Decarbonisation of the Transport Infrastructure Construction

Joint Final Report from the industry and scientific experts Working Groups chaired by Pat Cox, TEN-T coordinator, and Professor Konrad Bergmeister

Decarbonisation of the transport infrastructure construction

Joint Final Report
from the industry and scientific experts Working Groups chaired by Pat Cox, TEN-T coordinator, and Professor Konrad Bergmeister

Contents

Table of abbreviations

BBT	Brenner Base Tunnel
BIM	Building Information Model
BREEAM	Building Research Establishment Environmental Assessment Method
CCP	Climate Calculation Program
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilization
CEF	Connecting Europe Facility
DG MOVE	European Commission Directorate General for Mobility and Transport
EAD	European Assessment Document
EAF	Electric Arc Furnace
EEA	European Environment Agency
EIA	Environmental Impact Assessment
EIC	European International Contractors
EIF	European Innovation Fund
ENCORD	European Network of Construction Company for R&D
EOTA	European Organization for Technical Assessment
EPD	Environmental Product Declaration
ESG	Environment, Social, Governance
ETA	European Technical Assessment
EU	European Union
EU CEAP	EU Circular Economy Action Plan
FIEC	European Construction Industry Federation
FRP	Fiber Reinforced Polymer
GGBS	Ground Granulated Blast Furnace Slag
GHG	Greenhouse Gases
GPP	Green Public Procurement
HVAC	Heating, Ventilation, and Air Conditioning
HVO	Hydrotreated Vegetable Oil
IEA	International Energy Agency
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LEED	Leadership in Energy and Environmental Design
RRF	Recovery and Resilience Facility
RTSHM	Real-Time Structural Health Monitoring
SCM	Secondary Cementitious Materials
SHM	Structural Health Monitoring
STA	Swedish Transport Administration
TELT	Euralpine Tunnel Lyon-Turin
TEN-T	Trans-European Network for Transport
TSI	Technical Support Initiative
UN	United Nations
UNIFE	European Rail Supply Industry Association
WG	Working Group

Prologue

As underlined in the Sustainable and Smart Mobility Strategy published by the European Commission in December 2020, the success of the European Green Deal depends on Europe's ability to make the transport system sustainable. Many different policy initiatives have been launched in recent years to accelerate the green transition of the transport sector, but more are needed to reach the EU objective of delivering a 90% reduction in the transport sector's emissions by 2050.

In this context, and in parallel to a separate workstream addressing issues related to climate change adaptation, the European Commission (DG MOVE) invited two informal groups of external experts to explore the decarbonization potential of the construction sector with a special focus on transport infrastructure. Consultations of both the industry and the academic community were launched in the summer of 2023 aiming to draw up an inventory of existing best practices and emerging innovations for the climate transition of transport infrastructure construction and to make EU policy recommendations, regulatory and/or financial, to stimulate its decarbonization.

The two working groups comprised diverse participants in terms of geography, experience, gender, and function. On the industry side there were European sectoral associations, large construction companies, construction material producers, and infrastructure companies, all active in transport infrastructure projects and the sector's decarbonization. The scientific and academic dimension brought together an active transport decarbonization research community covering a wide range of competence and expertise in sustainability issues. These included the reduction of the carbon footprint of construction materials, circularity in the construction sector, and decarbonization of construction techniques and practices.

The two Working Groups met in person on three occasions in Brussels, in October and December 2023, and in February 2024. This report is a product of their collective input and wisdom and is based on their discussions and subsequent written exchanges. They also heard different services of the European Commission and acknowledged the existence of numerous existing EU policy initiatives relevant for this work.[1]

The report shows that a large range of decarbonization measures already are available covering all phases of the infrastructure life cycle from the pre-construction stage and extraction and manufacturing of materials to recycling and reuse at the end-of-life. It underlines the importance of an integrated approach to maximize decarbonization potential and identifies specific tools and measures to achieve this. The report highlights specific bottlenecks for the rapid and full deployment of those measures and provides a catalog of 24 EU policy recommendations to address them.

The report includes considerations and proposals for potential actions in line with the opinion of the members of the working groups and does not prejudice the official position of the European Commission. The report has not been subject to any specific assessment by the European Commission and hence does not imply its support.

Konrad Bergmeister ***Pat Cox***

[1] This report does not aim at providing an exhaustive inventory of all existing EU policy initiatives which can contribute to mitigating transport infrastructure GHG emissions. It only refers to some of them when they are directly related to its EU policy recommendations.

EXECUTIVE SUMMARY

Every new construction, including for transport infrastructures, must be considered according to its overall sustainability, including social, environmental, and economic aspects. Consequently, it must be designed, constructed, maintained, rebuilt, and dismantled/recycled reducing as much as possible emissions, the volume of natural resources used and primary energy consumption. To achieve this objective, there is a need to move away from the traditional 'linear' working methods to develop a circular economy with life-cycle management of infrastructures.

Best decarbonisation practices already exist across the transport infrastructure life cycle:

a. **Design phase**: The first phase of the transport infrastructure life cycle (materials production, selection and design) constitutes the single most important stage for the decarbonisation of its construction. Different approaches exist to mitigate the need for new construction, to limit the mass of primary materials and resources used and to prioritize the preservation and refurbishment of existing structures. This includes for instance, performance-based design, adaptive design, modular design and optimized structural design. Other strategies involve the selection of construction products, for example, using locally sourced materials, reusing construction products extracted from the deconstruction and demolition of existing structures and selecting low emission products available on the market, such as innovative cement and concrete, green asphalt or recycled steel. Additionally, the integration of energy-efficient design principles and the incorporation of renewable energy sources can play pivotal roles.

b. **Construction phase**: Rapid construction methods emerge as a promising avenue for expediting project timelines while concurrently curbing emissions. This may be done by investing in techniques such as preassembly or prefabricated construction techniques using components made off-site with a more efficient manufacturing process. Other options consist in optimising on-site activities, improving the efficiency of logistical operations and on-site production processes, using zero emission road vehicles, rail or inland navigation, operating machinery powered by renewable energy sources and developing on-site renewable energy generation and on-site waste management.

c. **Operations and maintenance phase**: Proactive maintenance fosters a cycle of continuous improvement and optimization, ultimately contributing to the extension of the infrastructure lifespan, reducing the frequency of resource-intensive construction activities, and consequently minimizing carbon emissions associated with them. Increasing the lifetime of products and assets also contributes to the circular economy by reducing waste generation. This is intrinsically linked with digitalisation, with tools such as Structural Health Monitoring (SHM) helping to accurately predict maintenance, assess performance, and extend lifespan.

d. **Dismantling, preparing for reuse and recycling phase:** A critical juncture lies in the end-of-life phase of infrastructure. In contrast with demolition, deconstruction, characterized by systematic dismantling and salvage of materials, minimizes waste generation and energy consumption while maximizing resource recovery. The principles of zero waste involve optimizing processes to prevent, reduce, and reuse materials, with a focus on minimizing disposal. Pre-demolition audits can play an important role in achieving this.

A key challenge is to mainstream existing best practices and stimulate the emergence of new ones. This requires removing existing obstacles and deploying new innovative tools, mobilising a comprehensive set of regulatory tools and financial instruments, and developing the necessary sectoral skills and administrative capacity.

1. **Moving toward a general use of robust life-cycle assessments (LCA):**

LCA calculations throughout the life cycle of a built asset should serve as a guiding mechanism to make investment decisions as well as identify and address environmental issues during construction, maintenance, and demolition of infrastructure. The EU should therefore ensure that standardised LCAs and whole-life carbon accounting and monitoring methods become a core element of the design process and part of environmental impact assessments for any transport infrastructure projects. This should be paired with the training of construction sector personnel.

To constitute a sound basis for LCAs, facilitate collaboration between all parties and ensure comparability, a European methodology for the calculation, monitoring and reporting of life-cycle carbon emissions at civil engineering works level should be created and promoted to the extent possible. This harmonized methodology should be applied for the assessment of life-cycle costs in tenders falling into the scope of the EU procurement directives. To provide transparency on the environmental performance of products, transport infrastructure needs should be adequately prioritized when implementing the revised Construction Product Regulation.

Digitalization is indispensable to ensure that LCAs can provide standardized analytical tools for all stages of a component or structure’s life. The use of BIM (7D) should be incentivised as an important element of the design and construction processes for all transport infrastructure projects throughout Europe.

2. **Accelerating the industrialisation and use of low emission products:**

There are still different financial and regulatory obstacles to the production, approval and use of low-carbon materials. EU funding should support R&D, validation, and industrialization of advanced materials, of digital tools, efficient construction processes as well as CCS technologies. The European Investment Fund (EIF) should consider specifically the needs of new industry players. To increase demand, the EU should explore the possibilities to introduce minimum shares of low carbon and locally supplied materials, phase-out the use of the most polluting products, require digital product passports and disassemble manuals and create EU-wide databases cataloging best practices. The recycling and reuse of construction products should be further stimulated, for instance by setting appropriate targets and providing guidance to achieve those targets and extend producers’ responsibility for construction waste.

The standardization process for construction materials helps ensure quality, safety, and reliability in the construction environment by providing a harmonized framework for evaluating and verifying product performance. Fast implementation of the new Construction Products Regulation with the adoption and revision of European harmonised standards is therefore crucial to accelerate the placing on the market and use of low carbon materials and stimulate innovation. The EU should promote the use of harmonized standards and European assessment documents (EADs) as the best source of technical information, including for insurance companies, as well as an adequate collaboration between the latter and product standards organizations. The EU should also explore possible ways to allow designers and contractors to use throughout Europe best-in-class low-carbon norms and standards available in specific Member States. As a complement to European standards, the EU should facilitate the rapid adoption of European Technical Assessments.

3. Public procurement and contractual requirements as steering tools:

Public procurement can have a strong steering effect and become a powerful tool to decarbonise construction projects. The EU procurement rules already provide the possibility for project promoters to select contractors based on sustainability criteria in addition to price. However, this is not sufficiently used. The European Commission should therefore consider possible ways to clarify and simplify the existing legal framework for Green Public Procurements (GPP), adopt EU guidance and disseminate existing best practices. Providing training and increasing the administrative capacity of public entities to manage green public procurements would also be important including, if possible, with EU funding.

Because the effect of decarbonization requirements enshrined in public regulation and/or public contracts depends on their transferability into the contractual obligations of contractors and suppliers, these obligations for sustainability performance should be precisely enshrined in contractual clauses. New remedial clauses specifically drafted for the enforcement of sustainability requirements should be developed. The European Commission should facilitate the dissemination of best practices in sustainability contractual clauses, supporting the development of a database of model contracts.

Fostering collaboration between all parties involved in construction projects at all stages of the infrastructure life cycle also plays an important role to optimise decarbonisation. Sustainable design relies critically on knowledge found in construction supply chains. The legal framework for public procurement, contractual law as well as digitalisation measures should facilitate and promote such a collaborative approach rather than an adversarial one.

4. Identifying and rewarding best practices

Developing and promoting robust green certification schemes for transport infrastructure is essential to ensure that best practices are identified, rewarded, and spread across the industry. A harmonized EU framework for green infrastructures (equivalent to Level(s) for buildings) should be developed to support the development of new European certification schemes. To stimulate private investments into green infrastructure projects, the ongoing EU taxonomy work on transport infrastructure maintenance and demolition should be extended to cover the construction phase and all types of transport infrastructure. The EU should also explore the possibility to create and maintain a publicly accessible EU database of green transport infrastructure projects and develop communication tools to promote them.

The European Commission can also have a real impact through the co-financing it provides to transport infrastructure projects. Building upon existing climate proofing and environmental impact assessment obligations, European funding programs should be used to progressively achieve that all projects provide transparency on the carbon impact of their full life cycle and adequately mitigate any potential impact. European funding programs could provide for a minimum set of decarbonization measures, such as minimum circular economy requirements, for all transport infrastructure projects co-financed. In addition, EU programs dedicated to transport infrastructure should consider prioritizing or allocating specific envelopes to flagship projects trialing new decarbonization solutions. For ongoing projects, it is proposed that a dedicated budget be set aside to integrate the latest decarbonization innovations. Finally, interactions between universities, research centers, transport infrastructure managers and the construction sector and education and training initiatives in favor of transport infrastructure decarbonization should be supported.

CHAPTER I – INTRODUCTION

Transport sector emissions and transport infrastructure emissions

Over the last three decades, the EU climate and energy policy framework has resulted in greenhouse gas (GHG) emission reductions in all sectors except in the transport sector[2]. The EU aims to be climate-neutral by 2050 – an economy with net-zero greenhouse gas emissions. This objective is at the heart of the European Green Deal and it is a legally binding target thanks to the European Climate Law[3]. The European Green Deal[4] states that achieving climate neutrality by 2050 requires a 90% reduction by 2050 in transport GHG emissions compared with 1990.

According to the European Environment Agency (EEA), the transport sector accounts for roughly 25 per cent of total EU greenhouse gas emissions. National projections compiled by the EEA suggest that, even with the measures currently planned in the Member States (to support sustainable mobility solutions), domestic transport emissions will only drop below their 1990 level in 2032 and international transport emissions (aviation and maritime) are projected to continue to increase.[5]

Within the construction sector, transport infrastructure, including roads, bridges, tunnels, railways and rail stations, maritime and inland ports, and airports[6], contribute to a significant portion of GHG emissions due to the energy used in the extraction, processing and production of materials ('embodied emissions'), but also heavy machinery used and transportation of materials during construction, as well as the operation and maintenance of the infrastructure and deconstruction. These factors also contribute to high energy usage.

Moreover, construction activities generate a substantial amount of waste, including excavation debris, unused materials, and packaging waste. Transport infrastructure projects often involve large-scale excavation and demolition activities, leading to increased waste generation compared to other types of construction projects. Construction and demolition waste accounted for as much as 37.5% of the EU total waste generation in 2020[7]. A recent study by the Joint Research Centre of the European Commission estimates the potential for ('high-quality') recycling and preparing for re-use of construction and demolition waste to be roughly 83%[8]. Realising this potential would lead to an additional 33-52 Mt GHG emission savings annually, equivalent to at least the combined annual emissions of the three Baltic States.

In this context, there is an urgent need to ensure that any new construction, including for transport infrastructures, is designed, constructed, and maintained while reducing as much as possible emissions, the volume of natural resources used and energy consumption.

---

[2] N.B. In the EU GHG accounting, transport infrastructure emissions are not part of the transport sector emissions, but, as construction emissions, are part of the industry emissions.

[3] Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) 401/2009 and (EU) 2018/1999 ("European Climate Law")

[4] European Commission Communication on the European Green Deal, COM/2019/640 final, 11 December 2019

[5] EEA, transport and environnement report 2021

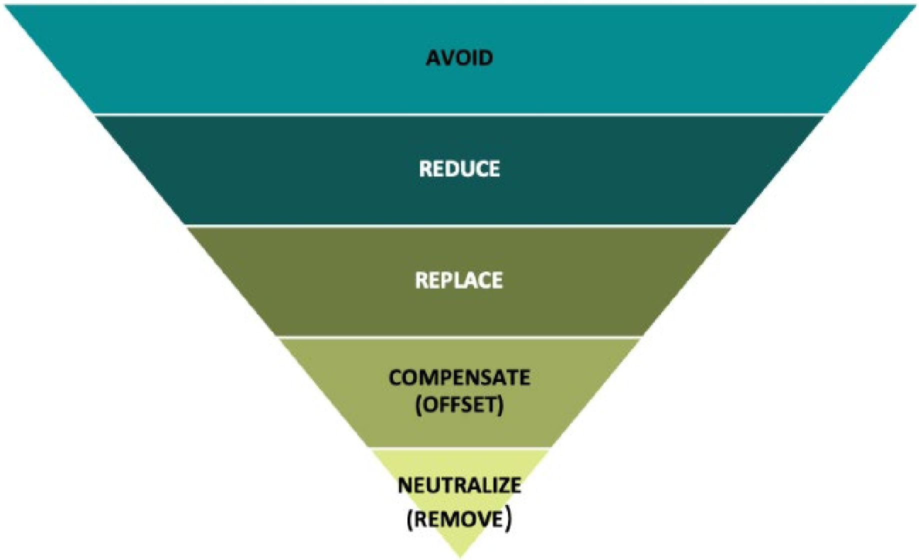
[6] This includes both civil engineering works and specific buildings.

[7] Eurostat, Waste generation by economic activities and households, EU, 2020

[8] Cristobal Garcia, J., Caro, D., Foster, G., Pristera, G., Gallo, F. and Tonini, D., Techno-economic and environmental assessment of construction and demolition waste management in the European Union, Publications Office of the European Union, Luxembourg, 2024, doi:10.2760/721895, JRC135470.

Overall approach to reduce GHG emissions

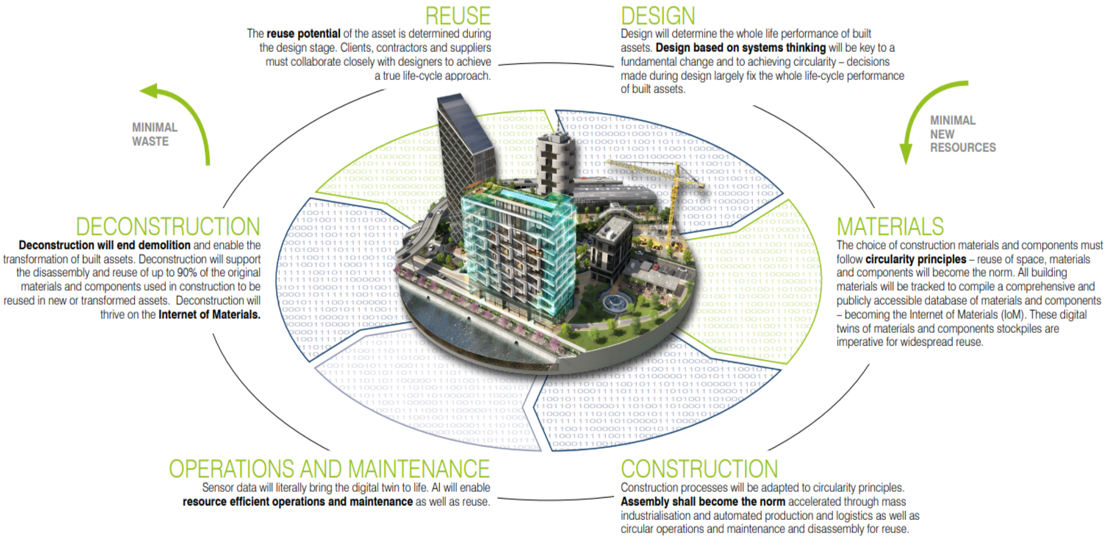
To reduce the climate impact of the construction of transport infrastructure, it is useful to turn towards models such as the "GHG Mitigation Hierarchy" which offer effective actions and strategies to mitigate climate change. This model typically consists of four main steps, often depicted as a pyramid. The first and preferred step in the hierarchy is to avoid projects that would result in greenhouse gas emissions altogether. If avoidance is not feasible, the next step is to minimize emissions as much as possible, notably by reducing the mass of primary materials and resources used. The third step involves restoring or enhancing natural systems that can sequester or absorb greenhouse gases. The final steps in the hierarchy are measures compensating and neutralizing any remaining emissions that cannot be avoided.



Towards a circular economy

Addressing decarbonization efficiently and achieving climate and resource neutrality by 2050 will imply a life-cycle management of infrastructures. A recent joint Manifesto (2023) published by the European International Contractors (EIC), European Construction Industry Federation (FIEC) and European Network of Construction Companies for Research and Development (ENCORD) advocates a shift from the linear to a circular business model to drastically reduce waste production and raw material consumption. 90% of primary resources will need to be reused to achieve carbon and resource neutrality by 2050.

Decarbonizing will therefore require an in-depth transformation of construction methods and practices, with all materials and resources integrated into a circular economy. The life cycle of any construction is divided into 4 main phases: design, construction, operation (including maintenance) and end of life (including deconstruction, recycling and, if needed, disposal). Traditionally, these phases are relatively independent from one another, which means they are each dealt with by different actors (designers, architects, engineers, contractors, infrastructure companies, demolition companies, waste suppliers…). There is a need to move away from such traditional 'linear' working methods to develop a circular economy with life-cycle management of infrastructures.



Every new construction must be reconsidered according to its overall sustainability, including social, environmental, and economic aspects, and consequently designed, constructed, maintained, rebuilt, and dismantled/recycled reducing its environmental impact with a constant focus on emissions, natural resources, and primary energy consumption.

CHAPTER II – BEST DECARBONISATION PRACTICES ACROSS THE TRANSPORT INFRASTRUCTURE LIFE CYCLE

Design phase

The first phase of the transport infrastructure life cycle (materials production, selection and design) constitutes the single most important stage for the decarbonisation of its construction. This phase serves as a critical juncture for limiting the size of the project and its consumption of materials, fostering innovation in design, and enabling the exploration of alternative approaches. This includes, for instance, the possibility to preserve and repurpose existing assets, to develop adaptive design or modular design strategies.

Performance-based design focuses specifically on identifying the necessary performances of the structures to be built in consultation with the relevant stakeholders (owners, operators, etc.) while integrating the various functions of the infrastructure, its serviceability and robustness needs, its durability and environmental exposures as well as its potential for decarbonisation and circularity. Under such an approach, the definition of a long service life can take on great importance.

The Brenner Base tunnel provides a good example of how this approach has led to the definition of a very long service life: while bridges and tunnels are typically designed for a service life of 100 years, its safety limits have been set for a 200-year long service life.

Adaptive design in the context of construction and infrastructure refers to a flexible approach to design structures or systems that can adjust and respond to changing needs or conditions over time. It involves creating solutions that can evolve and adapt to varying circumstances, such as shifts in user requirements, life-time extensions, technological advancements, or environmental changes.

Modular design subdivides construction systems into similarly designed modules, and components of infrastructure. Thereby it makes it easier to dismantle them for the modification, maintenance, and reuse of the infrastructure in question.

Such strategies not only mitigate the need for extensive new construction but also prioritize the **preservation and refurbishment of existing structures**, thereby prolonging their operational lifespan. This reduces the frequency of replacements and, consequently, the environmental impact associated with the construction and treatment/disposal of materials.

By prioritizing **circular economy** and life-cycle management in the conceptual design phase, engineers and architects have a crucial role to play to set the foundation for environmentally responsible and resilient infrastructures.

Designers have the possibility to further limit carbon intensity by working with circular methods, for example using **locally sourced materials** as well as the reuse of construction products, including structural elements extracted from the deconstruction and demolition of existing structures. The example below on the reuse of excavated materials for the Lyon-Turin base tunnel project illustrates how the use of excavated materials avoids the need to produce construction materials and therefore reduces associated emissions.

Case study – reuse of excavated materials for the TELT Lyon-Turin project (France-Italy)

The Lyon-Turin project foresees a total volume of 37.2 million tons of excavated material over a period of 10 years; a considerable part (up to 55%) of these materials will be used for the tunnel lining (concrete or railway embankments) and for the embankments of the open-air sectors, while the remaining part will be transported by rail, conveyor belts and heavy vehicles to the temporary and permanent storage sites managed by TELT and/or to external sites as part of material recovery operations. The key figures of this process are:

1) The distribution of the various emissions, observed in the perimeter of TELT, shows that the production of construction products, and in particular concrete, represents the main source of emissions (93.4%), followed by fuel consumption of construction machinery (3.2%) and by railway equipment (2.7%).

2) The transport of excavation materials represents a very low share of emissions, due to their reuse within the perimeter of the project. This ensures proximity between construction sites, processing sites and some of the disposal sites.

Emissions related to the transport of excavation materials represent around 19 kTeqCO2, that is only a quarter of what would have been emitted if the materials were not reused on site but transferred to disposal sites in the regions of Lyon and Milan.

Additionally, the integration of **energy-efficient design** principles and the **incorporation of renewable energy sources** play pivotal roles in enhancing the sustainability of construction processes for transport infrastructure. Energy efficiency within design practices relates to the production of products, the construction logistics and the operational phases. By implementing energy-efficient design strategies (e.g., integrating cables in other linear infrastructure such as roads, design metro stations to benefit from natural light, group renewable energy production systems to optimize the grid, incorporating advanced lighting, heating, ventilation, and air conditioning systems…) the overall energy consumption of infrastructure can be significantly reduced.

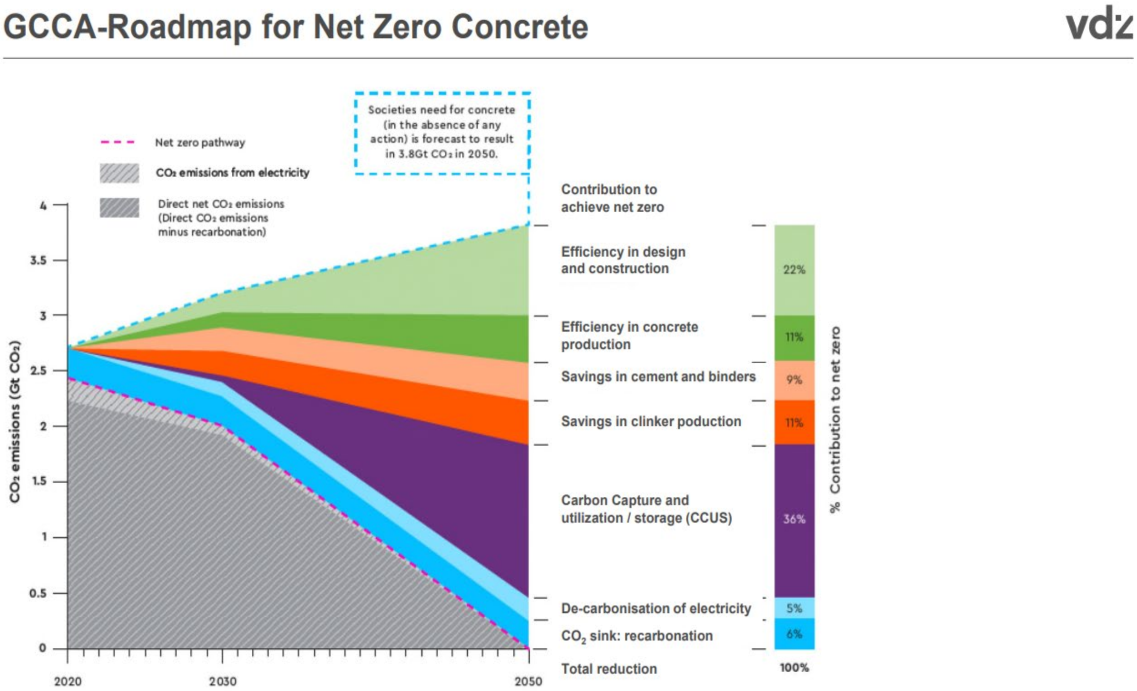
Limiting the carbon footprint of transport infrastructures also implies a focus on reducing the use of carbon intensive products. **Optimized structural design** is a process for designing structures in a way that maximizes performance, efficiency, and sustainability while minimizing material usage, primary energy consumption and waste.

Case study - Project Kalix Bridge (Sweden)

By using a higher steel quality, it was possible to decrease the amount of steel used with an estimated carbon reduction of 10-20 %. Through different measures, the project's climate impact has been reduced by 27 eqCO2 tons per year during the whole construction life cycle, amounting to 22% of the carbon impact.

To enhance the sustainability of construction infrastructures, a pivotal strategy involves combining the design and the selection of construction products to minimize carbon emissions. Concrete, steel, and asphalt are commonly selected in the design phase of construction for transport infrastructure. Reducing the carbon-intensity of such widely used materials can happen through carefully **selecting low emission products**.

The carbon roadmap of the cement industry presented by the German VDZ below illustrates the different technological avenues that have started to be implemented to reach net-zero by 2050 in the life cycle of concrete.



For concrete, decarbonization measures relate to the utilization of low-clinker cements already available and specified in European standards such as CEM III, CEM IV, CEM V and more recently CEM VI and CEM II-C, along with the integration of CO2-reduced concretes with performance-based concretes. Additionally, the incorporation of secondary cementitious materials (SCM), such as higher proportions of ground granulated blast furnace slag (GGBS) and fillers, recycled concrete fines and aggregates, and calcined clay has a clear decarbonization potential. These technologies are already widely used. Since 2023, new technologies for **innovative low carbon cement and concrete** have been implemented. These products are fully fit for transport infrastructure construction and renovation. They show a carbon reduction potential above 50%.

Regarding **asphalt production**, efforts are directed towards increasing recycled content, controlled storage of aggregates to reduce the need for drying, switching fuels for drying and substituting traditional bitumen with low-carbon materials. These different initiatives involve investigating alternative materials and fuels.

Furthermore, smart technologies in the production processes of both concrete and asphalt such as Carbon Capture and Utilization (CCU) are already used to store CO2 using it efficiently to benefit material durability.

Options for the substitution of traditional steel with **low emission steel products** or Fiber Reinforced Polymer (FRP) are investigated and already used in prototypes. In recent years, there also have been several innovations and progress in the production of more sustainable steel. Some green steel initiatives focus on developing alternative production methods that eliminate or reduce the reliance on carbon-intensive processes (e.g., renewable hydrogen-based ones). To reduce the need for virgin raw materials, circular economy processes have also become more common in this sector with the recycling of scrap steel to produce new steel. The Electric Arc Furnace (EAF) Technology utilizes scrap metal as the primary raw material. Compared to traditional blast furnaces, it has a lower primary energy consumption and emits thereby fewer greenhouse gases. The quality of steel produced thanks to these alternative technologies is largely sufficient to meet construction requirements.

The two examples below illustrate how transport infrastructure projects reduced the CO_2 impact of materials used in construction.

Case study – West Link Centralen subproject in Gothenburg (Sweden)

In the construction of the West Link subproject Centralen in Gothenburg (Sweden), low emission concrete where 30–50 percent of the cement has been replaced with granulated blast furnace slag, made Centralen one of Sweden's largest projects to use such improved concrete. This reduced carbon dioxide emissions by a full 45 percent compared to traditional concrete, equivalent to almost 36,000 tons in reduced CO_2 emissions. This also reduced the need for cement as a raw material. This solution was developed during the construction planning phase as a collaborative action between the contractor and the material developer.

Case study - U5 metro line in Hamburg (Germany)

Only low-clinker cements are used for the construction of the U5 metro line in Hamburg. From 2025, CO_2-reduced steel will be added, and from 2028, only cements with partial CO_2 capture (separation and storage of CO_2) will be used in the production process. By 2035, cements with 100% CO_2 capture in the manufacturing process should be available. With these savings at the material level, the CO_2 emissions from the construction of the entire U5 can be reduced to around 850,000 tonnes. If the U5 had been built without the CO_2 reduction strategy now in place, the value of CO_2 emissions would have been around 2.7 million tonnes.

Construction phase

Reducing emissions during the construction phase stands out as a pivotal step in the broader life cycle of construction works. In this phase, there are two main areas of intervention to reduce GHG emissions: the construction methods and the on-site activities. On-site activities relate to the efficiency of logistical operations (transport vehicles, machinery and production processes), on-site renewable energy production and on-site waste management.

Rapid construction methods emerge as a promising avenue for expediting project timelines while concurrently curbing emissions. Their efficiency lies in minimizing construction duration, thereby reducing primary energy consumption and emissions compared to traditional construction periods. This may be done by investing in time-saving construction technologies, for instance through preassembly or prefabricated construction techniques using components made off-site with a more efficient manufacturing process. Rapid construction techniques can also reduce hindrances to traffic, thereby mitigating the indirect CO_2 emissions associated with transport detours. As such, significantly shortening construction times and minimizing disruptions to traffic flow contribute to the decarbonization of the transport sector.

Zero-emission transport for materials, machinery, and people can play an important role. The deployment of alternative fuels for road transport along with modal shift to inland waterways and rail can lower emissions, reduce road congestion, and offer energy-efficient alternatives. Inland waterways and rail can be particularly efficient for transporting large quantities of materials, reducing the need for multiple trips by road, which can be both time and energy consuming.

The management of zero-emission machinery, particularly hybrid and fully electric drive on track machines, represents a transformative shift toward more sustainable construction methods for transport infrastructure. **On-site machinery** powered by renewable energy sources such as Hydrotreated Vegetable Oil (HVO), electricity from renewable sources or renewable hydrogen produces little to no direct emissions, improving air quality in construction areas. By eliminating or minimizing carbon emissions, they can help reducing the overall carbon footprint associated with construction activities. Some machinery also utilizes regenerative braking, converting kinetic energy back into stored energy, which can improve overall energy efficiency and reduce wear on braking systems. Moreover, certain zero-emission technologies tend to operate more quietly than traditional combustion engines, also reducing noise pollution in construction sites and surrounding areas. Although the availability of electric heavy machinery for construction sites is not yet widely available on the market, there are examples of best practices of actors making use of innovations within the industry.

Case study - NCC (Sweden)

NCC has tested electrical machinery such as excavators (15 and 30 tons, with and without cable), an electric piling machine and a mobile electric crusher in different construction projects. In the Bergsbyn project where a mobile electric crusher was used, CO_2 emissions were reduced by 99% by using renewable electricity. In the two projects where electric excavators were used, it was estimated that CO_2 emissions were reduced by 80%.

The NCC-OHLA consortium is responsible for the 4-track Malmö Lund project. The two largest transport companies there have switched 80–100 percent to Hydrotreated Vegetable Oil (HVO) diesel. The largest construction contractors use 100 percent renewable fuel for their machines. A tank station for HVO diesel has also been installed on the project site where both trucks and machines can refuel.

Establishing a **local supply chain** for secondary as well as primary raw materials, developing **efficient on-site production processes,** and strategically locating precast plants (e.g., situating concrete production on-site and utilizing excavated rock material as aggregate material) can also significantly reduce transport emissions, fostering an eco-friendly and efficient construction process. Emphasizing re-use in situ and the in-place recycling of materials becomes crucial and embracing innovative concepts such as 'Urban Mining’ not only maximizes benefits but also minimizes the environmental impact associated with long-distance transportation of recyclables.

The adoption of “lean logistics” principles ensures a streamlined and resource-efficient approach to transportation, emphasizing the importance of eliminating waste and optimizing processes. By filling trucks to capacity and avoiding unnecessary transport, the construction sector can minimize the environmental impact associated with transportation, contributing to a more sustainable and eco-friendly development of transport infrastructure.

Case study – Brenner Base Tunnel SE (Austria)

The tunnel spoil (21,5 Mio. m^3) is transported by conveyor belts (total length ca. 180km) with a capacity of about 300 m^3/h each from the tunnel advances (tunnel boring machines or dropping position for drill and blast advances) directly to the deposits. The segmental lining is produced on site or, if local conditions are not appropriate, it is directly transported by rail. This measure reduces the transport and reduces the inconvenience to local residents.

On-site energy generation and grid connection are another crucial factor. By optimizing site set-up, construction projects can achieve faster connections to grid electricity, facilitating the electrification of machinery, vehicles, and compounds (and avoiding the need for diesel generators). This not only reduces the reliance on traditional fossil fuel-powered generators but also minimizes on-site emissions, contributing to a cleaner and more sustainable construction process. In cases where grid electricity is not readily available, the incorporation of on-site energy generation, such as solar, wind power and geothermal energy, becomes instrumental. Additionally, the use of renewable hydrogen generators provides a viable alternative, offering a clean energy source when grid electricity is not feasible.

Case study – Brenner Base Tunnel SE (Austria)

The geothermal heat of the Brenner Base Tunnel drainage water (70L/s 18°C) is used within an energy network (low temperature network for heating and cooling, cold district heating) during building and operation phases. The energy network will be connected at the portal in Innsbruck to the network of local energy and heat suppliers. Thus, different facilities such as operational railway buildings, geothermal facilities, cooling devices, and other buildings will be connected to this grid for efficient local heat and cooling.

Effective **on-site waste management** and the adoption of zero waste techniques are integral and fundamental components in advancing sustainability within the construction of transport infrastructure. The principles of zero waste involve optimizing processes to prevent (e.g., through re-use), reduce, and recycle materials, with a focus on minimizing disposal. Construction projects can strive for zero waste by implementing practices such as prefabrication, which reduces on-site waste generation, and by incorporating circular economy principles to extend the lifespan of materials. On-side separate collection of waste is key in this process.

Case study - TELT Lyon-Turin site (Italy)

The contractor made the commitment to ensure zero emissions for the activities on its Italian work site. Moreover, the Turin-Lyon cross-border section project envisages the possibility of making geothermal resources available to the region. On the Italian side, for example, based on the minimum and maximum temperatures of the water intercepted, the available thermal powers ranged from 9.3 MW to 14.4 MW. These were determined on the assumption of exploiting the geothermal resource up to a temperature of 20 °C. Given these availabilities, the utilization solutions are varied, from district heating in the neighboring villages, to hydroponic greenhouses, to heating public buildings (e.g., swimming pools). To date, the resource is used to heat the TELT Visitor Centre in Chiomonte. Compared to a traditional heating system (e.g., a condensing boiler), the saving of primary energy is approx. 264 MWh, resulting in a reduction in CO_2 emissions of approx. 57 t/year.

Operations and maintenance phase

An efficient management of the operations, use, and maintenance phase of projects can significantly impact sustainability goals. By fostering **proactive maintenance practices**, the lifespan of infrastructure can be extended, reducing the frequency of resource-intensive construction activities and consequently minimizing carbon emissions associated with them. Increasing the lifetime of products and assets also contributes to the circular economy by reducing waste generation.

This is intrinsically linked with **digitalisation**. In fact, embracing a fully connected ecosystem with continuous monitoring capabilities not only ensures the optimal functioning of transport infrastructure but also facilitates real-time data collection. Incorporating comprehensive Structural Health Monitoring (SHM) for both new and existing structures can help accurately predict maintenance, assess performance, and extend lifespan. SHM is already often used within the sector to assess energy performance and structural defects in construction parts and materials. This is usually done involving the use of various sensors, data acquisition equipment, and computational techniques. In addition, by enabling data-informed assessment of performance, life span extension can be accurately verified, predictive and periodical maintenance organized, and input to proactive (condition-based) asset management provided. Integrating artificial intelligence alongside human expertise enhances the interpretation of this data, enabling swift identification of maintenance needs. Digital product passports can also support this aim.

Many of these existing technologies still have to be scaled up for larger infrastructure projects. Bridging the gap between science/research and industry through flexible testing and piloting stages would allow for the better incorporation of these sustainable innovations. The examples below showcase how the use of real-time SHM can address issues linked to the operations and maintenance phase of transport infrastructure.

Case study – Smart bridges project (Greece)

The project "Smart Bridges" in Greece that is going to start in 2024 (now in the final stages of the tendering process) focuses on the monitoring of 260 bridges through the Greek territory. Most of these bridges were constructed between the 1950s and 1980s and are now facing ageing problems due to their exposure to adverse and corrosive conditions. Additionally, the regulations under which these bridges were designed during this period are considered outdated today as they did not have specific provisions for durability, seismic resistance, and construction methods. The increasing trend in traffic volume and the size of transported loads leads to increased loads on the bridges. In several cases, these loads exceed the design loads and ultimately create structural integrity problems. Especially for bridges over water bodies, the maximum water levels are expected to significantly increase due to climate change. Furthermore, Greece is a seismic-prone country, and bridges in high seismic risk areas have been affected by earthquakes of moderate to strong intensity over time. The absence of a monitoring system, accurate documentation of structural condition, and regular inspection and maintenance of bridges may compromise their structural safety.

The proposed smart bridge project will consist of monitoring stations with a continuous real-time structural health monitoring system (RTSHM) on bridges under the responsibility of the respective regions. These stations will record the response of structural members to any external factors (moving loads, accidental loads, temperature changes, etc.) and send measurements to a central unified online platform to perform real-time assessment of the structural vulnerability of bridges under normal operating loads and the clear determination of maximum allowable crossings (control of maximum deformations). This approach achieves early failure prediction (situational awareness), allows for immediate decision-making, and ensures resource savings through prioritizing maintenance and reinforcements where they are truly needed.

Such tools should ideally be integrated in the infrastructure project as early as the preliminary design stage. This proactive maintenance approach fosters a cycle of continuous improvement and optimization, ultimately contributing to the extension of the infrastructure lifespan. Considering the operations, use, and maintenance phase within a holistic approach to the infrastructure development is a key strategy to reduce material consumption and waste generation over time.

Dismantling, preparing for re-use and recycling phase

By adopting circular approaches[9], such as reuse, preparing for re-use, recycling, and resource recovery, throughout the life cycle of infrastructure projects, substantial reductions in carbon emissions can be achieved. Some positive results can already be achieved during, and at the end of the construction phase already. Reusing products on-site or employing recycled materials in construction processes not only minimizes the environmental impact but also conserves valuable resources. However, a critical juncture lies in the end-of-life phase of these projects.

Traditional demolition practices not only contribute to significant waste generation but also require substantial energy inputs, exacerbating environmental burdens. In contrast, advocating for **deconstruction over demolition** and renovation over new built offer a more sustainable approach. Deconstruction, characterized by systematic dismantling and salvage of materials, minimizes waste generation and energy consumption while maximizing resource recovery. This shift necessitates strategic decisions during the design phase, emphasizing adaptive design principles that facilitate the disassembly and repurposing of structures (see above). The principles of zero waste involve optimizing processes to prevent, reduce, and reuse materials, with a focus on minimizing disposal. Pre-demolition audits can play an important role in achieving this.

Currently, principles for determining the design life and safety of a structure where some of the structural elements are derived from the dismantling of old structures need to be developed.

There is still too little emphasis on the maintenance and extension of the service life of existing structures, which are therefore demolished, to then be re-built again. The first consideration should always be given to whether existing structures can be saved – even if they require repair or significant upgrading – and at least to whether the entire structures or their components can be reused.

[9] in line with the Waste Hierarchy set out in the Waste Framework Directive (2008/98/EC)

CHAPTER III – HOW TO STIMULATE THE DEPLOYMENT OF DECARBONISATION MEASURES?

There are many examples of construction best practices which can already contribute to the decarbonisation of transport infrastructure and Chapter II provides some concrete cases where such measures have already been applied. A key challenge is to mainstream such measures and stimulate the emergence of new ones. This requires **removing existing obstacles and bottlenecks and deploying new innovative tools, mobilising a comprehensive set of regulatory tools and financial instruments, and developing the necessary sectoral skills and administrative capacity**. **The EU can play an essential role in this respect**.

Moving toward a general use of robust life-cycle assessments (LCA)

In the construction sector, a crucial tool for the consideration of environmental impacts of a product, process, or service throughout its entire life cycle has been the development of Life Cycle Assessments (LCA). LCA provides a comprehensive understanding of the environmental footprint associated with transport infrastructure. This includes emissions deriving from raw materials acquisition, manufacturing processes, transport of products and materials, installation, maintenance, reparation, refurbishment, energy consumption, water consumption, demolition, reuse, recycle and disposal of the infrastructure. However, for the robustness of the assessment, the quality of the used data is crucial. For the manufacturing process, specific data should be used (e.g. the data on manufacturing installations covered by the EU ETS as collected in the development of the ETS Benchmarks).

LCA as a crucial tool for a comprehensive understanding of an infrastructure carbon footprint

LCA calculations throughout the life cycle of a built asset should serve as a guiding mechanism to identify and address environmental issues. The use of LCA in quantifying environmental impacts, including within Environmental Impact Assessments (EIA), provides a robust framework for addressing mitigation measures, reinforcing the integration of environmental considerations into the core of infrastructure decision-making processes.

Conducting a comprehensive LCA can for instance inform decisions regarding design optimization and end-of-life considerations. It has also emerged as a pivotal tool to evaluate the environmental impact of products, offering key insights crucial for making informed decisions in product selection. The general layout and the selection of products for a construction project are often made by the designer, which shows the importance of targeting this stage of the construction process. LCA helps in requirements-based design and in the selection of products with lower environmental impacts. This includes considering different factors such as the primary energy intensity of production processes, the distance materials travel to the construction site, and the potential for reuse or recycling at the end of the infrastructure's life. Whole life carbon accounting and monitoring should then continue throughout the construction, operation, and demolition phases to identify areas for improvement and ensure compliance with environmental standards.

In certain countries, such as Sweden, conducting a comprehensive LCA is already mandatory for transport infrastructure projects above a certain budget.

Case study - Sweden

In 2016, the STA (Swedish Transport Administration) developed a LCA-based tool specifically for transport infrastructure projects called the *Climate Calculation Program* (CCP). The tool calculates the energy usage and climate impact of transport infrastructure from a life-cycle perspective. The program considers how changes related to both construction, operation and maintenance can contribute to reducing climate impact in road, railway and bridge projects.

According to the STA this tool plays an important role in identifying how the climate impact in relation to infrastructure construction can be further reduced. The tool follows the basic principles of a LCA according to the ISO 14044:2006 standard. Several versions of the tool are available, the latest one 7.0 since 2019. The latest version setting out its guidelines and purpose can be found on the STA's website (klimakalkyl.trafikverket.se), as well as a manual for using the tool. A public version of the tool is available online where analysis can be done in the same way as the non-public version of the CCP with equal emission factors but with own input of data. The tool is mandatory for projects exceeding SEK 50 million (€4.4 million) in investment costs but is not used retrospectively for completed projects.

<u>Suggested EU measures/policies:</u>

- ➔ Standardized LCAs, and whole-life carbon accounting should become a core element of the design process, ensuring a holistic and continuous evaluation of environmental and economic factors, while making sure that potential issues related to its practical application are adequately addressed. The working groups recommend that the use of such tools should become a part of Environmental Impact Assessments (EIA).
- ➔ Implementation of LCAs should be paired with the training of construction sector personnel, whether at a student, graduate, employee, or researcher level. Developing such skills among construction professionals, including at university level and as part of long-life learning, should be a core part of any new European skills initiative, such as the one taken as part of the EU Blueprint for Sectoral skills.

Common methods for reporting environmental impacts.

Different methodologies and software to measure, monitor and report emissions under LCAs might be used depending on the countries, projects, and companies where they are implemented. The comparability of LCA results therefore remains questionable today. Issues that may affect results include the limited availability of reliable life cycle data, the lack of practical calculation software tools, and the lack of trained professionals able to uptake LCAs in the construction sector. This highlights the need to establish common methodologies for measuring, monitoring and reporting carbon footprints, backed by third-party scientific committees.

A common method for the reporting of environmental impacts for construction products relies on the use of Environmental Product Declarations (EPDs). These standardized and verified reports communicate the environmental impact of a product throughout its life cycle and are based on a set of rules and guidelines, such as ISO 14025 and EN 15804, which ensure consistency and comparability across different products.

The new Construction Products Regulation will establish mandatory requirements as regards environmental information based on EN 15804 methodology. Products placed on the European market according to new harmonized standards will deliver information about their CO2 emissions over the life cycle of the product. The number of mandatory indicators will be increased in 2029 and 2031 to cover all relevant life cycle assessment indicators. The new regulation also includes the adoption of Digital Product Passports to transfer this information from construction products.

Suggested EU measures / policies:

- ➔ To the extent possible, a European common methodology for the calculation, monitoring and report of life-cycle carbon emissions at civil engineering works level should be created and promoted, notably to facilitate collaboration between all parties in any project and to ensure product environmental information is properly used and to ensure product environmental information is properly used. This common methodology would be applied for the assessment of life-cycle costs in tenders falling into the scope of the EU procurement directives.
- ➔ Implementing the recently revised Construction Product Regulation implies developing new transparency requirements on the environmental performance of products. In this context, transport infrastructure needs should be adequately prioritized.

Digitalisation, an essential enabler

Digitalisation is indispensable to ensure that LCAs can provide standardised analytical tools, considering different environmental indicators for all stages of a component or structure's life. Information needs to be collected and shared with all parties from the initial design phase and throughout the project life cycle and constantly updated to assess project changes and to contribute to an iterative process of LCA calculations' improvement. This is only possible through the help of smart, data-driven digital tools such as Structural Health Monitoring (SHM) and Building Information Model (BIM 7D) and digital twins. For instance, the use of BIM enables optimization, from the design phase, the logistics of dismantling and disposing of construction elements while reducing waste, emissions, and noise for the various phases.

Data should also be recorded and stored as "built structural data" to facilitate future reuse and refurbishment of infrastructure. This again is achievable through the BIM digital tool which supports a centralised structural database for sustainability reporting and allows for the integration of all project parties within the building project. A widespread use of high-level BIM relies on the development of digital standards, digital competencies, and standardized digital obligations in construction contracts.

The combination of LCA and BIM is key to implement LCA into all phases of a construction project. Life-cycle management requires accurate and extensive building information modelling for the various design disciplines and life-cycle phases. In certain countries, such as Italy, conducting building information modelling is already mandatory for public infrastructures.

Suggested EU measures / policies:

- ➔ The use of BIM (7D) should be incentivized as an important element of the design and construction processes for all transport infrastructure projects so that the digital twin of the construction project can be created, updated and followed throughout the different phases of construction and use.

Accelerating the industrialisation and use of low emission products

Elevating sustainability practices at the level of material production constitutes a fundamental step in fostering a more environmentally responsible construction of transport infrastructure. However, while low-carbon materials already exist, there are still different obstacles to their production, approval and use which need to be overcome.

From R&D to industrialisation of low emission materials and solutions

Full deployment of low emission materials still requires important R&D efforts. For example, ongoing research in technologies that capture and repurpose carbon dioxide in the production of materials showcases a commitment to mitigating greenhouse gas emissions which should be accelerated.

Upgrading existing manufacturing processes and shifting to new ones offers an important potential to enhance resource efficiency and reduces environmental impact. For construction products like cement, new sustainability techniques in production processes include incorporating blenders, energy-efficient mills, and kilns[10]. Optimized production methods can be achieved through powering material production facilities with renewable energy sources (e.g., 'green' steel produced with renewable hydrogen).

Other promising ways to reduce the carbon footprint associated with construction materials relate to increasing the durability and promoting lifespan extension of these materials as well as making sure they can be easily disassembled, re-used and recycled.

<u>Suggested EU measures / policies</u>

- ➔ The EU funding program Horizon Europe and its successor should dedicate particular attention to research and development and quick validation for the scaling-up and industrialization of advanced materials, of digital tools, efficient construction processes as well as Carbon Capture and Storage (CCS) technologies focusing on transport infrastructures.
- ➔ The European Innovation Fund supports demonstration of zero-emission technologies. In this context, it already provides funding to the green transition of industrial sectors involved in transport infrastructure construction, notably to large existing emitters belonging to the cement and steel industries. In the future, more attention should be dedicated to low-carbon innovative solutions brought forward by new industry players, so that the latter can scale up their innovative offers.
- ➔ There should be more incentives for circular construction solutions. Based on Member States best practices, the recycling and reuse of construction products should be further stimulated, for instance by setting appropriate targets and providing guidance to achieve those targets.
- ➔ The EU should explore the possibilities to introduce minimum shares of low carbon and locally supplied materials, phase-out the use of the most polluting products, extend

[10] Kiln: thermally insulated chamber, essentially a type of oven, that generates temperatures sufficient to complete various processes.

producers' responsibility for construction waste and require obligatory digital product passports and disassemble manuals.

➔ Creating EU-wide databases cataloging best practices would also serve as a valuable resource for designers, enabling informed material selection with referenced justifications.

Faster and easier standardisation of the most innovative construction products

The standardization process for construction products helps ensure quality, safety, and reliability in the construction environment by providing a harmonized framework for evaluating and verifying product performance.

Construction products are subject to harmonization based on European standards that provide reliable information based on their performance. The new Construction Products Regulation establishes the framework to revise and adopt European standards for construction products including detailed methodologies for the assessment of the environmental performance. Its implementation is key to ensure the provision of reliable and accurate information. Ensuring that these European standards are universally adopted and implemented is paramount for a cohesive and effective approach to sustainable material production.

The new European standards are expected to cover also innovative and new technologies because they will be based on the performance of the product instead of focus on their manufacturing process of the materials used. Simultaneously, existing national technical standards and guidelines should be adapted to foster innovation, aligning them with the European performance-based criteria and clarifying considerations for circularity and reuse.

Standards adopted at European level require the withdrawal of similar standards at national level. This approach ensures a more harmonized approach in Europe but is not applicable in the international market. Nevertheless, it is expected that the integration of technical and environmental methodologies in European harmonized standards will be replicated in the international markets as the best way to ensure homogeneous implementation of environmental policies.

A common issue is the long time required by the procedure to get new products assessed and placed into the market. More efforts should be made towards the development of fast-track product certification for key materials and the adoption of common guidelines for the identification and classification of low-carbon materials, based on emission levels akin to energy consumption certification. Additionally, enabling design-by-testing procedures should speed up knowledge transfer between R&D to on-field practical applications.

The Construction Products Regulation offers a parallel route for products outside of the scope of harmonized standards. They can be assessed using the same legal structure of the CPR but based on a European Assessment Document (EAD) developed for that purpose. This route is especially relevant for innovative products and offers the possibility to provide reliable technical and environmental information for those products not ready to be standardized. The European Organization for Technical Assessment (EOTA) is the organization responsible for coordinating the development of EADs.

Suggested EU measures / policies:

- ➔ Fast implementation of the new Construction Products Regulation is crucial to accelerate the placing on the market and use of low carbon materials and stimulate innovation. The working groups suggest exploring ways to accelerate the revision of existing European standards and the adoption of new ones, prioritising key materials.

- ➔ Promoting the use of harmonized standards and European assessment documents (EADs) as the best source of technical information for insurance companies as well as an adequate collaboration between the latter and product standards organizations are vital to ensure that innovative products are adequately covered by insurance, preventing any potential setbacks in project implementation.

- ➔ The EU should also explore possible ways to allow designers and contractors throughout Europe to use best-in-class low-carbon norms and standards available in specific Member States and to overcome the insurance companies' reluctance to allow deviations from local standards and practices.

- ➔ As a complement to European harmonized standards, the working groups suggest considering how the rapid adoption of European Technical Assessments can be facilitated and how to ensure that EOTA has sufficient internal resources to support this process.

Public procurement and contractual requirements as implementation tools

Facilitating green public procurement

Public procurement can have a strong steering effect in the construction sector and is a powerful tool to incentivise a shift towards low carbon construction projects. The EU procurement rules already provide the possibility for project promoters to select contractors based on sustainability criteria in addition to price. However, this is not sufficiently used due to complexities in defining such criteria, some legal uncertainties and risks associated with them, and because of a lack of administrative capacity to do so. The effect is that public entities are hesitant to award public contracts based on environmental criteria and to include sustainability requirements into their supply chains.

Suggested EU measures / policies:

- ➔ The European Commission should consider possible ways to clarify and simplify the existing legal framework for Green Public Procurements, adopt EU guidance and disseminate existing best practices, clarifying how environmental criteria should be introduced in tender documents under the form of technical specifications, selection criteria, award criteria and/or contract performance condition and calling for a systematic use of emission assessment calculations, and low emission products and processes in the construction sector.

- ➔ As there is a strong need to increase the administrative capacity of public entities to manage green public procurements, providing training to such entities, for instance through instruments such as its Technical Support Instrument (TSI), is considered important.

Enforceable sustainability provisions in contractual law

The effect of decarbonization requirements enshrined in public regulation and/or public contracts depends on their transferability into the contractual obligations of construction projects contractors and construction supply chains. The requirements for sustainability performance should be precisely enshrined in contractual clauses (regardless of whether they relate to emission calculations or the use of specific types of products), rather than defined by way of non-mandatory recommendations, due diligence, benchmark procedures or 'best effort' demands.

With LCA providing a standardized assessment of a project's environmental performance there is a degree of transparency allowing stakeholders to better understand and communicate potential environmental impacts and fostering accountability. However, it is important that contractual clauses define not only the environmental indicators to be assessed but also the measures that must be implemented based on this assessment. For example, legal solutions (i.e., in the form of long-term warranties or insurance) should be found to ensure the reuse of built structures. As reusing elements of existing structures will always be a more expensive solution, building a new structure will therefore remain the preferred option in the absence of legal obligations. Related best practices in contractual law should therefore be identified, collected, and promoted as contractual models.

Generally, **existing standard form contracts for construction and domestic construction contract law are not suitable to make sustainability requirements enforceable**. The employer's primary claim if the contractor does not comply with quality specifications is typically that the contractor remedies the defect. Such remedy (consisting of de- and reconstruction of works) will, as a rule, contradict the purpose of the sustainability requirements and negatively impact the overall footprint. New remedial clauses specifically drafted for the enforcement of sustainability requirements (such as the use of bonuses/awards, exit clauses, fines/liquidated damages, etc.) must therefore be developed and spread swiftly into supply chains and markets.

<u>Suggested EU measures / policies:</u>

➔ The European Commission should facilitate the dissemination of best practices and templates for sustainability contractual requirements, supporting the development of a database of model contracts for their collection and storage, building on the experience already gained with the "Big Buyers' Initiative on public procurement" launched by the European Commission.

Early involvement of contractors and new collaborative approach

In pursuit of a more sustainable construction approach in the transport infrastructure sector, fostering community engagement also plays an important role. Sustainable design relies critically on knowledge found in construction supply chains, i.e., with the subcontractors and suppliers for the specific project. To optimize access to this knowledge, contractors and suppliers should be involved in the projects as early as possible and at different milestones. For instance, they first could be selected on a competitive basis and remunerated to contribute to the design and then again when works are tendered out (under a so called 'two-bid procedure').

Furthermore, decarbonization will call for collaborative rather than discrete (adversarial) standard construction contracts for the governance of innovative sustainable design processes. Under such new type of contracts, contractors and suppliers would also benefit from innovative results and from the achievement of decarbonization targets. Contractors and suppliers' involvement in the design of decarbonization measures will enable alignment between commercial and climate policy interests and support both implementation and enforcement of emission requirements. Such alignment may be further strengthened by contractor involvement in operation and maintenance.

The complexity of decarbonization measures and the required early and collaborative involvement of contractors and suppliers in low-emission design also entails a need for the use of high-level digital documentation, tracking and monitoring systems in the design and construction phase. Low-emission construction contracts must include legal commitments for the use of high-level BIM. The use of digital tools (for instance integrating BIM with Digital Products Passports providing technical and environmental information, requiring digital twins in contracts, with data-driven asset management) should be promoted in public procurement, for the design and construction phases and supported by training efforts to enhance digital competences.

Suggested EU measures / policies:

➔ The legal framework for public procurement, contractual law as well as digitalisation measures should facilitate and promote collaboration between all involved parties in construction projects at all stages of the infrastructure life cycle.

Identifying and rewarding best practices

Certification of green transport infrastructures and taxonomy

Developing and promoting robust green construction certification schemes is essential to ensure that best practices are identified, rewarded, and spread across the industry. Existing green certification standards/methodologies (such as LEED and BREEAM) have been developed on a commercial basis primarily for buildings rather than civil engineering works and are therefore not fully suitable for transport infrastructures. The European Commission has also developed an assessment framework called Level(s) for buildings. Important certification schemes operating in the EU are aligning themselves with it. However, an assessment framework such as "Level(s)" does not exist so far for transport infrastructures.

The EU Taxonomy is a classification system that defines criteria for economic activities that are aligned with a net zero emission trajectory by 2050 and broader environmental goals other than climate[11]. It is conceived as a sustainable finance tool to help direct investments to the economic activities most needed for the green transition and to avoid greenwashing. At this stage, the technical screening criteria developed in this framework for transport infrastructure relate mainly to their usage rather than to their construction techniques. These criteria have not been designed for certification purposes.

Suggested EU measures / policies:

➔ In the short term existing green construction certification schemes could be adapted to become better suited to transport infrastructure projects. Subsequently, a harmonized EU framework for green infrastructures (equivalent to Level(s) for buildings), should be developed to support the development of new European certification schemes.

[11] Beside climate change mitigation and climate change adaptation, the taxonomy criteria relate to sustainable use and protection of water and marine resources, transition to a circular economy, pollution prevention and control and protection and restoration of biodiversity and ecosystems.

- ➔ The working groups recommend that, in order to stimulate private investments into green infrastructure projects, the EU Taxonomy is progressively extended beyond ongoing works on transport infrastructure maintenance and demolition, to cover the construction phase and all types of transport infrastructure, setting strategic priorities and mobilizing adequate expertise, with priority given to climate mitigation criteria. Ensuring that new screening criteria are robust enough and based on the necessary transitional green innovations is of particular importance. Furthermore, some of the EU taxonomy criteria for transport infrastructure construction could be integrated within European certification schemes.
- ➔ The EU should explore the possibility to create and maintain a publicly accessible EU database of green transport infrastructure projects and develop communication tools such as EU labels and awards to facilitate the identification and raise awareness of and disseminate best practices.

Stimulating the scaling up of best practices through EU funding

Architects, engineers and designers, project owners and construction managers, contractors, and suppliers, all have an important role to play to promote decarbonisation measures. But the European Commission can also have a real impact as it co-finances a substantial number of transport infrastructure projects, either on the trans-European transport network (TEN-T) or locally, through financing instruments such as the Recovery and Resilience Facility (RRF), Cohesion policy funds, and the Connecting Europe Facility (CEF). Flagship projects financed by the EU can help disseminate best practices within the construction sector, create a larger market for low-emission products and solutions and thereby have a leverage effect on the whole sector.

<u>Suggested EU measures / policies:</u>

- ➔ Building upon existing climate proofing and EIA obligations, European funding programs should be used to progressively achieve that supported projects provide transparency on the carbon impact of their full life cycle and adequately mitigate any potential impact. In addition, the working groups recommend that those programs promote the deployment of decarbonization practices through a minimum set of decarbonization measures applicable to all transport infrastructure projects, such as minimum circular economy requirements.
- ➔ EU programs specifically dedicated to transport infrastructure, such as CEF, should consider allocating specific envelopes or giving a clear priority to flagship infrastructure projects offering room for experimentation of new decarbonization techniques and innovation. For existing flagship projects already under construction, a dedicated budget could be set aside to increase support to quickly and systematically integrate the latest innovations aimed at reducing the CO2 impact of these projects.
- ➔ Interactions between universities, research centers, transport infrastructure managers and the construction sector at large are essential to offer new opportunities to young professionals and researchers and to give a better access to state-of-the-art knowledge to the industry. Education and training initiatives aimed at helping individuals involved in the construction process to make environmentally conscious decisions and collaborate, such as the Supply Chain Sustainability School, should therefore be supported.

CHAPTER IV – CONCLUDING REMARKS

Adaptation to climate change of existing transport infrastructures, their maintenance and upgrade, as well as the construction of missing links on the European, national, and local transport networks will require important investments in the years to come. These investments must become an opportunity to implement decarbonisation measures and contribute to the sector's climate transition.

Transport infrastructure construction has the potential to become a genuine testbed for the large-scale deployment of best decarbonisation practices as shown by different examples provided in this report. By disseminating the use of new tools, innovative approaches, and the necessary skills, this can have a leverage effect on the construction sector as a whole.

This report shows that a large range of decarbonisation products and solutions are already available. But more needs to be done to ensure that their use is mainstreamed. It therefore calls on the EU to mobilise its relevant regulatory and financing instruments and makes 24 recommendations for EU action to unleash the decarbonisation potential of these new construction products and solutions applicable to transport infrastructure.

The individual experts involved in the preparation of this report have all endorsed these recommendations. They are committed to supporting any effort to implement them and are ready, if necessary, to continue to advise the European Commission.

Annex 1 - Members of the Working Groups

Participants to the Industry WG on construction decarbonisation

Member	***Organisations***	***Title***
Pat Cox	European TEN-T Coordinator	WG Chair
Maurizio Bufalini / Manuela Rocca	Lyon-Turin TELT	Deputy Director General TELT Italia
Benoit Chauvin	European International Contractors EIC	President
Philippe Citroen	UNIFE	Director General
Christina Claeson-Jonsson	European Network of Construction Co. for R&D ENCORD	Chair
Tobias Cordes	Brenner Base Tunnel	Head of Green innovation
Philip Crampton	European Construction Industry Federation FIEC	President
Stephen Elderkin	UK National Highways	Head of the Environment division
Ines Ferguson	EFCA	President
Olivier Guise	ECOCEM	Managing Director, Strategy, New Business and Innovation
Jens Ole Kaslund / Emilie Juel-Helwig	Femern A/S	Technical Director / Director, Sustainability and Authorities Division
Martin Langer	STRABAG AG	Sustainability - Governance, Reporting & Data
Ana Peña Laseca	Ferrovial	Sustainability, Climate change and Environment Head
Isabelle Spiegel	Vinci	Global Head of Environment

Participants to the Academic WG on construction decarbonisation

Name	University
Konrad Bergmeister (Chair)	University of Natural Ressources and Life Sciences BOKU Vienna (AT)
Henk Akkermans	Tilburg University (NL)
Roberta Alfani	Toulouse and Paris-Saclay University (FR)
Agnieszka Bigaj-van Vliet	TNO research organisation (NL)

Rolf André Bohne	N.T.N.U. Trondheim (NO)
José Campos e Matos / Elisabete Teixeira	University of Minho (PT)
Wit Derkowski	Linné University (SE)
Willem van Groenendaal	Tilburg University (NL)
Ole Hansen / Maria Edith Lindholm Gausdal	Kopenhaguen University (DK)
Maria Giuseppina Limongelli	Politecnico Milano (IT)
Olga Markogiannaki	University of Western Macedonia (EL)
Christoph Müller	VDZ (DE)
Vikram Pakrashi	University College Dublin (IE)
Aljoša Šajna	Civil Engineering and Building Institute (SI)
Daan Schraven	T.U. Delf (NL)
Irina Stipanovic	University of Twente (NL)

Annex 2 – Some academic references

Marta Andhov and Roberto Caranta et. al. Sustainability Through Public Procurement: The Way Forward – Reform Proposals (March 23, 2020).

Maria Edith Lindholm Gausdal, Soft Law Business as Usual – Fundamental labour standards in private and public commercial contracts? (UCPH - 2022)

Vibe Ulfbeck and Ole Hansen, Sustainability Clauses in an Unsustainable Contract Law? (2020) 16 European Review of Contract Law 186-205

Maria Gausdal and Ole Hansen, Implementering af bæredygtighedskrav i kommercielle aftaleforhold, Juristen, Iss.5-6 (2023).

Stéphanie van Gulijk and Jonas Voorter, 'Systemic Review of Western European Public and Private Policies and (proposed) Legislation to implement a Circular Built Environment', International Construction Law Review (2023)

David Mosey et al., Procuring Net Zero Construction, Kings College, research paper (2022)

Contact details:
European Commission – Directorate General for Mobility and Transport
Directorate B – European Mobility Network
Unit B1 – Trans European Network
http://ec.europa.eu/transport/index_en.htm
email: move-info@ec.europa.eu

Offices:
Rue Demot 28
1049 Brussels Belgium

Design & Layout by TENtec