Finland

is planning to implement the embodied carbon emissions limits for new Buildings by 2025 and 2027.

Sweden

is planning to implement the embodied carbon emissions limits for new Buildings by 2025 and 2027.

Netherlands

have imposed limits on whole life cycle carbon emissions on construction of new buildings since 2018.

France

implemented RE2020 – A Whole life dynamic LCA requirements along with limits for future buildings construction.

Switzerland

has set a limit of 8.5 kg CO_2/Sqm for residential buildings as a target for 2050.

Germany

has implemented a Green rating program for all government projects which requires whole building life cycle analysis.

United Kingdom

has introduced LCA and Carbon reduction plan for public buildings/projects (in excess of £5 million per annum) on or after 30 September 2021

PAS 2050 and PAS 2080 are published in the UK for managing infrastructure carbon.

Canada

has established a net zero advisory body for guiding principles on carbon emissions across all sectors.

Zero Carbon Building Design Standards v3 in 2022 has put a limit on embodied carbon through absolute embodied carbon targets or relative improvements over a baseline.

City of Vancouver has mandated a 40 per cent reduction in embodied carbon by 2030 for new construction.

Quebec's Wood Charter was recognised under government undertaking to promote the use of wood in construction.

The USA has initiated

a procurement policy in 2017 to promote Low Embodied Energy and Carbon Materials by Federal Agencies for the state infrastructure projects. GWP(Global Warming Potential) limits have been established which is verified by EPD at the time of procurement.

As per " The Federal Sustainability plan" All new construction and major modernisation projects larger than 25,000 GSF entering the planning stage will be designed, constructed, and operated to be net-zero emissions by 2030,

GSA recommended a material approach for all projects requiring environmental product declarations for 75 per cent of materials used.

In 2022, New Zealand

published a whole of like embodied carbon assessment technical methodology for assessing embodied carbon for new buildings.

In 2021, Singapore

Green Building Council (SGBC) has launched the Singapore Built Environment Embodied Carbon Pledge to help unify and amplify industry action.

In Aug 2020, South Korea

has approved a standard emission baseline for 18 different residential building categories to benchmark embodied and operational carbon.

Priority of Implementing Low Carbon Initiatives

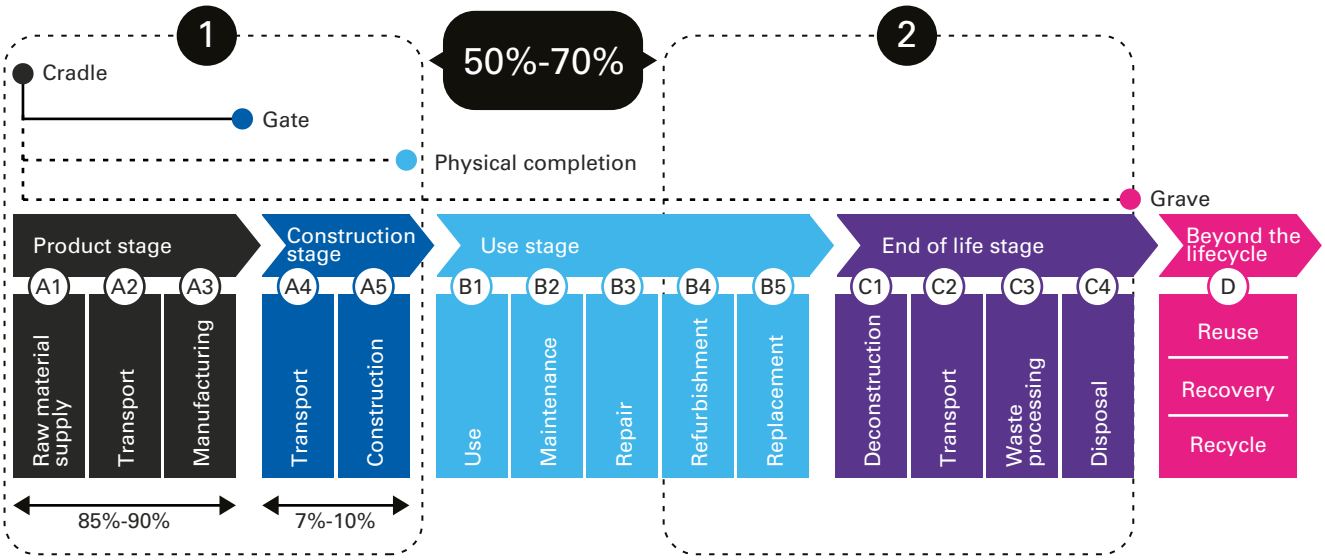
Geographies	Scenarios	Volume	Growth	Potential Way forward
India Indonesia	**Maximum opportunities to decarbonise depend on learning from global standards**	High	High	• Governing bodies to adapt from policies of developed markets • Developed markets to support on funds and investments for low carbon asset development
China USA Europe	**Setting standards for global usage**	High	Low	• Lead by example, implement low carbon measures, policies and share it with rest to follow • Strengthen supply value chain to be adopted by others quickly
Africa	**Opportunistic**	Low	High	• Follow standards and policies prepared by leaders and growing markets • Seek support on resources and funds from leader economies
Rest of the world	**Still evolving; however few EU countries have stringent policies**	Low	Low	• Follow standards and policies prepared by leaders and growing markets • Support through R&D

2.3 Embodied Carbon emission during project lifecycle

Across the life cycle of a project, typically 50-70 per cent of total embodied carbon gets emitted till the physical completion stage. Out of this, 85-90 per cent of emissions are during the product/ manufacturing stage, seven to ten per cent during the transportation, and three to five per cent during the construction stage. Both material selection and the respective processes adopted for extraction, manufacturing, transport, and, finally erection are chief contributors.

More than 80 per cent of embodied carbon is emitted during the material production and transportation stages, making them as hot spots in project life cycle to reduce embodied carbon footprint in capital projects.

Embodied carbon assessment across project lifecycle



16. BRE Global Methodology For The Environmental Assessment Of Buildings Using EN 15978:2011, January 2018

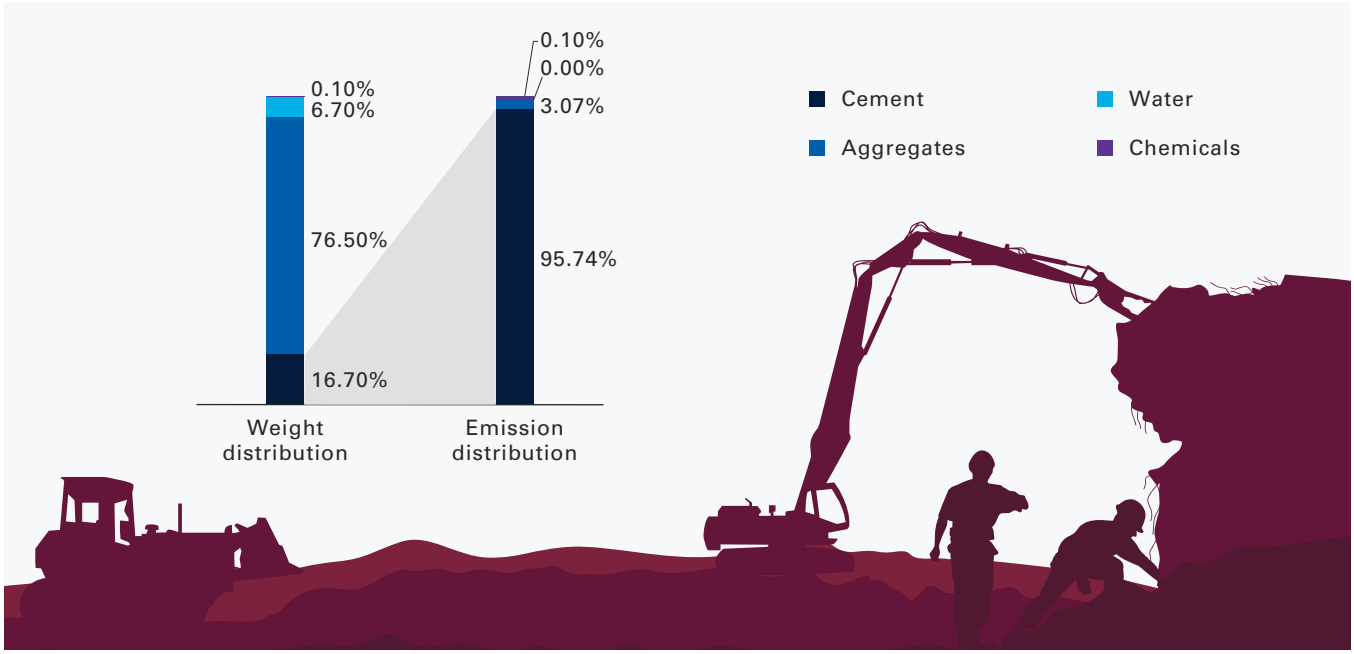
Impact of construction material

Concrete, steel, and aluminum are amongst the key carbon contributors for a typical construction project. These materials typically add up to more than two-thirds of the total embodied carbon emission.

In concrete, 90 per cent of emissions are from cement production and use. Cement is the second most consumed material[17] and contributes seven to eight per cent of global carbon emissions. The cement industry currently produces around four billion metric tons of cement annually and is expected to produce six billion metric tons by 2050.[18]

Typically, cement contributes 15 to 20 per cent of the concrete mix; however, it emits 95 to 97 per cent of total emissions from concreting works. Therefore, any marginal reduction in cement content and/or adopting green cement will considerably reduce total emissions.

In a typical scenario, the breakup of one cum concrete (M-40 grade), along with associated emissions, is depicted below[19]. The cement content varies basis the grade of concrete and design mix.



Steel is the second largest contributor to embodied carbon emissions in the construction industry. More than 50 per cent of steel is consumed in construction projects[20]. In 2021, around one billion MT of steel was consumed in the construction sector[21], of which approximately 25 per cent was used as TMT rebar, and 75 per cent was used as structural steel, pipes, sheets, etc. This market is expected to grow at four per cent CAGR[22] and the demand for steel in the construction sector will reach three billion MT[23].

Globally, steel manufactured for construction activities emits approximately 1.7 billion tCO_2e of embodied carbon emissions annually, around 12 per cent of which comes from the use of TMT rebar in concrete structures, and the balance 82 per cent is from the steel used for structure, equipment, and other miscellaneous items.

17. "Concrete the most destructive material on earth" , article by Jonathan Watts
18. "Cement makers across world pledge large cut in emissions by 2030", Article by The Guardian
19. Based on KPMG in India analysis
20. Steel Industry key facts published by World Steel Association, 2022
21. "No net zero by 2050 without industries report by WEF, 2022".
22. "Global Steel Market is projected to grow at a CAGR of 3.9per cent By 2031", report by Visiongain Ltd.
23. Iron ore and steel demand to see modest growth until 2030 by Rio Tinto

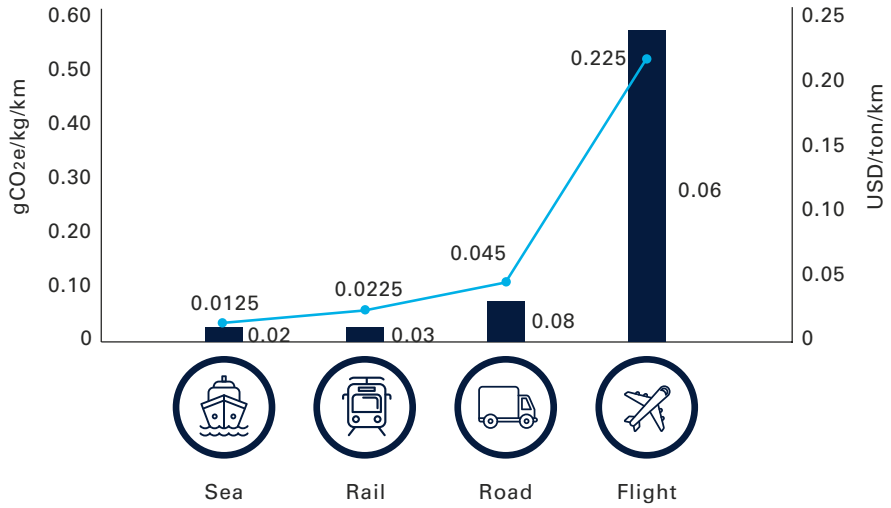
The emission from producing a KG of TMT rebar is around 0.78 Kg CO_2e, and for producing structural steel is around two kg tCO_2e[24]. Therefore, associated embodied carbon emission is typically lower in roads and buildings, in comparison to warehouses, manufacturing, and process plants.

Impact of Supply chain and Transportation

For material and equipment transportation in construction projects, fuel consumption is the key source of emission, which varies on the mode of transport and the type of carrier. For major projects, substantial amount of fuel is consumed for transportation of building materials and equipment across domestic and international routes.

Supply chain and logistics are essential components of capital projects delivery, especially with capital goods/materials from overseas. With multiple transport options, the construction industry should evaluate these to reduce the project logistics cost, time, and to become carbon efficient for supply and receipt of goods.

Comparison of Transportation Modes[25]



Any material transported via flight emits around eight times more emissions compared to road transport, with sea transport as the least carbon-emitting option; however, the project requirements should govern the most optimum option on a case-to-case basis.

24. "Can industry decarbonise steelmaking? by Mark Peplow, June 2021"
25. "Department for Business, Energy & Industrial Strategy, Istructe Report"

Case example[26]:

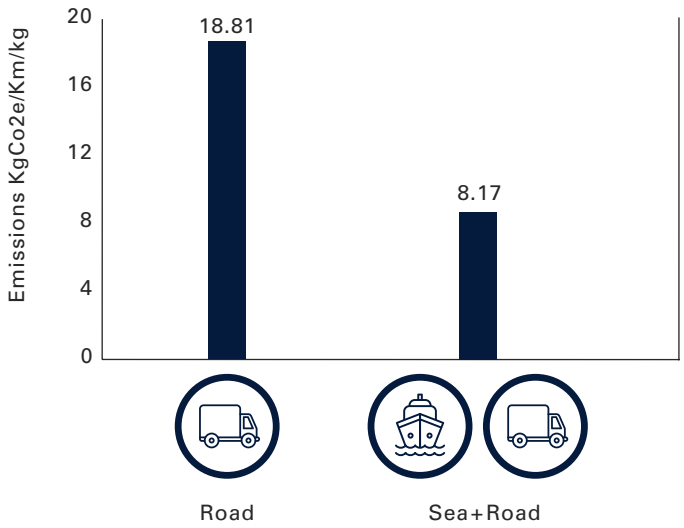
For a project site, which is 250 km away from a material manufacturer can transport a material either by:

a. Complete distance by road, which would emit around 19kg CO_2e/km, or

b. A combination of Road and Sea transport, which would emit around 8.1 kg CO2e/km assuming 70 Km by road and 180 km by sea transport.

Emission per KM per KG through road transport is ~ 2.5 times of hybrid transport (waterways + road) and four times of road transport.

Comparison of emissions from different Modes of Transport

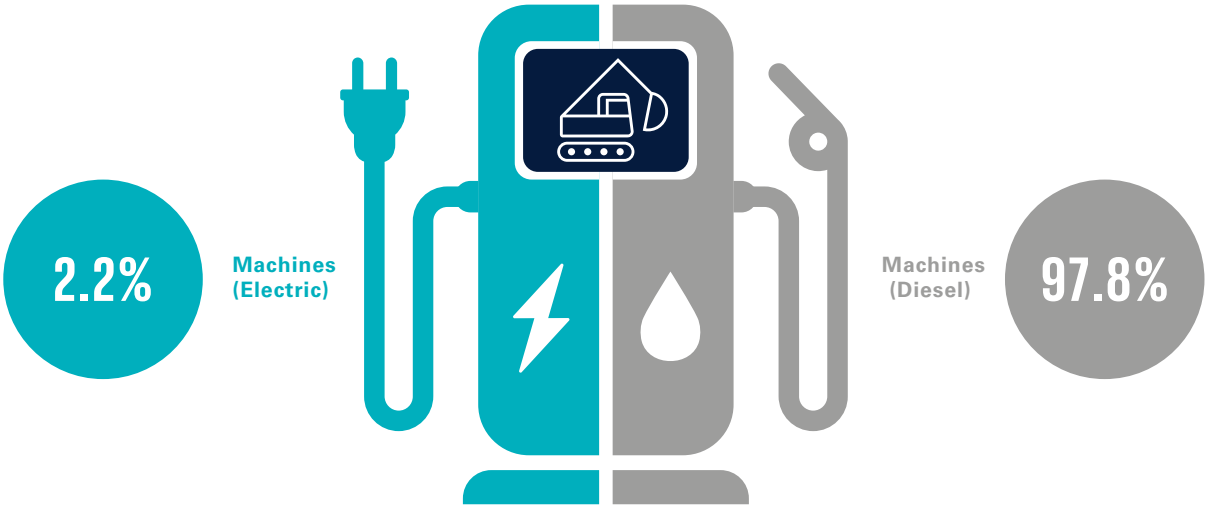


26. Based on KPMG in India analysis

Impact of plant & machinery[27]

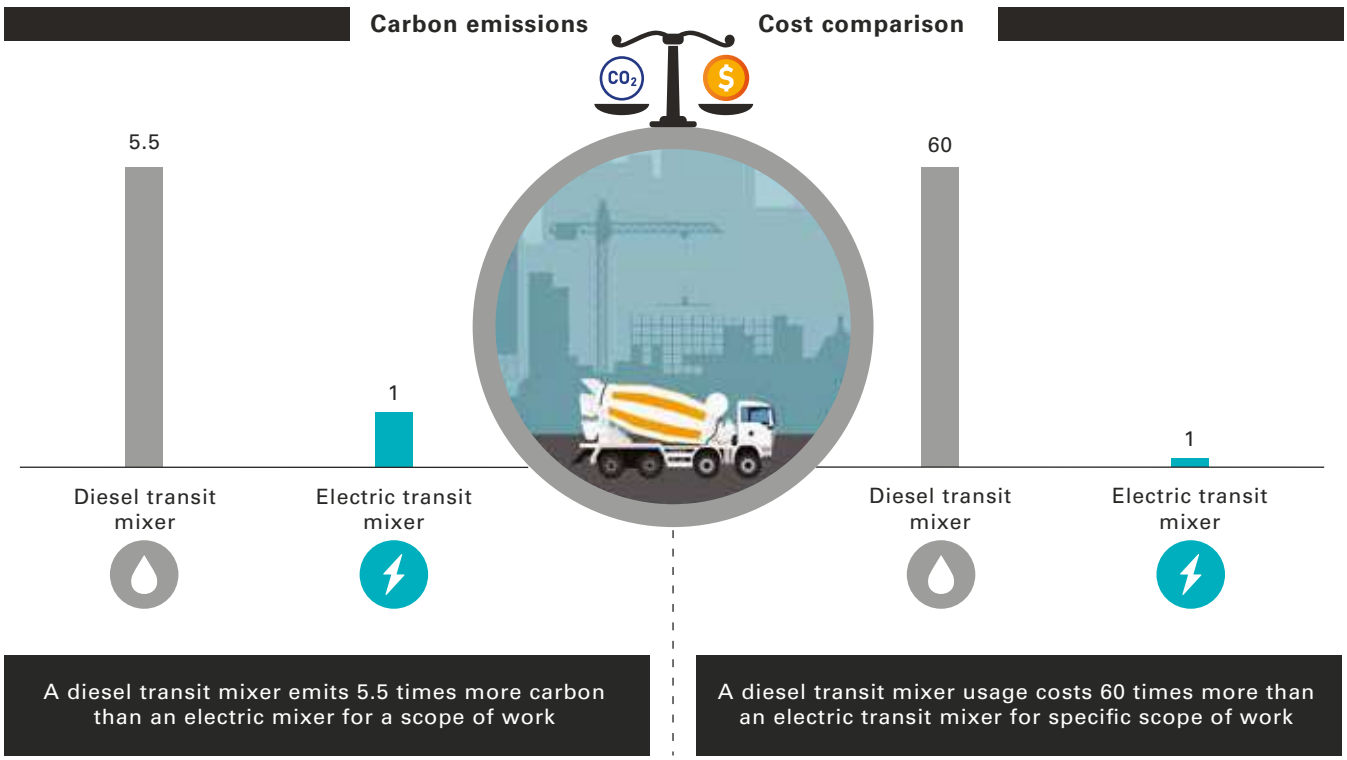
Besides emissions generated during material sourcing and transportation, site execution works also contribute to carbon emissions. More than 90 per cent of machinery and equipment used at the site, operate on conventional fuels. Below is a comparative example from an industrial project in India.

Comparison between Electric and Diesel Machines



Case example in India:

Comparison between transit mixer types used in construction projects for carbon emission and deployment cost reveals that 'Electric type' option would be beneficial in the long run, however subject to adequate availability from equipment suppliers and supporting charging infrastructure.



27. Based on KPMG in India analysis

03

Solutions for embodied carbon

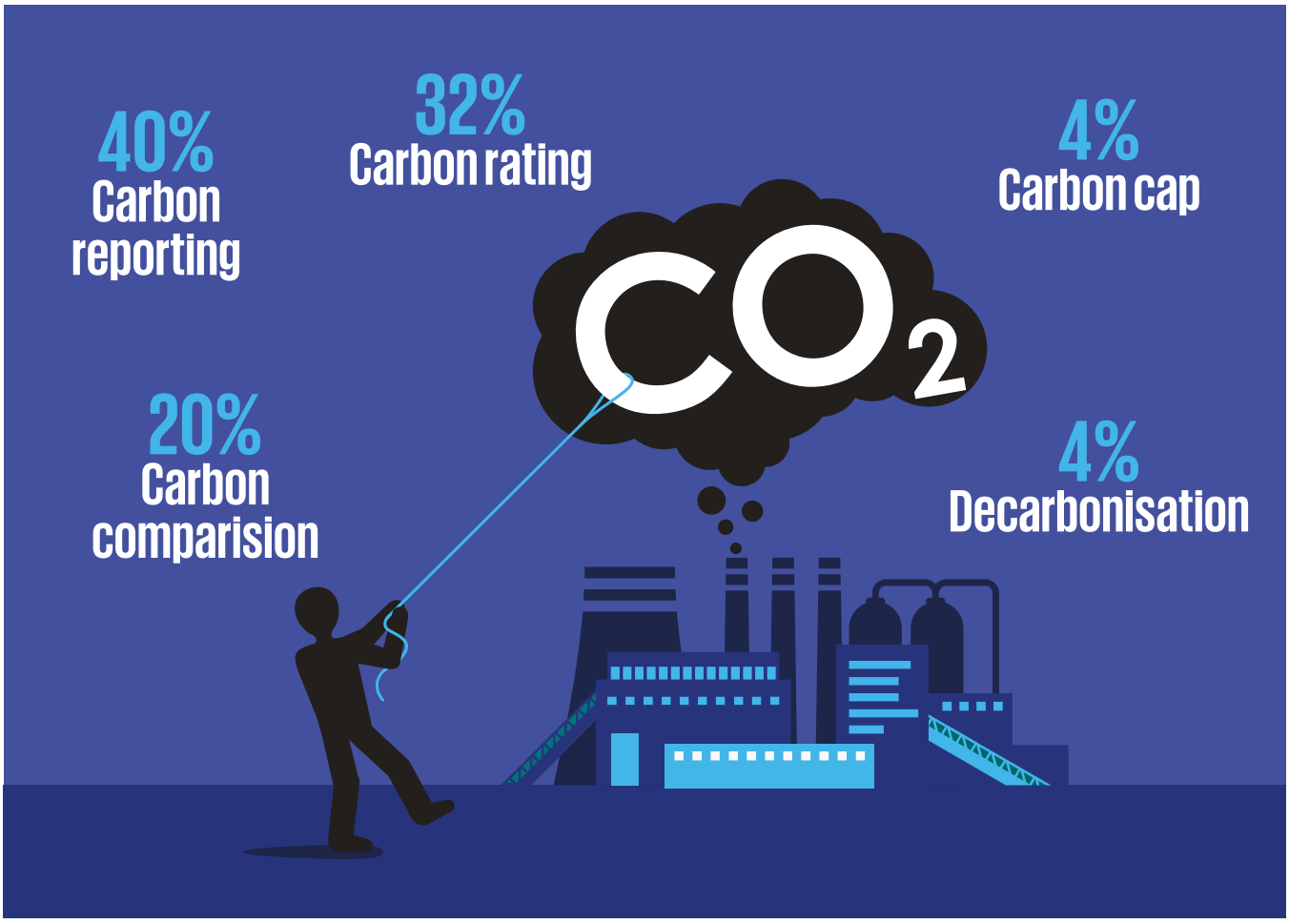
3.1 Existing carbon related solutions in construction industry

The number of solutions addressing carbon emissions in the construction industry has nearly doubled in the last five years; however, most of them do not directly solve the problem of embodied carbon emission. Majority of these solutions focus on carbon reporting, carbon rating, and carbon comparison, and only a handful address embodied carbon through prescribed practices such as recycled material use, waste reduction, and material efficiency measures.

Globally there are only a few certifications, regulations, and standards, such as living building challenge, Nollco2, BREEAM, PAS 2080, Ceequal, DGNB, etc., which largely suggest carbon reduction methods.[28] Moreover, there is an absence of a single tool or platform for a holistic approach towards carbon modeling for both embodied and operational carbon, which can integrate the building model with carbon emission reduction strategy at various stages.

Considering the growth and importance of embodied carbon, a rapid thrust is required for developing direct solutions in this area.

Research suggests that only less than five per cent of globally available solutions offer embodied carbon reduction for capital projects.

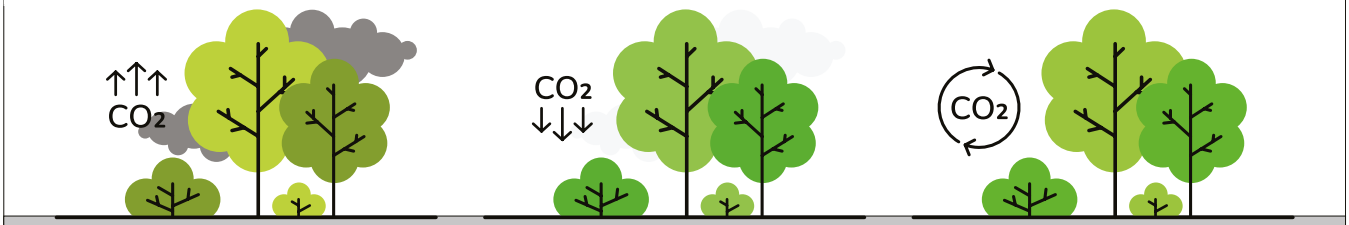


28. THE EMBODIED CARBON REVIEW I BIONOVA LTD 2018

With the current state, it is imperative to have an integrated solution for capital project owners for embodied carbon reduction across the project lifecycle, further feeding into the asset operations stage.

Desired state of an integrated solution for an embodied carbon management

#	Attributes for an integrated solution	Current state of available solutions	Desired state
1	**Material coverage**	For select materials on stand alone basis (structure steel or cement etc.)	Integrated coverage across all material & equipment substantially
2	**Asset Lifecycle Coverage**	Project delivery or Asset O&M	Whole life cycle approach
3	**Carbon Type analysis**	Operations or embodied	Combined Embodied & Operations
4	**Timeline**	One-time or Static	Dynamic



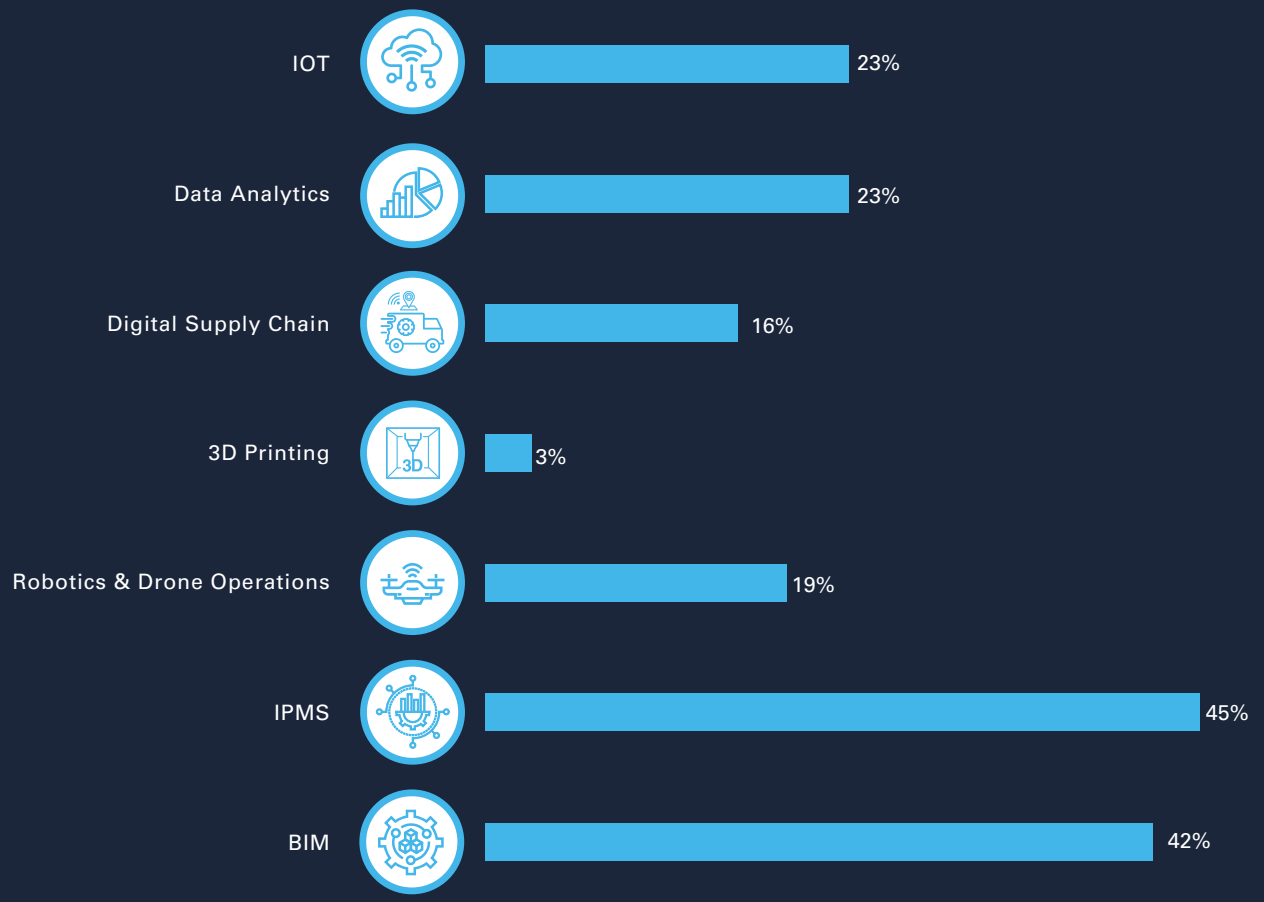
3.2 Leveraging technology to manage embodied carbon

Despite being amongst the largest industries, the construction sector globally lags others in adopting technology, with merely 35 per cent of digital penetration. The KPMG International in its Global Construction Survey 2021 suggests that Integrated Project Management System (IPMS) has the highest level of adoption followed by Building Information Modeling (BIM) and Data Analytics[30].

Managing embodied carbon through technology will first require leveraging the current implementation levels of such tools and platforms. In parallel, the development of core products should be considered, riding the current technological advancements taking place in the industry such as digital twin, 3-D printing, robotics, and others.

29. Based on KPMG in India analysis
30. Global construction survey conducted by KPMG International, 2021

Technologies with their overall ROI for the organisations[31]



Further technological development can be fueled by emphasising the importance of embodied carbon as a critical key performance indicator (KPI) to be governed through-out the project lifecycle. Organisational leadership, management, and boards should mandate reporting the carbon footprint of capital projects with a reduction strategy while making investment decisions and further procurement decisions. Overall, carbon should be regarded as a golden thread of information across the project lifecycle stitching various stakeholders and influencing their decisions.

This will also drive the technology original equipment manufacturer (OEMs) and service providers to evolve their products for embedding carbon management just as important as cost, time, safety, quality, and other KPIs.

31. Global construction survey conducted by KPMG International, 2021.

Current digital landscape in the construction sector

The current technology landscape allows embodied carbon management with limited potential on a case-to-case basis. While IPMS and carbon measurement tools with minimal updates can be implemented for carbon reporting, BIM, digital twins, and data analytics platforms will need to be upgraded for carbon reduction strategies and multi-scenario simulation. KPMG in India has conducted a pilot study on BIM usage and observed significant potential for automatic measurement of embodied carbon through 3D BIM which can lead to design optimisation for carbon reduction.

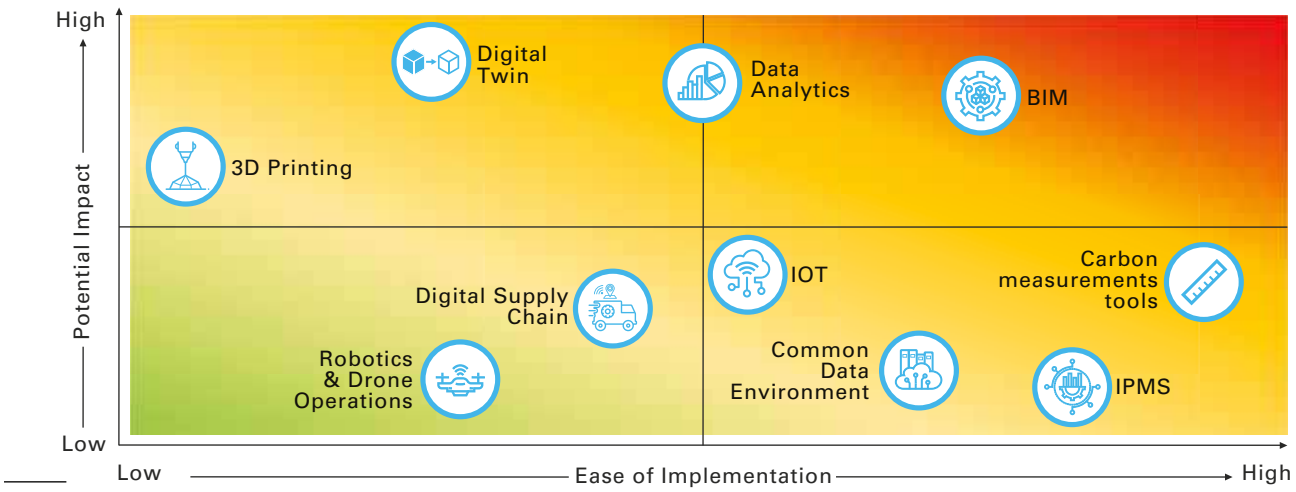
Initiatives across 3D printing can promote pre-cast construction, thus reducing the embodied carbon emissions observed during conventional methods. Through drones, inspections can be simplified, thus reducing travel at the site, and they can also be integrated into the local supply chain network for last-mile material supply subject to payload limitations, thus reducing fuel-based emissions.

32. Based on KPMG in India analysis

Potential impact of technology solutions towards low carbon construction

S. No.	Technology	Potential to manage carbon	Potential level
1	Digital Twin	• Integrated platform for managing whole life carbon from Design to Operations phase for both embodied and operational carbon, by combining energy analysis with embodied carbon assessment • Simulating design options with carbon prediction analysis for selecting the most optimum options	
2	Building Information Modelling (BIM)	• Model embedded carbon information for building elements leading to carbon conscious planning while designing/engineering • Plan vs actual carbon assessment along project lifecycle enabled through 4D and 5D BIM	
3	3 D Printing	• Formulating pre-cast/off site construction strategies which can lead to approximately 30-40 per cent of embodied carbon reduction as compared to on-site construction methods	
4	Robotics and Drone Operations	• Reduce carbon emissions by bringing site efficiencies in multiple operations • Material handling and transport by drones at the site can curtail timeline and fuel usage, eventually reducing the embodied carbon	
5	Digital Supply Chain	• A connected platform for suppliers and buyers to exchange EPD information. This can also target scope 3 emissions, which contributes to ~90 per cent of embodied carbon emissions.	
6	Carbon Measurement Tools	• Measure and benchmark embodied carbon for construction material such as concrete, steel etc. Few examples of such tools include EC3, OneClick LCA etc.	
7	Internet of Things (IOT)	• Real-time monitoring of carbon emission through site machinery/equipment / vehicles and construction power.	
8	Common Data Environment	• Collaborative platform for connecting stakeholders and exchange of information through a common source • Further integration with data analytics and standards would allow quicker decision making as well	
9	Data Analytics	• Cost-carbon trade-off assessment to enable informed decision-making processes • Historical benchmark emissions basis completed projects data (Big data) • Deep insights to the leadership by tracking carbon linked KPIs such as but limited to: a.) 'Current stage footprint' and 'Carbon at Completion' b.) Variance of carbon reduction vis-à-vis planned c.) Opportunity cost of Emission reduction	
10	Integrated Project Management System (IPMS)	• Set-up of emission goals, and baseline • Actual emission tracking against baseline • Real time status updates and triggers • Carbon status dashboards	

Ease of implementation of tools and their impact in current scenario



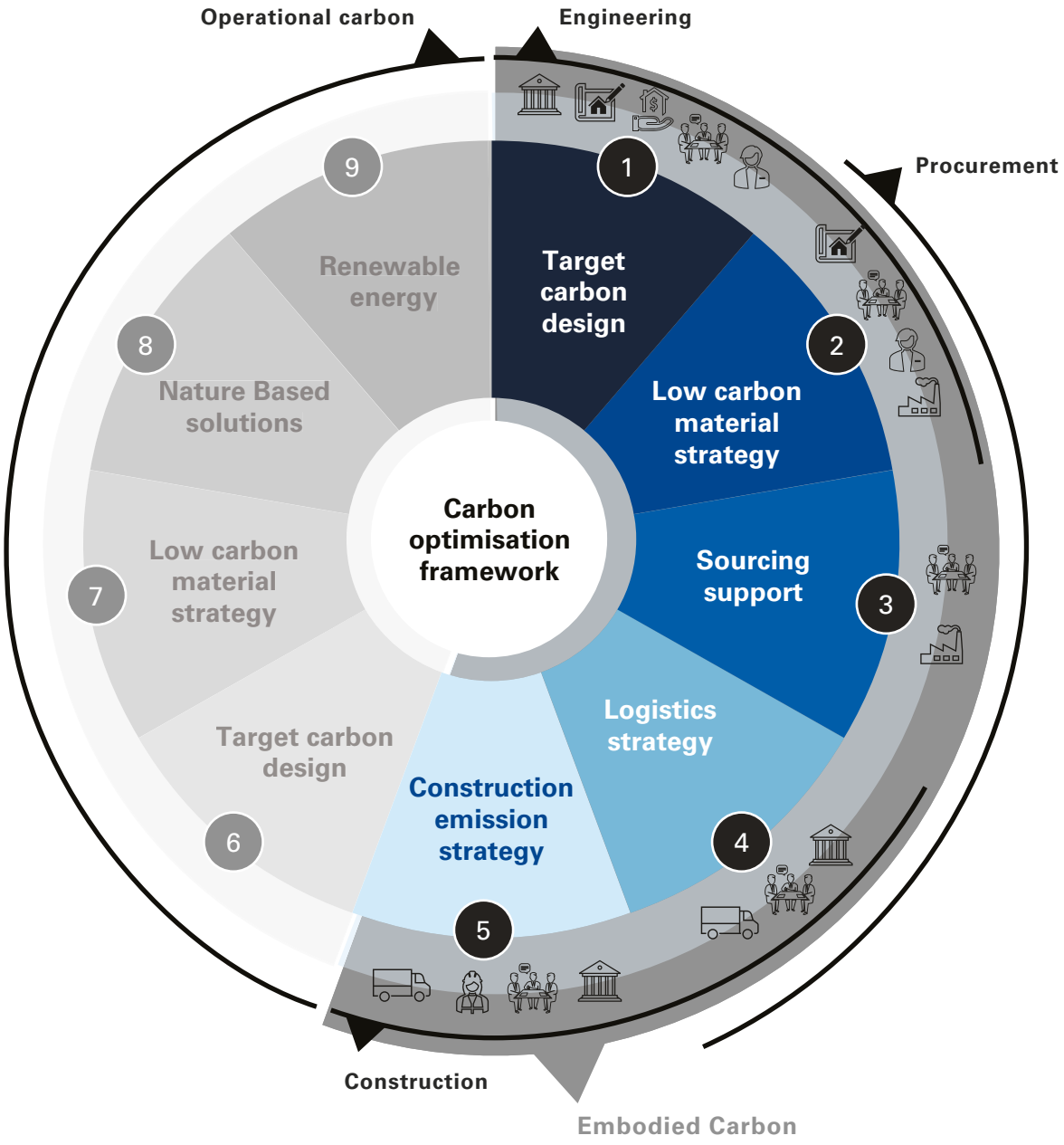
33. Based on KPMG in India analysis

04

Collective call for action from the construction industry

4.1 A cultural transformation is warranted from the construction ecosystem

Suggested carbon optimisation framework with stakeholders' influence in construction projects[34]



Legends

Policy makers and Government bodies	Architects/ Engineers	Investors/Lenders/ Funds	Asset Owners/ Developers
Tenants/ Corporates	Contractor/ Sub Contractor	Supplier/Manufacturer/ Vendors	Transporter/ Freight Forwarders

34. Based on KPMG in India analysis

Reducing embodied carbon can become achievable with ease, if each of the following stakeholders will play their role[35]:

Key Stakeholders	Potential actions
Policymakers and Governing bodies 	• Frame policies and modify existing policies specific to embodied carbon • Incentivise the market by phasing out subsidies on green materials and green vehicles • Implement a carbon tax on embodied carbon emissions above a limit • Regulatory compliance monitoring.
Investors/Lenders/ Funds 	• Encourage investments in low carbon infra • Provide green loans and encourage low-carbon pathway • Investments across the decarbonisation solutions, material, and transport • Provide transition support to other stakeholders to create a highly sustainable infra value • Ensure due diligence before investments with respect to climate risks to avoid severe effects of the climate, thus bringing in monetary gains.
Asset owners/ Developers 	• Encourage low carbon infra development and enable processes aligned to the net zero goals • Decarbonise existing assets, if possible • Promote the use of a renewable source of energy and greener material across the built environment • Set up high building performance standards.
Tenants/ Corporates 	• Prefer low-carbon buildings over the conventional buildings • Benchmark existing/newly build assets to evaluate the embodied carbon assets • Report scope 1, 2, and 3 not only for operational but also for embodied carbon.
Architects/ Engineers 	• Selection of low-carbon sustainable material or alternative materials • Promote carbon modeling for the selection of suitable material • Collaboration with the stakeholders to encourage create sustainable low carbon infrastructure.
Contractors/ Sub-contractors 	• Accelerate new technologies adoption which promotes low embodied carbon emission due to installation and site transfers.
Suppliers/ Manufacturers/ Vendors 	• Opportunity from gray to green across the project lifecycle value chain from electric construction equipment to green materials • Creating emission databases.
Transporters/ Freight forwarders 	• Provision of sustainable transport • Create transparency across the supply chain • Become agile to the market demands.

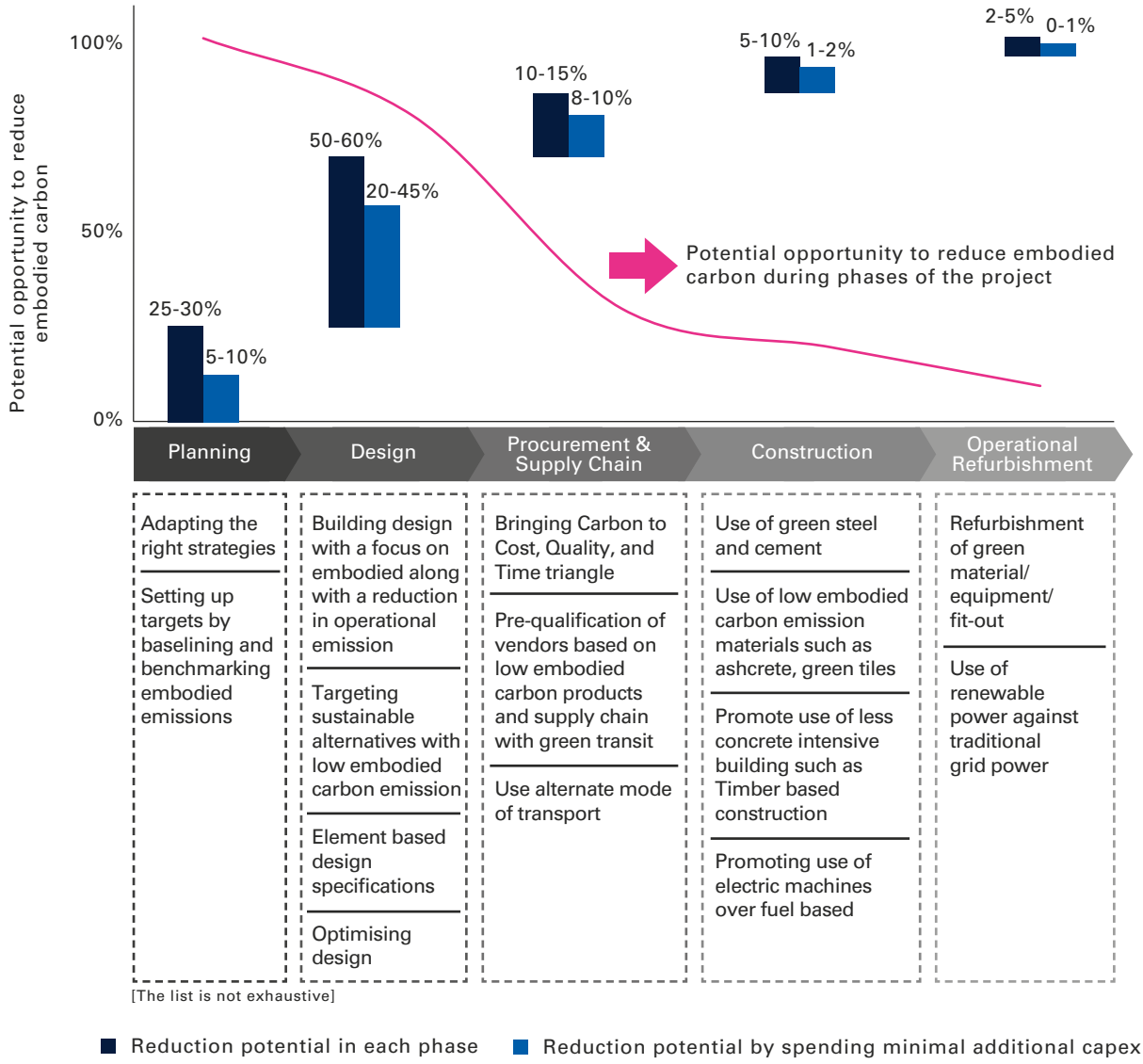
35. Based on KPMG in India analysis

4.2 Overcoming the inertia and making it affordable for capital project owners

There exists a widespread notion of increased cost for carbon reduction in the industry. However, it is established that up to 46 per cent of embodied carbon emissions can be curtailed in capital projects by additional spending of a mere half to one per cent of Capex.[36] Based on the KPMG in India study for Indian construction projects, this can be increased to 65 per cent of total embodied carbon emissions, mainly based on right decisions undertaken in the planning, design, and procurement stages.

The industry can overcome this inertia through improved awareness around embodied carbon leading to structured policies, initiatives, contracting process, and its monitoring. Additionally, net carbon reduction warrants a collective change in stakeholders' mindsets, leadership orientation, and its governance across the project value chain.

Opportunity to reduce carbon in a project life cycle with marginal spend



36. Reducing embodied carbon in buildings report by RMI, July'2021
37. Based on secondary analysis carried out by KPMG in India over RMI report on reducing embodied carbon in building.

4.3 Accelerating this change

A few additional measures will be the key to further accelerating the embodied carbon reduction including but not limited to:

Leadership commitment

Project leadership and/or senior management should be at the helm of carbon-conscious development with a commitment to build low carbon assets and drive the initiative by unlocking innovation and enforcing value

.

Incentivising contractors/ Suppliers

Both owners and tenants should structure contracts that incentivise project suppliers or contractors to use low-carbon material and collaborate to achieve project carbon emissions goals

Building a strong knowledge foundation

Inclusion of decarbonisation of embodied carbon in academia for respective course streams related to the infrastructure domain

Exploring transport alternatives

With the current thrust on electric trucks, project owners/developers should demand the use of the same. Additionally, waterways should be used as a mode of transport to optimise cost and carbon

Industry collaboration

Cross collaboration is warranted between stakeholders in various dimensions. Designers or Engineering firms, prevailing OEMs should collaborate with agencies such as EC3, Oneclick LCA for software upgradation or integration to design low carbon assets

Green Construction

Using electric machinery and equipment helps reduce emissions during site construction. Currently, the usage of conventional fuel constitutes 10-15 per cent of emissions from a construction project

Integrating with global initiatives

Backward integration with global initiatives such as green steel and green cement is required for providing green alternatives at incremental costs. Owners/designers/ developers need to create substantial demand for low-carbon projects, leading to the market price correction of such material

Technology

Leveraging technologies such as Building Information Modeling and Digital Twins, which are already getting established for improved project management.

Acknowledgements

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