disruptive innovations in asphalt, but this takes time and money and there is little trust in politics creating uncertainty. Sudden policy changes in the past have created nervousness around investing for the future, despite a desire to change and improve.

ECI / KPIs

There was a feeling from Dutch participants that ECI, whilst OK, is not necessarily the right approach and has been pushed too hard, particularly the goals set for 2030. Despite the goal, there is a requirement for the tender to be less expensive, yet the innovation comes at a price due to the initial costs. There needs to be an overall set of environmental impacts assessed. There was also an opinion that effort was put into tricks to achieve the best LCA, but there was an enabler required to have long term strategic planning to work towards circularity.

Another problem, at the moment, is that we use ECI calculations at higher level, but we do not know if the numbers that used are good enough.

One company looks to use less materials at the design stage using the 10Rs principles. They also follow the Circular Bouwen (CB23) definition and the guidelines on how to

measure circularity. Nevertheless, people tend to forget that in the CE concept we shouldn't have any waste.

Training / culture
There is a feeling that new graduates, don't really know enough about end of life uses for materials, and this needs to be changed, with education and training with a focus on circularity.

Conversely, there was a view that in road authorities, there seems to be a new generation of people that wants to push these topics, but procurement is outdated, so e.g., they could procure only for products services that are in their system

Procurement
Clients and organisations want sustainable solutions in theory, but ultimately cost is the key factor. An example was given of epoxy-modified binders, which has a high initial investment but in the life-cycle is more cost-efficient (due to high durability and less need for maintenance). However, the budgets for investments are from a different pot that the budget for maintenance so it is difficult to see the whole picture.

In the UK, there is no circularity/sustainability KPIs or requirements, with price again the driver. There are also established supply chains, and a traditional market. It was felt there should be top-down government intervention to break this. It was also felt there was a lack of leadership in the local bodies, who should engage more with the market, suppliers and contractors. Local authorities have decided to stop with laboratory work, losing specialists on materials etc, with the responsibility passed to the contractors on how to maintain and what materials to use.

In Australia there is an infrastructure sustainability council, that has established a database of EPDs and encourage contractors to use products with lower environmental impacts

Standards
It was also felt that there should be more flexible contracts with options, so if a more sustainable option becomes available, it can be actioned, trialled or included in future contracts. There was also a view that clients can be more flexible than perceived in allowing deviations from standards.

Clients provide boundaries related to quality standards, but some pilots (e.g., ECOPAVE) stays as a pilot as they have their own rules. This sometimes makes innovations difficult to get into the project due to boundaries and can take a long time to move from pilot to implementation.

Within the rail sector, there is now discussion of whole life carbon, and scope 4 emissions (emissions that can be avoided using a particular product or service). This could prove to be a useful enable for circularity.

Innovations / new business models
Pilots projects are undertaken, for example the circular road as a service in the Netherlands, where agreements are made with provinces about providing the economic ownership to the contractors who are obliged to maintain the roads to the agreed functional requirements but also receive the residual value of the road at the end of the contract; this gives a financial incentive to the contractor to optimize the maintenance and (re) use

durable, long lasting materials for constructing the road. The pilot is focused on how to put these circular schemes forward and how do you do it, so it is a win-win for all stakeholders. Another project was lighting as a service; there was a pilot that will continue. So, procurement follows along in some of these projects

Enablers

- Sometimes clients can be more flexible than contractors think.
- Consistent long-term strategic government plans will engage contractors and give confidence to innovate.
- Pilot projects to have benchmark processes.

Barriers

- No training of civil engineers and designers on circularity / sustainability.
- The norms and legislation are outdated and does not conform with circularity / sustainability principles.
- There is uncertainty in legislation and policies which acts as barriers to disruptive innovation.
- A change of mentality is needed to develop understanding and examples to be able to bring people into RECE. There is a steep learning curve needed.