TECHNICAL REFERENCE FOR EMBODIED CARBON INVENTORY DATA AND CALCULATION OF CONSTRUCTION MATERIALS

CIDB TECHNICAL PUBLICATION NO: 2502

CIDB MALAYSIA

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Technical Reference for Embodied Carbon Inventory Data and Calculation of Construction Materials

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FOREWORD

The construction industry plays a critical role in shaping the built environment, but it is also a significant contributor to global greenhouse gas (GHG) emissions. In Malaysia, advancing sustainability in the construction sector is not only a national priority but also a responsibility shared by all industry stakeholders.

This documents represents the collaborative efforts between the Construction Research Institute of Malaysia (CREAM) and Universiti Teknologi MARA (UiTM), with the valued support of the Construction Industry Development Board (CIDB). The project titled “Technical Reference for Embodied Carbon Inventory Data and Calculation of Construction Materials” is a timely initiative aligned with CIDB’s long-term vision for a greener, more sustainable construction industry under the Construction ESG Framework (cESG).

The purpose of this document, is to establish the groundwork for enhancing inventory embodied carbon inventory data and for developing a practical calculator to aid practitioners in evaluating carbon footprint values at the building element level. The initiative is expected to bridge critical data gaps, enhance decision-making processes, and promote transparency in carbon reporting throughout the project lifecycle. We are confident that this initiative will serve as a catalyst for the integration of low-carbon strategies in design and construction practices across Malaysia.

We extend our sincere appreciation to CIDB and CREAM for their leadership, and to all stakeholders whose insights and contributions will help ensure the success of this project. It is hoped that this initiative will benefit to all industry stakeholders as a valueable kick-start towards environmental and sustainable practices.

Construction Research Institute of Malaysia (CREAM)
December 2025



EXECUTIVE SUMMARY

Reducing embodied carbon in buildings is critical to achieving low-carbon construction targets. However, awareness, technical understanding, and the availability of reliable data on embodied carbon remain at an early stage within the Malaysian construction sector. Addressing this gap is essential to support national commitments towards climate change mitigation and sustainable development.

In response, the Construction Industry Development Board Malaysia (CIDB), through its research arm, the Construction Research Institute of Malaysia (CREAM), has undertaken this initiative to develop a comprehensive embodied carbon inventory database and calculation reference for construction materials and building elements. This effort supports the Government of Malaysia in strengthening the construction sector's capacity to measure, manage, and reduce carbon emissions in line with national and global sustainability goals.

This Technical Reference for Embodied Carbon Inventory Data and Calculation of Construction Materials presents a curated dataset comprising 600 construction materials and 583 building elements, providing embodied carbon values across a wide range of commonly used components in the construction industry. In addition, indicative material cost information is included to enable stakeholders such as designers, architects, and contractors to make informed comparisons between environmental impact and cost considerations, thereby supporting more balanced and sustainable decision-making.

In terms of calculation, this document establishes a standardised approach to quantify embodied carbon at both material and building element levels by integrating inventory data with quantity take-offs. It provides guidance on emission factors, system boundaries, and result aggregation for lifecycle carbon reporting. The document also introduces a digital embodied carbon calculator that integrates updated inventory data and enables users to perform data-driven calculations at the building-element level based on selected materials and quantities.

This technical reference enhances transparency, consistency, and comparability in embodied carbon assessments, and supports the integration of carbon considerations into planning, design, procurement, and construction processes.

GLOSSARY

Building component
A prefabricated assembly of materials that form a product with a specific function, e.g. a precast concrete floor unit or a facade unit.

Building element
A major physical part of a building that fulfils a specific function, or functions, irrespective of its design, specification or construction, e.g. floors, frames, external walls.

Carbon factor
Normally measured in $kgCO_2e$ per unit of product e.g. $kgCO_2e/kg$.

Cradle-to-gate
Carbon emissions within the boundaries of the 'cradle' (earth) up to the factory gate of the final processing operation. This includes mining, raw material extraction, processing and manufacturing.

Cradle-to-site
Cradle-to-gate emissions plus delivery to the site of use (construction or installation site).

Cradle-to-end of construction
Cradle-to-site plus site construction and assembly activities.

Cradle-to-grave
Cradle-to-end of construction plus maintenance, refurbishment, demolition, waste treatment and disposal ('grave').

Cradle-to-cradle
The process of manufacturing component or product and then, at the end of its life, converting it into a new component of (a) the same quality (e.g. recycling of aluminium cans) or (b) a lesser quality (downcycling of a computer plastic case into a plastic container that is later turned into a building insulation board and eventually becomes waste).

Embodied carbon
Carbon emissions associated with energy consumption (embodied energy) and chemical processes during the extraction, manufacture, transportation, assembly, replacement and deconstruction of construction materials or products. Embodied carbon can be measured from cradle-to-gate, cradle-to-site, cradle-to-end of construction, cradle-to-grave, or even cradle-to-cradle. Typical embodied carbon datasets are cradle-to-gate. It is usually expressed in kilograms of CO_2e per kilogram of product or material.

$kgCO_2e$
Carbon dioxide equivalent emissions. This term may also be referred to as 'global warming potential' (GWP).

Life Cycle Assessment (LCA)
A systematic analysis of the potential environmental impacts of products or services throughout their entire life cycle.

Life Cycle Inventory
The methodological step that involves creating an inventory of input and output flows for a product system.

GLOSSARY

Operational carbon
Carbon emissions associated with energy consumption (operational energy) while the building is occupied. This includes the so-called regulated load (e.g. heating, cooling, ventilation, lighting) and unregulated or plug load (e.g. ICT equipment, cooking and refrigeration appliances).



INTRODUCTION

1.1 Background

Throughout the last two decades, global concerns about the threat of climate change have intensified. Consequently, the 2015 Paris Agreement, which build on the 1997 Kyoto Protocol, has committed the international community to tackling the worsening impacts of climate change.

Under the United NationsFramework Convention on Climate Change (UNFCCC) 2015, Malaysia declared its determination to reduce the intensity of its carbon emissions by 40% (compared with 2005 levels) by 2020 and by 45% (compared with 2005 levels) by 2030 (Susskind et al., 2020).

At the 26th UN Climate Change Conference of the Parties (COP26), which was held in Glasgow from 31 October to 13 November 2021, over 190 countries came together to accelerate action towards the goals of the Paris Agreement and the UN Framework Convention on ClimateChange. The Malaysia's Government has reiterated its commitment to reduce the intensity of its greenhouse gas emissions relative to GDP by 45% by 2030, compated with 2005 levels, and to achieve net-zero by 2050. Malaysia plans to launch a carbon pricing policy in phases and aims for a 31% share of renewable energy capacity by 2025 and 40% by 2035 in the national grid.

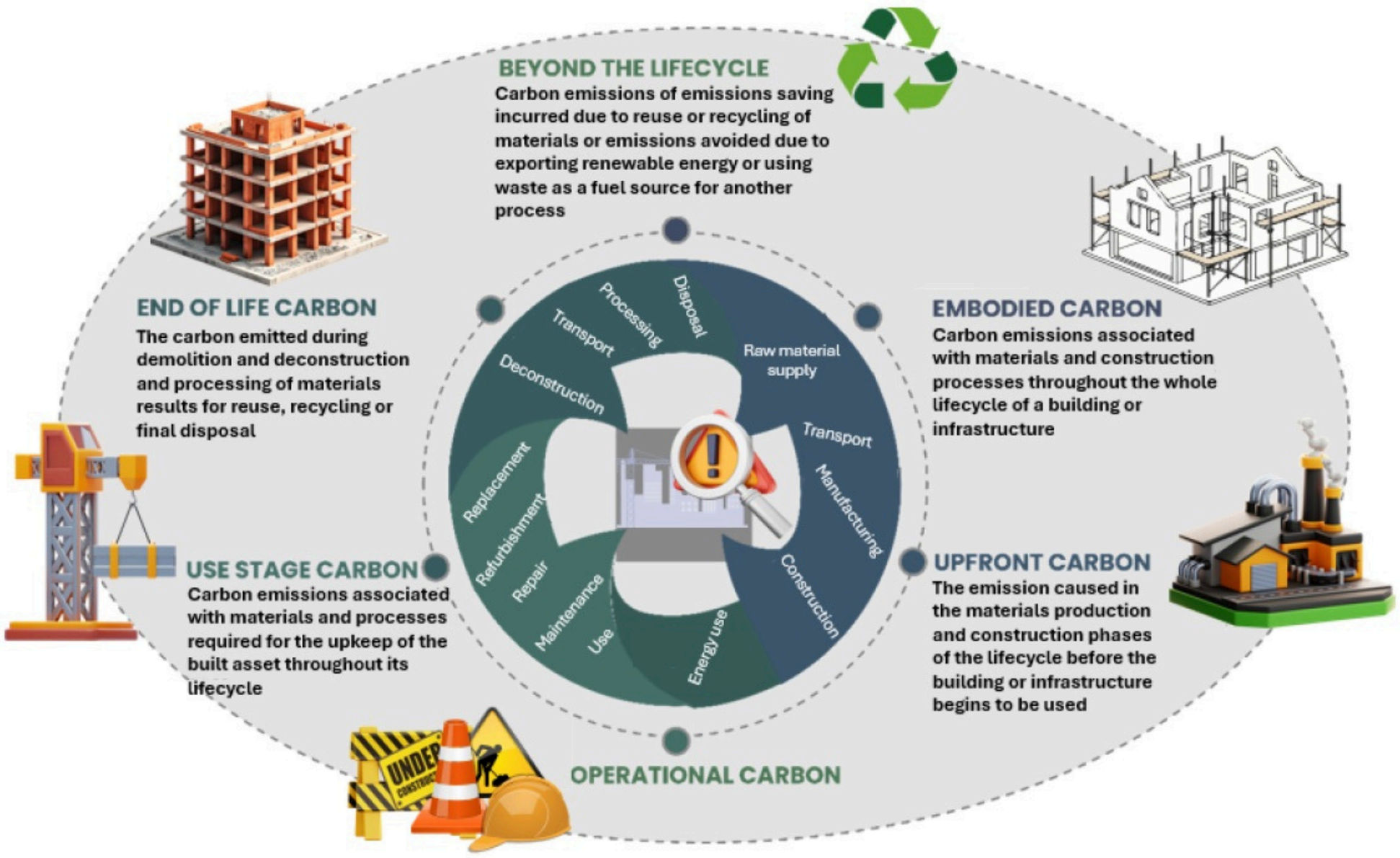


Figure 1: Life cycle of carbon emissions

Building construction and maintenance accounted for 36% of worldwide energy consumption and an estimated 40% of energy-related emissions of CO2 emissions in 2018 (IEA, 2019). The construction sector has a substantial impact, as construction materials and products contribute to carbon dioxide emissions through mining, transportation, manufacturing, and the composition of chemical products.

The term ‘embodied carbon’ refers to the total impact of all greenhouse gas emissions associated with building materials throughout their life-cycle processes of extraction, transport, manufacture, disposal, and maintenance. Thus, lowering our carbon emissions by investigating the entire life cycle of a structure is an extremely important aspect in determining the total carbon footprint of a building.

1.2 Project Aim & Objectives

Aim

The project focuses on improving embodied carbon inventory data for construction materials and developing a calculator for determining carbon footprint values by building element intended to serve as a guideline for the Malaysian construction industry.

Objectives of the Study

The objectives of this study are as follows:

Two (2) objectives to be achieved in this project are as follows:

1. To develop an Embodied Carbon Inventory Data for Construction Materials document within the context of the Malaysian construction industry. The construction materials will include the main materials commonly used in construction works, such as concrete, reinforcement bars and bricks (including cement bricks), as well as materials with high carbon emission factors

2. To provide a calculator that facilitates the calculation of the carbon footprint value by building element (tonnes CO_2e) for a construction project based on the reference document to be developed.

1.3 Scope of Project

The scope of this project encompasses the enhancement of embodied carbon inventory data specific to construction materials commonly used in Malaysia and the development of a digital calculator to estimate carbon footprint values by building element. This project aims to support the construction industry in adopting more sustainable practices by providing reliable data and practical tools for evaluating and reducing embodied carbon emissions.

Specifically, the project will cover the following areas:

1. **Review and Assessment of Existing Data:**
   - Conduct a comprehensive desktop study and literature review to assess current practices, challenges, and limitations related to embodied carbon data in the construction industry.
   - Benchmark international standards and tools to identify best practices relevant to the Malaysian context.
2. **Enhancement of Embodied Carbon Inventory Data:**
   - Update and enhance the existing embodied carbon inventory for construction materials and building elements.
   - Include key materials that are commonly used in Malaysia such as concrete, steel, brick, timber, glass, and insulation materials, among others.
3. **Focus Group Discussion:**
   - Engage with subject matter experts and industry professionals through workshops.
   - Validate the enhanced inventory data and digital calculator by gathering insights to ensure relevance and practical application.
4. **Design and Development of a Carbon Footprint Calculator:**
   - Develop a user-friendly calculator tool that enables users to estimate the carbon footprint of building elements based on material quantities and types.
   - Ensure the tool is adaptable to various project types and includes appropriate emission factors (tonnes CO_2e).

1.4 Synopsis of Report

Part 1 : Introduction

Provides the background, aims, scope of work, and synopsis of the report, highlighting the importance of addressing embodied carbon in the construction industry.

Part 2 : Desktop Study and Literature Review

Reviews key issues, challenges, policies, and best practices related to embodied carbon, including benchmarking of local and international frameworks and current industry practices.

Part 3 : Embodied Carbon Inventory Data

Describes the development of updated embodied carbon inventory data for selected construction materials and building elements using local data and international benchmarks.

Part 4 : Digital Embodied Carbon Calculator

Outlines the development, methodology, and application of the digital calculator for building-element-level embodied carbon assessment.

Part 5 : Conclusion and Recommendations

Summarises key findings and provides recommendations and a way forward, focusing on data enhancement, capacity building, and industry adoption of decarbonisation tools.

DESKTOP STUDY AND LITERATURE REVIEW

DESKTOP STUDY AND LITERATURE REVIEW

1.0 National Initiatives on the Implementation of Embodied Carbon Reduction in Other Sectors

National initiatives and strategies related to the reduction of embodied carbon in the manufacturing, automotive, and construction sectors, reflecting policy commitments, frameworks, and key programmes based on:

- **The Paris Agreement:** Nationally Determined Contributions (NDCs) under the Paris Agreement embody efforts by each country to reduce national GHG emissions intensity against GDP by 45% by 2030 relative to 2005 levels and to adapt the impacts of climate change. The government encourages life-cycle emissions reduction, including embodied emissions in products and infrastructure.
- **Twelfth Malaysia Plan (12MP) 2021–2025:** The 12MP focuses on green growth and the circular economy. The government encourages low-carbon practices in industries, including the use of sustainable materials and product life-cycle assessments.
- **Low Carbon Nation Aspiration 2040 (under the National Energy Transition Roadmap, NETR):** The government sets strategic directions towards a net-zero-carbon economy by 2050. Accordingly, the government encourages energy efficiency, green manufacturing, and sustainable construction practices.

Malaysia's national initiatives reflect a growing commitment to embed embodied carbon reduction strategies into sectoral development policies. Through a mix of certification schemes, regulatory guidelines, incentive frameworks, and data-driven tools, the country is aligning its industrial growth with low-carbon principles. These initiatives not only support the achievement of Malaysia's Nationally Determined Contributions (NDCs) but also drive innovation, enhance competitiveness, and promote sustainable practices across industries.

Sector	Initiatives	Description
Manufacturing	i. Green Industry Certification (MyHIJAU)	• MyHIJAU Mark & Directory is a government initiative to promote the sourcing and purchasing of green (eco-labelled) products and services in Malaysia. • Malaysian Green Technology and Climate Change Corporation (MGTC) manages MyHIJAU Mark & Directory and is responsible for the promotion, business advisory, verification, and monitoring of certified green products and services. • It certifies environmentally friendly products, equipment, and companies. • It also incentivises low carbon products in manufacturing which significantly lower embodied carbon
	ii. Green Practices Guideline for Manufacturing Sector	• This guideline is coordinated by MGTC and was endorsed by the Ministry of Environment and Water in 2021 as part of the Twelfth Malaysia Plan (12MP) under SDG 12.6. • It aims to promote the adoption of sustainable practices and the integration of sustainability information into the reporting cycle of companies in the manufacturing sector. • It focuses on enhancing awareness, perception, knowledge and capacity building regarding green resources, processes and technologies, collectively known as green practices. The envisioned outcome of implementing green practices in the industry is cleaner, more efficient, and more environmentally friendly operations, processes, and premises throughout Malaysia • It addresses the use of key indicators: Materials, Waste, Water, Energy, Innovation and Management.
	iii. Green Technology Master Plan Malaysia (GTMP) 2017–2030	• GTMP prioritises industrial process optimisation and green manufacturing practices. • It promotes Life Cycle Assessment (LCA) in product design and development.
	iv. ISO 14064 and 14067 Adoption Encouraged	• ISO 14064 and ISO 14067 are international standards for quantifying and reporting greenhouse gas (GHG) emissions at different levels: ISO 14064 is for organisational GHG emissions, while ISO 14067 focuses on product carbon footprints • Their adoption helps Malaysian manufacturers align with export market regulations for example the EU Carbon Border Adjustment Mechanism.
	v. SIRIM Eco-Labelling and Carbon Certification	• They support carbon-footprint verification and eco-labelling for locally manufactured goods. • They drive low-carbon product innovation by enhancing market trust and competitiveness.
	vi. .Low Carbon Operating System (LCOS) (https://lcosbasic.mgtc.gov.my/)	• LCOS is a cloud-based carbon management platform designed specifically to help corporates and SMEs easily measure, manage, and mitigate their greenhouse gas (GHG) emissions.It can be used to measure Scope 1, Scope 2, and Scope 3 GHG emissions across an entire business. • LCOS is aligned with ISO14064 and the GHG Protocol, the two most widely used standards for corporate GHG emissions measurement and reporting. • LCOS is also pre-configured with locally approved emission factors and major sources such as IPCC 2006, EFDB, DEFRA, and EPA.

Sector	Initiatives	Description
Automotive	i. National Automotive Policy (NAP) 2020	• The National Automative Policy (NAP) promotes Energy Efficient Vehicles (EEVs) and Next Generation Vehicles (NGVs). • It includes eco-design and green supply chains, which indirectly target embodied carbon through materials and processes
	ii. Low Carbon Mobility Blueprint 2021–2030	• It provides a strategic roadmap to promote public transport, EV adoption, and green logistics. • NAP recognises embodied carbon in transport infrastructure and vehicle production by promoting local parts manufacturing, low-carbon vehicle design, and sustainable material sourcing
	iii. Energy Efficient Vehicles (EEVs) Incentives	• It provides tax exemptions and investment incentives for vehicles and components with lower life-cycle emissions.
Construction	i. Malaysia Carbon Reduction and Environmental Sustainability Tool (MyCREST)	• MyCREST aims to guide, assist, and quantify, and hence reduce, the built environment's impact in terms of reduced carbon emissions and environmental effects, while taking a holistic life-cycle view of the built environment. i. It is a rating tool that guides sustainable building design and construction. ii. It integrates Life Cycle Assessment (LCA) methods to estimate embodied carbon in materials and building systems. iii. Buildings are rated using a star system based on carbon-emissions performance, water efficiency, and construction waste reduction. iv. MyCREST is required for government buildings, promoting best practices in green procurement and construction.
	ii. Green Building Index (GBI)	• It is a voluntary green-building rating tool that includes Materials and Resources and Energy Efficiency components. • It encourages the use of recycled or renewable construction materials, low-carbon cement, and efficient building systems. • It also includes carbon-offset mechanisms and credit points for reduced embodied energy through design optimisation
	iii. Industrialised Building System (IBS)	• It promotes the reduction of construction waste, time, and labour. • Prefabrication minimises material use and enhances precision, reducing embodied emissions from errors and rework. • CIDB and the Construction Industry Transformation Programme (CITP) 2016–2020 made IBS adoption a priority.
	iv. JKR Green Procurement Guidelines	• It requires assessment of embodied carbon in material selection and design for public infrastructure. • It also promotes the integration of MyCREST and LCA in project planning and procurement.

Sector	Initiatives	Description
Automotive	v. Green Practices Guideline for Construction Sector	• This guideline is coordinated by MGTC and was endorsed by the Ministry of Environment and Water in 2021 as part of the Twelfth Malaysia Plan (12MP) under SDG 12.6. • It aims to promote the adoption of sustainable practices and the integration of sustainability information into the reporting cycle of companies in the construction sector. • It focuses on enhancing awareness, perception, knowledge, and capacity-building regarding green resources, processes, and technologies, collectively known as green practices. The envisioned outcome of implementing green practices in the industry is the promotion of cleaner, more efficient, and more environmentally friendly operations, processes, and premises throughout Malaysia. • It addresses the use of key indicators: Materials, Waste, Water, Energy, Innovation and Management.
	vi. Green Product Scoring System (GPSS) – JKR/SIRIM	• Green Product Scoring System (GPSS) is developed in line with the government initiatives to promote and encourage the use of green products in the construction industry and to construct more sustainable buildings. • It is a systematic and structured assessment method that can be used to consistently evaluate the green products that are used in a project.

2.0 National Initiatives on the Implementation of Embodied Carbon Reduction in the Construction Sector

Malaysia's construction sector is undergoing a significant transformation towards low-carbon and sustainable development, driven by a suite of national initiatives targeting embodied carbon reduction. Several tools have been developed by integrating environmental performance and life cycle thinking into construction practices, particularly in public sector projects. These efforts are supported by clear guidelines, certification frameworks, and procurement policies that encourage the use of low-carbon materials, promote waste reduction, and incentivise sustainable design. Collectively, these initiatives reflect Malaysia's growing commitment to decarbonising its built environment and supporting its long-term goal of becoming a net-zero carbon nation by 2050. Several initiatives focus on improving material efficiency, promoting sustainable procurement, encouraging prefabrication methods, and integrating life-cycle assessment into project planning and design.

Organisation	Policy/ Framework/ Guidelines/ Tools	Description	Relevance to Embodied Carbon Reduction
EPU (Economic Planning Unit)	12th Malaysia Plan (RMK-12, 2021 - 2025)	• The RMK-12 outlines a strategic commitment to low-carbon and climate-resilient development, specifically: • Chapter 6: Advancing Green Growth for Sustainability and Resilience • It introduces carbon pricing mechanisms and encourages green procurement in construction. • It emphasises the adoption of the Green Technology Master Plan (GTMP) in public infrastructure. • It prioritises low-carbon building materials, energy efficiency, and life cycle assessments (LCA) to reduce embodied carbon.	• It mainstreams green development, the circular economy and carbon pricing by the government.
MGTC	Green Technology Master Plan (GTMP)	• It provides a roadmap for green practices in five focus sectors, including construction. • It calls for eco-labelling, green procurement, and the promotion of sustainable building materials such as bamboo, geopolymers, and recycled aggregates.	• It promotes low-carbon solutions in construction that will significantly lower embodied carbon.
CIDB	MyCREST (Malaysian Carbon Reduction and Environmental Sustainability Tool)	• It evaluates carbon emissions over the entire building life cycle, including embodied carbon from materials and construction. • MyCREST essentially combines three basic tools in order to construct a 'scoring plan' which is then used to assess a building for certification.	• A rating tool focused on the carbon footprint and sustainability of a building

Organization	Policy/ Framework/ Guidelines/ Tools	Description	Relevance to Embodied Carbon Reduction
CIDB	National Construction Policy (NCP 2030)	• Thrust 2 (Embrace Sustainable Built Environment - Sustainability): Promote Eco-friendly Construction Materials and Strengthen Waste Management • Develop Environmentally Friendly Design.	• The Policy serves as a key reference and guide for both the public and private construction sectors in achieving inclusive and sustainable national development by 2030.
CIDB	Sustainable INFRASTAR Rating Tool	• Sustainable INFRASTAR acts as a design and measurement tool to ensure that considerations and sustainable elements are incorporated early in the development of the project. • Assessment takes place at two project stages; namely design and construction incorporating materials sustainability, LCA elements and GHG emission tracking, including embodied carbon.	• A rating tool focused on the carbon footprint and sustainability of infrastructure projects. Material sustainability and emissions tracking
CIDB	Industrialised Building System (IBS) Implementation Programme	Role in embodied carbon through: • Reducing wastage, overproduction, and inefficiencies, which are indirect contributors to embodied emissions. • Promoting off-site prefabrication, which uses less energy and fewer materials than traditional methods.	• It reduces construction waste and emissions
CIDB	Embodied Carbon Inventory Data	• An inventory contains a summary of approximately 500 records of embodied carbon for construction materials and building elements. • The compilation of the embodied carbon data has been carried out by providing various alternatives for each type of construction material and building element.	• Material-level carbon footprint
JKR/SIRIM	Green Product Scoring system (GPSS) - JKR/SIRIM	• The Green Product Scoring System (GPSS) serves as a quantitative evaluation tool to measure the environmental performance of products used in construction projects. • It provides a systematic and consistent method to score and assess green products based on multiple sustainability criteria. • The scoring system enables government agencies and industry stakeholders to identify and select materials that align with green building standards and carbon reduction goals.	• Government tenders that utilise GPSS ensure that selected construction materials comply with low-carbon criteria, thereby reducing the total embodied emissions of public infrastructure projects

3.0 Issues and Challenges in Embodied Carbon Reduction

A. Issues and Challenges in Embodied Carbon Reduction in the Global Context

Efforts to reduce embodied carbon at the global level face several critical barriers. A primary issue is the absence of harmonised standards for assessment, leading to inconsistencies across regions and projects. Despite growing awareness of climate targets, embodied carbon remains under-represented in policy, with most regulations still focused on operational emissions. Data limitations, particularly in developing countries, exacerbate the challenge, as available emission factors often fail to reflect local contexts. Furthermore, low awareness among industry professionals, the complexity and cost of life cycle assessments (LCAs), and the lack of integrated thinking between embodied and operational carbon contribute to inertia in mainstream adoption. These findings suggest the need for unified guidelines, localised carbon databases, training, and comprehensive whole-life carbon strategies to enable meaningful progress.

No.	Issues / Challenges	Description
1	Lack of unified global standards (Zabalza Bribián et al., 2009)	Global standards for embodied carbon (EC) calculation vary significantly. Differences in system boundaries, emission factors, and LCA stages cause inconsistencies in assessments across projects and countries.
2	Limited integration into policy (Zabalza Bribián et al., 2009)	Embodied carbon is not widely embedded in national legislation. Most regulations only focus only on operational emissions, overlooking upstream carbon impacts from material use.
3	Data uncertainty and variability (Zabalza Bribián et al., 2009)	Carbon factors vary by material source, process, and geographic location. Without verified and harmonised data, results from embodied carbon assessments can be misleading.
4	Industry inertia and low awareness (Pomponi & Moncaster, 2016)	Many professionals in the building sector remain unaware of, or unconvinced about, the significance of embodied carbon. Awareness and training are lacking compared with energy efficiency.
5	High cost and complexity of LCA (Asif et al., 2007)	Life Cycle Assessment (LCA) is resource-intensive, involving complex data inputs, modelling software, and expert interpretation, which can deter small-scale projects or early-stage decisions.
6	Limited database coverage in developing countries (Gardezi et al., 2015)	Developing nations often rely on foreign carbon datasets (e.g. ICE UK, ecoinvent) that do not reflect local materials, production processes, or energy sources—leading to inaccurate results.
7	Trade-offs between embodied and operational carbon (Moncaster & Song, 2012)	Focusing only on reducing operational energy (e.g. through insulation or mechanical systems) can sometimes lead to higher embodied carbon, especially if material use increases. A whole life carbon approach is needed.

B. Issues and Challenges in Implementing Embodied Carbon Reduction in Malaysia

Malaysia's progress in embodied carbon reduction is hindered by a combination of regulatory, technical, and practical challenges. The lack of mandatory policies and the absence of local carbon databases result in inconsistent practices and data inaccuracies. Additionally, industry professionals often lack the knowledge and tools required to evaluate carbon impacts effectively. High up-front costs of sustainable materials and the fragmentation of green policy frameworks further complicate efforts to mainstream low-carbon strategies. Finally, the limited number of pilot studies and research initiatives constrains evidence-based implementation and local innovation.

No.	Issues / Challenges	Description
1	Lack of regulatory framework (Fadhlin, 2018)	Malaysia currently lacks specific regulations mandating the assessment or reduction of embodied carbon in construction projects. This absence of a regulatory framework hinders the widespread adoption of practices aimed at minimising embodied carbon emissions.
2	Absence of local embodied carbon databases (Gardezi et al., 2015)	The reliance on foreign data sources, such as the Inventory of Carbon and Energy (ICE) from the UK, leads to inaccuracies in assessing embodied carbon in the Malaysian context. Local databases reflecting regional materials and construction practices are essential for precise evaluations.
3	Low industry awareness and technical knowledge (Kamarazaly et al., 2024)	Many professionals in Malaysia's construction industry are unfamiliar with concepts related to embodied carbon, Life Cycle Assessment (LCA) tools, and Environmental Product Declarations (EPDs). This knowledge gap impedes the integration of embodied carbon considerations into project planning and execution.
4	High upfront cost of low-carbon materials (Sam et al., 2025)	Sustainable building materials often come with higher initial costs compared with conventional options. This financial barrier discourages developers and contractors from opting for low-carbon alternatives, despite their long-term environmental benefits.
5	Fragmented policy landscape (Fadhlin, 2018)	While Malaysia has introduced various green building initiatives, such as the Green Building Index (GBI) and MyCREST, there is a lack of cohesive policies specifically targeting embodied carbon. This fragmentation leads to inconsistent practices and standards across the industry.
6	Limited research and pilot studies (Gardezi et al., 2015)	There is a scarcity of local research and pilot projects focusing on embodied carbon in Malaysia. This limitation hampers the development of context-specific strategies and the demonstration of best practices in reducing embodied carbon emissions.

4.0 Current Practice and Strategies to Minimise Embodied Carbon in Construction

A. Literature Findings

Current construction practices in Malaysia remain predominantly conventional, with a strong reliance on materials such as Ordinary Portland Cement (OPC), traditional bricks, and reinforced concrete, all of which have high embodied carbon emissions. While frameworks such as the Green Building Index (GBI) encourage some sustainable practices, their adoption is largely voluntary and varies by project. The use of Life Cycle Assessment (LCA) tools, carbon calculators, or material screening based on carbon impact is minimal, and many projects lack access to national carbon benchmarks or standardised databases. In seismically prone regions, structural safety and economic concerns continue to overshadow carbon considerations, leading to the prioritisation of steel and concrete over low-carbon alternatives.

Globally, several innovative practices are being explored, such as the use of EcoSphere for automated carbon assessment and the integration of Building Information Modelling (BIM) with multi-criteria decision-making (MCDM) tools to optimise material selection. Other practices include AI-driven rating systems, optimisation of building envelopes to reduce material use, and cradle-to-gate assessments for bio-based materials such as biochar concrete. Despite the availability of these advanced tools and concepts, Malaysia's construction industry still struggles with low awareness, insufficient policy support, and inconsistent data, all of which hinder the widespread adoption of low-carbon design and construction methods.

To move towards low-carbon construction, several strategies have been proposed both in Malaysia and internationally. At the material level, replacing OPC with supplementary cementitious materials such as fly ash and biochar has shown significant potential in reducing embodied carbon. The strategic use of prefabricated or modular systems, early adoption of LCA tools, and the integration of carbon accounting into cost estimating software and BIM platforms can guide informed material choices. The establishment of local embodied carbon benchmarks and databases is essential for setting performance standards, particularly in sectors such as office buildings and public housing. These efforts can be supported through regulatory frameworks, fiscal incentives, and green procurement policies aimed at enforcing low-carbon material usage use in large-scale developments.

International practices suggest that more comprehensive approaches are also feasible. These include promoting engineered timber and hybrid structures in seismic zones, using platforms such as EcoSphere for urban-scale carbon modelling, and designing intuitive interfaces to help non-technical stakeholders engage in carbon planning. Circular economy principles are reflected in the reuse of waste materials such as bagasse ash and fly ash bricks, supported by comparative performance analyses. To ensure credibility and adoption, guidelines from certification bodies (e.g., SIRIM and ISO) are also needed to standarsize the use of innovative materials such as biochar in mainstream construction. Collectively, these strategies represent a shift toward integrating carbon performance into every stage of a project's life cycle from design to delivery

Current Practice	Paper 1 (Gardezi et al. 2015)	Paper 2 (Klufallah et al., 2013)	Paper 3 (Klufallah et al., 2023)	Paper 4 (Tsai et al., 2024)	Paper 5 (Ghorbany et al., 2025)	Paper 6 (Jangam et al., 2025)	Paper 7 (Ee et al., 2025)
Practice 1	Reliance on conventional materials, especially Ordinary Portland Cement (OPC), which contribute significantly to embodied carbon.	Use of traditional concrete and brick materials with high embodied carbon.	Most Malaysian construction projects lack a standard method for quantifying embodied carbon.	Predominant use of steel and reinforced concrete structures, especially in seismically prone regions, due to structural safety and market familiarity.	A tool called EcoSphere is used to automate the assessment of both embodied and operational carbon emissions in urban buildings.	Material selection using BIM with MCDM (multi-criteria decision making).	Use of biochar-enhanced concrete as a partial cement replacement.
Practice 2	Voluntary adoption of the Green Building Index (GBI), which encourages some aspects of sustainable design (e.g. energy savings and material selection).	Conventional construction methods dominate, with low adoption of prefabricated or modular building systems.	In the absence of national embodied carbon databases tailored to the office building sector, the industry relies on inconsistent project-level estimates.	In high-seismic zones, the carbon footprint is rarely considered a primary design factor, structural safety and cost dominate.	It uses data from national building inventories, combined with computer-vision and AI models, including Google Street View and satellite imagery	Building-envelope optimisation to reduce material intensity.	Circular economy practices in concrete production.
Practice 3	Use of conventional design methods without embedded LCA tools; sustainability is not prioritised in material decisions.	Very limited use of carbon calculators or carbon accounting tools in design or project planning stages.	Embodied carbon is not integrated into early-stage building design or cost evaluations.	Limited implementation of steel–timber hybrid systems, despite emerging evidence of a reduced carbon footprint and competitive performance.	It is capable of generating building-specific carbon baselines and modelling policy and design trade-offs (emissions versus cost).	Decision support systems for low-carbon envelope design.	Substitution of cement with low-embodied energy materials.
Practice 4	No carbon intensity benchmarks are available for comparison or goal setting, making carbon-reduction efforts inconsistent across housing developments.	Minimal attention is given to on-site material waste separation or reuse.	Projects typically follow conventional material selection, without structured low-carbon screening.	Life-cycle cost or carbon metrics are not widely integrated into structural system selection in practice.	Combined evaluation of embodied and operational carbon over the life-cycle.	Integration of AI-driven material rating tools.	Environmental performance optimisation with bio-based materials.

Current Practice	Paper 1 (Gardezi et al. 2015)	Paper 2 (Klufallah et al., 2013)	Paper 3 (Klufallah et al., 2023)	Paper 4 (Tsai et al., 2024)	Paper 5 (Ghorbany et al., 2025)	Paper 6 (Jangam et al., 2025)	Paper 7 (Ee et al., 2025)
Practice 5	Developers, contractors, and consultants have low exposure to embodied carbon concepts, resulting in business-as-usual approaches in material procurement and construction.	GBI is acknowledged, but compliance remains largely voluntary and implementation varies widely by project type.	No standard carbon performance benchmarks exist for reference in office design projects.	Embodied carbon and structural weight data are systematically collected across three systems: steel (1024 t CO_2e), hybrid (693 t CO_2e), and timber (552 t CO_2e)	The platform enables policymakers to model mitigation strategies and assess cost–carbon trade-offs at urban scale	Multi-Criteria Decision Making (MCDM) tools such as TOPSIS are beginning to be explored for material choice, although uptake remains low.	A cradle-to-gate LCA was conducted to assess environmental impacts, focusing on carbon intensity and preliminary toxicity data.
Strategy 1	Promote the replacement of OPC with supplementary cementitious materials such as fly ash, which have lower embodied carbon.	Promote prefabricated and modular construction methods to reduce material waste, speed up construction, and lower carbon emissions.	Introduce a national benchmark model for embodied carbon in purpose-built office buildings, to guide designers and policymakers.	Advocate for greater use of engineered timber (e.g., glulam, CLT) and steel–timber hybrids in seismic regions to lower embodied carbon while maintaining performance.	Scale embodied carbon assessment by automating data capture and analysis across large urban areas, reducing time and resource intensity	Combine BIM datasets with TOPSIS-based MCDM to weigh cost, operational energy, embodied energy, and thermal properties simultaneously	Encourage further use and development of biochar as a sustainable substitute for OPC.
Strategy 2	Encourage government incentives or mandates to enforce the use of low-carbon materials in public housing projects.	Integrate carbon calculators and LCA software into project assessments to measure embodied carbon systematically.	Establish a localised embodied carbon dataset specific to Malaysian construction materials and systems.	Encourage early-stage comparison of structural options using LCA and life cycle costing (LCC) to support carbon-conscious material decisions	Support comprehensive carbon planning by assessing upfront (embodied) and lifetime (operational) emissions together	Assess multiple combinations including fly-ash bricks, AAC blocks, sugar-cane bagasse bricks, and various glass options to identify optimal trade-offs	Integrate agricultural or industrial waste materials such as biochar, into mainstream construction through national policy or incentives.

Current Practice	Paper 1 (Gardezi et al. 2015)	Paper 2 (Klufallah et al., 2013)	Paper 3 (Klufallah et al., 2023)	Paper 4 (Tsai et al., 2024)	Paper 5 (Ghorbany et al., 2025)	Paper 6 (Jangam et al., 2025)	Paper 7 (Ee et al., 2025)
Strategy 3	Introduce Life Cycle Assessment (LCA) tools at early design stages to evaluate carbon impacts before construction begins.	Establish guidelines and incentives for on-site waste segregation and recycling practices.	Propose the integration of carbon benchmarks into cost estimating software and Building Information Modelling (BIM) tools.	Suggest that building codes and incentives could promote hybrid or timber adoption in place of high-carbon materials.	Provide policymakers with evidence-backed insights to directly shape effective carbon-reduction policies	Highlight materials such as fly-ash bricks and sugar-cane bagasse ash (SBA) bricks for their lower embodied energy and competitive performance.	Continue conducting cradle-to-gate assessments for diverse biochar blends to verify environmental and structural advantages.
Strategy 4	Educate developers and contractors on embodied carbon concepts and how to interpret LCA data to make informed material choices.	Use comparative project data to evaluate low-carbon alternatives in terms of carbon, cost, and time enabling informed decision-making.	Suggest building capacity among professionals to apply carbon benchmarks and interpret results during tendering and early design stages.	Highlight the need to include environmental performance as a parameter in structural optimisation, not just safety or cost.	Design intuitive interfaces that enable stakeholders without technical expertise to engage meaningfully in carbon reduction efforts .	Demonstrate that integrating embodied energy considerations alongside cost does not necessarily increase expenses, enabling truly sustainable choices .	To encourage adoption, the paper recommends policy support through green procurement frameworks for example by awarding points or tax incentives for using low-embodied carbon materials such as biochar-enhanced concrete in public projects or MyCREST/GBI-certified buildings.
Strategy 5	Develop local carbon benchmarks for typical housing projects, so planners can compare and improve upon average embodied emissions.	Suggests the need for regulatory support or mandatory requirements for reporting carbon emissions in major developments.	Recommends adoption of carbon benchmarking in government projects and regulatory frameworks	Develop and use carbon and performance benchmarks for timber-based systems to validate adoption in commercial and seismic applications.	Use EcoSphere to simulate interventions (e.g., retrofits, material upgrades) and understand their effects on emissions and costs	Include glass properties like visible transmittance, U-value, and solar heat gain coefficient in the material selection criteria to optimize thermal comfort and energy use	The paper highlights the need to develop national or international certification standards (e.g., SIRIM, ISO) for biochar as a partial cement substitute, to enhance industry confidence and facilitate its structural application.

B. Current Practice in Embodied Carbon Management in the Malaysian Construction Industry

The reviewed literature on embodied carbon management in Malaysia reveals a diverse and evolving research landscape. Many studies focus on the role of the Industrialised Building System (IBS), with findings showing both its advantages and drawbacks in reducing embodied carbon. While IBS reduces on site waste and transport related emissions, its prefabrication phase often contributes significantly to overall carbon output due to energy-intensive processes and material choices. Several papers recommend hybrid construction strategies and the integration of Life Cycle Assessment (LCA) during early design stages to optimise materials and construction methods. Design parameters, material transport logistics, and green procurement policies are highlighted as critical factors influencing embodied carbon. Tools such as AI modelling and simplified carbon calculators are also proposed to support design decisions and emissions forecasting in buildings.

Other research highlights systemic issues in policy implementation, market behaviour, and certification frameworks. Despite the availability of green material certification schemes (e.g., SIRIM Eco Label), industry uptake remains low due to cost perceptions and a lack of enforcement. Government support exists in policy form, yet the lack of standard databases, technical expertise, and regulated mandates slows down LCA adoption. Studies emphasise the need for national benchmarks, capacity building, and mandatory LCA integration at project approval stages. Innovations such as oil palm plywood and timber hybrid systems offer lower carbon alternatives but face material durability and market acceptance challenges. Overall, the findings collectively stress the importance of bridging the gap between policy intent, technological tools, and practical industry adoption to achieve meaningful embodied carbon reduction in Malaysia's construction sector.



No.	Author (year)	Title	Findings
1	Sukor et al. (2023)	Carbon Footprint of Construction Using Industrialised Building System	• Conducted LCA of construction projects using the Industrialised Building System (IBS) in Malaysia. • IBS structures were assessed at material production and site assembly stages. • The findings showed that transportation and heavy equipment use remain significant contributors to the carbon footprint. • Advocated for logistics planning, on site energy management, and green procurement in IBS projects to reduce embodied emissions.
2	Jalil (2025)	A Review on the Implementation Barriers to Low-Carbon Practices in Malaysia's Real Estate	• Reviewed policy, technical, and market barriers affecting LCA and low carbon adoption in Malaysia's construction sector. • Found that the lack of standard databases, limited local expertise, and the absence of regulation hinders progress. • Recommends the development of Malaysia-specific carbon benchmarks and greater support for LCA integration at the project approval level
3	Ting (2024)	Quantitative Study of Embodied Carbon in the Housing Development Project	• Used process based LCA to quantify embodied carbon across a typical Malaysian housing development. • Identified foundations, wall systems, and roofing as high impact areas. • Emphasised the benefit of early stage design LCA modelling to guide material choices. • Stressed the need for contractor training and simplified carbon calculators for practical use.
4	Mazlan et al. (2025)	Comparison of Sustainable Life Cycle Assessment on Building Construction Methods: IBS Versus Conventional	• Compared LCA outputs between IBS and conventional methods in Malaysian construction. • Found that IBS significantly reduces on-site waste and transport emissions. • However, IBS systems had higher emissions during prefabrication due to energy intensive machinery. • Suggests the hybrid use of IBS for structure and conventional methods for finishing to balance embodied carbon.
5	Ng et al. (2024)	Predicting Life Cycle Carbon Emission of Green Office Buildings via an Integrated LCA-MLR Framework	• Developed a hybrid model combining Life Cycle Assessment (LCA) and Multiple Linear Regression (MLR) to forecast emissions of office buildings. • Found that design parameters such as glazing ratio, floor area, and facade materials greatly influence embodied carbon. • Recommended the use of predictive tools during the design stage to reduce future emissions. • Supports the use of AI-driven design support tools in Malaysian green building planning.
6	Ishak et al. (2017)	The Green Manufacturer's Compliance with Green Criteria Throughout the Life Cycle of Building Material	• Focused on assessing manufacturers' compliance with green material life cycle criteria in Malaysia. • Found that green building material certification is available (e.g. SIRIM Eco-Label), but industry uptake is low. • Fewer than 20 manufacturers nationwide were SIRIM-certified, reflecting weak market penetration of certified low-carbon products. • Identified that green certification is not enforced, and many manufacturers avoid participation due to perceived cost or low awareness. • Although tools exist, voluntary frameworks lack the power to influence supply chain carbon practices. • Indicates a disconnect between available LCA tools and actual market behaviour, which hinders embodied carbon tracking at the material level. • Supports the need for policy-based enforcement and industry training as part of national embodied carbon management strategies.

No.	Author (year)	Title	Findings
7	Hafizan et al. (2020)	Life Cycle Assessment Framework Application in Malaysia	• Reviewed the current application of the Life Cycle Assessment (LCA) framework in Malaysia, with a focus on both government and industry adoption. • Found that LCA has been integrated into government policies, such as the Carbon Reduction Initiative and efforts to build a national environmental database. • Industry uptake remains low, mainly due to a lack of awareness, insufficient demand, and minimal enforcement. • Highlighted barriers including limited expertise, insufficient data, and the complexity of LCA implementation for material-specific carbon tracking. • The National Life Cycle Inventory (LCI) developed by SIRIM includes 161 datasets but is still limited in scope and industry coverage. • Revealed that, even with government support, the disconnect between planning and practice hampers the meaningful application of LCA in material level carbon management. • Emphasised the need for improved technical training, cross-sector involvement, and standardised LCA data to enhance embodied carbon management across the construction industry.
8	Annuar et al. (2014)	An Exploratory Review of Life Cycle Assessment Activities in the Malaysian Building Industry	• Reviewed the development and current state of LCA implementation in the Malaysian building industry. • Found that LCA-related activities were still in the early development stage, with most efforts confined to academic or legislative reference only. • ISO 14040 standards were formally adopted as national guidelines, but there is no legal obligation for industries to implement them. • Compliance is client-driven, meaning that LCA use typically depends on project-specific or international client requirements. • Despite this, the study noted a growing awareness of the importance of life cycle thinking in response to global sustainability expectations. • Identified a need for regulatory enforcement, training, and market incentives to mainstream LCA in construction practices. • The gap between formal standard adoption and practical implementation reflects limited progress in embodied carbon assessment for construction materials in Malaysia.
9	Moayedi et al. (2017)	Quantification of Carbon Footprint from Major Construction Materials for Office Projects in Malaysia	• Investigated the carbon footprint from the cradle-to-gate phase of office building materials in Malaysia, including manufacturing and transport stages. • Focused on major construction materials such as cement, steel, and aggregates commonly used in commercial office projects. • Utilised input-output (IO) and process-based LCA methods to track embodied carbon associated with each material. • Found that manufacturing and transport stages are responsible for significant GHG emissions, highlighting the carbon intensity of conventional building materials. • The study emphasised that office buildings, due to their size and complexity, generate 10–20 times more emissions than residential buildings. • Warned that business-as-usual construction practices could lock Malaysia into long-term unsustainable development pathways. • Recommended strategic policy shifts and the mainstreaming of green practices to reduce the sector's overall carbon emissions.

No.	Author (year)	Title	Findings
10	Ayob et al. (2020)	Carbon Footprint Assessment of Hostel Building Construction Using the Industrialized Building System in Pauh Putra, Perlis	• Conducted a cradle-to-gate carbon footprint (CF) assessment for a hostel construction project in Perlis using the Industrialised Building System (IBS). • Focused on prefabricated sandwich panels (Prefab-SP) and measured emissions during both manufacturing and on-site installation stages. • Found that actual site installation, especially floor construction using excavators, contributed a large proportion of emissions (81.59 tCO_2eq or 34%). • The shotcrete plaster mix had the highest embodied carbon (360.04 tCO_2eq or 73.11%) due to its high cement content and energy-intensive production. • Revealed that building work, including foundation and structural construction, accounted for the majority (63.87%) of total emissions. • Showed that even industrialised methods such as IBS can produce significant carbon footprints if not carefully optimised. • Suggested that policy attention is needed to reduce emissions during construction phases, not just in material production.
11	Balasbaneh and Marsono (2017)	Strategies for Reducing Greenhouse Gas Emissions from Residential Sector by Proposing New Building Structures in Hot and Humid Climatic Conditions	• Conducted a cradle-to-grave Life Cycle Assessment (LCA) using SimaPro to evaluate six prefabricated residential building systems in Malaysia. • Aimed to reduce greenhouse gas (GHG) emissions by modifying conventional Industrialised Building System (IBS) structures. • Found that timber prefabricated structures had the lowest global warming potential, making them the most climate-friendly option. • Proposed two new hybrid composites for prefabricated housing: GLT (glued laminated timber) plus steel studs and LVL (laminated veneer lumber) plus steel studs. • These composites performed significantly better than concrete or steel-only systems in reducing embodied carbon. • Despite their environmental benefit, timber structures are rarely used in Malaysia due to material durability issues and declining market adoption (from 60% to 7% over 40 years). • Suggested that design innovation, coupled with LCA-backed evidence, can guide housing policy and construction decisions in hot and humid climates such as Malaysia.
12	Balasbaneh and Ramli (2020)	A Comparative Life Cycle Assessment (LCA) of Concrete and Steel-Prefabricated Prefinished Volumetric Construction Structures in Malaysia	• Conducted a cradle-to-grave Life Cycle Assessment (LCA) comparing steel and concrete-based Prefabricated Prefinished Volumetric Construction (PPVC) modules in Malaysia. • Also performed a Life Cycle Cost (LCC) analysis to examine the combined environmental and economic performance of both systems. • Found that steel PPVC structures consume more electricity but perform better in non-renewable energy use, land occupation, and material recyclability. • In contrast, concrete PPVC systems generate higher greenhouse gas (GHG) emissions but perform better in GHG reduction metrics by 54%. • The study showed that steel PPVC is 4% more cost-efficient than concrete when long-term reuse and recyclability are factored in.

No.	Author (year)	Title	Findings
			• Demonstrated that hybrid decision-making using both LCA and LCC provides a more holistic view of embodied carbon performance. • Suggested that material choice, especially in industrialised systems, should consider GHG impact, energy use, recyclability, and cost trade-offs for sustainable design.
13	Lim et al. (2017)	Carbon Footprint of Construction Using Industrialised Building System	• Conducted a Life Cycle Assessment (LCA) of carbon emissions generated from the Industrialised Building System (IBS) construction method in Malaysia. • Evaluated emissions from manufacturing, transportation, and on-site construction activities, comparing IBS against conventional construction systems. • Found that Ordinary Portland Cement (OPC), steel bars, diesel, and autoclaved aerated concrete (AAC) blocks were the most significant contributors to the embodied carbon in IBS. • Highlighted that IBS, although marketed as sustainable, can still accumulate high carbon emissions depending on material choice and transportation. • Suggested the need for material substitution, optimised logistics and improved on-site efficiency to maximise the environmental benefits of IBS. • The study supports more rigorous carbon accounting in IBS projects and a stronger integration of LCA tools into design and procurement processes.
14	Wen et al. (2015)	Assessment of Embodied Energy and Global Warming Potential of Building Construction Using Life Cycle Analysis Approach: Case Studies of Residential Buildings in Iskandar Malaysia	• Performed a comparative Life Cycle Assessment (LCA) study between Industrialised Building System (IBS) and conventional building systems in Malaysia. • Focused on residential construction in Iskandar Malaysia, a region targeted for low-carbon urban development. • Found that concrete and steel are the largest contributors to embodied energy and global warming potential (GWP) in both construction systems. • Identified material production and transportation as hotspots for environmental impact during the assembly phase. • Recommended substituting Ordinary Portland Cement (OPC) with fly ash and using alternative low-impact materials to reduce embodied carbon. • Demonstrated that LCA can inform early design decisions and material choices to align with national low-carbon goals. • Reinforced the need to standardise LCA methodology and create material-specific carbon databases for Malaysia.
15	Jahandideh et al. (2020)	Carbon Footprint Assessment in the Life-Cycle Design of Concrete Structures in the Tropics: A Case Study of Residential Buildings in Malaysia	• Conducted a Life-Cycle Carbon Footprint Assessment (LCCFA) of two reinforced concrete residential buildings located in tropical Malaysian conditions. • Applied a phase-based approach analysing material production, construction, use, and end-of-life (demolition/reuse). • Found that the production phase (especially cement manufacturing) was the dominant contributor to CO_2 emissions, exceeding those from operational or demolition phases. • Demonstrated that life-cycle-based modelling is critical for understanding the long term environmental impacts of concrete based systems. • Emphasised that LCA at the design stage enables the selection of less carbon-intensive materials and optimisation of concrete mix design.

No.	Author (year)	Title	Findings
			• Recommended the integration of LCA tools into structural engineering processes to reduce embodied carbon at the design specification level. • Supports policy development and professional training to encourage life-cycle design thinking in Malaysia's housing development sector.
16	Ahmad et al. (2014)	Life Cycle Assessment for Oil Palm Based Plywood: A Gate-to-Gate Case Study	• Conducted a gate-to-gate Life Cycle Assessment (LCA) on oil palm trunk-based plywood production in Malaysia. • Defined a scope that excluded the cultivation phase, focusing only on manufacturing and processing stages. • Found that oil palm plywood is currently used mainly for non-structural applications, such as formwork, cabinetry, and packaging. • Quantified emissions and energy use during cutting, bonding, pressing, and finishing processes in the factory. • Highlighted the potential of underutilised biomass to reduce embodied carbon in the materials sector, while noting that more research is needed on full cradle-to-grave performance. • Suggested expanding this gate-to-gate study into full LCA frameworks to assess the total environmental impact of oil palm-based products.

5.0 Policy and Implementation Perspectives on Embodied Carbon in Malaysian Construction

The reviewed papers collectively reveal that Malaysia's construction and real estate sectors are grappling with substantial structural, technical, and policy-related barriers in managing embodied carbon. A major recurring theme is the absence of a localised cost estimation framework to guide embodied carbon mitigation, leading to its perception as an additional cost rather than a value-generating design opportunity (Yee & Karim, 2024). The lack of technical capacity, particularly in Life Cycle Assessment (LCA) and cost-benefit modelling, limits the ability of firms to adopt carbon-reducing practices effectively. This challenge is compounded by the fragmented coordination among stakeholders, as highlighted by Challender (2024), who suggests that structured collaboration toolkits can enhance transparency and collective accountability in carbon-related decisions.

From a policy standpoint, Jalil and Noor (2024, 2025) emphasise that Malaysia’s current carbon-reduction strategy remains voluntary and fragmented, in contrast with mandatory frameworks implemented in countries such as Germany. They emphasise the need for tax incentives, green procurement policies, and enforceable carbon limits to strengthen regulatory effectiveness. Malaysia’s reliance on tools such as MyCREST and GreenRE has primarily emphasised operational rather than embodied emissions. As a way forward, the literature strongly recommends developing centralised carbon databases, performance benchmarks, and urban-scale pilot projects to test enforceable strategies. Embedding environmental ethics and carbon literacy at the planning stage is also essential for a holistic low-carbon transition.



No.	Author (year)	Title	Findings
1	CC Yee & SBA Karim (2024)	Estimation and Optimisation of Embodied Carbon Reduction Costs in the Malaysian Construction Industry	• Highlights the absence of cost estimation frameworks specific to embodied carbon mitigation in Malaysian construction projects. • Finds that the technical capability of local firms is limited, particularly in LCA modelling and cost-benefit analysis related to carbon reduction. • Suggests that embodied carbon reduction is often perceived as an added cost rather than a design opportunity, discouraging voluntary adoption. • Recommends training and upskilling industry professionals in the LCA application and carbon cost modelling. • Points to the need for a localised carbon database and guidelines to support cost optimisation in sustainable building design.
2	MAA Jalil & NAM Noor et al. (2024)	Policy Measures for Reducing Emissions in the Real Estate Sector – A Review	• Provides a comprehensive review of Malaysia's current policy instruments targeting carbon reduction in the built environment. • Identifies a critical gap: Malaysia lacks mandatory embodied carbon regulations, relying primarily on voluntary tools such as the Green Building Index (GBI). • Notes that current frameworks focus more on operational energy than on life-cycle or embodied emissions. • Recommends the adoption of incentive-based policies, including tax rebates and green procurement standards, to encourage low-carbon construction practices. • Highlights the potential of carbon performance benchmarks to support future regulation and certification initiatives.
3	J. Challender (2024)	Case Study Analysis on Enhancing Environmental Ethics through a Collaboration Toolkit	• Explores how a collaboration toolkit can be used to promote ethical decision-making in sustainable construction. • Uses Malaysia as one of the case settings to analyse how stakeholders (consultants, developers, and local authorities) interact in carbon related decision-making. • Identifies fragmented coordination among project stakeholders as a key barrier to effective carbon management. • Recommends the use of structured collaboration tools to facilitate dialogue, transparency, and shared responsibility in relation to LCA and embodied carbon choices. • Encourages embedding environmental ethics and carbon literacy in the early design review and planning stages.
4	MAA Jalil (2025)	Implementation Barriers to Low-Carbon Practices in Malaysia's Real Estate Sector	• Identifies systemic, technical, and market-based barriers that hinder the widespread adoption of embodied carbon practices. • Notes a shortage of trained professionals with expertise in Life Cycle Assessment (LCA) and carbon management. • Highlights the limited availability of localised data, which hinders accurate carbon measurement at the material level. • Points out that carbon reduction strategies are primarily voluntary and poorly integrated into mainstream construction workflows. • Recommends establishing a central carbon data repository, capacity building programmes, and stronger alignment between policy and project-level decision-making.

No.	Author (year)	Title	Findings
5	MAA Jalil & NAM Noor (2025)	Policy Measures for Reducing Emissions in the Real Estate Sector: A Comparative Perspective	• Compares Malaysia's embodied carbon policy landscape with that of Germany, a leader in low-carbon regulation. • Shows that Malaysia's approach remains largely voluntary, whereas Germany enforces mandatory carbon caps, product category rules, and carbon reporting for new buildings. • Emphasises the need for urban scale pilot programmes in Malaysia to test and validate embodied carbon reduction strategies. • Recommends introducing enforceable carbon limits, performance-based incentives, and region-specific benchmarks. • Suggests that Malaysia could learn from international frameworks by integrating life-cycle emissions metrics into urban planning and zoning.

6.0 Current Practices Regarding Life Cycle Assessment (LCA) Development and Carbon Assessment in Malaysia

Malaysia has made notable strides in institutionalising Life-Cycle Assessment (LCA) and carbon footprint accounting through a series of national programmes and certification schemes, primarily led by SIRIM Berhad and the Malaysian Green Technology and Climate Change Corporation (MGTC). One of the foundational efforts is the SIRIM–JETRO Project, which catalysed the creation of Malaysia's first Life Cycle Inventory (LCI) datasets, spanning the power generation, oil and gas, steel, and agriculture sectors. This initiative, alongside the National LCA Project, has enabled Malaysia to develop sector-specific LCA frameworks and align its environmental declarations with ISO 14040 standards. In parallel, MyLCID, the Malaysian LCI Database, now serves as the national repository of emissions data for LCA studies and supports GHG reporting and benchmarking across key industrial sectors such as construction and palm oil.

Supporting these initiatives are several certification and eco-labelling schemes that integrate LCA thinking into product and system assessments. The SIRIM Eco-Labelling Scheme, aligned with ISO 14024, provides Type I environmental labels for products that meet stringent life-cycle criteria, while the Environmental Management System (EMS) certification (ISO 14001) encourages organisations to embed life-cycle thinking in their operations. Meanwhile, the MyHIJAU Mark and Directory, managed by MGTC, consolidates certified green products and suppliers, facilitating low-carbon material selection for green procurement and public infrastructure projects. Collectively, these programmes not only support carbon footprint tracking and eco-label transparency but also help standardise embodied carbon practices across Malaysia's construction and manufacturing sectors, paving the way for future integration into national policy and regulatory frameworks.



No.	Programme / Scheme	Organisation	Description	Key Areas of Focus	Contributions to Carbon Management
1	**SIRIM–JETRO Project (Japan–Malaysia Green Partnership Programme)**	**SIRIM Berhad (Malaysia), Japan External Trade Organization (JETRO)**	This programme was launched under a collaborative framework between Malaysia and Japan to advance the country's capabilities in Life-Cycle Assessment (LCA) and environmental product labelling. The core component involved developing Life Cycle Inventory (LCI) datasets, which provide the foundational background data required to conduct LCA studies and produce Type III environmental declarations (eco-labels).	i) Developed LCI datasets for key industrial sectors, including: • Power generation • Water supply • Oil and gas production • Steel manufacturing ii) Conducted sector-specific Life Cycle Impact Assessment (LCIA) studies on: • Air conditioners • Crude palm oil • PET bottles iii) Engaged major industry players such as FELDA, Golden Hope, the Malaysian Palm Oil Board (MPOB), and IOI Group. iv) As of 2017, SIRIM had completed 161 national LCI datasets, covering categories such as: • Electrical and electronics • Chemicals • Construction • Agriculture	This project laid the groundwork for enabling product-level carbon tracking and eco-label compliance in Malaysia. It represents one of the earliest and most structured efforts to align the local industrial ecosystem with ISO 14040 LCA standards.
2	**SIRIM Eco-Labelling Scheme**	**SIRIM QAS International (subsidiary of SIRIM Berhad)**	The SIRIM Eco Labelling Scheme is Malaysia's official Type I environmental labeling programme, designed to certify products and services that meet stringent environmental performance criteria throughout their life cycle. This programme aims to stimulate market transformation by encouraging manufacturers to adopt sustainable production practices, and by helping consumers identify environmentally preferable products. It is governed by international principles outlined in ISO 14024, and administered by SIRIM QAS International, Malaysia's national certification body.	i) The scheme is supported by the Environmental Technology Research Centre (ETRC) of SIRIM Berhad. ii) As of the latest update: a. Forty-one eco labelling criteria have been developed, covering a wide range of products and services. b. Thirteen Product Category Rules (PCRs) were established specifically for construction materials, such as paints, adhesives, insulation, and concrete products.	• Promotes the development of product-specific LCA datasets, which are a prerequisite for eco-labelling. • Encourages manufacturers to improve their environmental declarations and transparency. • Indirectly supports embodied carbon accounting by setting criteria based on material sourcing, energy use, emissions, and end-of-life management.

No.	Program / Scheme	Organization	Description	Key Areas of Focus	Contribution to Carbon Management
			It is governed by international principles outlined in ISO 14024, and is administered by SIRIM QAS International, Malaysia's national certification body.	iii) The programme has received funding and technical support from international partners, including the EU Switch-Asia Programme. iv) The eco-label is recognised under the MyHIJAU Mark, Malaysia's green product consolidation framework.	• Indirectly supports embodied carbon accounting by setting criteria based on material sourcing, energy use, emissions, and end-of-life management.
3	**National Life Cycle Assessment (LCA) Project**	**SIRIM Berhad**	The National LCA Project was Malaysia's first coordinated national-level initiative to integrate Life Cycle Assessment (LCA) into industry, policy, and sustainability reporting. It was launched in response to global alignment with the ISO 14040 series, and was mandated to SIRIM Berhad to develop national infrastructure for lifecycle-based environmental management. The project was established as a strategic tool to promote cleaner production, reduce resource intensity, and provide data-driven support for eco-labelling, environmental declarations, and green public procurement.	i. Primary industries, including: • Electricity generation • Petrochemical production • Oil and gas refining ii. LCA research and development for Malaysia's high-impact sectors, with a strong emphasis on: • Palm oil • Petrochemicals • Manufacturing iii. Collaboration with various ministries and academic institutions to expand LCA awareness and develop sector-specific methodologies.	• Establishes the foundation for quantifying embodied carbon in materials and processes. • Supports the integration of life-cycle emissions accounting in environmental policy and product certification. • Paves the way for more granular LCI data development, particularly in sectors with high carbon intensity (e.g. construction, energy, palm oil).
4	**Malaysian Life Cycle Inventory Database (MyLCID)**	**SIRIM Berhad**	The Malaysian Life Cycle Inventory Database (MyLCID) serves as the national repository of Life-Cycle Inventory data for products, processes, and sectors in Malaysia. It was developed to support a wide range of LCA-related applications, including eco-design, eco-label certification, environmental declarations (EPDs), and LCA-based policy tools. The database is a critical output of the National LCA Project, intended to address Malaysia's longstanding gap in localised environmental data for life cycle modelling.	• Facilitates the quantification of embodied carbon across materials and sectors using local emissions data. • Supports the development of low-carbon product declarations and benchmarking tools for the Malaysia's construction industry. • Enables carbon footprint studies at both product and sectoral levels, essential for GHG reporting and reduction target planning.	• Facilitates the quantification of embodied carbon across materials and sectors using local emissions data. • Supports the development of low-carbon product declarations and benchmarking tools for the Malaysia's construction industry. • Enables carbon footprint studies at both product and sectoral levels, essential for GHG reporting and reduction target planning.

No.	Program / Scheme	Organization	Description	Key Areas of Focus	Contribution to Carbon Management
5	**Environmental Management System (EMS) Certification Scheme**	**SIRIM QAS International (subsidiary of SIRIM Berhad)**	The Environmental Management System (EMS) certification programme provided by SIRIM QAS International enables Malaysian companies to align their operations with the internationally recognised ISO 14001 standard. This standard outlines systematic approaches for organisations to identify, manage, monitor, and improve their environmental performance, including carbon management. Although not specific to Life Cycle Assessment (LCA), EMS serves as an enabling framework within which LCA, carbon accounting, and sustainability reporting tools are integrated.	• Promotes the adoption of structured environmental policy frameworks. • Helps organisations set and achieve environmental objectives and targets, including energy efficiency and GHG reduction. • Requires continuous monitoring, internal audits, and documentation of environmental aspects across the organisation. • Encourages integration with life cycle thinking, as noted in ISO 14001:2015, which explicitly introduces life cycle perspectives for the first time.	• Provides a framework for carbon risk identification, including embodied emissions where organisations voluntarily integrate LCA. • Encourages supplier engagement and life cycle awareness, particularly in procurement and materials management. • Serves as a foundation for more advanced environmental tools, such as carbon footprint analysis, EPDs, and carbon disclosures aligned with global frameworks such as GRI or CDP.
6	**MyHIJAU Mark and Directory**	**Malaysian Green Technology and Climate Change Corporation (MGTC)**	The MyHIJAU Mark is Malaysia's official green product certification consolidation system, developed by MGTC under the Ministry of Natural Resources, Environment and Climate Change (NRECC). It merges multiple green certifications, including SIRIM Eco-Labelling, ISO 14001, and various international eco-labels (e.g. ENERGY STAR, Singapore Green Label), into a unified public directory known as the MyHIJAU Directory. This platform is designed to support green procurement, public sector environmental compliance, and market incentives for sustainable construction and manufacturing.	i) The MyHIJAU Directory provides searchable listings of: • Certified green products (e.g. building materials, furniture, and appliances) • Green service providers (e.g. waste management, and sustainable architecture) ii) The MyHIJAU Mark enables inclusion in government green procurement programmes and eligibility for financial incentives, such as tax exemptions or green financing schemes. iii) As of the last verified update in 2021: • Over 200 building materials were registered. • These products were supplied by forty-three manufacturers certified under one or more recognised environmental standards.	• Acts as a national green supply chain reference, aiding the selection of low-carbon materials in public and private construction. • Supports LCA-based and eco-label-certified materials through pre-approved listings, reducing duplication in material validation. • Helps standardize embodied carbon practices by encouraging consistent use of third-party verified, LCA-supported products.

7.0 Guidelines and Standards in Malaysia for Embodied Carbon Assessment of Construction Materials

Malaysia's approach to embodied carbon assessment in the construction industry is deeply rooted in internationally recognised Life Cycle Assessment (LCA) standards, particularly the ISO 14000 series. The ISO 14040:2006 provides the foundational framework, outlining the four mandatory LCA phases from goal and scope definition, inventory analysis, and impact assessment to interpretation which are essential for understanding and modelling the environmental impacts of materials across their life cycle. Building on this, ISO 14044:2006 introduces technical procedures and data quality requirements, making it the most detailed and frequently applied standard in material-based LCA assessments. These standards are indispensable for evaluating carbon emissions linked to the extraction, manufacturing, and disposal of construction materials, and they form the backbone of Environmental Product Declarations (EPDs) and carbon labelling schemes.

Further enhancing specificity, ISO 14067:2018 offers comprehensive guidance on quantifying the Carbon Footprint of Products (CFP), including cradle-to-gate and cradle-to-grave assessments, which is particularly crucial for comparing low-carbon building materials such as concrete and cement. To localise these global standards, MS ISO 14044:2008 was adopted as Malaysia’s national equivalent, embedding ISO methodology within the country’s regulatory and industrial context. It ensures standardised procedures for carbon-related claims, particularly for projects supported by the Malaysian government. Together, these standards not only enable consistent and credible carbon accounting but also support Malaysia’s broader goals in green procurement, sustainable construction, and alignment with global green-building frameworks such as GBI, LEED, and BREEAM

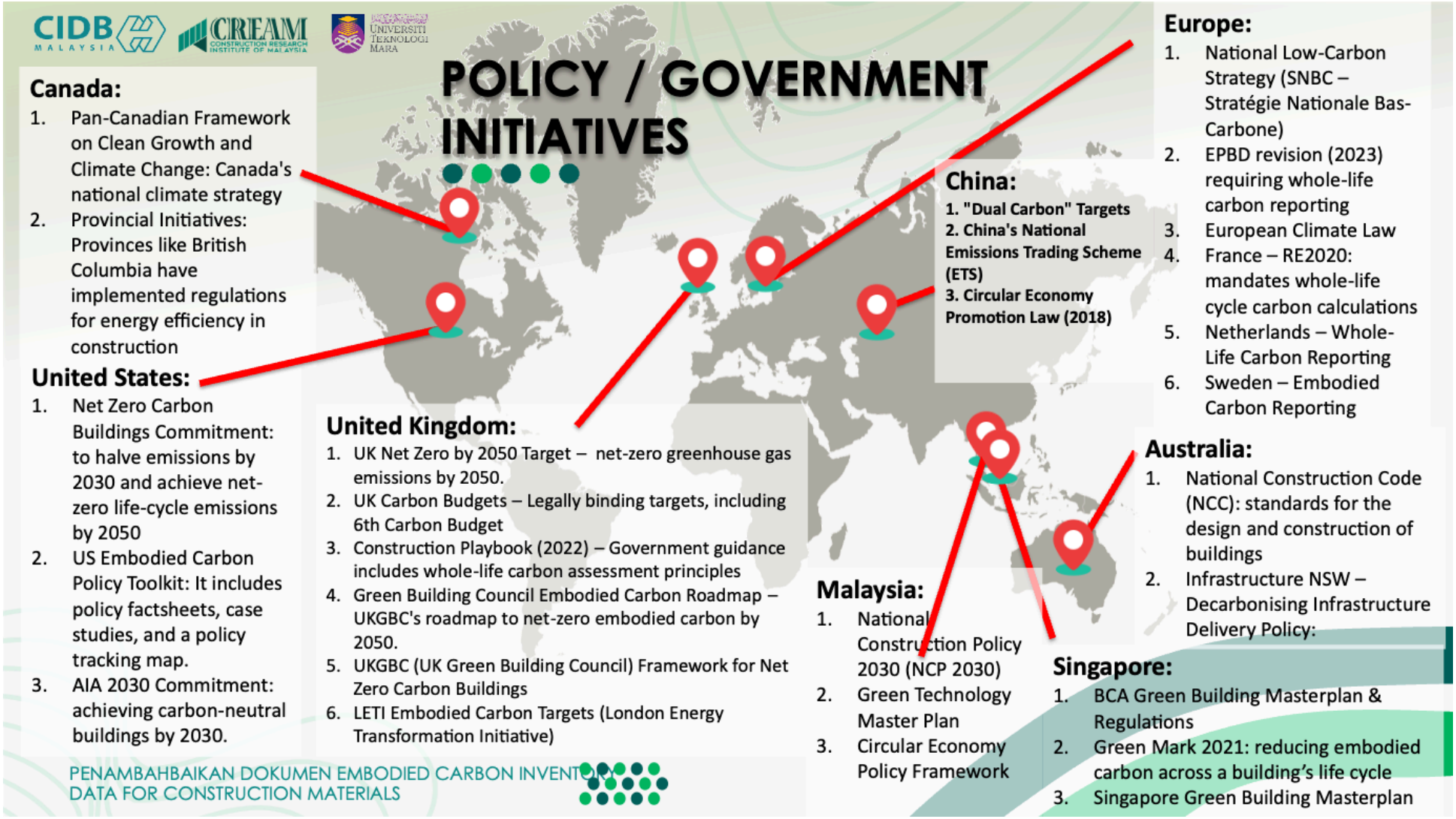


No.	Guideline / Standard	Organisation	Description	Key Components	Relevance to Construction and Embodied Carbon
1	**ISO 14040:2006 – Environmental Management – Life Cycle Assessment – Principles and Framework**	**International Organization for Standardization (ISO)**	ISO 14040:2006 outlines the core principles and framework for conducting Life Cycle Assessment (LCA). It establishes the logical structure and stages involved in a complete LCA study, with a focus on ensuring transparency, reproducibility, and scientific consistency in environmental impact evaluation across a product's life cycle.	i. Defines the four mandatory phases of LCA: • Goal and scope definition • Life Cycle Inventory (LCI) analysis • Life Cycle Impact Assessment (LCIA) • Interpretation ii. Emphasises the relationships between phases, showing how methodological choices affect final outcomes. iii. Provides guidance on: • Assumptions and system boundaries • Functional units and allocation procedures • Limitations of LCA results • Reporting requirements and critical review	• Serves as the starting point for any LCA-based carbon assessment in construction, including embodied carbon calculations. • Lays the foundation for quantifying emissions associated with raw material extraction, manufacturing, transport, installation, and disposal of construction materials. • Ensures that such assessments follow globally recognised best practices, allowing results to be compared or certified (e.g., through EPDs or carbon labelling).
2	**ISO 14044:2006 – Environmental Management – Life Cycle Assessment – Requirements and Guidelines**	**International Organization for Standardization (ISO)**	ISO 14044:2006 provides the technical backbone for conducting LCA studies, building directly on the structure introduced in ISO 14040. While ISO 14040 outlines the conceptual framework, ISO 14044 details the step-by-step requirements, procedures, and methodological choices needed to conduct a robust, credible LCA. It is the most widely used international standard for performing Life Cycle Assessments across industries, including the construction and materials sectors.	• Elaborates specific rules and procedures for all four LCA phases: • Goal and scope definition: clarifies the purpose, audience, and decision context of the study. • Inventory analysis (LCI): requires detailed data on inputs (raw materials, energy) and outputs (emissions, waste). • Impact assessment (LCIA): guides the selection of impact categories (e.g. climate change, resource depletion), classification, and characterisation. • Interpretation: provides a structure for drawing meaningful conclusions and identifying limitations or trade-offs. • Mandates data quality assessments, sensitivity analysis, and allocation rules (e.g., when processes serve multiple functions). • Includes instructions for critical review, whether internal or third-party, particularly when LCA results are disclosed to the public or used for comparative assertions.	• Defines how to properly collect and analyse data related to material sourcing, manufacturing processes, transportation, and end-of-life scenarios — all of which are key to embodied carbon assessment. • Supports the development of Environmental Product Declarations (EPDs), carbon footprint labels, and sustainable procurement frameworks. • Is frequently applied in eco-design, green building material certification, and policy support tools.

No.	Guideline / Standard	Organization	Description	Key Component	Relevance to Construction and Embodied Carbon
3	**ISO 14067:2018 – Greenhouse Gases – Carbon Footprint of Products – Requirements and Guidelines for Quantification**	**International Organization for Standardization (ISO)**	ISO 14067:2018 is the primary international standard for quantifying and reporting the Carbon Footprint of Products (CFP). It builds on the foundational LCA methods established in ISO 14040 and ISO 14044, but focuses specifically on greenhouse gas emissions over the product's life cycle including both direct and indirect emissions. It is particularly important for industries aiming to: - Make public carbon claims (e.g., low-carbon materials) - Develop Environmental Product Declarations (EPDs) - Support carbon-conscious procurement	i. Defines rules for calculating product-related CO_2-equivalent emissions, covering the following: • Cradle-to-gate • Cradle-to-grave • Gate-to-gate ii. Includes mandatory requirements for: • Goal and scope definition • Emissions data collection • Calculation methods • Reporting and interpretation iii. Also provides optional guidelines on: • Use of renewable energy credits • Carbon offsetting (for full carbon neutrality claims) • Uncertainty analysis and sensitivity testing	i) ISO 14067 provides a standardised method to measure embodied carbon, specifically: • CO_2e from material extraction, processing, transportation, use, and end-of-life disposal. ii) It is widely used in the construction industry for: • Concrete and cement benchmarking • Low-carbon product labelling • Comparative building material selection iii) Enables consistent product-to-product comparison based on GHG intensity, which supports green procurement, carbon credit validation, and sustainability certification (e.g. GBI, LEED, BREEAM).
4	**MS ISO 14044:2008 – Environmental Management – Life Cycle Assessment – Requirements and Guidelines**		MS ISO 14044:2008 is Malaysia's formal adoption of the international ISO 14044 standard. It provides detailed guidance for conducting Life Cycle Assessments (LCA), tailored for compatibility with Malaysia's legal, institutional, and industrial contexts. This standard ensures regulatory consistency, promotes the use of local environmental data use, and serves as the technical benchmark for certification, eco-labelling, and carbon reporting efforts in Malaysia.	i. Maintains the same structure and methodology as ISO 14044, covering: • Goal and scope definition • Inventory analysis (LCI) • Impact assessment (LCIA) • Interpretation and reporting ii. Specifies national-level terms of reference, audit procedures, and acceptable documentation practices. iii. Supports critical reviews, particularly when LCA results are used for: • Comparative assertions (e.g., between products) • Environmental product claims (e.g., EPDs or carbon labels)	• Serves as a mandatory reference in all government-funded or endorsed LCA projects (e.g., under the National LCA Project). • Is supported by SIRIM Berhad for training, compliance checking, and PCR (Product Category Rules) development. • Is commonly cited in academic, consultancy, and industry-led carbon assessment reports in Malaysia's built environment sector.

8.0 Benchmarking on the Initiatives Related to Embodied Carbon in Construction Industry

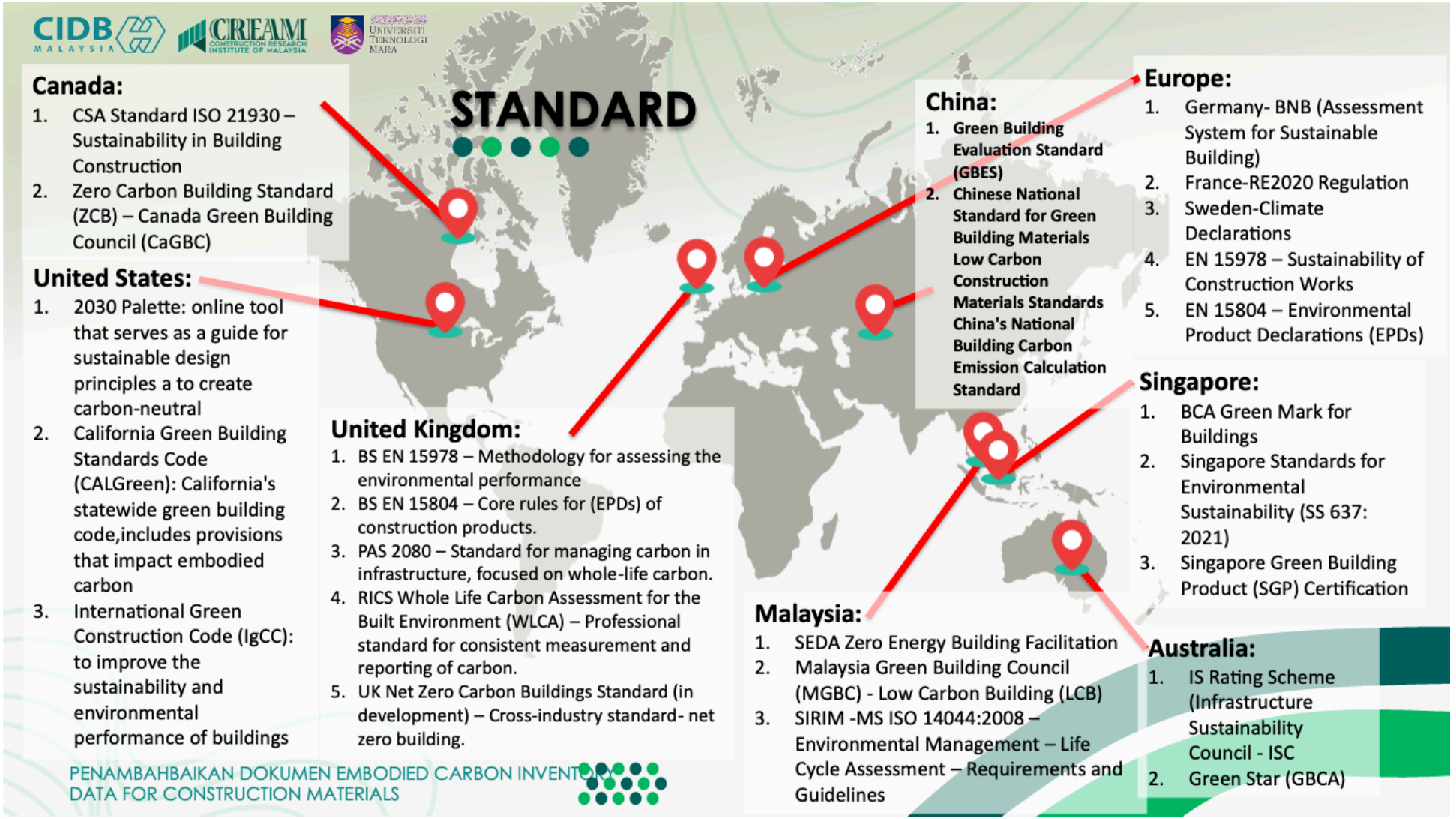
A. Policy / Government Initiatives



	US	UK	EUROPE	CANADA	AUSTRALIA	SINGAPORE	CHINA	MALAYSIA
POLICY / GOVERNMENT INITIATIVES	1)**World Green Building Council (WorldGBC) Net Zero Carbon Buildings Commitment**: In 2021, the WorldGBC updated its Commitment to include embodied carbon, urging the building and construction sector to halve emissions by 2030 and achieve net-zero life-cycle emissions by 2050 2**)Embodied Carbon Policy Toolkit:** Developed by the Carbon Leadership Forum, this toolkit provides resources for policymakers to understand and implement strategies to reduce embodied carbon in buildings and infrastructure. **3) AIA 2030 Commitmen**t: A programme by the American Institute of Architects that encourages architecture firms to commit to achieving carbon-neutral buildings by 2030.	1)**UK Net Zero by 2050 Target –** Legal commitment under the Climate Change Act to reach net-zero greenhouse gas emissions by 2050. 2**)UK Carbon Budgets** – Legally binding targets, including the Sixth Carbon Budget which addresses embodied emissions. 3)**Construction Playbook (2022)** – Government guidance that includes Whole-Life Carbon Assessment principles for public projects. 4)**Future Homes and Buildings Standard (2025)** – Although mainly operational, it influences materials and indirectly affects Embodied Carbon. 5)UK **Green Building Council Embodied Carbon Roadmap –** UKGBC's roadmap to Net-Zero Embodied Carbon by 2050.	1) **France: Stratégie nationale bas-carbone (SNBC)** Established a clear **roadmap to 2050**, with intermediate goals: – 40 % GHG reduction by 2030 and –75 % by 2050 (relative to 1990) **2)EPBD revision (2023**) - Requiring Whole-Life Carbon Reporting 3) **France – RE2020:** RE2020 mandates whole-life cycle carbon calculations for all new residential and refurbished buildings. The policy sets progressively stricter emissions targets, aiming for net-zero emissions by 2050. **4)Netherlands – Whole-Life Carbon Reporting:** Since 2013, the Netherlands has required new buildings larger than 100m² to calculate Whole-Life carbon emissions using a national assessment	1)**Pan-Canadian Framework on Clean Growth and Climate Change**: Canada's national climate strategy, released in 2017, outlines strategies for reducing greenhouse gas emissions across various sectors, including buildings. It emphasises the importance of sustainable building practices and the adoption of low-carbon technologies in the construction industry. 2)**Provincial Initiatives:** Provinces such as British Columbia have implemented regulations such as the BC Energy Step Code, which sets performance targets for energy efficiency in new construction. While primarily focused on operational energy use, these codes indirectly influence	1)**National Construction Code (NCC)**: The NCC sets the minimum required standards for the design and construction of buildings in Australia. While it is primarily focused on operational energy efficiency, there is an increasing emphasis on incorporating embodied carbon considerations. 2) **Infrastructure NSW** – Decarbonising Infrastructure Delivery Policy: This policy mandates that all new infrastructure projects delivered by NSW Government infrastructure agencies with a capital value over $50 million must measure and report on embodied carbon	1)**BCA Green Building Masterplan & Regulations:** The Green Building Masterplan (GBMP) is a strategic initiative by Singapore's Building and Construction Authority (BCA) to drive the adoption of sustainable design, construction, and operation of buildings. 2)**Green Mark 2021:** The Building and Construction Authority (BCA) introduced the Green Mark 2021 certification scheme, which emphasises reducing embodied carbon across a building's life cycle. This initiative encourages the industry to collaborate and develop green building solutions, raising sustainability standards in Singapore's built environment	1)**"Dual Carbon" Targets (Peak Carbon and Carbon Neutrality**)- China's overarching "dual carbon" policy targets — reaching peak carbon emissions by 2030 and achieving carbon neutrality by 2060 2) **China's National Emissions Trading Scheme (ETS)-** The emissions trading system currently covers the power sector, with a long-term goal is to expand this to other sectors, including construction and industrial production 3) **Circular Economy Promotion Law (2018)-** The law advocates for the use of sustainable construction materials, waste reduction, and more efficient use of resources throughout the life cycle of construction projects**.**	1)**National Construction Policy 2030 (NCP 2030**) Launched by the Ministry of Works, the NCP 2030 aims to transform Malaysia's construction sector towards digitalisation and sustainability. **2) National Circular Economy Roadmap (2021–2040)** Seeks to transition Malaysia into a sustainable, circular, and low-carbon economy by 2040, improving resource productivity while reducing environmental impact across sectors. **3)National Low Carbon Cities Masterplan (2021–2050)** Emphasises Measurement–Management–Mitigation (3M) at city scale and outlines absolute carbon reduction targets,

	US	UK	EUROPE	CANADA	AUSTRALIA	SINGAPORE	CHINA	MALAYSIA
POLICY / GOVERNMENT INITIATIVES	Participants agree to create a sustainability action plan and report the annual predicted energy use of their projects.	6) **LETI Embodied Carbon Targets (2020 and beyond)** The London Energy Transformation Initiative (LETI) is a UK-based Volunteer-led network of Built-Environment professionals that has developed clear and ambitious embodied carbon targets to support the transition to a Net-Zero-Carbon Built Environment 7) **RIBA 2030 Climate Challenge-** Launched by the Royal Institute of British Architects (RIBA), this Challenge sets Performance-Based Targets for architects and project teams to help the UK Built Environment achieve net zero carbon by 2030.	method, database, and approved tools. **5)Sweden – Embodied Carbon Reporting**: Sweden requires the calculation and reporting of Embodied Carbon emissions for new buildings to receive building permit approvals. This regulation aims to gather data on Embodied emissions and set limits for future projects	embodied carbon by encouraging the use of energy efficient materials and construction practices.		3) **The Singapore Green Building Masterplan**- developed by the Building and Construction Authority (BCA), is the cornerstone of Singapore's sustainable built environment strategy. First launched in 2006, the Masterplan has evolved through multiple phases and is now in its fourth edition, aligning closely with the Singapore Green Plan 2030 and the nation's Long Term Low Emissions Development Strategy.		embedding low-carbon actions—including built environment emissions—into urban planning 4) **National Energy Policy 2022–2040 & Low Carbon Aspiration 2040** Under the policy launched in September 2022, Malaysia commits to achieving net-zero greenhouse gas emissions by 2050 5) **Green Technology Master Plan (2021–2030)** This sectoral plan includes decarbonisation strategies across buildings, energy, transport, and industry, targeting 40% renewable energy by 2035 and encouraging energy-efficient building design.

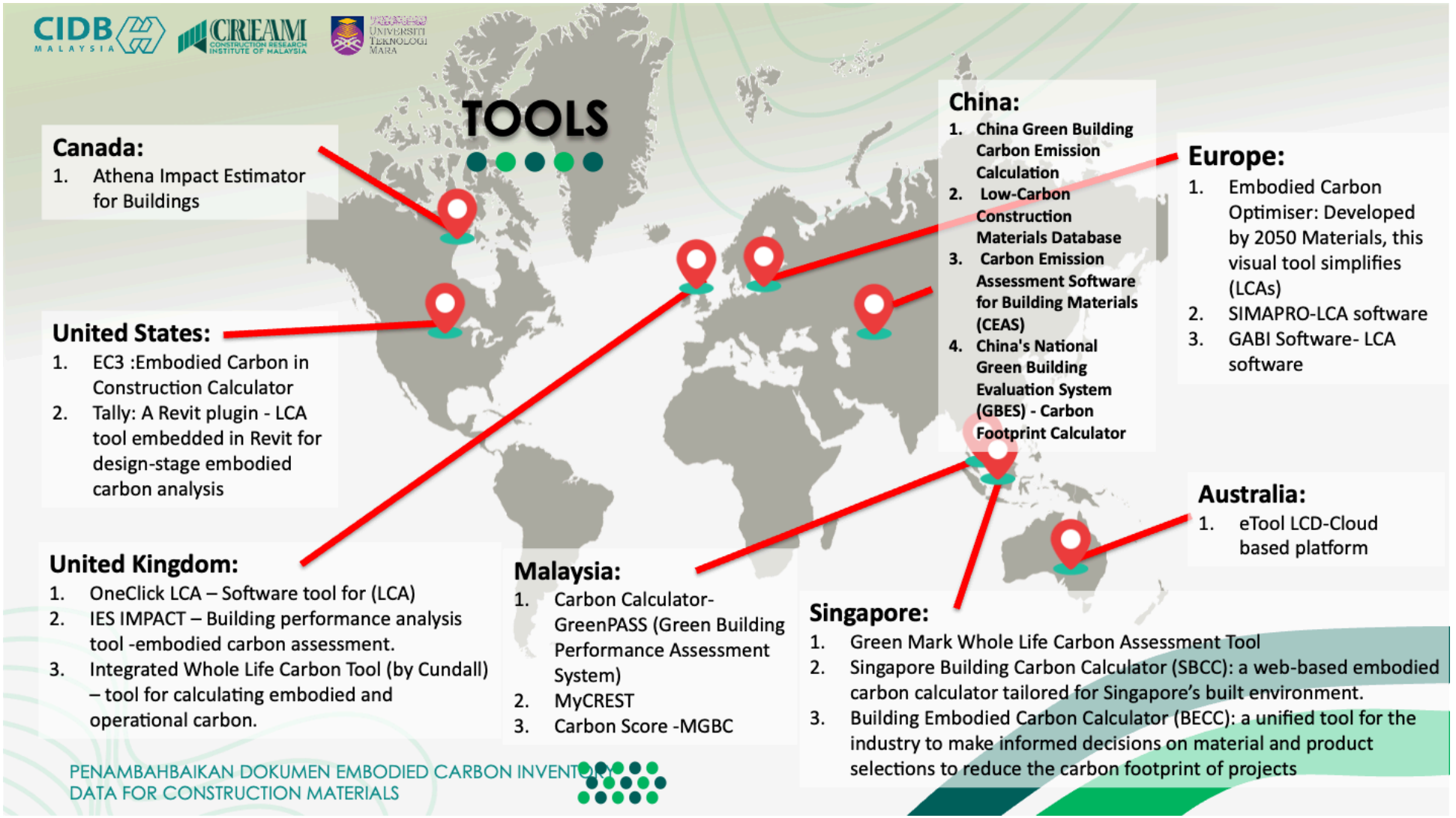
B. Standard


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STANDARD
Canada:
1. CSA Standard ISO 21930 – Sustainability in Building Construction
2. Zero Carbon Building Standard (ZCB) – Canada Green Building Council (CaGBC)
United States:
1. 2030 Palette: online tool that serves as a guide for sustainable design principles a to create carbon-neutral
2. California Green Building Standards Code (CALGreen): California's statewide green building code,includes provisions that impact embodied carbon
3. International Green Construction Code (IgCC): to improve the sustainability and environmental performance of buildings
United Kingdom:
1. BS EN 15978 – Methodology for assessing the environmental performance
2. BS EN 15804 – Core rules for (EPDs) of construction products.
3. PAS 2080 – Standard for managing carbon in infrastructure, focused on whole-life carbon.
4. RICS Whole Life Carbon Assessment for the Built Environment (WLCA) – Professional standard for consistent measurement and reporting of carbon.
5. UK Net Zero Carbon Buildings Standard (in development) – Cross-industry standard- net zero building.
China:
1. Green Building Evaluation Standard (GBES)
2. Chinese National Standard for Green Building Materials Low Carbon Construction Materials Standards China's National Building Carbon Emission Calculation Standard
Europe:
1. Germany- BNB (Assessment System for Sustainable Building)
2. France-RE2020 Regulation
3. Sweden-Climate Declarations
4. EN 15978 – Sustainability of Construction Works
5. EN 15804 – Environmental Product Declarations (EPDs)
Singapore:
1. BCA Green Mark for Buildings
2. Singapore Standards for Environmental Sustainability (SS 637: 2021)
3. Singapore Green Building Product (SGP) Certification
Malaysia:
1. SEDA Zero Energy Building Facilitation
2. Malaysia Green Building Council (MGBC) - Low Carbon Building (LCB)
3. SIRIM -MS ISO 14044:2008 – Environmental Management – Life Cycle Assessment – Requirements and Guidelines
Australia:
1. IS Rating Scheme (Infrastructure Sustainability Council - ISC
2. Green Star (GBCA)
PENAMBAHBAIKAN DOKUMEN EMBODIED CARBON INVENTORY DATA FOR CONSTRUCTION MATERIALS

	US	UK	EUROPE	CANADA	AUSTRALIA	SINGAPORE	CHINA	MALAYSIA
STANDARD	**1) 2030 Palette**: An online tool that serves as a guide to sustainable design principles and strategies needed to create carbon-neutral and resilient built environments, applicable at all scales from regional planning to building details **2) California Green Building Standards Code (CALGreen):** California's statewide green building code, CALGreen, includes provisions that affect embodied carbon. 3)**International Green Construction Code (IgCC)**: A model code developed by the International Code Council, the IgCC aims to improve the sustainability and environmental performance of buildings during design, construction, and operation.	**1)BS EN 15978** – Methodology for assessing the environmental performance of buildings using a life cycle approach. **2)BS EN 15804** – Core rules for Environmental Product Declarations (EPDs) of construction products. **3)PAS 2080** – Standard for managing carbon in infrastructure, focused on whole-life carbon. **4)RICS Whole Life Carbon Assessment for the Built Environment (WLCA)** – Professional standard for consistent measurement and reporting of carbon. **5)UK Net Zero Carbon Buildings Standard (in development)** – Cross-industry standard to define what constitutes a net zero building.	**1)Germany – BNB (Bewertungssystem Nachhaltiges Bauen)-** Scope: evaluates the sustainability of public buildings, covering environmental, economic, and sociocultural criteria. **2)France – RE2020 Regulation (Réglementation Environnementale 2020)**- Scope: building energy and environmental regulation for new residential and commercial buildings. **3)Sweden – Climate Declarations (Klimatdeklaration)** Scope: Mandatory climate impact declaration for new buildings in specified Swedish regions. **4)EN 15978 – Sustainability of Construction Works** Scope: European standard for assessing the	1) **CSA Standards and ISO 21930: Alignment for Embodied Carbon in Buildings** - ISO 21930:2017 is an international standard that provides principles and framework for Environmental Product Declarations (EPDs) of construction products and services, outlining how to apply Life Cycle Assessment (LCA) to building materials and products. **2)Green Procurement Standard for Embodied Carbon** Procurement Canada requires major public projects (valued at 10 million or more and using over 100 m³ of concrete) to disclose and reduce embodied carbon in structural concrete by at least 10 %, aligning government procurement with national climate targets.	**1) IS Rating Scheme – Infrastructure Sustainability Council (ISC)**- Mandatory reporting of embodied carbon emissions through Life-Cycle Assessment (LCA) for materials used in infrastructure projects. **2) EN 15978 – Sustainability of Construction Works: Building LCA** Scope: defines how to assess the environmental performance of buildings over their full life cycle. **3) EN 15804 – Environmental Product Declarations (EPDs)** Scope: standard for creating EPDs for construction materials. **4) Green Star – Design & As Built (2020+)** Not a standard per se, but functions as a de facto	1)**Singapore Standard SS 637:2021 – Environmental Sustainability for Buildings-** This is the national standard for environmental sustainability performance of new and existing buildings, developed by Enterprise Singapore in collaboration with BCA. **2) BCA Green Mark 2021 –** Whole Life Carbon (WLC) Framework Core national assessment tool for green buildings in Singapore 3) **EPDs – Environmental Product Declarations (via EN 15804 / ISO 21930)** Singapore Green Building Product (SGBP) certification requires product EPDs aligned with: -EN 15804 (European standard for EPDs)	1) **Green Building Evaluation Standard (GBES)-** National standards that evaluates the environmental performance of buildings. 2)**Chinese National Standard for Green Building Materials (GB/T 50785-2012)-** Part of China's broader effort to promote the use of green and sustainable materials in construction 3) **Low Carbon Construction Materials Standard (GB/T 35265-2017)-** Provides specific guidelines for evaluating and selecting low-carbon construction materials 4) **China's National Building Carbon Emission Calculation Standard (GB/T 51284-2019)-** Outlines the methodologies for calculating carbon emissions in the	1) **MyCREST**- LCA encouraged; aligns with ISO/EN standards 2) **GreenRE**- Points awarded for EPDs, and recycled or low-carbon materials 3) **GBI** (Green Building Index)- Embodied carbon is not a core focus, but some points are awarded for material reuse, local sourcing, durability and life-cycle thinking 4) **SIRIM -MS ISO 14044:2008 – Environmental Management – Life Cycle Assessment – Requirements and Guidelines**

	US	UK	EUROPE	CANADA	AUSTRALIA	SINGAPORE	CHINA	MALAYSIA
STANDARD			environmental performance of buildings over their full life cycle**.** **5)EN 15804 – Environmental Product Declarations (EPDs**) Scope: European standard specifying rules for creating EPDs for construction products.	3) **CaGBC Zero Carbon Building (ZCB) Standard**- Embodied Carbon Requirements (ZCB Standard – Design v3) Projects must complete a Life Cycle Assessment (LCA) to estimate embodied carbon emissions in line with the standard's minimum performance and reporting thresholds	national building sustainability framework	-ISO 21930 (global standard for EPDs in construction)	construction and operation of buildings	

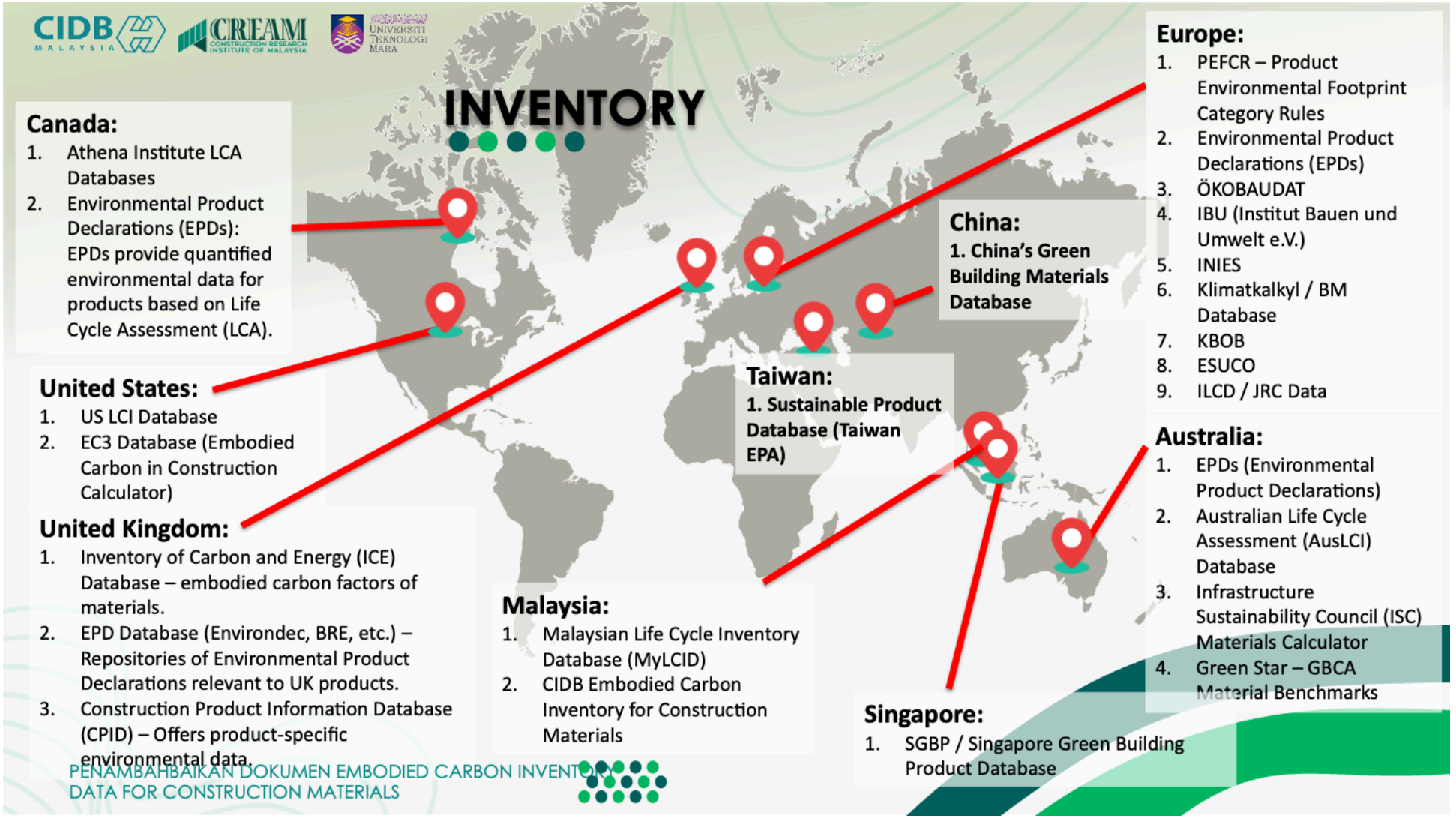
C. Tools


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TOOLS
Canada:
1. Athena Impact Estimator for Buildings
United States:
1. EC3 :Embodied Carbon in Construction Calculator
2. Tally: A Revit plugin - LCA tool embedded in Revit for design-stage embodied carbon analysis
United Kingdom:
1. OneClick LCA – Software tool for (LCA)
2. IES IMPACT – Building performance analysis tool -embodied carbon assessment.
3. Integrated Whole Life Carbon Tool (by Cundall) – tool for calculating embodied and operational carbon.
Malaysia:
1. Carbon Calculator-GreenPASS (Green Building Performance Assessment System)
2. MyCREST
3. Carbon Score -MGBC
China:
1. China Green Building Carbon Emission Calculation
2. Low-Carbon Construction Materials Database
3. Carbon Emission Assessment Software for Building Materials (CEAS)
4. China's National Green Building Evaluation System (GBES) - Carbon Footprint Calculator
Europe:
1. Embodied Carbon Optimiser: Developed by 2050 Materials, this visual tool simplifies (LCAs)
2. SIMAPRO-LCA software
3. GABI Software- LCA software
Australia:
1. eTool LCD-Cloud based platform
Singapore:
1. Green Mark Whole Life Carbon Assessment Tool
2. Singapore Building Carbon Calculator (SBCC): a web-based embodied carbon calculator tailored for Singapore's built environment.
3. Building Embodied Carbon Calculator (BECC): a unified tool for the industry to make informed decisions on material and product selections to reduce the carbon footprint of projects
PENAMBAHBAIKAN DOKUMEN EMBODIED CARBON INVENTORY DATA FOR CONSTRUCTION MATERIALS

	US	UK	EUROPE	CANADA	AUSTRALIA	SINGAPORE	CHINA	MALAYSIA
TOOLS	1**)EC3** (Embodied Carbon in Construction Calculator). 2**) Tally**: A Revit plug-in that allows design teams to perform Whole-Building Life-Cycle Assessment (WBLCA) within their design model, evaluating the impacts of materials across all life-cycle stages.	1)**One Click LCA** – Software tool for Life-Cycle Assessment (LCA) of buildings and infrastructure. 2) **IES IMPACT** – Building performance analysis tool including embodied carbon assessment. 3**) Integrated Whole Life Carbon Tool** (by Cundall) – Free-to-use tool for calculating embodied and operational carbon.	1) **Embodied Carbon Optimiser**: Visual tool that simplifies Life Cycle Assessments (LCAs) during early building design phases. 2) **SimaPro** LCA software 3) **GaBi-LCA** software	**1)Athena Impact Estimator for Buildings**	1) **eTool LCD** – Cloud-based platform for full LCA of building and infrastructure projects.	1)**Green Mark Whole Life Carbon Assessment Tool** 2) **Singapore Building Carbon Calculator (SBCC):** Web-based embodied carbon calculator tailored for Singapore's built environment. 3) **Building Embodied Carbon Calculator (BECC**): Provides a unified tool for the industry to make informed decisions on material and product selections to reduce the carbon footprint of projects.	1) **China Green Building Carbon Emission Calculation Tool** Allows the calculation of carbon emissions from construction projects 2) **Low-Carbon Construction Materials Database-** Specialised database developed to evaluate the carbon footprint of construction materials 3) **Carbon Emission Assessment Software for Building Materials (CEAS)**- Software that helps evaluate embodied carbon in building materials and construction processes. 4) **China's National Green Building Evaluation System (GBES) -** Carbon Footprint Calculator, a tool that calculates the carbon footprint of a building based on its embodied carbon content and energy usage.	1. **MyCREST Carbon Calculator.** Includes calculators for the design, construction, and operation stages, providing a holistic approach to carbon management in construction. 2. **Carbon Calculator GreenPASS (Green Building Performance Assessment System)**- GreenPASS is a voluntary, industry-driven initiative that assesses the energy performance and carbon footprint of buildings. 3. **CarbonScore** - Initiative of the Malaysia Green Building Council

Tool Name	One Click LCA	Tally	Athena Impact Estimator	eToolLCD	EC3 (Embodied Carbon in Construction Calculator)	SimaPro	GaBi Software	Carbon Designer 3D	CARE Tool	EPDs (Environmental Product Declarations)
Origin	Bionova Ltd (Finland)	Kieran Timberlake + Autodesk + thinkstep (USA)	Athena Sustainable Materials Institute (Canada)	eTool (Australia/UK)	Building Transparency + Skanska + Microsoft (USA)	PRé Sustainability (Netherlands)	Sphera / thinkstep (Germany)	One Click LCA Ltd, a Finnish software company	LETI (UK)	Sweden – Birthplace of the first international EPD Program
Type of tool	Cloud-based LCA software	Revit plug-in / BIM integrated tool	Desktop software	Cloud-based platform	Web-based tool / EPD database	Professional LCA modelling software	LCA modelling software	Conceptual design tool	Simplified carbon calculator	Data source / Disclosure tool
Purpose	Full building life cycle carbon analysis and certification support (LEED, BREEAM).	Real-time LCA integrated with BIM (Revit) for the design phase	LCA modelling for North American buildings	Life cycle design and carbon-foot printing for buildings	Material comparison and embodied carbon estimation for procurement	Detailed product and process-level LCA	Comprehensive environmental modelling for products and buildings	Quick early stage embodied carbon estimates with minimal data	Estimating whole-life carbon of retrofit versus new build	Third-party verified environmental impact reports for products
Assessment Method / Standard	EN 15978, ISO 14044, EPDs	ISO 14040, EN 15978	ISO 14044, ISO 21930	EN 15978, ISO 14040/44	EPD-based comparison (EN 15804, ISO 14025)	ISO 14040/44, custom LCIA	ISO 14044, EN 15804	EN 15978-based estimate	RICS WLCA, PAS 2080	ISO 14025 & EN 15804

D. Inventory Database



Country	Database	Key Description
UK	**ICE Database**	Inventory of Carbon and Energy, managed by Circular Ecology. Offers embodied carbon factors for common construction materials (kg CO_2e per unit).
	BRE EPDs / Green Book Live	RICS-compliant carbon assessments
International	**One Click LCA (UK/EU-compatible platform)**	Commercial platform with more than 200,000 LCA/EPD data points. Covers national and generic datasets for more than 100 countries.
International/ Sweden	**EPD International**	Global EPD programme with thousands of product specific carbon data entries, used widely in Europe and Asia.
Germany	**ÖKOBAUDAT**	Government-managed LCA database for construction materials aligned with EN 15804 and widely used in German projects and by IBU
Germany	**IBU (Institut Bauen und Umwelt e.V.)**	Germany's national EPD programme operator
France	**INIES**	National French EPD and LCA database, used for RE2020 compliance and including standardised and specific EPDs.
Sweden	**Klimatkalkyl / BM Database**	Public database for building material emissions factors, used in Climate Declarations
Switzerland	**KBOB**	Database maintained by the Swiss Federal Government, containing environmental data for building materials, energy, and construction.
Spain	**ESUCO**	Spanish EPD and carbon database, linked with the PEP eco-passport and other European schemes.
US / International	**EC3 Database (Embodied Carbon in Construction Calculator)**	Open access North American database for embodied carbon data in construction materials
Canada	**Athena Impact Estimator Database**	LCA database integrated into Athena software, based on North American data.
US / International	**US LCI Database**	Life-Cycle Inventory managed by NREL, broader than construction but including material data for LCA use.

Country	Database	Key Description
South Korea	**KEITI LCI Database**	Korean Environmental Industry & Technology Institute's LCI and EPD repository, used for the Green Standard for Energy and Environmental Design (G-SEED).
Taiwan	**Sustainable Product Database (Taiwan EPA)**	Includes carbon footprint data and product declarations.
China	**China's Green Building Materials Database**	Comprehensive database developed to support green building initiatives in China, particularly focused on the embodied carbon content of materials used in construction materials.
Australia	**EPiC Database – Environmental Performance in Construction**	Open-access Life-Cycle Inventory (LCI) database tailored for Australian construction materials
Australia/NZ	**EPD Australasia**	EPD platform providing EPDs with carbon data, aligned with Green Star requirements
New Zealand	**NZGBC Embodied Carbon Database**	Mixing product-specific EPDs and generic data
Singapore	**SGBP / Singapore Green Building Product Database**	Certifies products with low environmental impact including embodied carbon performance.
International/ Switzerland	**Ecoinvent**	Swiss-based global LCI database used widely in LCA software (e.g., SimaPro, GaBi, One Click LCA).
EU	**ILCD / JRC Data**	EU Joint Research Centre's official life cycle database aligned with the ILCD Handbook.
International	**GaBi Database**	Commercial LCA database. Used in global construction and product LCA
Italy	**EPD Italy**	EPD for specific products
Norway	**EPD Norge**	EPD for specific products
Spain	**GlobalEPD**	EPD for specific products
Canada	**CSA EPD / Athena**	EPD for specific products
USA	**ASTM EPD Program**	EPD for specific products

EMBODIED CARBON INVENTORY DATA ASSESSMENT

EMBODIED CARBON INVENTORY DATA ASSESSMENT

This chapter reports the updated embodied carbon inventory data. This inventory contains a summary of approximately 600 records of embodied carbon data for construction materials and 583 records for building elements. The compilation of the embodied carbon data has been carried out by providing various alternatives for each type of construction material and building element.

The inventory data consist of relevant information as mentioned below:

Classification	The inventory data are divided into two (2) classifications: construction materials and building elements. Construction and building materials include raw materials that have been used in construction, while building elements involve the main components of building structures.
Types	Various types of construction materials and building elements have been categorised according to common categories. This provides alternatives for stakeholders to compare and select the data values based on the impact on the environment and cost.
Embodied Carbon Indicator	The inventory data consist of indicators for embodied carbon values. The range of embodied carbon values in the scale is referenced from the UK Inventory of Carbon & Energy(ICE) database. The Inventory of Carbon & Energy (ICE) provides a database of the embodied carbon values of building materials per kilogram, which can be used to compare the relative emissions associated with materials.
Embodied Carbon Factor	The embodied carbon factoris usually expressed in kilograms of CO2e per kilogram of product or material. The embodied carbon factor is also known as the embodied carbon coefficient. The embodied carbon factor (kg of CO2e per kg) is calculated by multiplying the emissions factor by the quantity of each material (kg).
Unit	The functional unit for embodied carbon factors is kilograms of CO2e per kilogram of material.
Boundary	The embodied carbon factor published here is based on the cradle to gate life-cycle boundary. The cradle to the gate boundary includes the extraction and processing of raw materials and the manufacture of products.

Source of Embodied Carbon	The embodied carbon factors data are collated based on a combination of local and international sources, including MyLCID SIRIM, Environmental Product Declaration (EPDs), the Inventory of Carbon and Energy (ICE v3.0), the Integrated Carbon Metrics Embodied Carbon Life Cycle Inventory Database (ICM), Building for Environmental and Cost Sustainability (BEES), the Building Research Establishment (BRE), and other published resources.
Value Used	The embodied carbon values used are based on the data sources available and are categorised as local, Asia, or global. • Local data: Data obtained from Malaysian sources, including local manufacturers, industry reports, and project-specific data, were prioritised and used wherever available, as they best reflect local materials, production processes, and construction practices. • Regional (Asia) data: Where local data were unavailable or insufficient, regional data from Asia were adopted. These data provide closer alignment to Malaysian contexts in terms of technology, supply chains, and production methods. • Global data: In the absence of suitable local or regional data, international or global datasets were used as reference values. These data serve as interim proxies and will be progressively replaced as more local data become available.
Country of Owner	The Country of Owner data indicate the country in which the company or entity that owns the construction material or product is registered. This information provides context on the origin of the manufacturer or supplier, which can influence factors such as production methods, regulatory standards, and embodied carbon values. It also helps in distinguishing between local, regional, and international sources for more accurate assessment and benchmarking.
Description	Detailed information is also provided on the application, properties, and performance of construction materials and building elements.

Table 1 shows the range of embodied carbon indicators for construction materials.

Table 1. Range of embodied carbon indicators for construction materials.

Embodied carbon indicator range (kg CO2e/kg)	Colour	Description	Colour coding
0 – 0.5	Dark green	Very low	
0.5 – 2.0	Light green	Low	
2.0 – 2.8	Yellow	Medium	
2.8 – 5.0	Orange	High	
>5.0	Red	Very high	

Table 2 shows the range of embodied carbon indicators for building elements.

Table 2. Range of embodied carbon indicators for building elements.

Embodied carbon scales indicator (kg CO2e/m2)	Colour	Description	Colour coding
≤ 10	Dark green	Very low	
11 - 100	Light green	Low	
101- 250	Yellow	Medium	
251-350	Orange	High	
>350	Red	Very high	

The report consists of 500 embodied carbon data records, of which 300 records are construction materials covering 25 classes of materials used in construction. Additionally, 200 records are building elements, covering 13 classes of building elements. The results of analysis for the embodied carbon value relative to environmental impact and cost indicators are presented in Section 3.2.

Results analysis for embodied carbon of construction materials and building elements

Table 3. Embodied carbon inventory data

Embodied Carbon Inventory V1 (2021)	Embodied Carbon Inventory V2 (2025)
301 construction materials	600 construction materials
200 building elements	583 building elements

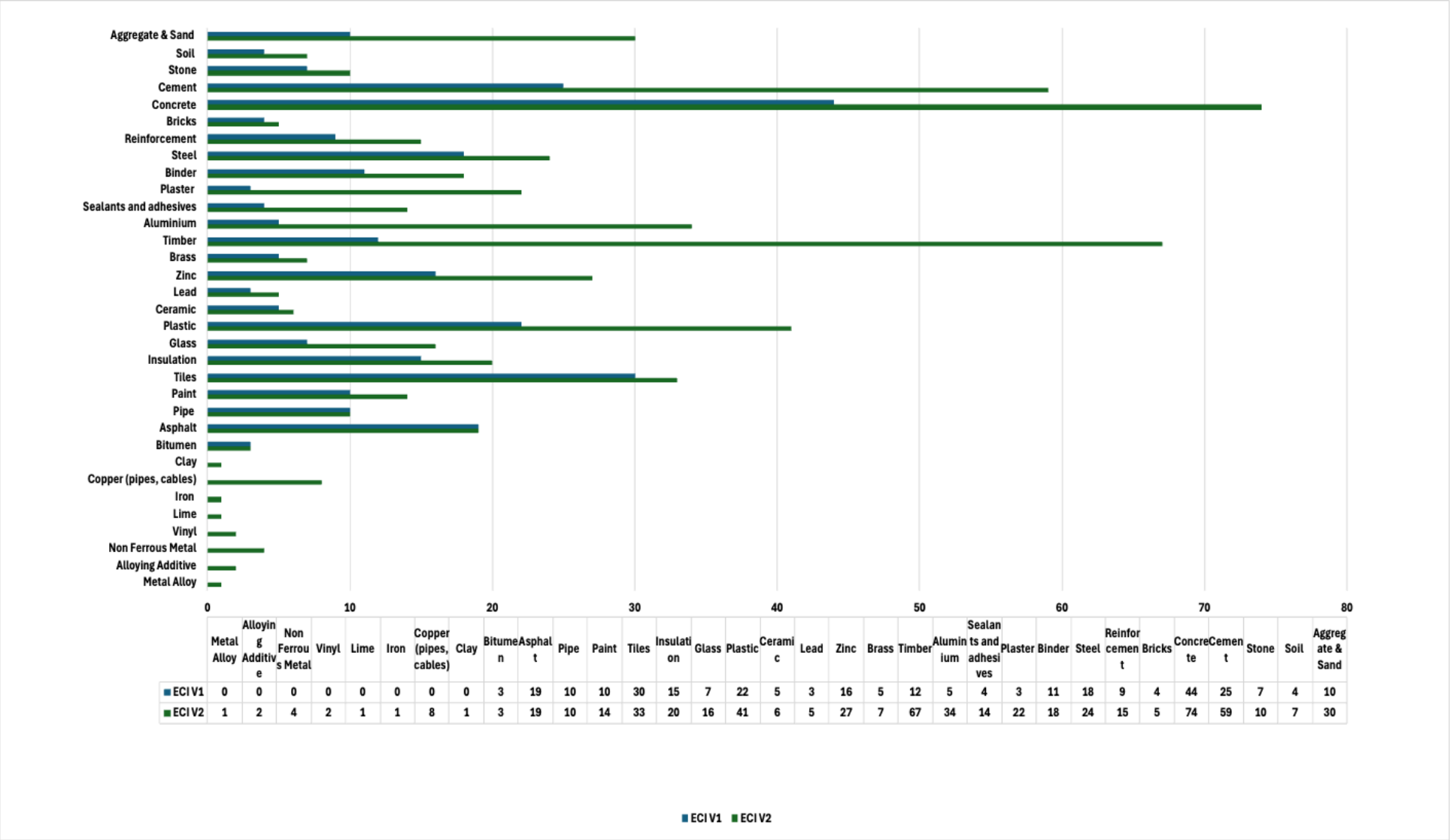
The Embodied Carbon Inventory V1 (2021) of the CREAM CIDB in Malaysia initially included data for 301 construction materials and 200 building elements, providing a foundational tool for assessing and reducing the carbon footprint of construction materials and components. While it helped promote sustainable building practices, its scope was relatively limited. The updated V2 (2025) significantly expands the inventory to include 600 materials and 583 building elements, with a key focus on local

data as the primary source, followed by Southeast Asian data and international data. This prioritisation ensures that the carbon data are regionally specific, reflecting the actual production processes in Malaysia and its neighbouring countries. With its broader material coverage, improved life-cycle data, and focus on regional specifics, V2 provides a more comprehensive and accurate tool for reducing embodied carbon emissions, supporting Malaysia's sustainability goals, and advancing its move towards a low carbon-built environment.

Table 4 and Figure 2 present the Embodied Carbon Inventory (ECI) data compares two versions: V1 (2021) and V2 (2025), while Table 5 and Figure 3 compare the Embodied Carbon Inventory (ECI) for building elements between V1 (2021) and V2 (2025). Table 6 and Figure 4 show the sources of Embodied Carbon Inventory (ECI) data across various construction materials while Table 7 and Figure 5 show the sources of Embodied Carbon Inventory (ECI) data across various building elements. Table 8 and Figure 6 provide a breakdown of construction materials and their associated embodied carbon entries across three geographic categories: International, Southeast Asia, and Malaysia. Table 9 and Figure 7 provide the data provides a breakdown of building elements and their associated embodied carbon entries across three geographic categories: International, Southeast Asia, and Malaysia.

Table 4. Embodied Carbon Inventory (ECI) data compares two versions: Version 1 (2021) and Version 2 (2025).

Construction Materials	Embodied Carbon Inventory Version 1	Embodied Carbon Inventory Version 2
Aggregate & Sand	10	30
Soil	4	7
Stone	7	10
Cement	25	59
Concrete	44	74
Bricks	4	5
Reinforcement	9	15
Steel	18	24
Binder	11	18
Plaster	3	22
Sealants and adhesives	4	14
Aluminium	5	34
Timber	12	67
Brass	5	7
Zinc	16	27
Lead	3	5
Ceramic	5	6
Plastic	22	41
Glass	7	16
Insulation	15	20
Tiles	30	33
Paint	10	14
Pipe	10	10
Asphalt	19	19
Bitumen	3	3
Clay	0	1
Copper (pipes, cables)	0	8
Iron	0	1
Lime	0	1
Vinyl	0	2
Non Ferrous Metal	0	4
Alloying Additive	0	2
Metal Alloy	0	1
Total	**301**	**600**

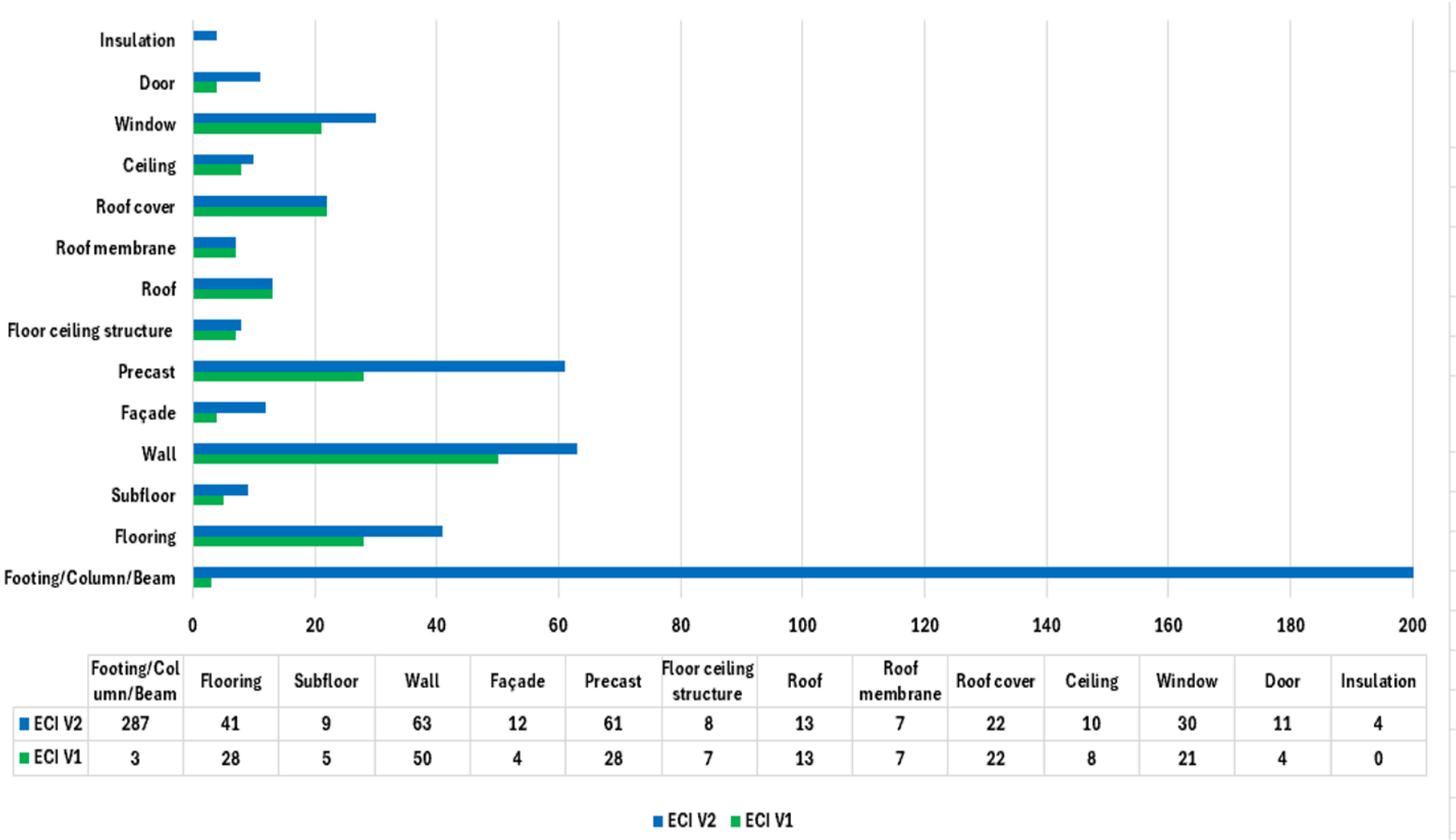


	Metal Alloy	Alloying Additive	Non Ferrous Metal	Vinyl	Lime	Iron	Copper (pipes, cables)	Clay	Bitumen	Asphalt	Pipe	Paint	Tiles	Insulation	Glass	Plastic	Ceramic	Lead	Zinc	Brass	Timber	Aluminium	Sealants and adhesives	Plaster	Binder	Steel	Reinforcement	Bricks	Concrete	Cement	Stone	Soil	Aggregate & Sand
ECI V1	0	0	0	0	0	0	0	0	3	19	10	10	30	15	7	22	5	3	16	5	12	5	4	3	11	18	9	4	44	25	7	4	10
ECI V2	1	2	4	2	1	1	8	1	3	19	10	14	33	20	16	41	6	5	27	7	67	34	14	22	18	24	15	5	74	59	10	7	30

Figure 2: Embodied Carbon Inventory (ECI) data compares two versions: Version 1 (2021) and Version 2 (2025).

Table 5. Embodied Carbon Inventory (ECI) for building elements between Version 1 (2021) and Version 2 (2025).

Building Element	Embodied Carbon Inventory Version 1	Embodied Carbon Inventory Version 2
Footing / Column / Beam	3	287
Flooring	28	41
Subfloor	5	9
Wall	50	63
Facade	4	12
Precast	28	61
Floor ceiling structure	7	8
Roof	13	13
Roof membrane	7	7
Roof cover	22	22
Ceiling	8	10
Window	21	30
Door	4	11
Insulation	0	4
Air filtration	0	5
Total	**200**	**583**



	Footing/Column/Beam	Flooring	Subfloor	Wall	Façade	Precast	Floor ceiling structure	Roof	Roof membrane	Roof cover	Ceiling	Window	Door	Insulation
ECI V2	287	41	9	63	12	61	8	13	7	22	10	30	11	4
ECI V1	3	28	5	50	4	28	7	13	7	22	8	21	4	0

Figure 3: Embodied Carbon Inventory (ECI) for building elements between Version 1 (2021) and Version 2 (2025).

Table 6. Sources of Embodied Carbon Inventory (ECI) data across various construction materials

Source	Entries
ICE	234
ICM	96
EPD International	40
EPD Southeast Asia	39
Academic Literatures	20
BECC, Singapore	117
MyLCID	54

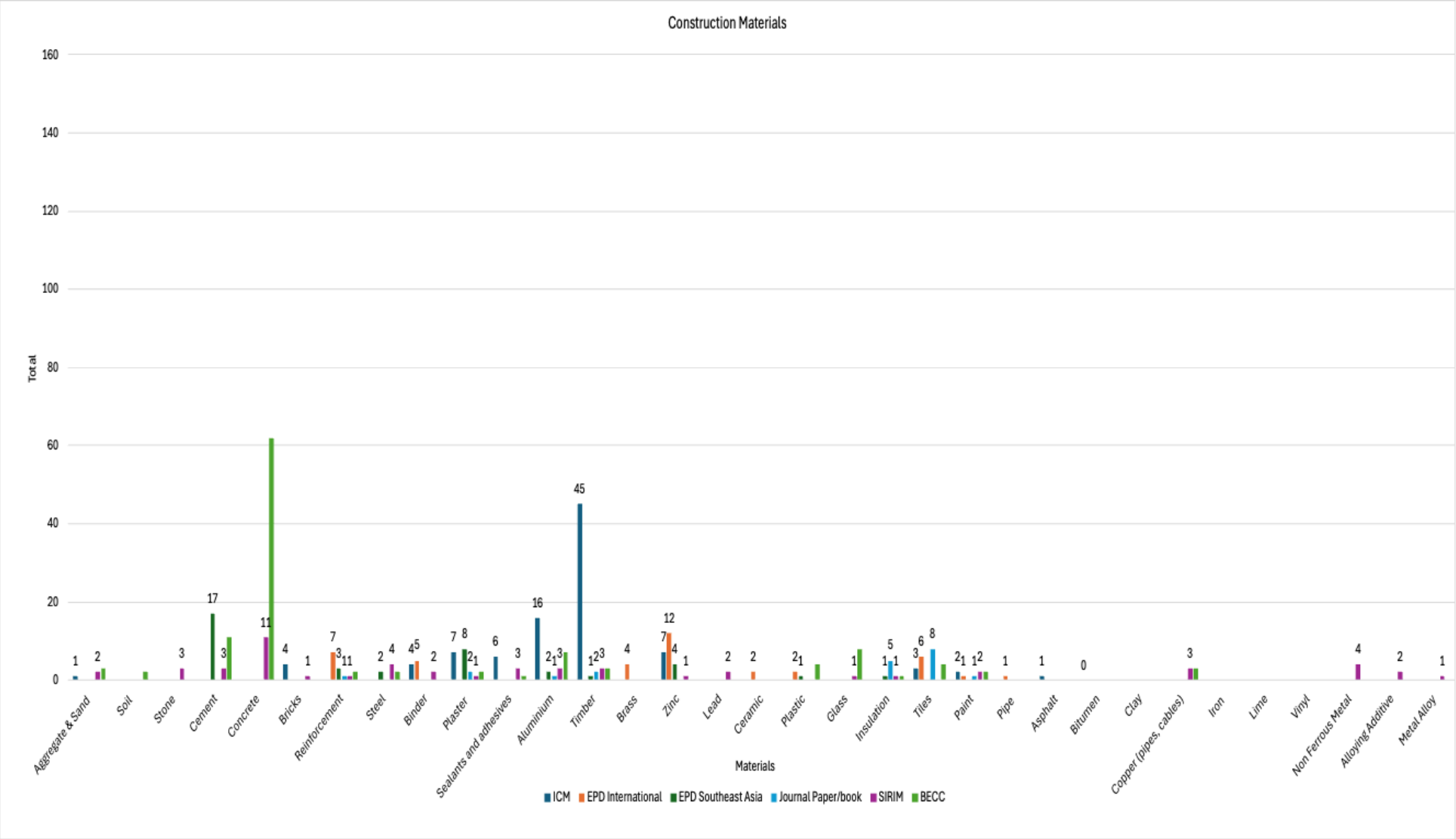


Figure 4: Sources of Embodied Carbon Inventory (ECI) data across various construction materials.

Table 7. Sources of Embodied Carbon Inventory (ECI) data across various building elements

Source	Entries
ICE	327
ICM	21
EPD International	77
EPD Southeast Asia	21
Academic Literatures	12
BECC, Singapore	120
MyLCID	5

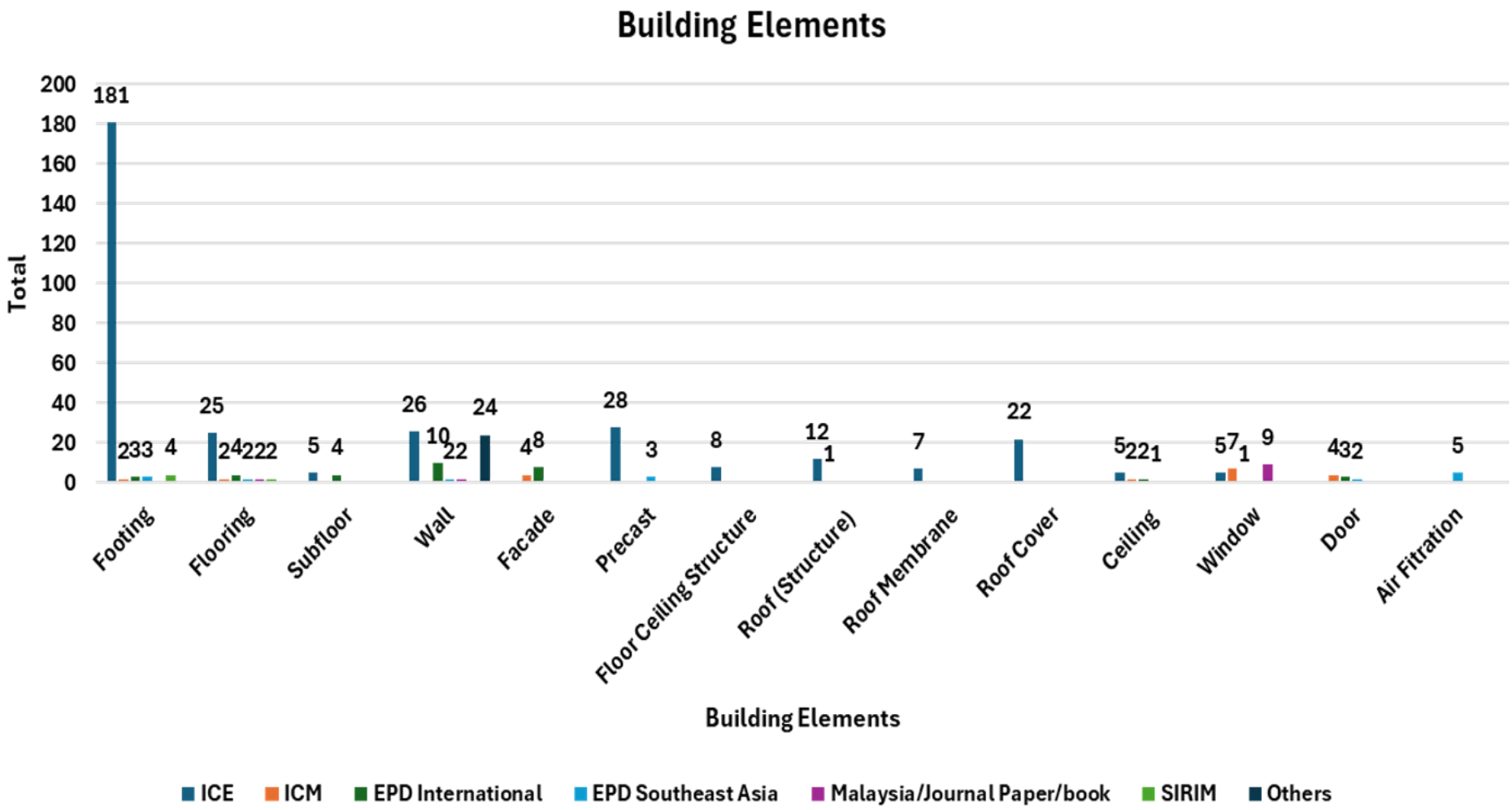


Figure 5: Sources of Embodied Carbon Inventory (ECI) data across various building elements.

Table 8. Breakdown of construction materials and their associated embodied carbon entries across three geographic categories: International, Southeast Asia, and Malaysia

Construction Materials	International	Southeast Asia	Malaysia
Aggregate & Sand	25	3	2
Soil	5	2	0
Stone	7	0	3
Cement	28	28	3
Concrete	1	62	11
Bricks	0	4	1
Reinforcement	8	5	2
Steel	16	4	4
Binder	16	0	2
Plaster	9	10	3
Sealants and adhesives	10	1	3
Aluminium	21	8	5
Timber	58	4	5
Brass	7	0	0
Zinc	22	4	1
Lead	3	0	2
Ceramic	6	0	0
Plastic	36	5	0
Glass	7	8	1
Insulation	17	2	1
Tiles	21	12	0
Paint	10	2	2
Pipe	10	0	0
Asphalt	19	0	0
Bitumen	3	0	0
Clay	1	0	0
Copper (pipes, cables)	2	3	3
Iron	1	0	0
Lime	1	0	0
Vinyl	2	0	0
Non Ferrous Metal	0	0	4
Alloying Additive	0	0	2
Metal Alloy	0	0	1
Total	**372**	**167**	**61**

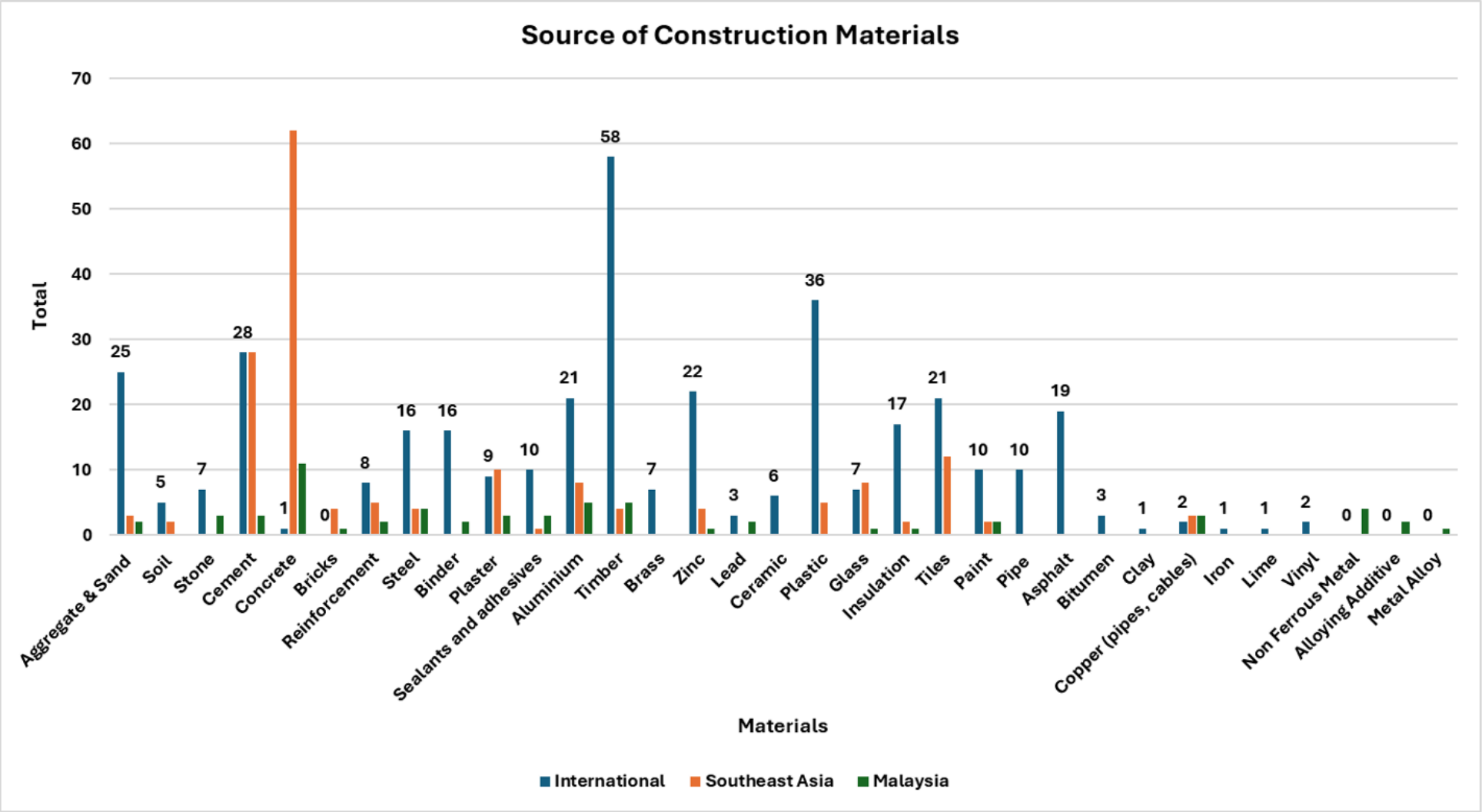


Figure 6: Breakdown of construction materials and their associated embodied carbon entries across three geographic categories: International, Southeast Asia, and Malaysia.

Table 9. Breakdown of building elements and their associated embodied carbon entries across three geographic categories: International, Southeast Asia, and Malaysia

Building Element	International	Southeast Asia	Malaysia
Footing / Column / Beam	194	89	4
Flooring	32	6	3
Subfloor	9	0	0
Wall	60	2	1
Facade	12	0	0
Precast	28	33	0
Floor ceiling structure	8	0	0
Roof	13	0	0
Roof membrane	7	0	0
Roof cover	22	0	0
Ceiling	9	0	1
Window	26	4	0
Door	5	6	0
Insulation	1	0	3
Air filtration	0	0	5
Total	426	140	17

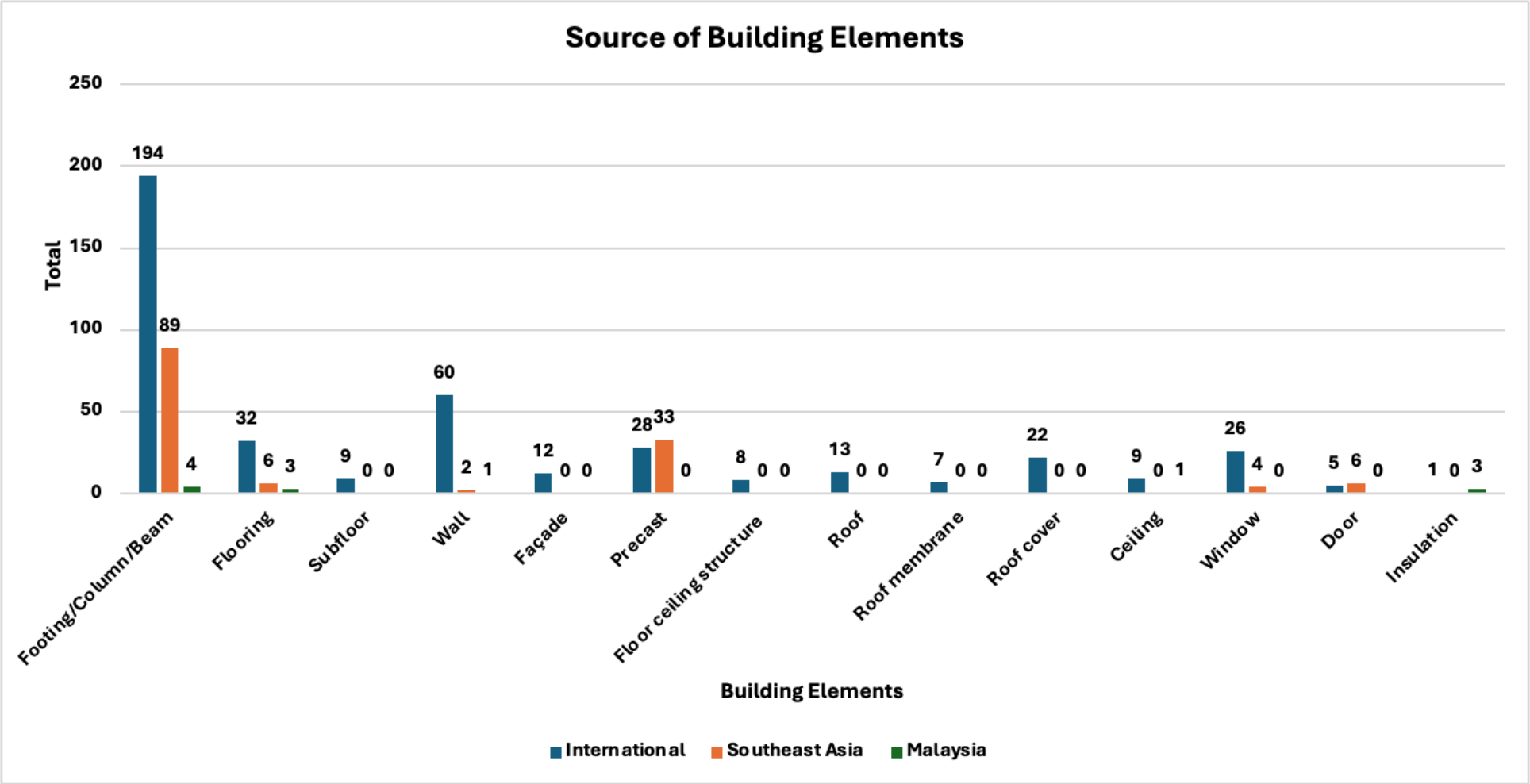


Figure 7: Breakdown of building elements and their associated embodied carbon entries across three geographic categories: International, Southeast Asia, and Malaysia.

EMBODIED CARBON INVENTORY DATA (CONSTRUCTION MATERIAL)

NO.	CLASSIFICATION	TYPES	EMBODIED-CARBON INDICATOR	EMBODIED-CARBON FACTOR	UNIT	BOUNDARY	SOURCE OF EMBODIED-CARBON	VALUE USED	COUNTRY OF OWNER	DESCRIPTIONS
1	Aggregate & Sand	Sand		**0.0001475**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Sand with a grain size of 0/2 is used as a standard mineral product and natural aggregate in the construction industry, particularly for concrete production, mortar, plaster, road-base layers, and other structural and civil engineering works. 2. Properties: It is obtained from wet and dry quarrying, followed by crushing, washing, and processing to remove impurities such as clay, wood, and metal. The final product consists largely of quartz grains with SiO_2 content exceeding 96%, giving it chemical stability, durability, and suitability for blending into cementitious systems. The material is regionally modelled with Malaysia-specific energy supply chains to ensure representativeness of local production. 3. Performance: Sand provides consistent performance as a fine aggregate by ensuring good workability, strength development, and durability of concrete and mortar. Its inert mineralogical nature contributes to stable mechanical and chemical behaviour in construction applications. From a sustainability perspective, the Malaysian LCI confirms its performance under cradle-to-gate conditions, highlighting quantified energy and emission flows and enabling integration into life-cycle

										assessments of construction materials.
2		Gravel		**0.000092**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Gravel is a standard mineral product widely used as a natural aggregate in the construction industry. It serves as a primary material for concrete production, road-base layers, drainage systems, and other civil engineering works requiring stable and durable aggregates. 2. Properties: The dataset covers gravel with a grain size of 2–32 mm, obtained through open-pit mining and subsequent beneficiation processes such as washing, sorting, and drying. High-quality gravel with SiO_2 content above 96% is categorised as silica sand or quartz gravel. After washing to remove clay and impurities, the material is dried in kilns to achieve moisture content below 0.2%, ensuring consistency and durability. 3. Performance: Gravel provides strong mechanical stability, load-bearing capacity, and durability in structural and infrastructural applications. Its performance is enhanced by beneficiation steps that remove foreign matter, thereby ensuring uniformity and long service life. From an environmental perspective, the cradle-to-gate dataset reflects Malaysia-specific energy conditions, offering reliable inputs for life-cycle assessments of construction projects.
3		Recycled Concrete		**0.00667**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used in road bases, non-structural concrete, drainage

		Aggregates (RCA)								layers, and sustainable construction applications. 2. Properties: Produced from crushed demolished concrete; contains reclaimed coarse aggregates with residual mortar attached. 3. Performance: Reduces embodied-carbon emissions, improves waste diversion, and provides adequate mechanical performance for non-structural and moderate-strength uses.
4		Granite		**0.00743**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used in high-strength concrete, structural elements, pavements, and heavy-duty civil engineering works. 2. Properties: Hard, dense natural rock aggregate with low porosity and excellent durability characteristics. 3. Performance: Delivers strong compressive performance, high stability, and long-term durability, especially in heavily loaded structures.
5		Aggregates		**0.0048**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used as the primary component in concrete, mortar, asphalt, and general civil engineering applications. 2. Properties: Composed of coarse or fine mineral particles providing bulk, strength, and dimensional stability to mixes. 3. Performance: Ensures reliable workability, structural integrity, and consistent performance across a wide range of construction uses.
6		Aggregates and Sand, General UK, Mixture		**0.007**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Used in general concrete, mortar, and civil works requiring blended aggregate sources.

		of Land Won, Marine, Secondary and Recycled, Bulk, Loose								2. Properties: A mixed-source aggregate combining land-won, marine, secondary, and recycled materials, providing a balanced grading profile. 3. Performance: Offers stable workability and suitable strength characteristics while reducing embodied-carbon emissions through recycled content.
7		Aggregates and Sand, General, Virgin Mixture of Land Won and Marine, Bulk, Loose		**0.009**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Used in structural concrete, precast elements, and general civil engineering works. 2. Properties: Composed of virgin aggregates sourced from land-won and marine deposits, providing consistent grading and cleanliness. 3. Performance: Ensures reliable mechanical performance and uniform quality across structural and civil engineering applications.
8		Aggregates and Sand, from Virgin Land Won Resources, Bulk, Loose		**0.006**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Used in high-quality concrete mixes, foundations, pavements, and structural works. 2. Properties: Extracted from quarries and land-based deposits; typically clean, hard, and well-graded. 3. Performance: Provides strong mechanical stability, good compaction, and dependable long-term durability.
9		Aggregates and Sand, from Virgin Marine Resources, Bulk, Loose		**0.119**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Used in concrete production, reclamation works, and large civil engineering projects. 2. Properties: Marine-dredged aggregates requiring washing; generally lightweight with low fines content. 3. Performance: Offers good workability and volume stability but

										may require quality control to manage chloride content.
10		Aggregates and Sand, from Recycled Resources, No Heat Treatment, Bulk, Loose		**0.063**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Used in non-structural concrete, road subbase, and fill material. 2. Properties: Derived from crushed concrete and masonry waste without additional heat processing. 3. Performance: Reduces embodied-carbon emissions and landfill waste while providing adequate performance for low-strength applications.
11		Aggregates and Sand, from Recycled Resources, with Heat Treatment, Bulk, Loose		**0.014**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Used in structural and higher-grade concrete requiring improved recycled aggregate quality. 2. Properties: Recycled aggregates processed with heat treatment to reduce impurities and enhance particle strength. 3. Performance: Offers improved consistency and performance compared to non-treated recycled aggregates, supporting sustainable construction.
12		Aggregates and Sand, Expanded Clay, Bulk, Loose		**0.013**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Used in lightweight concrete, geotechnical backfilling, and insulation layers. 2. Properties: Produced by heating clay to create lightweight, porous particles with good thermal properties. 3. Performance: Provides reduced density, improved thermal resistance, and enhanced workability in lightweight systems.
13		Aggregates, Expanded Foamed		**0.007**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Used in lightweight concrete, insulation fills, drainage layers, and eco-friendly construction materials.

		Glass, Bulk, Loose								2. Properties: Manufactured from recycled glass expanded into lightweight, cellular particles. 3. Performance: Extremely lightweight, with excellent insulation and high recyclability, contributing to low embodied-carbon emissions.
14		Aggregates and Sand, from Secondary Resources, Bulk, Loose		**0.005**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Used in general fill, landscaping, and low-strength concrete applications. 2. Properties: Produced from industrial by-products or secondary materials such as slags or mineral residues. 3. Performance: Provides functional performance for non-structural applications while reducing waste-disposal needs.
15		Aggregates and Sand, Mixture of Recycled and Secondary Resources, Bulk, Loose		**0.006**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Used in sustainable construction projects, road bases, and general concrete with moderate-strength requirements. 2. Properties: Combination of recycled aggregates and secondary industrial by-products, offering eco-efficient material utilisation. 3. Performance: Delivers acceptable strength and durability while significantly lowering embodied-carbon emissions.
16		Sand-Lime Brick		**0.150**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	UK	1. Application: Used in walling, partitions, façades, and architectural masonry units. 2. Properties: Manufactured from sand, lime, and water, pressed and cured under steam to produce dense masonry blocks. 3. Performance: Provides high dimensional accuracy, good compressive strength, thermal efficiency, and a clean architectural finish.

17		Aggregates		**0.007**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	The weighted average of aggregates represents the consolidated environmental-impact data for various aggregate types, calculated as a weighted average based on production volumes and usage proportions.
18		Limestone		**0.016**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Crushed stone 0/2 (grain size 0/2) is a fine aggregate used in construction applications requiring precise particle grading. Its consistent quality makes it suitable for high-performance mixes in both structural and finishing works.
19		Limestone Fines		**0.016**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Crushed stone 0/2 (grain size 0/2), sourced from Ökobaudat, is a fine aggregate material with uniform grading, ideal for use in various cementitious applications and construction projects.
20		Lime, Hydrated		**0.891**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Fine crushed stone 0/2 (grain size 0/2) is generally used in mortar production. It provides good workability and strength in masonry and plastering applications.
21		Lime, Quicklime		**1.136**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Fine crushed stone 0/2 (grain size 0/2) is generally used in cement production. It contributes to the overall strength, stability, and durability of cement-based products.
22		Aggregates, General, Virgin Mixture of Land Won and Marine, Bulk, Loose		**0.005**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Excludes recycled and secondary aggregates. The model comprises 89% land-won and 11% marine-won aggregates. Consumption statistics are sourced from the British Marine Aggregates Producer Association, a member of the Mineral Products Association (MPA) [Tenth Sustainable Development Report for the British Marine Aggregate Industry, Dec 2016]. Marine-aggregate consumption is assumed to equal total marine-aggregate production, with 68% used in the GB market, 11% exported to

										the European market, and 21% utilised for beach replenishment or fill.
23		Aggregates, from Virgin Land Won Resources, Bulk, Loose		**0.004**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
24		Aggregates, from Virgin Marine Resources, Bulk, Loose		**0.009**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Marine-won aggregates are used in a variety of construction applications, including concrete production, road building, and coastal-protection works. In the UK, they are also applied for beach replenishment and fill, with significant volumes supplied to both domestic and European markets. Their usage supports infrastructure development, residential and commercial projects, and environmental-restoration works in marine and coastal zones.
25		Aggregates, from Recycled Resources, No Heat Treatment, Bulk, Loose		**0.006**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Recycled aggregates (no heat treatment) are sourced from construction and demolition waste, excluding secondary aggregates such as blast-furnace slag or bottom ash. They are used in various construction applications, though data variability adds uncertainty to embodied-impact assessments.
26		Aggregates, from Recycled Resources, With Heat Treatment, Bulk, Loose		**0.119**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Recycled aggregates (heat treated) originate from construction and demolition waste, excluding secondary aggregates such as blast-furnace slag or bottom ash. They are used in construction works where heat treatment enhances material properties, though data variability remains high.
27		Aggregates, Expanded Clay, Bulk, Loose		**0.335**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Expanded clay aggregates, based on ICE database averages, are lightweight aggregates used in structural and geotechnical applications, providing

										thermal insulation, low density, and high strength-to-weight performance.
28		Aggregates, Expanded Foamed Glass, Bulk, Loose		**0.274**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Expanded foamed-glass aggregates, based on ICE database averages, are lightweight aggregates typically used in civil engineering, insulation, and drainage applications, offering low density, durability, and resistance to moisture and chemicals.
29		Aggregates, from Secondary Resources, Bulk, Loose		**0.063**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Secondary aggregates include blast-furnace slag, bottom ash, road plannings, mining spoil, and other by-products from secondary resources. They are applied in road construction, concrete production, and bulk fill, with composition and data derived from UK regional surveys.
30		Aggregates, Mixture of Recycled and Secondary Resources, Bulk, Loose		**0.014**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Mixed recycled and secondary aggregates are composed of approximately 33% secondary and 67% recycled materials. They are used in concrete, road-base, and general construction, combining the benefits of resource recovery with performance in structural and non-structural applications.
31	Soil	Washed Copper Slag (WCS)		**0.28185**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used as a partial replacement for sand in concrete, mortar, and abrasive-blasting applications. 2. Properties: A by-product from copper smelting that is washed to remove impurities; it provides angular, dense particles suitable for use as a fine aggregate. 3. Performance: Improves durability, enhances abrasion resistance, and reduces the demand for natural sand while supporting sustainable material use.

32		Sand		**0.00438**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used as a fine aggregate in concrete, mortar, plastering, backfilling, and general construction works. 2. Properties: Natural granular material with controlled grading, typically sourced from river, land, or marine deposits. 3. Performance: Provides workability, stability, and uniform texture in mixes, ensuring reliable finishing quality and consistent mechanical behaviour.
33		General (Rammed Soil)*		**0.024**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Application: Rammed earth is a building material made by compacting certain soils. The most durable of the earth-building forms, rammed earth may be used for making building blocks or for constructing whole walls in place, layer by layer.
34		Cement Stabilised Soil @ 5%		**0.061**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Stabilised soil with 5% cement by mass of dry soil (balance natural soil). Used for low- to moderate-strength improvement; specify moisture and compaction controls.
35		Cement Stabilised Soil @ 8%		**0.084**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Stabilised soil with 6% cement + 2% lime (8% total stabiliser). Suited to higher strength and early stiffness; verify sulphate conditions for lime use.
36		GGBS Stabilised Soil		**0.047**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Stabilised soil using GGBS with lime activation. Text states 8% stabiliser, with 8% GGBS + 2% lime (sum 10%); retained as provided. Confirm dosage in the project specification.
37		Fly Ash Stabilised Soil		**0.041**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Stabilised soil with 8% fly ash + 2% lime (10% total stabiliser). Pozzolanic system; strength develops with curing. Check availability and class of fly ash and sulphate conditions.

38	Stone	Stone, General*		**0.079**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Generic natural building stone for cladding, paving, landscaping, and structural or masonry blocks. 2. Properties: Mixed quarry sources; cutting, dressing, and transport dominate impacts. ICE database average (statistical), uncertain; see material profile. 3. Performance: Durable and low-maintenance; verify density and absorption, and slip or skid resistance, against project standards.
39		Stone, Granite		**0.7**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: High-durability exterior and interior cladding, paving, kerbs, bridge and parapet stones, countertops, and memorials. 2. Properties: Very hard, with low porosity; energy from sawing and polishing contributes to GWP. Estimated from Ref. 116. 3. Performance: Excellent abrasion and freeze–thaw resistance; specify finishing (flamed, polished, honed) and anchorage details.
40		Limestone		**9.3×10^{-5}**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Limestone is widely applied as a construction material, serving as a key raw material for cement, lime production, and aggregates. It is also used in soil stabilisation, flue-gas desulphurisation, and as a filler in various industrial processes. 2. Properties: This dataset represents limestone flour with a grain size of 5 mm. It is a sedimentary rock extracted through open-pit quarry mining using drilling, blasting (with ANFO explosives), and heavy machinery such as excavators,

										drillers, and dumpers. The processing involves conveying, sizing, and crushing with vibratory screens and multi-step roller mills. The material is abundant, durable, and regionally available, with a consistent physical and chemical composition suitable for construction and industrial use. 3. Performance: Limestone performs effectively as a fundamental raw material, offering high durability, compressive strength, and versatility across construction and industrial applications. Its processing ensures a uniform grain size, making it suitable for downstream uses such as cement and mortar. The dataset provides cradle-to-gate environmental performance under Malaysia-specific energy and transport conditions, ensuring reliable inputs for life-cycle assessments of construction materials.
41		Stone, Marble		**0.13**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Interior cladding, flooring, stairs, columns, and monuments. 2. Properties: Metamorphic carbonate rock; takes a high polish; cutting and polishing energy is significant but generally lower than for dense granites. 3. Performance: Sensitive to acids and staining; specify sealers and a maintenance regime; verify slip resistance for wet areas.
42		Stone, Marble Tile		**0.21**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Thin tiles and slabs for interior floors and wall linings.

										2. Properties: Higher processing per kilogram due to thin cutting, calibration, and polishing; increased wastage factors (Ref. 40). 3. Performance: Provides an aesthetic finish with uniform thickness; requires a proper substrate, adhesives, and grout; protect from acidic cleaners.
43		Sandstone		**0.06**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Paving, cladding, landscaping, and masonry. 2. Properties: Quartz-rich sedimentary stone; typically easier to saw; porosity varies by quarry. Uncertain estimate based on Ref. 262. 3. Performance: Good slip resistance; check salt crystallisation and freeze–thaw durability; select bedding orientation for slabs.
44		Stone, Shale		**0.002**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Typically used as crushed material, aggregates, or raw feed for bricks or cement; rarely as dimension stone. 2. Properties: Fine-grained laminated sedimentary rock; requires minimal processing when used crushed. 3. Performance: Low embodied-carbon intensity reflects the limited processing; not commonly specified as a facing stone due to lamination and durability constraints.
45		Stone, Slate		**0.007 to 0.063**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Roofing slates, cladding tiles, and paving flags. 2. Properties: Metamorphic and fissile; split into thin sheets with limited cutting energy; density and thickness govern the data range. Large data range. 3. Performance: Excellent weathering performance for roofing; ensure

										correct grading, fixing, and overlap; verify slip resistance for paving.
46		Pumice Imported		**0.0002106**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	Malaysia	1. Application: Pumice is primarily applied as a standard mineral product used as a natural aggregate in the construction industry, where it serves as a lightweight aggregate for concrete, blocks, and insulation materials. 2. Properties: The material has a low bulk density of approximately 0.25 g/cm^3, making it exceptionally lightweight compared with other mineral aggregates. It is characterised by high porosity, an inert chemical composition, and good thermal-insulation capacity, while remaining sufficiently strong for structural use in certain applications. 3. Performance: In practice, pumice contributes to reduced dead loads in structural elements, improved fire and acoustic insulation, and enhanced energy efficiency due to its thermal properties. The Malaysian LCI data confirm its sustainable performance profile through a cradle-to-gate assessment, in which the life-cycle boundary considers mining in Indonesia, transport to Malaysia, and consumption at the end user, showing good alignment with local construction technologies and energy mixes.
47		Silica		**9.20×10^{-5}**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	Malaysia	1. Application: Silica, also known as quartz, is widely applied in the construction and manufacturing industries, where it is used as a fine aggregate in concrete, mortar, and

										speciality building products, as well as a raw material in glass, ceramics, and foundry applications. 2. Properties: The material is sourced from quartz mining, followed by cleaning, grinding, and screening processes to achieve the specified grain size of 0/2 mm. It consists predominantly of silicon dioxide (SiO_2) with high chemical purity and stability, offering hardness, abrasion resistance, and thermal durability. The dataset is regionalised for Malaysia, reflecting local energy mixes and supply chains to ensure representativeness of production conditions. 3. Performance: Silica performs effectively as a durable, chemically stable, and mechanically strong material in construction composites, enhancing the compressive strength and long-term durability of concrete and mortar. Its high purity and thermal resistance also make it suitable for glassmaking and refractory applications. From a sustainability perspective, the Malaysian LCI data confirm that silica production has quantified cradle-to-gate impacts, allowing integration into life-cycle assessments and enabling performance evaluation in terms of environmental efficiency.
48	Cement	Average CEM II/A-M Cement from Kien Luong plant		**0.740**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL	VIETNAM	Average CEM II/A-M cement from the Kien Luong plant is designed for producing high-quality concrete with excellent workability and early strength. It is widely applied in large-scale projects and industrial concrete

										production, including batching plants, precast and prestressed concrete factories, centrifugal-pile plants, and concrete brick or tile manufacturing. Formulated for marine and saline environments, it offers strong protection against sulphate attack, making it ideal for wharfs, marinas, sea walls, dams, reservoirs, sewage systems, offshore platforms, and submerged structures in tidal and splash zones.
49		Kien Luong Clinker Product		**0.055**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL	VIETNAM	Clinker from the Kien Luong plant is produced in compliance with the EN 197-1 standard for manufacturing high-quality cement. Applications include residential, commercial, and industrial buildings, as well as infrastructure projects such as roads, bridges, ports, and airports, where consistent quality, durability, and superior cement performance are essential.
50		Average CEM II/A-M Cement from Cam Ranh Grinding Terminal		**0.675**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL	VIETNAM	Designed to produce high-quality concrete with excellent workability and early strength, making it suitable for large-scale projects and manufacturing at concrete batching plants, precast and prestressed concrete factories, centrifugal-pile plants, and concrete brick or tile factories. Formulated for marine and saline environments requiring high strength and durability, it is ideal for wharfs, marinas, sea walls, dams, reservoirs, sewage systems, offshore platforms, and submerged structures in tidal and splash zones.
51		Average CEM II/C-M Cement from Cam Ranh		**0.162**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL	VIETNAM	A general-purpose Portland-blended cement suitable for residential, commercial, and industrial construction, supporting concrete strengths from M150 to M450, and applicable for

		Grinding Terminal								masonry, plastering, tile adhesive, and floor finishing. An eco-friendly version of PCB40 is also available for the same applications, supporting concrete strengths from M200 to M450, and ideal for sustainable projects in masonry and plastering. For demanding applications requiring high strength, waterproofing, or chemical resistance, it is used in bridges, highways, dams, reservoirs, wastewater plants, and industrial facilities. A specialised formulation for marine and saline environments provides protection against sulphate attack, making it suitable for coastal housing, sea walls, wharfs, reservoirs, offshore platforms, sewage systems, and submerged structures in tidal zones.
52		Vicem Ha Tien Masonry Cement from Phu Huu Grinding Terminal		**0.406**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL	VIETNAM	Vicem Ha Tien Masonry Cement conforms to Vietnam Standard TCVN 9202:2012. This cement is primarily used in masonry and plastering construction, with outstanding properties for these applications.
53		Vicem Ha Tien Deep Soil Mixing Cement (DSMC) from Phu Huu Grinding Terminal		**0.334**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL	VIETNAM	Vicem Ha Tien Deep Soil Mixing Cement enhances soil strength for tunnels, piers, airports, and high-rise foundations, preventing landslides, stabilising embankments, and protecting deep excavations with high waterproofing performance.
54		Average CEM II/C-M Cement from Phu Huu		**0.459**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL	VIETNAM	General-purpose cement for residential, commercial, and industrial projects, suitable for concrete (M150–M450), masonry, plastering, and tile adhesive. Eco-friendly PCB40 alternative for sustainable construction, plus

		Grinding Terminal								high-performance grades for bridges, dams, treatment plants, and refineries.
55		Average CEM I & ASTM C150 Cement from Phu Huu Grinding Terminal		**0.778**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL	VIETNAM	Vicem Ha Tien Portland Cement (PC40, PC50, ASTM C150 Type I) is a general-purpose cement for industrial and civil construction, used in concrete for bridges, culverts, reservoirs, and reinforced-concrete components, with PC50 offering higher early and long-term strength. Vicem Ha Tien Sulphate-Resisting Portland Cement (ASTM C150 Type V, PCMSR40) is formulated for high-sulphate environments such as coastal and saline areas, reducing steel corrosion and water permeability, and is ideal for wharfs, marinas, offshore platforms, sea walls, dams, reservoirs, sewage systems, and submerged structures in tidal and splash zones.
56		Average CEM II/A-M Cement from Phu Huu Grinding Terminal		**0.713**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL	VIETNAM	Vicem Ha Tien Portland-Blended Cement PCB40 (Industrial Application) is designed for producing high-quality concrete with excellent workability and high early strength, and is widely used in large-scale projects and industrial applications such as ready-mix batching plants, precast and prestressed concrete factories, centrifugal-pile manufacturing, and concrete brick or tile production. Vicem Ha Tien Portland-Blended Cement PCB50 is suitable for residential, high-rise, and industrial structures, offering high early strength for faster formwork removal and reduced construction time, with enhanced durability and resistance to water and chemical erosion for long-term performance.

57		Average CEM I & ASTM C150 Cement from Binh Phuoc Plant		**0.768**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL	VIETNAM	Vicem Ha Tien Portland Cement (PC40, PC50, ASTM C150 Type I) is a general-purpose cement suitable for a wide range of applications in industrial and civil construction. It is commonly used for producing concrete in bridges, culverts, reservoirs, and reinforced-concrete structures, with PC50 offering higher strength for demanding applications.
58		Average CEM II/A-M Cement from Binh Phuoc Plant		**0.673**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL	VIETNAM	Vicem Ha Tien PCB40_MS (Sulphate-Resisting) – for marine and saline constructions, protecting against sulphate attack in buildings, wharfs, marinas, sea walls, reservoirs, sewage systems, offshore platforms, and submerged structures. Vicem Ha Tien PCB50_MS (High-Strength Sulphate-Resisting) – for high-strength marine and coastal structures exposed to sulphates, such as wharfs, marinas, dams, pipelines, treatment plants, offshore platforms, bridges, and submerged structures. Vicem Ha Tien PCB40 (Industrial Application) – for high-quality concrete with good workability and early strength in large-scale projects, ready-mix plants, precast factories, centrifugal-pile production, and concrete brick or tile production.
59		Average CEM II/C-M Cement from Binh Phuoc Plant		**0.521**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL	VIETNAM	Suitable for diverse applications including residential, high-rise, and industrial projects, for concrete (M150–M450), masonry, plastering, and tile or stone adhesion. It is applied in foundations, slabs, columns, beams, plastering, and masonry works. It is ideal for high-strength structures such

										as bridges, roads, and high-rise buildings, as well as waterproofing projects like reservoirs and dams, and corrosion-resistant facilities including chemical plants, wastewater-treatment plants, and refineries. It is also used in general construction for ready-mix concrete and finishing mortar.
60		Binh Phuoc Clinker Product		**0.044**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL	VIETNAM	Clinker from the Binh Phuoc plant is produced to EN 197-1 standards for manufacturing high-quality cement with consistent strength, durability, and performance. It is used to produce various cement grades for residential, commercial, and industrial construction projects, meeting diverse market demands for superior cement quality.
61		Vicem Ha Tien Portland Blended Cement Industrial Appliance PCB40 from Long An Grinding Terminal		**0.726**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL	VIETNAM	Vicem Ha Tien Portland-Blended Cement PCB40 (Industrial Application) is formulated to produce high-quality concrete with excellent workability and high early strength. It is widely used in large-scale projects and industrial production, including concrete batching plants, precast and prestressed concrete factories, centrifugal-pile manufacturing, and concrete brick or tile production.
62		Average CEM II/C-M Cement from Long An Grinding Terminal		**0.491**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL	VIETNAM	Suitable for a wide range of applications, including residential houses, high-rise buildings, and industrial projects, for concrete (M150–M450), masonry, and plastering mortar. It is applied in foundations, slabs, columns, beams, plastering, and masonry, as well as for tile, marble, granite, and natural-stone adhesion on concrete surfaces. It is ideal for high-strength structures such as bridges, roads, and high-rise buildings, waterproofing works like reservoirs and dams, and

										corrosion-resistant facilities including chemical plants, wastewater-treatment plants, and refineries. It is also used in general construction for ready-mix concrete and finishing mortar.
63		Average CEM II/C-M Cement from Kien Luong Plant		**0.501**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL	VIETNAM	Applicable for residential houses, high-rise buildings, and industrial projects, and suitable for concrete (M150–M450), masonry, and plastering mortar. It is commonly used in foundations, slabs, columns, beams, plastering, and masonry, and as an adhesive for tiles, marble, granite, and natural stones on concrete surfaces. It is ideal for high-strength structures such as bridges, roads, and high-rise buildings, as well as waterproofing works like reservoirs and dams, and corrosion-resistant facilities including chemical plants, wastewater-treatment plants, and refineries. It is also suited for general construction, including residential and industrial works, and for ready-mix concrete and finishing mortar.
64		Average CEM I & ASTM C150 Cement from Kien Luong Plant		**0.774**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL	VIETNAM	General-purpose Portland cements are suitable for diverse industrial and civil construction projects and are commonly used to produce concrete for structural elements such as bridges, culverts, reservoirs, and reinforced-concrete components. PC50 is preferred for applications requiring higher strength performance.
65		Fiber Cement Panel		**4.088**	kgCO2/panel	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: The fibre-cement panel is mainly applied for cladding and ceiling panelling in both residential and commercial buildings, serving as a durable and versatile construction material. 2. Properties: It is a wood-based composite produced by mixing pulp

										fibres with cement and sand, which is then formed into continuous sheets of specific thickness. The sheets are cut to size and autoclaved to ensure dryness and dimensional stability, combining the strength and fire resistance of cement with the flexibility and lightweight nature of cellulose fibres. 3. Performance: The resulting panel demonstrates good durability, resistance to moisture, and dimensional consistency, making it suitable for ceiling applications. Its production process, which includes autoclaving, enhances long-term performance by reducing shrinkage and improving stability under varying climatic conditions.
66		Cement CEM I 32.5		**1.019**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Cement CEM I 32.5 is primarily used as a mineral binder in the construction sector, where it serves as a key ingredient for producing concrete and mortar. Its applications span structural elements, infrastructure works, and general building materials. 2. Properties: This cement belongs to strength class 32.5, indicating its compressive strength after 28 days. It is produced from finely ground clinker combined with minor constituents such as calcium sulphate, which ensures proper setting during mixing; the clinker itself is obtained by heating limestone, clay, and other raw materials to about 1450 °C in rotary kilns, forming calcium silicates and

										aluminates that give cement its hydraulic-hardening properties. 3. Performance: Cement CEM I 32.5 provides reliable strength development and durability suitable for conventional construction applications. It ensures structural stability by hardening upon contact with water, making it versatile for both reinforced and non-reinforced concrete, although its energy-intensive production, relying largely on coal with a smaller share of palm-kernel shells as alternative fuel in Malaysia, results in an embodied-carbon intensity of about 1.02 kg CO_2e per kilogram of cement under cradle-to-gate conditions.
67		Cement CEM I 42.5		**1.15**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Cement CEM I 42.5 is primarily applied as a mineral binder in the construction industry, where it is used for concrete production, mortar, precast elements, and other building and infrastructure works requiring high strength and durability. 2. Properties: This cement is produced through raw-material extraction, clinker production, and cement grinding; limestone, chalk, and clay are heated to approximately 1450 °C in a rotary kiln to form clinker phases such as calcium silicates and aluminates, which are then finely ground with gypsum to control setting. Classified as strength class 42.5, it provides high early and final strength, and the dataset represents cradle-to-gate production under Malaysian

										conditions with fuels assumed as 95% coal and 5% palm-kernel shell, plus imported gypsum from Thailand. 3. Performance: Cement CEM I 42.5 delivers strong mechanical properties, reliable setting and hardening behaviour, and long-term durability in structural applications. Its consistent performance makes it suitable for high-strength concrete in both infrastructure and building projects, and the Malaysian life-cycle inventory defines its cradle-to-gate environmental profile so it can be integrated into life-cycle assessments of construction materials.
68		Ordinary Portland Cement (OPC)		**0.923**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used as the primary binder in concrete production, mortar, grouts, precast products, and structural elements requiring high compressive strength and reliable setting characteristics. 2. Properties: Manufactured through clinker production and fine grinding, it delivers high early-age and long-term strength, with the emission factor covering cradle-to-gate impacts from raw-material extraction through clinker burning, grinding, and packaging. 3. Performance: Provides consistent strength development and mechanical performance across a wide range of concrete grades and is widely used in structural, precast, and ready-mix applications, representing the highest

										embodied-carbon component in typical concrete mixes.
69		Fly Ash		**0.056**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used as a supplementary cementitious material in blended concrete, precast elements, and mass concrete where improved durability and reduced heat of hydration are required. 2. Properties: A pozzolanic by-product from coal combustion that reacts with calcium hydroxide to form additional cementitious compounds, with its emission factor reflecting cradle-to-gate impacts associated with processing, handling, and beneficiation. 3. Performance: Enhances long-term strength, reduces permeability, and improves resistance to sulphates and chloride ingress, and contributes significantly to lowering embodied carbon when used as a partial cement replacement.
70		Ground-Granulated Blast-Furnace Slag (GGBS)		**0.079**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used as an SCM in concrete, particularly for precast, structural, and durability-critical applications such as marine structures, foundations, and mass concrete. 2. Properties: Produced by quenching molten iron slag and grinding it into a fine hydraulic powder, offering a lower-carbon alternative to ordinary Portland cement, with the emission factor covering cradle-to-gate processes including slag quenching, drying, milling, and handling. 3. Performance: Improves durability, reduces heat of hydration, and

										increases long-term strength development, and is commonly incorporated into eco-concrete mixes to reduce embodied carbon and enhance service life.
71		Limestones		**0.102**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used as filler material in cement and concrete, enhancing mix cohesiveness and improving workability in both cast-in-situ and precast applications. 2. Properties: Finely ground natural limestone added to improve particle packing and reduce clinker demand in blended cements, with the emission factor reflecting quarrying, crushing, grinding, and material preparation. 3. Performance: Enhances concrete flowability, reduces bleeding, and improves finish quality, while supporting embodied-carbon reduction through partial replacement of energy-intensive clinker.
72		Limestones Fines		**0.087**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used as a fine filler in mortar, concrete, and precast mixes to optimise grading, increase paste volume, and improve surface texture. 2. Properties: Manufactured through fine grinding of high-purity limestone, it contributes to improved packing density and mix stability, with the emission factor reflecting cradle-to-gate processes including extraction, crushing, and fine milling. 3. Performance: Improves cohesiveness and early-age workability while enabling reductions in cement content,

										enhancing compaction, reducing segregation, and supporting the production of smoother precast finishes.
73		Plasticising and Superplasticising		**0.486**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used in ready-mix and precast concrete to enhance workability, increase slump, and facilitate placement in heavily reinforced or complex structural elements. 2. Properties: Chemical admixtures formulated to disperse cement particles, reduce water demand, and improve rheology; the emission factor covers cradle-to-gate manufacturing of the chemical constituents and additives. 3. Performance: Enables production of high-strength, low water–cement-ratio concrete; improves pumpability, reduces segregation, and enhances durability, making it essential for high-performance and precast applications.
74		Air Entrainers		**0.527**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used to improve freeze–thaw resistance and enhance durability in exposed concrete. 2. Properties: Chemical agents that introduce microscopic air bubbles to improve workability and reduce bleeding. 3. Performance: Enhances resistance to scaling, improves long-term durability, and stabilises the concrete mix.
75		Water Resisting		**2.670**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used to reduce water ingress in concrete for basements, retaining walls, foundations, and other watertight structures.

										2. Properties: Hydrophobic or pore-blocking chemicals that limit moisture penetration and reduce capillary absorption. 3. Performance: Improves impermeability, reduces leakage, and enhances durability in wet environments.
76		Retarders		**1.310**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used to delay setting time in hot weather, for long transport distances, or for large pours requiring extended workability. 2. Properties: Chemical admixtures that slow the hydration rate to maintain workable concrete for a longer duration. 3. Performance: Prevents premature stiffening, reduces the risk of cold joints, and ensures consistent finishing quality.
77		Hardening Accelerators		**2.280**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used when early strength gain is required, such as in precast concrete, cold-weather concreting, and fast-track construction. 2. Properties: Compounds that accelerate early hydration reactions and promote faster strength development. 3. Performance: Shortens formwork-removal time, improves early strength, and enhances construction productivity.
78		Set Accelerators		**1.330**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used to shorten initial setting time for rapid repairs, shotcrete, and concreting at low temperatures. 2. Properties: Chemical admixtures that trigger earlier hydration

										reactions, causing quicker stiffening after placement. 3. Performance: Enables faster setting, improves early stability, and supports efficient time-critical concrete operations.
79		Cement*		**0.812**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Density: 1440 kg/m³. The mixture is taken from the average UK-sector cement EPD S-P-05825 and consists, by weight, of 87.34% clinker, 5.05% gypsum, 5.21% limestone, and 2.40% MAC, estimated using the ICE Cement, Mortar, and Concrete model.
80		Cement CEM I – Portland Cement		**0.840**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Density: 1440 kg/m³. CEM I is a “pure” cement, Ordinary Portland Cement (OPC); the mixture is taken from a typical UK CEM I EPD S-P-05824 and consists, by weight, of 90.8% clinker, 5.0% gypsum, 4.0% limestone, and 0.2% MAC, estimated using the ICE Cement, Mortar, and Concrete model.
81		Cement CEM II-A-S – 13% GGBS – Portland-Slag Cemen		**0.745**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Density: 1440 kg/m³. This cement permits between 6–20% GGBS, as estimated from the ICE Cement, Mortar, and Concrete model.
82		Cement CEM II/B-S – 28% GGBS – Portland-Slag Cement		**0.630**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Density: 1440 kg/m³. This cement permits between 21–35% GGBS, as estimated from the ICE Cement, Mortar, and Concrete model.
83		Cement CEM II/A-P – 13% Natural Pozzolanic Ash –		**0.735**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Density: 1440 kg/m³. This cement permits between 6–20% natural pozzolanic ash, as estimated from the ICE Cement, Mortar, and Concrete model.

		Portland-Pozzolana Cement								
84		Cement CEM II/B-P – 28% Natural Pozzolanic Ash – Portland-Pozzolana Cement		**0.610**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Density: 1440 kg/m³. This cement permits between 21–35% natural pozzolanic ash, as estimated from the ICE Cement, Mortar, and Concrete model.
85		Cement CEM II/A-V – 13% Fly Ash Siliceous – Portland-Fly Ash Cement		**0.730**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Density: 1440 kg/m³. This cement permits between 6–20% siliceous fly ash, as estimated from the ICE Cement, Mortar, and Concrete model.
86		Cement CEM II/B-V – 28% Fly Ash Siliceous – Portland-Fly Ash Cement		**0.610**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Density: 1440 kg/m³. This cement permits between 21–35% siliceous fly ash, as estimated from the ICE Cement, Mortar, and Concrete model.
87		Cement CEM II/A-W – 13% Fly Ash Calcareous – Portland-Fly Ash Cement		**0.735**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Density: 1440 kg/m³. This cement permits between 6–20% calcareous fly ash, as estimated from the ICE Cement, Mortar, and Concrete model.
88		Cement CEM II/B-W – 28% Fly Ash Calcareous		**0.609**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Density: 1440 kg/m³. This cement permits between 21–35% calcareous fly ash, as estimated from the ICE Cement, Mortar, and Concrete model.

		– Portland-Fly Ash Cement								
89		Cement CEM II/A-L – 13% Limestone – Portland-Limestone Cement		**0.735**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Density: 1440 kg/m³. This cement permits between 6–20% limestone, as estimated from the ICE Cement, Mortar, and Concrete model.
90		Cement CEM II/B-L – 28% Limestone – Portland-Limestone Cement		**0.609**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Density: 1440 kg/m³. This cement permits between 21–35% limestone, as estimated from the ICE Cement, Mortar, and Concrete model.
91		Cement CEM II/A-LL – 13% Limestone – Portland-Limestone Cement		**0.736**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Density: 1440 kg/m³. This cement permits between 6–20% limestone replacements, as estimated from the ICE Cement, Mortar, and Concrete model.
92		Cement CEM II/B-LL – 28% Limestone – Portland-Limestone Cement		**0.612**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Density: 1440 kg/m³. This cement permits between 21–35% limestone replacements, as estimated from the ICE Cement, Mortar, and Concrete model.
93		Cement CEM II/A-M – 16% Cement Replacement – Portland-Composite Cement		**0.716**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Density: 1440 kg/m³. This cement permits between 12–20% cement replacements, as estimated from the ICE Cement, Mortar, and Concrete model.

94		Cement CEM II/B-M – 28% Cement Replacement – Portland-Composite Cement		**0.619**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Density: 1440 kg/m³. This cement permits between 21–35% cement replacements, as estimated from the ICE Cement, Mortar, and Concrete model.
95		Cement CEM III/A – 50.5% GGBS – Blast Furnace Cement		**0.458**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Density: 1440 kg/m³. This cement permits between 36–65% GGBS, as estimated from the ICE Cement, Mortar, and Concrete model.
96		Cement CEM III/B – 73% GGBS – Blast Furnace Cement		**0.286**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Density: 1440 kg/m³. This cement permits between 66–80% GGBS, as estimated from the ICE Cement, Mortar, and Concrete model.
97		Cement CEM III/C – 88% GGBS – Blast Furnace Cement		**0.172**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Density: 1440 kg/m³. This cement permits between 81–95% GGBS, as estimated from the ICE Cement, Mortar, and Concrete model.
98		Cement CEM IV/A – 23% Cement Replacement – Pozzolanic Cement		**0.650**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Density: 1440 kg/m³. This cement permits between 11–35% pozzolanic materials, such as fly ash or natural pozzolanic ash, as estimated from the ICE Cement, Mortar, and Concrete model.
99		Cement CEM IV/B – 46% Cement Replaceme		**0.462**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Density: 1440 kg/m³. This cement permits between 38–55% pozzolanic materials, such as fly ash or natural pozzolanic ash, as estimated from the

		nt – Pozzolanic Cement								ICE Cement, Mortar, and Concrete model.
100		Cement CEM V/A – 24% GGBS and 24% Cement Replacement – Composite Cement		**0.461**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Density: 1440 kg/m³. This cement permits between 18–30% GGBS and 18–30% pozzolanic materials, as estimated from the ICE Cement, Mortar, and Concrete model.
101		Cement CEM V/B – 36% GGBS and 36% Cement Replacement – Composite Cement		**0.277**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Density: 1440 kg/m³. This cement permits between 31–49% GGBS and 31–49% pozzolanic materials, as estimated from the ICE Cement, Mortar, and Concrete model.
102		Clinker		**0.919**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Extrapolated from the EPD for average UK cement. EN 15804 EPD number: New: EPD S-P-05825 https://www.environdec.com/library/epd5825
103		Gypsum		**0.002**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Source: Ökobaudat – gypsum stone ($CaSO_4$-dihydrate); ground and purified product, [https://oekobaudat.de/OEKOBAU.DAT/datasetdetail/process.xhtml?uuid=fbd76e49-0fb1-47e0-abba-903ce1272684&version=20.19.120], 2018 year of data
104		GGBS		**0.080**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	EN 15804 EPD, BRE 000245
105		Fly Ash		**0.004**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Based on two data points.

106		Natural Pozzolanic Ash		**0.007**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	For example, volcanic ash. There were no carbon-footprint data; however, the production process is comparable to that of aggregates and sand, consisting of extraction and crushing. Therefore, it was assumed to have the same impact as aggregates.
107	Concrete	Concrete, General		**0.103**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Generic ready-mixed concrete baseline. 2. Properties: From BRMCA/MPA EPD-RMC-20180095-CBG1-EN; indicative recipe ≈200 kg CEM I, 95 kg GGBS, 15 kg fly ash, 1915 kg aggregates, 139 kg water, 1.55 kg admixture per m^3. 3. Performance: Use only as a placeholder; strongly recommended to switch to a strength-class entry or an actual cement-content record/EPD for accuracy.
108		Concrete C20/25; Strength Class C20/25		**0.142**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: General structural works for slabs, beams, columns, and foundations at about 20 MPa cylinder strength. 2. Properties: Ready-mix concrete produced in Malaysia; cement, water, and mineral aggregates; reflects 2013 local energy and supply chains. 3. Performance: Suitable for typical RC elements; align cover, exposure class, and curing to meet durability.
109		Concrete C30/37; Strength Class 30/37		**0.109**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Structural elements requiring higher capacity such as beams, columns, and floors. 2. Properties: Malaysian ready-mix C30/37; cement, water, aggregates; dataset represents cradle-to-gate conditions in 2013. 3. Performance: Provides higher compressive strength; ensure

										compaction and steady curing, especially in hot climates.
110		Concrete C8/10; Strength Class 8/10		**0.108**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Non-structural works including blinding layers, pathways, and simple foundations. 2. Properties: Low-strength, normal-weight concrete prepared at plant; designed for about 8 MPa cylinder strength. 3. Performance: Adequate for bedding and fill; maintain curing to prevent surface weakness or dusting.
111		Concrete Masonry Unit; Concrete Masonry; Site Specific, At Plant		**0.137**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Masonry blocks for walls and partitions with thermal mass and fire resistance. 2. Properties: Plant-produced CMU using cement, water, and aggregates; Malaysian cradle-to-gate inventory. 3. Performance: Durable and dimensionally stable when properly cured; use appropriate mortar and reinforcement details.
112		Aerated Concrete Block 400		**0.318**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Lightweight walling and infill for residential and commercial buildings. 2. Properties: Mineral-based AAC with average density about 400 kg/m^3; produced via dosing, mixing, pore formation, casting, cutting, and steam curing. 3. Performance: Excellent thermal and acoustic insulation; reduced dead load; easy handling; ensure protection during transport and installation.
113		Aerated Concrete Block 500		**0.143**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Lightweight partitions and infill walls where reduced structural load and insulation are desired.

										2. Properties: AAC with average density about 500 kg/m³; manufactured with steam curing for dimensional accuracy. 3. Performance: Good durability and energy efficiency; verify compressive capacity for non-load-bearing use.
114		Concrete C20-25		**0.175**	$kgCO_2e/kg$	$kgCO_2e/kg$	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Structural elements in buildings and transport infrastructure such as slabs, beams, columns, pavements, and foundations. 2. Properties: Strength class C20/25; ready-mix with cement, water, mineral aggregates, and optional additives; Malaysian energy and supply conditions. 3. Performance: Provides moderate compressive strength and durability; tailor aggregate grading and mix proportions to performance needs.
115		Concrete C30-37		**0.201**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Load-bearing elements in buildings and infrastructure requiring higher strength and durability. 2. Properties: Ready-mix C30/37 made from cement, water, aggregates, with optional admixtures; Malaysian cradle-to-gate dataset. 3. Performance: High compressive strength with reliable performance; manage curing to avoid thermal and shrinkage issues.
116		Concrete C8-10v		**0.179**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Non-structural works such as blinding, simple foundations, and filling where high load-bearing capacity is not critical. 2. Properties: Strength class C8/10 produced from cement, water, and

										aggregates with optional additives; characteristic cylinder strength about 8 MPa. 3. Performance: Provides adequate bedding and support; focus on compaction and curing to avoid settlement and moisture ingress.
117		Lightweight Concrete 1600		**0.0042**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Non-load-bearing walls, partitions, and elements needing lower weight and thermal insulation. 2. Properties: Pumice concrete with density about 1600 kg/m³; mixed, moulded, vibration compacted, and cured for 6 weeks. 3. Performance: Reduced dead load and improved thermal performance; not intended for heavy load-bearing; ensure curing for durability.
118		Lightweight Concrete 800		**0.00975**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Lightweight blocks and infill where reduced structural weight and insulation are required. 2. Properties: Pumice concrete with density about 800 kg/m³; moulded, vibration compacted, and stored for 6 weeks before use. 3. Performance: Eases handling and installation; enhances energy efficiency; verify suitability where structural loads are present.
119		Concrete (Natural) Grade 20		**0.121**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for non-structural or lightly loaded elements such as small foundations, blinding layers, footpaths, and simple slabs where lower compressive strength is acceptable. 2. Properties: Normal-weight concrete using natural aggregates with a characteristic strength of 20 MPa; provides adequate workability and moderate durability for general use.

										3. Performance: Offers sufficient compressive capacity for low-load applications; not recommended for critical structural members; curing is required to ensure long-term durability.
120		Concrete (Natural) Grade 25		**0.129**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Commonly used for residential slabs, beams, columns, and general reinforced concrete works requiring moderate strength. 2. Properties: Normal-weight concrete with 25 MPa strength; composed of natural aggregates and suitable for reinforced applications with improved density and stiffness. 3. Performance: Provides reliable structural performance for most low- to medium-load elements; supports better crack control and durability compared to lower grades.
121		Concrete (Natural) Grade 30		**0.149**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Widely used in commercial buildings, structural floors, beams, and columns requiring higher load-bearing capability. 2. Properties: Normal-weight concrete reaching 30 MPa strength; designed for improved mechanical properties and enhanced durability in typical structural works. 3. Performance: Offers good resistance to cracking and long-term deformation; suitable for structural components with moderate to significant loading.
122		Concrete (Natural) Grade 35		**0.161**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used for heavily loaded structural components such as transfer beams, foundation pads, and industrial floors. 2. Properties: Normal-weight, 35 MPa concrete made with natural

										aggregates; provides higher compaction quality, stiffness, and durability. 3. Performance: Supports increased load demands with improved structural integrity; suitable for elements requiring enhanced strength and serviceability performance.
123		Concrete (Natural) Grade 40		**0.172**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for high-strength applications including multi-storey building frames, prestressed members, and heavily loaded foundations. 2. Properties: Normal-weight concrete with characteristic strength of 40 MPa; designed with well-graded natural aggregates and optimised mix proportions. 3. Performance: Demonstrates excellent load-bearing capacity, reduced creep, and improved durability in demanding structural environments.
124		Concrete (Natural) Grade 50		**0.19**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Applied in high-rise buildings, bridges, prestressed concrete components, and critical structural elements requiring high compressive strength. 2. Properties: High-strength normal-weight concrete achieving 50 MPa; incorporates high-quality natural aggregates and low water–cement ratios to enhance performance. 3. Performance: Provides superior resistance to cracking, high stiffness, and long-term structural reliability; suitable for advanced structural systems.

125		Concrete (Natural) Grade 80		**0.2325**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used in specialised heavy-duty structures including long-span bridges, offshore platforms, and deep foundations needing very high strength. 2. Properties: High-performance concrete with 80 MPa compressive strength; optimised with high-grade natural aggregates and advanced mix design for superior mechanical response. 3. Performance: Offers exceptional strength, durability, and resistance to aggressive environmental exposure; suitable for complex engineering structures.
126		Concrete (Natural) Grade 100		**0.227**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Utilised in ultra-high-strength structural elements such as high-rise core walls, post-tensioned systems, and critical bridge components. 2. Properties: Ultra-high-performance concrete achieving 100 MPa; formulated with premium aggregates, admixtures, and dense microstructure for maximum strength. 3. Performance: Delivers outstanding load capacity, exceptional durability, very low permeability, and enhanced long-term structural stability under extreme conditions.
127		Eco Concrete (15% Fly Ash Replacement) Grade 20		**0.111**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for low-load structural and non-structural elements such as slabs-on-grade, pathways, small foundations, and residential components where moderate strength is sufficient. 2. Properties: Normal-weight concrete incorporating 15% fly ash as partial cement replacement; enhances

										workability and reduces embodied carbon while meeting 20 MPa compressive strength requirements. 3. Performance: Provides adequate strength for light-duty applications; offers improved durability and reduced heat of hydration; not intended for high-load-bearing elements.
128		Eco Concrete (15% Fly Ash Replacement) Grade 25		**0.118**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Commonly used for general reinforced concrete works in residential and small commercial structures, including beams, slabs, and columns with moderate loading. 2. Properties: Incorporates 15% fly ash to lower carbon footprint and improve long-term durability; achieves a characteristic strength of 25 MPa with enhanced cohesiveness. 3. Performance: Offers reliable mechanical performance and improved resistance to cracking; suitable for typical RC elements where moderate strength is required.
129		Eco Concrete (15% Fly Ash Replacement) Grade 30		**0.139**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used for structural components in medium-rise buildings, including slabs, beams, and columns requiring higher strength and improved durability. 2. Properties: Fly ash–modified concrete designed to reach 30 MPa; provides enhanced microstructure, reduced permeability, and better sulphate resistance compared with plain OPC concrete. 3. Performance: Ensures good structural performance with lower carbon emissions; suitable for

										elements needing consistent strength, durability, and long-term stability.
130		Eco Concrete (15% Fly Ash Replacement) Grade 35		**0.149**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for heavily loaded structural members such as deep beams, floor systems, and foundation pads in commercial structures. 2. Properties: High-quality concrete incorporating 15% fly ash to achieve 35 MPa; improves resistance to chloride ingress and reduces overall cement consumption. 3. Performance: Supports increased load demands while enhancing durability and environmental performance; recommended for structural elements where higher compressive strength is required.
131		Eco Concrete (15% Fly Ash Replacement) Grade 40		**0.159**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used for high-strength applications including high-rise building frames, critical beams and columns, and load-intensive foundation elements. 2. Properties: Engineered concrete mix with 15% fly ash replacement achieving 40 MPa; offers better long-term strength development and reduced embodied carbon. 3. Performance: Provides superior mechanical strength, improved durability, and reduced cracking; suitable for demanding structural environments with higher load expectations.
132		Eco Concrete (15% Fly Ash Replaceme		**0.174**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for specialised high-strength components including prestressed members, high-rise core walls, and structural systems

		nt) Grade 50								exposed to aggressive environments. 2. Properties: High-strength eco-concrete incorporating 15% fly ash to achieve 50 MPa compressive strength; enhances durability, decreases permeability, and contributes to sustainability goals. 3. Performance: Delivers excellent structural capacity, extended service life, and reduced CO_2 footprint; ideal for advanced engineering applications requiring high mechanical performance.
133		Eco Concrete (30% Fly Ash Replacement) Grade 20		**0.099**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for non-structural or lightly loaded elements such as footpaths, lean concrete layers, ground slabs, and simple residential works where lower early strength is acceptable. 2. Properties: Concrete incorporating 30% fly ash as cement replacement, resulting in significantly reduced embodied carbon and improved workability; develops strength more gradually while meeting 20 MPa characteristic strength. 3. Performance: Provides adequate structural capacity for low-load applications; offers enhanced durability, reduced heat of hydration, and improved sustainability; not recommended for heavy structural loads.
134		Eco Concrete (30% Fly Ash Replaceme		**0.105**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Commonly used for general reinforced concrete in residential construction, slabs, beams, and small columns that require moderate compressive strength.

		nt) Grade 25								2. Properties: Modified concrete mix with 30% fly ash to lower clinker content; improves cohesiveness, reduces permeability, and enhances long-term durability while achieving 25 MPa strength. 3. Performance: Delivers stable performance with reduced cracking potential; suitable for typical RC elements, especially where environmental sustainability is prioritised.
135		Eco Concrete (30% Fly Ash Replacement) Grade 30		**0.125**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for medium-strength structural components such as slabs, beams, and columns in commercial and low-rise buildings requiring enhanced durability. 2. Properties: Utilises 30% fly ash replacement for lower carbon emissions; produces a dense microstructure with improved resistance to sulphates and chloride ingress; achieves 30 MPa target strength. 3. Performance: Offers reliable structural performance with slower early strength gain but superior long-term mechanical properties; ideal for durable construction in non-time-critical projects.
136		Eco Concrete (30% Fly Ash Replacement) Grade 35		**0.133**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used for heavily loaded members such as foundations, floor systems, transfer beams, and commercial building frames. 2. Properties: High-durability concrete containing 30% fly ash to achieve 35 MPa strength; reduces cement usage, enhances workability, and improves resistance to aggressive environments.

										3. Performance: Provides strong load-carrying capability with long-term durability advantages; suitable for structural elements requiring consistent strength and environmental performance.
137		Eco Concrete (30% Fly Ash Replacement) Grade 40		**0.142**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for high-strength structural elements, including high-rise frames, critical beams and columns, and load-bearing foundations. 2. Properties: Designed with 30% fly ash replacement to achieve 40 MPa; improves long-term strength development, reduces permeability, and supports sustainability objectives. 3. Performance: Delivers excellent mechanical strength with enhanced resistance to cracking and chemical attack; recommended for demanding structural applications where long service life is required.
138		Eco Concrete (30% Fly Ash Replacement) Grade 50		**0.155**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used for advanced high-strength components including prestressed elements, high-rise structural cores, and elements exposed to aggressive environments. 2. Properties: High-performance concrete with 30% fly ash replacing cement; provides superior durability, reduced embodied carbon, and a refined microstructure to achieve 50 MPa compressive strength. 3. Performance: Ensures outstanding load-bearing capacity, improved durability, and significant sustainability benefits; ideal for high-performance construction

										needing both strength and environmental efficiency.
139		Eco Concrete (25% GGBS Replacement) Grade 20		**0.094**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for low-load structural and non-structural elements such as ground slabs, walkways, blinding layers, and simple residential components where early-age strength demand is minimal. 2. Properties: Concrete incorporating 25% GGBS as cement replacement; offers reduced embodied carbon, improved workability, and enhanced long-term durability with 20 MPa strength. 3. Performance: Provides adequate strength for light-duty applications; delivers better sulphate and chloride resistance; not intended for heavy structural loads.
140		Eco Concrete (25% GGBS Replacement) Grade 25		**0.1**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used for general reinforced concrete works in low-rise and residential buildings, including slabs, beams, and small columns requiring moderate compressive strength. 2. Properties: Mix with 25% GGBS replacement, improving mix cohesiveness and lowering heat of hydration; achieves characteristic strength of 25 MPa while enhancing durability. 3. Performance: Offers consistent performance with improved crack control and reduced permeability; suitable for common RC structural applications.
141		Eco Concrete (25%		**0.12**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for middle-strength structural elements such as slabs, beams, and columns in

		GGBS Replacement) Grade 30								commercial and institutional buildings requiring enhanced durability. 2. Properties: Designed with 25% GGBS to reduce cement usage and produce a denser microstructure; provides effective resistance against chemical attack and achieves 30 MPa strength. 3. Performance: Ensures reliable mechanical capacity with improved long-term durability; recommended for projects with sustainability requirements and moderate to high structural loading.
142		Eco Concrete (25% GGBS Replacement) Grade 35		**0.129**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used for heavily loaded structural members including deep beams, foundation pads, and industrial floors where higher mechanical strength is required. 2. Properties: High-durability concrete incorporating 25% GGBS to achieve 35 MPa; reduces heat of hydration and enhances resistance to chloride ingress and carbonation. 3. Performance: Provides strong load-bearing capability and improved service life; suitable for structural systems that benefit from enhanced mechanical and durability performance.
143		Eco Concrete (25% GGBS Replacement) Grade 40		**0.138**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for high-strength applications in multi-storey building frames, critical beams and columns, and load-bearing foundation systems. 2. Properties: GGBS-modified concrete achieving 40 MPa; contributes to sustainability by reducing clinker content and

										improving long-term strength development. 3. Performance: Delivers excellent structural performance with enhanced durability and reduced permeability; ideal for demanding structural environments.
144		Eco Concrete (25% GGBS Replacement) Grade 50		**0.153**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used for advanced high-strength components, including prestressed members, high-rise structural cores, and bridge elements subjected to significant loading. 2. Properties: High-performance concrete with 25% GGBS replacement; enhances durability, lowers embodied carbon, and creates a refined microstructure capable of achieving 50 MPa strength. 3. Performance: Provides superior load-bearing capacity, reduced cracking potential, and long-lasting durability; suitable for critical infrastructure requiring high mechanical performance and environmental efficiency.
145		Eco Concrete (50% GGBS Replacement) Grade 20		**0.068**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for non-structural and lightly loaded components such as ground slabs, lean concrete layers, pavements, and residential elements where early strength is not critical. 2. Properties: Concrete formulated with 50% GGBS replacing Portland cement; delivers substantial embodied carbon reduction, improved workability, and enhanced long-term durability while meeting 20 MPa strength.

										3. Performance: Exhibits slower early strength development but superior long-term resistance to chemical attack and chloride ingress; ideal for sustainability-oriented low-load applications.
146		Eco Concrete (50% GGBS Replacement) Grade 25		**0.072**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for non-structural and lightly loaded components such as ground slabs, lean concrete layers, pavements, and residential elements where early strength is not critical. 2. Properties: Concrete formulated with 50% Ground Granulated Blast Furnace Slag (GGBS) replacing Portland cement; delivers substantial embodied carbon reduction, improved workability, and enhanced long-term durability while meeting 20 MPa strength. 3. Performance: Exhibits slower early strength development but superior long-term resistance to chemical attack and chloride ingress; ideal for sustainability-oriented low-load applications.
147		Eco Concrete (50% GGBS Replacement) Grade 30		**0.089**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for medium-strength structural members such as slabs, beams, and walls in commercial and institutional buildings prioritising sustainability and durability. 2. Properties: Incorporates 50% GGBS to reduce cement consumption and promote a dense, refined microstructure; achieves 30 MPa with improved sulphate and chloride resistance. 3. Performance: Provides dependable structural integrity with excellent long-term durability; slower early

										curing may require consideration in fast-track construction.
148		Eco Concrete (50% GGBS Replacement) Grade 35		**0.095**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Designed for heavier structural loads such as foundation pads, transfer beams, and industrial structural floors where enhanced durability is beneficial. 2. Properties: High-performance concrete utilising 50% GGBS replacement; produces low heat of hydration and superior resistance to aggressive environments while delivering 35 MPa strength. 3. Performance: Offers strong mechanical capability with improved long-term behaviour; suitable for elements subjected to higher loads and durability demands.
149		Eco Concrete (50% GGBS Replacement) Grade 40		**0.102**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for high-strength structural components including high-rise building frameworks, major beams and columns, and heavy foundation systems. 2. Properties: Mix engineered with 50% GGBS to achieve 40 MPa strength; significantly lowers embodied carbon while enhancing resistance to chloride ingress, carbonation, and chemical attack. 3. Performance: Provides excellent long-term strength and durability; ideal for high-load environments where sustainability and performance objectives must be balanced.
150		Eco Concrete (50% GGBS Replaceme		**0.115**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used for advanced high-strength applications such as prestressed elements, high-rise structural cores, and critical

		nt) Grade 50								infrastructure components exposed to harsh environments. 2. Properties: High-strength eco-concrete with 50% GGBS replacement, resulting in lower permeability, lower carbon footprint, and superior durability characteristics; achieves 50 MPa compressive strength. 3. Performance: Delivers outstanding mechanical capacity, long-term durability, and reduced degradation risk; best suited for high-performance construction with stringent sustainability requirements.
151		Precast Concrete (Natural) Grade 20		**0.139**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for light-duty precast components such as small wall panels, pavement slabs, partition panels, and non-load-bearing architectural elements where low structural demand is sufficient. 2. Properties: Factory-produced concrete using natural aggregates with a characteristic strength of 20 MPa; benefits from controlled curing, consistent compaction, and improved surface finish. 3. Performance: Provides adequate strength for light precast applications; dimensional accuracy and durability are improved compared with cast-in-situ concrete of similar grade.
152		Precast Concrete (Natural) Grade 25		**0.147**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used for moderate-load precast elements such as floor planks, wall panels, small beams, and non-critical structural units requiring reliable quality control.

										2. Properties: Manufactured under controlled conditions using natural aggregates to achieve 25 MPa strength; ensures uniform quality, reduced voids, and enhanced material consistency. 3. Performance: Offers better mechanical performance and improved durability relative to site-cast mixes; suitable for repetitive modular precast production.
153		Precast Concrete (Natural) Grade 30		**0.168**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for primary precast building components such as wall panels, staircases, hollow-core slabs, and beams in residential and commercial projects. 2. Properties: High-quality precast mix achieving 30 MPa strength; benefits from precision batching, controlled curing, and lower moisture variability than cast-in-situ work. 3. Performance: Demonstrates reliable load-bearing capacity, good dimensional stability, and improved crack resistance; ideal for structural precast systems.
154		Precast Concrete (Natural) Grade 35		**0.179**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used for precast beams, columns, floor units, façade systems, and structural components where higher compressive strength is required. 2. Properties: Precast concrete produced under stringent factory standards to achieve 35 MPa; incorporates optimised aggregate gradation and controlled vibration for dense, uniform material. 3. Performance: Provides strong structural performance with reduced shrinkage and improved durability; ensures consistent mechanical

										behaviour for critical precast installations.
155		Precast Concrete (Natural) Grade 40		**0.191**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for high-strength precast structural elements including bridge components, large beams, columns, and prestressed units. 2. Properties: Manufactured using natural aggregates to achieve 40 MPa; benefits from high-precision curing regimes that improve strength development and material uniformity. 3. Performance: Offers excellent structural reliability, reduced permeability, and enhanced long-term durability; suitable for demanding precast structural applications.
156		Precast Concrete (Natural) Grade 50		**0.208**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used for advanced high-strength precast systems such as prestressed girders, heavy-duty wall panels, high-rise building components, and infrastructure elements requiring high performance. 2. Properties: High-strength precast concrete achieving 50 MPa through controlled production, optimised mix design, and superior curing methods; ensures minimal defects and enhanced structural capacity. 3. Performance: Delivers outstanding strength, durability, and dimensional precision; ideal for applications requiring high load-bearing capability and long service life.
157		Precast Eco Concrete (15% Fly Ash		**0.13**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for light-duty precast components such as partition panels, pavement slabs, small architectural units, and non-

		Replacement) Grade 20								load-bearing elements where lower strength is acceptable. 2. Properties: Precast concrete mix incorporating 15% fly ash as partial cement replacement; factory-controlled curing enhances consistency, reduces embodied carbon, and provides improved surface finish. 3. Performance: Offers adequate strength for low-load applications with improved durability and reduced permeability; suitable for sustainable precast production but not intended for high-load structural use.
158		Precast Eco Concrete (15% Fly Ash Replacement) Grade 25		**0.137**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used for residential and light commercial precast elements including wall panels, small beams, stairs, and slabs where moderate compressive strength is required. 2. Properties: Contains 15% fly ash replacement, improving workability and long-term durability; controlled precast manufacturing ensures consistent compaction and reliable 25 MPa strength. 3. Performance: Provides stable structural performance with reduced cracking potential and enhanced durability; ideal for environmentally efficient precast systems.
159		Precast Eco Concrete (15% Fly Ash Replacement) Grade 30		**0.158**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for standard structural precast units such as hollow-core slabs, wall panels, beams, and stair flights used in residential and commercial buildings. 2. Properties: Mix designed with 15% fly ash to reduce clinker content and improve microstructure; precast

										curing accelerates strength gain and ensures dimensional accuracy at 30 MPa grade. 3. Performance: Demonstrates strong and consistent mechanical behaviour with improved durability; suitable for repetitive structural precast fabrication.
160		Precast Eco Concrete (15% Fly Ash Replacement) Grade 35		**0.167**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used for heavier precast structural members such as deep beams, foundation units, façade panels, and industrial floor components requiring higher load capacity. 2. Properties: Incorporates 15% fly ash for reduced embodied carbon and enhanced chemical resistance; precast production ensures high compaction quality and uniform strength at 35 MPa. 3. Performance: Provides reliable performance with reduced permeability and improved long-term durability; well suited for structural applications demanding consistent strength.
161		Precast Eco Concrete (15% Fly Ash Replacement) Grade 40		**0.177**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for high-strength precast elements including major beams, columns, structural walls, and prestressed units in multi-storey and industrial buildings. 2. Properties: Engineered with 15% fly ash replacement to enhance sustainability while achieving 40 MPa strength; benefits from controlled curing that improves density and surface quality. 3. Performance: Offers excellent load-bearing capability, enhanced durability, and reduced cracking;

										appropriate for demanding precast structural systems.
162		Precast Eco Concrete (15% Fly Ash Replacement) Grade 50		**0.203**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used for advanced high-strength precast units such as prestressed girders, high-rise building components, and infrastructure modules requiring high structural performance. 2. Properties: High-strength precast mix incorporating 15% fly ash; optimised production conditions produce dense, durable concrete with consistent achievement of 50 MPa strength. 3. Performance: Delivers outstanding structural capacity, improved service life, and reduced carbon footprint; suitable for critical precast elements requiring superior performance and durability.
163		Precast Eco Concrete (30% Fly Ash Replacement) Grade 20		**0.117**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for light-duty precast components such as pavement slabs, partition panels, drain segments, and architectural elements where early strength demand is low. 2. Properties: Precast concrete incorporating 30% fly ash, offering significant embodied carbon reduction; controlled production improves compaction, dimensional accuracy, and curing uniformity. 3. Performance: Exhibits slower early strength gain but improved long-term durability; suitable for sustainable precast products not intended for heavy structural loading.
164		Precast Eco Concrete (30% Fly		**0.124**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used for moderate-load precast elements including wall

		Ash Replacement) Grade 25								panels, slabs, small beams, stairs, and modular building components. 2. Properties: Contains 30% fly ash replacement, which enhances workability and reduces permeability; precast curing ensures consistent 25 MPa strength and improved surface quality. 3. Performance: Provides stable structural performance with enhanced long-term strength development; offers durability benefits suitable for environmentally focused precast systems.
165		Precast Eco Concrete (30% Fly Ash Replacement) Grade 30		**0.144**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for standard precast structural members such as hollow-core slabs, beams, staircases, load-bearing wall panels, and composite floor units. 2. Properties: Mix with 30% fly ash reduces clinker content and produces a denser microstructure; factory-controlled curing ensures uniform achievement of 30 MPa compressive strength. 3. Performance: Ensures reliable structural capacity with better resistance to chemical attack and reduced cracking; ideal for medium-strength precast applications.
166		Precast Eco Concrete (30% Fly Ash Replacement) Grade 35		**0.151**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Designed for heavier precast structural elements such as deep beams, foundation blocks, façade panels, and industrial precast units where higher strength is required. 2. Properties: Incorporates 30% fly ash to enhance sustainability, decrease heat of hydration, and improve long-term durability; precast fabrication ensures high

										compaction quality and uniform curing. 3. Performance: Provides strong load-bearing capacity with excellent durability characteristics; suitable for structural systems requiring consistent performance and reduced carbon footprint.
167		Precast Eco Concrete (30% Fly Ash Replacement) Grade 40		**0.16**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for high-strength structural precast components including columns, main beams, prestressed units, structural walls, and bridge elements. 2. Properties: Engineered with 30% fly ash replacement to achieve 40 MPa; benefits from controlled factory curing that enhances strength development, density, and dimensional accuracy. 3. Performance: Delivers excellent mechanical strength, enhanced durability, and lower permeability; ideal for demanding structural precast applications.
168		Precast Eco Concrete (30% Fly Ash Replacement) Grade 50		**0.184**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used for advanced high-performance precast systems such as prestressed girders, high-rise elements, heavy-duty wall panels, and infrastructure components requiring high strength. 2. Properties: High-strength precast mix incorporating 30% fly ash; optimised production results in very dense concrete with consistent achievement of 50 MPa strength and reduced embodied carbon. 3. Performance: Offers outstanding structural capacity, improved durability, and superior long-term performance; suitable for critical

										precast elements requiring high strength and sustainability.
169		Precast Eco Concrete (25% GGBS Replacement) Grade 20		**0.113**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for light-duty precast elements such as pavement slabs, drain components, partition panels, and non-load-bearing architectural units requiring modest structural capacity. 2. Properties: Precast concrete incorporating 25% GGBS as partial cement replacement; factory-controlled curing ensures improved consistency, reduced porosity, and enhanced sustainability. 3. Performance: Provides adequate strength for low-load applications with improved chemical resistance and reduced heat of hydration; not intended for high-load structural components.
170		Precast Eco Concrete (25% GGBS Replacement) Grade 25		**0.119**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used for precast units such as wall panels, slabs, small beams, stairs, and modular elements requiring moderate strength and good dimensional accuracy. 2. Properties: Contains 25% GGBS replacement, improving durability and reducing embodied carbon; controlled precast production enhances compaction and achieves consistent 25 MPa strength. 3. Performance: Offers reliable structural behaviour with reduced permeability and better long-term strength; suitable for sustainable precast systems in residential and commercial applications.
171		Precast Eco Concrete (25%		**0.139**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for standard load-bearing precast components such as hollow-core slabs, beams,

		GGBS Replacement) Grade 30								wall panels, and stair flights used in residential and commercial projects. 2. Properties: Incorporates 25% GGBS to reduce cement consumption and improve microstructure; precast curing promotes uniform strength development and refined surface finish. 3. Performance: Provides dependable structural capacity with enhanced durability and reduced shrinkage; ideal for precast elements requiring consistent 30 MPa performance.
172		Precast Eco Concrete (25% GGBS Replacement) Grade 35		**0.148**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for standard load-bearing precast components such as hollow-core slabs, beams, wall panels, and stair flights used in residential and commercial projects. 2. Properties: Incorporates 25% GGBS to reduce cement consumption and improve microstructure; precast curing promotes uniform strength development and refined surface finish. 3. Performance: Provides dependable structural capacity with enhanced durability and reduced shrinkage; ideal for precast elements requiring consistent 30 MPa performance.
173		Precast Eco Concrete (25% GGBS Replacement) Grade 40		**0.157**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for high-strength precast structural components including major beams, columns, prestressed units, and high-rise wall systems. 2. Properties: Engineered with 25% GGBS replacement to achieve 40 MPa; precast curing optimises strength gain, reduces permeability,

										and enhances overall material stability. 3. Performance: Provides excellent load-bearing capacity, improved durability, and long-term performance; suitable for structurally demanding precast systems.
174		Precast Eco Concrete (25% GGBS Replacement) Grade 50		**0.182**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used for advanced high-strength precast systems such as prestressed girders, high-rise core elements, bridge components, and infrastructure units requiring superior structural performance. 2. Properties: High-strength precast concrete incorporating 25% GGBS; offers reduced embodied carbon, enhanced durability, and refined microstructure capable of achieving 50 MPa. 3. Performance: Delivers outstanding mechanical strength, reduced cracking risk, and long service life; ideal for critical structural precast applications with stringent performance requirements.
175		Precast Eco Concrete (50% GGBS Replacement) Grade 20		**0.086**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for light-duty precast components such as pavement slabs, boundary elements, drain units, and non-load-bearing panels where early strength is not critical. 2. Properties: Precast concrete with 50% GGBS replacement; significantly reduces embodied carbon, lowers heat of hydration, and improves long-term microstructure. 3. Performance: Develops strength more slowly but offers superior long-term durability, reduced

										permeability, and enhanced chemical resistance; ideal for sustainable but low-load precast applications.
176		Precast Eco Concrete (50% GGBS Replacement) Grade 25		**0.09**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used for moderate-load precast units including wall panels, small beams, slabs, and stair components in residential or commercial projects. 2. Properties: Mix containing 50% GGBS replacement, giving improved workability and reduced carbon footprint; factory-controlled curing ensures consistent achievement of 25 MPa strength. 3. Performance: Provides reliable structural performance with improved crack resistance and enhanced durability; suitable for slower-strength-gain precast systems.
177		Precast Eco Concrete (50% GGBS Replacement) Grade 30		**0.107**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for common structural precast members such as hollow-core slabs, beams, staircases, load-bearing wall panels, and composite floor units. 2. Properties: Incorporates 50% GGBS to enhance sustainability and durability; precast curing accelerates strength gain and produces uniform, high-quality 30 MPa concrete. 3. Performance: Offers dependable structural capacity with excellent long-term performance, though early-age strength requires controlled curing conditions.
178		Precast Eco Concrete (50% GGBS		**0.114**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Designed for heavier precast structural components such as industrial slabs, deep beams,

		Replacement) Grade 35								façade units, and foundation precast blocks. 2. Properties: Mix with 50% GGBS replacement promotes a dense microstructure, reduced permeability, and better resistance to aggressive environments; precast processes improve strength uniformity. 3. Performance: Provides strong load-bearing capability with enhanced durability benefits; suited for structural precast applications requiring consistent 35 MPa strength.
179		Precast Eco Concrete (50% GGBS Replacement) Grade 40		**0.12**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Suitable for high-strength precast structural elements such as major beams, columns, prestressed components, and load-bearing wall systems in high-rise and industrial buildings. 2. Properties: Engineered with 50% GGBS replacement to achieve 40 MPa; benefits from controlled precast curing, which improves density, minimises shrinkage, and enhances durability. 3. Performance: Delivers excellent structural capacity with superior resistance to chemical attack and chloride ingress; well suited for demanding structural environments.
180		Precast Eco Concrete (50% GGBS Replacement) Grade 50		**0.144**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used for advanced high-performance precast systems such as prestressed girders, bridge elements, high-rise core structures, and infrastructure units requiring high strength and durability. 2. Properties: High-strength precast concrete incorporating 50% GGBS; factory-controlled production

										3. Performance: Provides outstanding mechanical strength, long-term durability, and reduced carbon footprint; ideal for critical structural precast applications with stringent performance specifications.
181	Bricks	Common Bricks*		**0.21**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Brick used to build walls, pavements, and other elements in masonry construction; bricks are used as an alternative to stone for construction purposes. 2. Properties: Single brick size is 9", with a density of approximately 1,500–1,800 kg/m³. 3. Performance: Bricks are durable, and temperature changes do not generally cause significant expansion or shrinkage; they are well suited to large buildings, and their porous structure provides useful thermal mass through heat accumulation.
182		A Single Brick		**0.45**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
183		Sand-Lime Brick		**0.15**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	UK	
184		Light Clay Brick		**0.15**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	UK	
185		Concrete Masonry Unit		**0.0973**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Concrete masonry units (CMUs), also known as concrete blocks or bricks, are primarily used to construct masonry walls in residential, commercial, and industrial buildings, and are widely used in Malaysia due to their availability and adaptability. 2. Properties: CMUs are produced from sand, cement (CEM I 42.5), gravel, and water, with energy inputs from grid electricity and diesel for transport; the dataset is defined per 1 kg of CMU at the factory gate (cradle-to-gate, A1–A3), excluding transport to site, and

										the locally sourced units provide modular, uniform shapes for versatile construction. 3. Performance: Concrete masonry units provide durability, thermal mass, and dimensional consistency for structural and non-structural walls, combining strength, fire resistance, and sound insulation, while local production helps limit transport-related impacts and supports robust environmental assessment for Malaysian construction.
186	Reinforcement	Primary Reinforcement Bar and Rod		**2.51**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used as the main steel reinforcement in beams, slabs, columns, foundations, and all structural concrete elements. 2. Properties: Manufactured from virgin steel with controlled chemical composition, offering high tensile strength, ductility, and weldability. 3. Performance: Provides reliable structural capacity, resists bending and shear forces, and ensures long-term durability and safety in reinforced concrete structures.
187		Recycled Reinforcement Bar and Rod		**0.86204**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used as reinforcement in structural and non-structural concrete where sustainable material choices are prioritised. 2. Properties: Produced using recycled steel scrap via electric arc furnace (EAF) processes while maintaining required mechanical and chemical standards. 3. Performance: Delivers comparable strength and ductility to primary steel while reducing embodied carbon and supporting circular construction practices.

188		Hot Rolled Stainless Steel		**2.74**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD INTERNATIONAL	GLOBAL	SWEDEN	1. Application: Hot-rolled products are used widely in building and construction, particularly for load-bearing structures such as heavy transport components, bridges, floodgates, building fixings, traffic barriers, and façade elements. 2. Properties: Density 7,900 kg/m³; coefficient of thermal expansion 14×10^{-6} K^{-1}; thermal conductivity 19 W/(m·K); modulus of elasticity 205 GPa; melting point 1,450 °C; proof strength Rp0.2 200–530 MPa; tensile strength Rm 450–950 MPa; elongation A 18–45%; impact strength KV 40–90 (transverse). 3. Performance: Supplied as coil or plate, hot-rolled stainless steel offers excellent durability and strength, with a range of sheet and plate sizes available to meet varied design specifications.
189		Steel Deformed Bars for Concrete Reinforcement		**0.527**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD INTERNATIONAL	GLOBAL	SWEDEN	1. Application: Hot-rolled deformed bars are the most commonly used steel reinforcement for reinforced concrete structures; ribs formed during rolling improve bond with concrete. 2. Properties: Adherence and surface geometry fR or fP: for Ø ≤ 8 mm, fR or fP ≥ 0.035; for 8 < Ø ≤ 12 mm, fR or fP ≥ 0.040; for Ø > 12 mm, fR or fP ≥ 0.056; weldability Ceq < 0.52; typical yield stress Cv 400–600 MPa; elongation Agt ≥ 5%; recycled content ≥ 98%; successful in bend, rebend, strength, and oligocyclic strength tests. 3. Performance: Ribs on the bar surface provide strong mechanical

										interlock with concrete; typical yield strength is around 60,000 psi (≈ 415 MPa), enabling effective tension and compression reinforcement.
190		Cold Rolled Stainless Steel		**3.39**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD INTERNATIONAL	GLOBAL	SWEDEN	1. Application: Cold-rolled products are widely used in building envelopes, interior cladding and panelling, heating, cooling and ventilation components, and lifts and elevators. 2. Properties: Density 7,900 kg/m³; coefficient of thermal expansion $14 \times 10^{-6}\ K^{-1}$; thermal conductivity 19 W/(m·K); modulus of elasticity 205 GPa; melting point 1,450 °C; proof strength Rp0.2 200–530 MPa; tensile strength Rm 420–950 MPa; elongation A 18–45%. 3. Performance: Cold-rolled stainless steel provides excellent dimensional tolerances and high surface quality, with a wide range of sheet sizes available; service life depends on exposure and correct alloy selection.
191		Reinforcing Steel*		**1.99**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	Global	UK	1. Application: Reinforcing steel bars (rebar) are used as tension devices in concrete for buildings, bridges, roads, and other civil works. 2. Properties: Tensile strength (CA25) 300 N/mm²; weldability Ceq ≤ 0.55; yield strength (CA25) 250 N/mm²; yield strength (CA50/AP 500/AH 500) 500 N/mm². 3. Performance: Steel reinforcement, strong in both tension and compression, compensates for concrete's low tensile capacity, limits cracking under tension, and has a thermal expansion coefficient

										compatible with concrete to minimise temperature-induced stresses; surface patterning improves bond with concrete.
192		Steel CA60 Rebar, Welded Mesh and Truss		**1.62**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD INTERNATIONAL	GLOBAL	SWEDEN	1. Application: Steel CA60 rebar, welded mesh, and trusses are used to reinforce concrete slabs, floors, prefabricated slab joists, and transfer bars in buildings, bridges, roads, and other civil works. 2. Properties: Density 7,850 kg/m³. 3. Performance: These products provide additional mechanical resistance to concrete, with their service life governed by the service life of the host structure.
193		Stainless Steel Rebar*		**3.78**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD INTERNATIONAL	GLOBAL	SWEDEN	1. Application: Stainless steel rebar is used as reinforcement where non-magnetic behaviour or high durability is required, such as long-life structures and marine or chloride-exposed environments. 2. Properties: Density 7,900 kg/m³; modulus of elasticity 205,000 N/mm²; coefficient of thermal expansion $14 \times 10^{-6}\ K^{-1}$; thermal conductivity 19 W/(m·K); melting point 1,450 °C. 3. Performance: Stainless rebar offers high resistance to carbonation- and chloride-induced corrosion, enabling very long service lives (potentially up to centuries) when grade selection matches the exposure conditions.
194		Reinforcement Bar*		**0.684**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BRC (2019)	Global	UK	1. Application: Carbon-steel rebar is the most common reinforcement type, used as a tensioning device in reinforced concrete and masonry to keep concrete in compression.

										2. Properties: Typically used within concrete to provide enhanced tensile strength; easily bent and formed to suit detailing requirements. 3. Performance: Extremely versatile but prone to corrosion in high-humidity or frequently wet environments, making alternative types preferable in aggressive exposure; otherwise widely regarded as the default choice for conventional construction.
195		Cold-Rolled Reinforcing Steel and Electrowelded Mesh		**0.772**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD INTERNATIONAL	GLOBAL	SWEDEN	1. Application: Coils and cold-formed sections are used for structural and non-structural items such as columns, beams, joists, studs, floor decking, built-up sections, and other components; electro-welded wire mesh (WWM) reinforces slabs and retaining or shear walls. 2. Properties: Coil diameters 6–12 mm, weights 2,100–5,000 kg; electrowelded mesh diameters 4.5–12 mm, lengths 2.00–2.40 m, widths 3–6 m, weights 9.24–177.70 kg; typical yield stress 400–600 MPa; elongation Agt > 5%; high recycled content (≥ 97%). 3. Performance: Cold-formed steel systems offer low weight, high strength and stiffness, ease of prefabrication, rapid erection, accurate detailing, no shrinkage or creep at ambient temperatures, no formwork requirements, resistance to termites and rot, uniform quality, transport and handling economy, non-combustibility, recyclability, and the ability for panels and decks to provide enclosed service cells.

196		Structural Steel: Sections and Plates		**1.13**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD INTERNATIONAL	GLOBAL	SWEDEN	1. Application: Structural steels are intended for bolted, welded, or otherwise connected constructions of buildings, bridges, and other structures, including composite steel–concrete systems, for example single-storey industrial and storage halls, multi-storey offices, residential buildings, shops, car parks and high-rise developments, railway, road and pedestrian bridges, and other works such as power plants, stadiums, convention centres, airports and stations. 2. Properties: Density about 7,850 kg/m³; modulus of elasticity about 210,000 N/mm²; coefficient of thermal expansion approximately $12 \times 10^{-6}\ K^{-1}$; thermal conductivity at 20 °C roughly 48 W/(m·K); melting point up to around 1,536 °C depending on alloy composition; shear modulus about 81,000 N/mm². 3. Performance: The chemical composition of structural steel is extremely important and highly regulated. It is a fundamental factor that defines the mechanical properties of the steel.
197		Rebar		**0.739**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2024)	GLOBAL	VIETNAM	Steel rebar, or reinforcing bar, is a critical material in reinforced concrete structures, providing tensile strength for buildings, bridges, and infrastructure. VAS rebars are produced from high-quality materials to meet rigorous standards, including TCVN 1651-1:2008, TCVN 1651-2:2018, JIS G 3112:2010, ASTM A615/A615M-20, BS 4449:1997, and CS02:2012. Specifications such as dimensions and

										mechanical properties vary by grade and size. Rebars are bundled with double wire ties for safe handling, painted on both ends for lot identification, and labelled at both ends with detailed product and origin information.
198		Deformed Bar, Wire Rod, Deformed Bar in Coil		**1.01**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2024)	GLOBAL	VIETNAM	Deformed bars, wire rods, and deformed bars in coils are widely used in building structures, public construction works, and various industrial structures, providing essential reinforcement and strength for concrete applications.
199		Steel Bar		**2.61**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2024)	GLOBAL	VIETNAM	Steel bars manufactured by PT Putra Baja Deli, Indonesia, meet AS/NZS 4671:2019, MS 146:2014, SNI 2052:2017, and SS 560:2016 standards, with sizes ranging from 8 mm to 50 mm. They are produced from high-quality billet using advanced NCO machinery and a fully automated rolling line with horizontal and vertical configurations, in-line thermo-mechanical processing, high-speed delivery, automatic cooling, packing, tying, and weighing systems, and are designed with the latest automation/HMI technology and eco-friendly water treatment systems. These bars are commonly used in reinforced concrete structures, high-rise buildings, bridges, flyovers, industrial and commercial facilities, foundations, slabs, beams, retaining walls, columns, and pillars.
200		Steel Rebar		**0.0148**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Steel rebar is primarily applied as a reinforcing material in concrete structures, where it provides tensile strength and structural integrity to highways, bridges, and buildings. It is also

										used as a primary input for the wire rod process in steel manufacturing. 2. Properties: Rebar is produced by hot rolling carbon steel in mills, using either the blast furnace–basic oxygen furnace (BF–BOF) or the electric arc furnace (EAF) route. The process includes raw material extraction, coke making, sintering, smelting, steelmaking, and hot rolling, with inputs of iron ore, coal, and energy. The resulting product has ribbed surfaces for mechanical anchorage in concrete and offers high tensile strength, ductility, and weldability. The Malaysian LCI dataset ensures regional representativeness by modelling local energy mixes and import statistics. 3. Performance: Steel rebar performs effectively by significantly improving the load-bearing capacity and crack resistance of reinforced concrete, ensuring structural safety and durability in civil engineering works. Its versatility makes it essential for both infrastructure and building applications. From a sustainability perspective, the Malaysian LCI confirms its cradle-to-gate inventory profile, quantifying emissions, energy use, and resource flows, though without credits for end-of-life recycling, making it suitable for integration into life cycle assessments.
201	Steel	Steel, Tin-Free Electrolytic Chrome		**2.87**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Food cans, closures, industrial packaging, small drums, appliance casings.

		Coated Steel Sheet–Tin-Free (ECCS)								2. Properties: Electro-chromium-plated cold-rolled sheet; typical thickness 0.13–0.49 mm, width 600–1,100 mm; system expansion applied (slag/co-products); end-of-life recovery 85%. 3. Performance: Corrosion-resistant substrate for organic coatings with good formability; Module D: −1.40 kg CO_2e/kg (benefit); indicative net (A1–A3 + D): 1.47 kg CO_2e/kg.
202		Steel, Electrogalvanized Steel		**2.71**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Building elements (walls, roofing), automotive body/underbody parts, lighting fixtures, profiled sheets, domestic appliances. 2. Properties: Zinc or Zn-Ni electro-plated cold-rolled coil; thickness 0.3–3 mm, width 600–2,100 mm; excellent formability, paintability, and weldability; system expansion; end-of-life recovery 85%. 3. Performance: Smooth, paint-ready surface with corrosion protection; Module D: −1.34 kg CO_2e/kg; net: 1.37 kg CO_2e/kg.
203		Steel, Welded Pipe		**2.51**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Conveyance of oil, gas, water, and chemicals; structural pipe. 2. Properties: Flat plate/coil formed and welded into tube; available in heavy-wall; system expansion; end-of-life recovery 85%. 3. Performance: Reliable pressure containment when correctly specified; Module D: −1.40 kg CO_2e/kg; net: 1.11 kg CO_2e/kg.
204		Steel, Organic		**2.88**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Roofing, wall/ceiling cladding, HVAC, office furniture,

		Coated Sheet								domestic appliances, IT casings, packaging. 2. Properties: Painted/laminated layer on galvanised/electro-galvanised/cold-rolled or tin-free substrate; thickness 0.15–1.5 mm, width 600–1,300 mm; system expansion; end-of-life recovery 85%. 3. Performance: Durable pre-finished surface allowing rapid installation; Module D: −1.27 kg CO_2e/kg; net: 1.61 kg CO_2e/kg.
205		Steel, Tinplate		**2.7**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Food cans and industrial packaging. 2. Properties: Electro-tin-plated cold-rolled coil; thickness 0.13–0.49 mm, width 600–1,100 mm; system expansion; end-of-life recovery 85%. 3. Performance: Excellent formability, solderability, and printability; Module D: −1.28 kg CO_2e/kg; net: 1.42 kg CO_2e/kg.
206		Steel, Finished Cold-Rolled Coil		**2.57**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Appliances, automotive, electrical components (stators/rotors), roofing, profiled sheets, wall elements. 2. Properties: Annealed and skin-passed cold-rolled coil; thickness 0.3–3 mm, width 600–2,100 mm; high surface quality; system expansion; end-of-life recovery 85%. 3. Performance: Good formability, dimensional accuracy, and paintability; Module D: −1.22 kg CO_2e/kg; net: 1.35 kg CO_2e/kg.
207		Steel, Hot-Dip		**2.62**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Building envelopes, automotive body parts, lighting fixtures, drums, profiled sheets.

		Galvanized Steel								2. Properties: Molten-zinc-coated cold-rolled coil; thickness 0.3–3 mm, width 600–2,100 mm; excellent corrosion resistance; system expansion; end-of-life recovery 85%. 3. Performance: Robust outdoor durability; Module D: −1.21 kg CO_2e/kg; net: 1.41 kg CO_2e/kg.
208		Steel, Plate		**2.38**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Structural members, shipbuilding, pipes, pressure vessels, boilers, offshore and heavy steelwork. 2. Properties: Hot-rolled flat steel; typical thickness 2–20 mm, maximum width 1,860 mm; system expansion; end-of-life recovery 85%. 3. Performance: High-strength sections with good weldability; Module D: −1.22 kg CO_2e/kg; net: 1.16 kg CO_2e/kg.
209		Steel, Cold Rolled Coil		**2.47**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Feedstock for finished cold-rolled and coated coils; general manufacturing. 2. Properties: Pickled hot-rolled coil, cold-reduced; thickness 0.15–3 mm, width 600–2,100 mm; requires further finishing; system expansion; end-of-life recovery 85%. 3. Performance: Tight tolerances and a smooth surface for coating and forming; Module D: −1.20 kg CO_2e/kg; net: 1.27 kg CO_2e/kg.
210		Steel, Pickled Hot-Rolled Coil		**2.38**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Transport, construction, shipbuilding, gas containers, pressure vessels, pipelines. 2. Properties: Hot-rolled coil with mill scale removed by pickling; thickness 2–7 mm, width 600–2,100

										mm; system expansion; end-of-life recovery 85%. 3. Performance: Cleaner surface for downstream forming, welding, and coating; Module D: −1.17 kg CO_2e/kg; net: 1.21 kg CO_2e/kg.
211		Steel, Wire Rod		**2.16**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Wire drawing, strands, mesh, fasteners, springs; supplied in coils. 2. Properties: Rolled rod with round or rectangular sections; suitable for cold drawing; system expansion; end-of-life recovery 85%. 3. Performance: High ductility for deformation processes; Module D: −1.00 kg CO_2e/kg; net: 1.16 kg CO_2e/kg.
212		Steel, Hot Rolled Coil		**2.26**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Transport, construction, shipbuilding, containers, pressure vessels, pipelines; chequer plate for stairs, floors, and tailboards. 2. Properties: Thickness 2–7 mm, width 600–2,100 mm; system expansion; end-of-life recovery 85%. 3. Performance: Versatile feedstock with good toughness and weldability; Module D: −1.19 kg CO_2e/kg; net: 1.07 kg CO_2e/kg.
213		Steel, Rebar		**1.72**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Reinforced concrete in buildings, bridges, pavements; feedstock for wire rod. 2. Properties: Hot-rolled ribbed bars; grades to project standard; system expansion; end-of-life recovery 85%. 3. Performance: High bond and ductility for structural and seismic design; Module D: −0.56 kg CO_2e/kg; net: 1.16 kg CO_2e/kg.

214		Steel, Section		**1.61**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: I-, H-, and wide-flange beams, sheet piling; buildings, bridges, industrial structures, highway supports, riverbank works. 2. Properties: Hot-rolled sections for direct use; system expansion; end-of-life recovery 85%. 3. Performance: High stiffness-to-weight ratio, rapid erection, and reuse potential; Module D: −0.20 kg CO_2e/kg; net: 1.41 kg CO_2e/kg.
215		Steel, Engineering Steel		**1.64**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Tools, dies, engine and transmission components, shafts, and gears. 2. Properties: Hot-rolled engineering grades for machining and heat treatment; system expansion; end-of-life recovery 85%. 3. Performance: High strength, toughness, and hardenability; Module D: +0.10 kg CO_2e/kg (burden); net: 1.74 kg CO_2e/kg.
216		Steel, Global Seamless Tube		**1.9**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: High-pressure pipelines, boilers, heat exchangers, and mechanical or structural tubing. 2. Properties: Seamless tubes (no weld seam); dimensions to standard; system expansion; end-of-life recovery 85%. 3. Performance: Excellent pressure integrity and fatigue resistance; Module D: −0.38 kg CO_2e/kg; net: 1.52 kg CO_2e/kg.
217		Prestressed Concrete Steel Wire Strand (PC Strand)		**2.21**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2022)	GLOBAL	THAILAND	PC strand is a high-strength steel product used in prestressed concrete elements such as piles, bridges, railway sleepers, hollow-core slabs, and other components that require high tensile capacity. It is made from seven cold-drawn high-carbon wire rods, with

										six outer wires surrounding a slightly larger central wire, spun together in the same direction with equal lay length and subjected to thermo-mechanical treatment (annealing) to improve performance. It is supplied in master coils of about 20–27 tonnes that are rewound into smaller coils for distribution, and is produced in several common types whose dimensional and mechanical variations have little effect on overall environmental performance, so results are often reported as a grouped product.
218		Prestressed Concrete Steel Wire (PC Wire)		**2.18**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2022)	GLOBAL	THAILAND	Prestressed concrete steel wire (PC wire) is a high-strength alloy steel wire made from cold-drawn high-carbon wire rod and further treated by thermo-mechanical processes, annealing, and tempering to provide excellent tensile performance and durability. It is used in prestressed concrete applications including piles, pipes, electric poles, railway sleepers, precast panels, hollow-core slabs, and ground or rock anchors, and is typically supplied in one-tonne units. Its environmental performance is reported to EN 15804:2012+A2:2019 on a cradle-to-gate with options basis, including transport, end-of-life stages, and module D, enabling its use in life cycle assessment.
219		Stainless Steel Cold Rolled		**3.798**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Stainless steel cold-rolled coil grade 304 is widely applied across multiple industrial sectors including automotive, construction, packaging, chemical plants and equipment, food and beverage preparation and storage,

										as well as household kitchen appliances. 2. Properties: This austenitic stainless steel consists of approximately 18% chromium and 10% nickel, produced via an electric arc furnace (EAF) route followed by argon oxygen decarburisation, ladle refining, continuous casting, hot rolling, annealing, pickling, and cold rolling with skin-passing. It offers excellent corrosion resistance, high ductility, good weldability, and a smooth surface finish due to the annealed and pickled treatment; the dataset represents cradle-to-gate production under Malaysian energy supply conditions. 3. Performance: Grade 304 stainless steel cold-rolled coil provides strong resistance to oxidation and corrosion in a wide range of environments while maintaining formability and strength for structural and aesthetic applications; its durability and recyclability support sustainability and allow integration into life cycle assessments for construction, manufacturing, and consumer products.
220		Stainless Steel Hot Rolled		**1.937**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Stainless steel hot-rolled coil grade 304 is extensively applied in automotive, construction, packaging, chemical plants and equipment, and food and beverage preparation, as well as kitchen utensils and household appliances. 2. Properties: This austenitic stainless steel contains about 18% chromium and 10% nickel, produced through

										the electric arc furnace route followed by argon oxygen decarburisation, ladle refining, continuous casting, hot rolling, annealing, and pickling; the process yields a robust, corrosion-resistant alloy with excellent weldability, formability, and surface finish, represented by a Malaysian LCI dataset. 3. Performance: Grade 304 stainless steel hot-rolled coil provides high resistance to oxidation and corrosion across varied environments while maintaining mechanical strength and ductility; its durability, recyclability, and versatility support both industrial and consumer uses and enable cradle-to-gate life cycle assessment under Malaysian conditions.
221		Steel Cold Rolled		**2.079**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Steel cold-rolled coil is used as a semi-finished rolling product for further processing into steel construction parts, automotive components, appliances, packaging, and industrial equipment. 2. Properties: It is produced via the blast furnace–basic oxygen furnace (BF–BOF) route from iron ore, pellets, and hard coal, through sintering, coking, blast furnace smelting, oxygen steelmaking, continuous casting, hot rolling, and cold rolling; this yields carbon steel with improved surface finish, dimensional accuracy, and mechanical strength, in a dataset regionalised for Malaysia using local energy conditions and import mixes.

										3. Performance: Steel cold-rolled coil offers high strength, durability, and excellent formability, with surface finish and dimensional accuracy that enhance reliability in downstream industries, and its Malaysian LCI profile supports quantified cradle-to-gate emissions and energy use in regional life cycle assessments.
222		Steel Hot Rolled		**2.071**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Steel hot-rolled coil is used widely in transport, construction, shipbuilding, gas containers, pressure vessels, and energy pipelines; anti-slip hot-rolled sheets (diamond or teardrop patterns) are applied to stairs, industrial floors, and vehicle tailboards. 2. Properties: It is produced via the blast furnace–basic oxygen furnace route from iron ore, coal, and other raw materials, through coke making, sintering, blast furnace smelting, basic oxygen steelmaking, and hot strip rolling; the resulting carbon steel coil is supplied as coil or sheet for further processing, with a dataset regionalised for Malaysia that reflects local energy and import mixes. 3. Performance: Steel hot-rolled coil delivers strong mechanical performance with durability, ductility, and reliability across a wide range of structural and industrial applications; its versatility and formability suit both heavy-duty and everyday products, and the Malaysian LCI supports cradle-to-gate assessment of resource use and emissions.

223		Primary Steel Section		**2.84**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used in main load-bearing structures such as beams, columns, trusses, frames, and heavy civil engineering works. 2. Properties: Manufactured from virgin iron ore via blast furnace/basic oxygen furnace processes, providing high strength, stiffness, and reliable structural performance. 3. Performance: Offers excellent load capacity, stability, and durability, and is widely used in buildings and infrastructure that require consistent mechanical properties and robust structural integrity.
224		Recycled Steel Section		**0.82**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	1. Application: Used in structural steelwork for buildings, bridges, frames, and general construction where sustainability and reduced embodied carbon are prioritised. 2. Properties: Produced from recycled scrap steel using electric arc furnace processes, meeting required mechanical standards while significantly reducing carbon emissions. 3. Performance: Provides comparable strength and stiffness to primary steel, supports circular-economy objectives, and delivers environmental benefits without compromising structural performance.
225	Binder	Mortar (1:3 cement:sand mix)		**0.183**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Mortar 1:3, suitable for masonry construction and all work in moist situations. 2. Properties: The compressive strength tested with prisms is 0.577 MPa (Shah et al., 2019).

										3. Performance: Cement mortar is suitable as a binding material in all types of construction work due to its strong and durable properties.
226		Mortar (1:4)		**0.149**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Mortar 1:4, suitable for ordinary masonry work, external plaster, and ceiling plaster. 2. Properties: The compressive strength tested with prisms is about 0.516 MPa (Shah et al., 2019). 3. Performance: Cement mortar is suitable as a binding material in all types of construction work due to its strong and durable properties.
227		Mortar (1:5)		**0.127**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Mortar 1:5, suitable for internal plaster. 2. Properties: The compressive strength tested with prisms is lower than 0.506 MPa. 3. Performance: Cement mortar is suitable as a binding material in all types of construction work due to its strong and durable properties.
228		Mortar (1:6)		**0.110**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Mortar 1:6, suitable for ordinary masonry work with brick, architectural work, and internal plaster. 2. Properties: The compressive strength tested with prisms is 0.501 MPa (Shah et al., 2019). 3. Performance: Cement mortar is suitable as a binding material in all types of construction work due to its strong and durable properties.
229		Mortar (1:½:4½ Cement:Lime:Sand mix)		**0.157**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Mortar 1:½:4½, indicating the volume of Portland cement, followed by the volume of hydrated lime, and finally the volume of sand. 2. Properties: The bulk density of hydrated lime is about 640 kg/m^3.

										3. Performance: Lime mortar improves workability and water retention, promotes economy in use, improves bond quality to substrates, and enhances general durability.
230		Mortar (1:1:6 Cement:Lime:Sand mix)		**0.142**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Mortar 1:1:6, used for higher-strength and durable work. 2. Properties: The bulk density of hydrated lime is about 640 kg/m³. 3. Performance: Lime mortar improves workability and water retention, promotes economy in use, improves bond quality to substrates, and enhances general durability.
231		Mortar (1:2:9 Cement:Lime:Sand mix)		**0.127**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Mortar 1:2:9, used for restoration and repair of old buildings. 2. Properties: The bulk density of hydrated lime is about 640 kg/m³. 3. Performance: Lime mortar improves workability and water retention, promotes economy in use, improves bond quality to substrates, and enhances general durability.
232		Acrylic Binder, 34% in H_2O, at Plant		**1.760**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Acrylic binder is used to optimise the coating characteristics of a metal surface for protecting the metal against corrosion, and can be applied as a glue, paint, or spray. 2. Properties: Acrylic binders are thick, liquid, and milky white when wet, and colourless and transparent when dry; the density is about 1.06 g/cm³ (wet) and 1.14 g/cm³ (dry). 3. Performance: Acrylic binders provide excellent adhesion to alkyds, good stain and grease resistance, and good exterior durability.

233		Adhesive Mortar*		**1.350**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Adhesive mortar is used for pasting interior and exterior wall tiles in buildings and for bonding substrates such as EPS polystyrene insulation board, XPS extruded board, concrete, masonry brick blocks, and aerated blocks in external wall insulation systems. 2. Properties: Adhesive mortar is a polymer-reinforced, cement-based, ready-mixed dry adhesive mortar. 3. Performance: Adhesive mortar has excellent flexibility and adhesion, as well as good sag resistance, water retention, and water resistance, enhancing bond and tensile strength and helping to prevent hollowing.
234		Cement Mortar*		**0.240**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Cement mortar is used for masonry work, plastering, repairing damaged concrete, patching or filling, rendering, floor levelling, and precast product manufacture. 2. Properties: The density of cement mortar is around 2,162 kg/m^3. 3. Performance: Cement mortar is workable and durable and can maintain its appearance for a long period.
235		Light Mortar		**0.539**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Light mortar is used for pointing and plastering to protect joints and the surfaces of brick and stone masonry. 2. Properties: The bulk density of light mortar is less than 15 kN/m^3. 3. Performance: Light mortar has a high specific strength (strength-to-density ratio) and provides good thermal insulation.

236		Calcium Aluminate Binders– Medium Alumina Content: TERNAL® Calcoat– TERNAL® Xtrem		**806.000**	kg CO_2 eq./kg	Cradle to gate (Extraction to Manufacturing)	EPD International (2022)	GLOBAL	FRANCE	Calcium aluminates are obtained by reacting lime (from limestone) with alumina-bearing minerals such as bauxite at high temperature. The cooled product is a hard mineral, calcium aluminate clinker, which when ground to a fine powder becomes a calcium aluminate binder that forms a paste when mixed with water. This paste hardens and forms a rigid solid in less than 24 hours, and calcium aluminates are used both as high-performance binders and as mineral reactants in various industries.
237		Adhesive Mortar		**0.700**	kg CO_2 eq./kg	Cradle to gate (Extraction to Manufacturing)	EPD International (2025)	GLOBAL	GREECE	A comprehensive selection of high-performance tile adhesives engineered for professional applications, ensuring robust adhesion and long-term durability. These adhesives are compatible with a wide variety of substrates and can be applied in both horizontal and vertical orientations. They are particularly effective in environments subjected to high vibration and persistent humidity.
238		Thermabond ULTRA: fine-grained, fibre-reinforced, polymer-modified, cementitious adhesive and base coat mortar for thermal insulation boards		**2.990**	kg CO_2 eq./kg	Cradle to gate (Extraction to Manufacturing)	EPD International (2024)	GLOBAL	GREECE	This is a product-specific EPD (International) for a fine-grained, fibre-reinforced, polymer-modified, cementitious adhesive and base-coat mortar for thermal insulation boards: THERMABOND ULTRA FINE-GRAINED, FIBRE-REINFORCED, POLYMER-MODIFIED, CEMENTITIOUS ADHESIVE AND BASE-COAT MORTAR FOR THERMAL INSULATION BOARDS

239		Thermabond FIX: polymer-modified, cementitious adhesive mortar for EPS thermal insulation boards		**2.000**	kg CO_2 eq./kg	Cradle to gate (Extraction to Manufacturing)	EPD International (2024)	GLOBAL	GREECE	Polymer-modified, cementitious adhesive mortar for EPS thermal insulation boards:
240		Chemical Binder (Aluminium Chloride)		**1.176**	kg CO_2 eq./kg	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Aluminium chloride is mainly used as an industrial catalyst in chemical synthesis, particularly in Friedel–Crafts reactions, and is also used in the production of aluminium, petrochemicals, and pharmaceuticals. 2. Properties: It is an inorganic compound with the formula $AlCl_3$, produced via chlorination of aluminium or alumina in fluidised-bed or ceramic-tube reactors at high temperatures (500–850 °C). It has a density of about 2.44 g/cm³ and a molar mass of about 133.34 g/mol, occurring as a hygroscopic crystalline solid that readily sublimes. 3. Performance: In industrial processes, aluminium chloride demonstrates high catalytic efficiency, thermal stability under controlled conditions, and versatility across a wide range of organic and inorganic reactions. However, it is highly corrosive and moisture-sensitive, requiring careful handling and storage to maintain performance.

241		Lime		**7.580**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Lime (CaO) is mainly used in the construction industry for making cement and mortar. It also serves as a binding and stabilising agent in soil treatment, steel production, and various chemical processes. 2. Properties: The dataset represents quicklime with a density of about 3.34 g/cm³ and a molar mass of 56.08 g/mol. It is produced by calcining limestone ($CaCO_3$) at temperatures above 900 °C, a process that releases CO_2 as a chemically determined emission (about 7.58 kg CO_2 per tonne of lime). The production mix reflects Malaysian-specific conditions, with energy supply based on approximately 95% coal and 5% palm kernel shell (PKS) as fuel. 3. Performance: Lime provides high performance as a binder due to its strong reactivity, making it essential for cement, mortar, and soil stabilisation. It contributes to durability and strength in construction applications while also being versatile for industrial and chemical uses. From an environmental standpoint, lime production is CO_2-intensive because of both process and fuel emissions, but the dataset provides cradle-to-gate inventory data under Malaysian energy supply conditions, making it suitable for life-cycle assessment studies.
242		Webertherm A1 Plus Adhesive		**0.260**	kg CO_2 eq./kg	Cradle to gate (Extraction to Manufacturing)	EPD International (2023)	GLOBAL	TURKEY	Cement-based, polymer-modified adhesive mortar for thermal insulation systems.

		Mortar for Thermal Insulation Systems								Advantages: • In conformity with ETAG 004* • Has high bonding strength • Resistant to thermal shock Range of application: Used for bonding XPS, EPS, and mineral wool thermal insulation panels on all types of buildings.
243	Plaster	General (Gypsum)*		**0.13**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Interior wall and ceiling finishing, base/skim coats, and as an adhesive or bedding layer in systems where a gypsum-based plaster is acceptable. Commonly used to achieve smooth, paint-ready surfaces and to level minor substrate irregularities. 2. Properties: Factory-blended gypsum binder with fine mineral fillers and workability modifiers, mixed with clean water to form a creamy, trowellable paste. It sets by recrystallisation of calcium sulphate dihydrate, providing good workability, low shrinkage, and a smooth finish. 3. Performance: Provides a fast, predictable set with low cracking when applied within the recommended thickness and protected from rapid drying. Maintain dry storage, control substrate suction (priming where needed), and reinforce joints and corners to minimise hairline cracking.
244		Plasterboard*		**0.39**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Plasterboard is a panel made of calcium sulphate dihydrate (gypsum), usually pressed between

										a facer and a backer, and is used to form interior walls and ceilings. 2. Properties: Plasterboard helps builders and designers meet building regulations for fire protection, acoustic insulation, and thermal efficiency, and can also help control condensation and potential damage in areas of high humidity.
245		Plaster Mixing		**0.0821**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Cement plaster is made by mixing cement and sand in the required proportions and is applied to both interior and exterior walls to give them a smooth surface. 2. Properties: Cement plaster offers greater moisture resistance than gypsum plaster.
246		Plastering Mortar MU-387 (Thinbed Mortar MU-387 AireThinbed)		**0.131**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	EPD International (Indonesia)	GLOBAL, ASIA	INDONESIA	1. Application: Instant mortar for lightweight brick (AAC) installation work at about 3 mm thickness. 2. Properties: Made from selected sand, cement, filler, active lite particles, and additives mixed homogeneously, providing up to about 40% wider spread and easier application.
247		Cement Cast Plaster Floor		**0.199**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Thin cement-based topping used as a hard-wearing floor finish in residential and commercial interiors. 2. Properties: Site-cast cement mortar laid over a prepared substrate, typically including cement, fine sand, water, and optional polymer modifiers for adhesion and crack control. 3. Performance: Durable and easy to maintain once sealed, but sensitive to substrate movement and curing conditions; control joints, moisture,

										and curing to minimise shrinkage cracking and dusting.
248		Clay Plaster		**0.045707**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Interior wall and ceiling finish where low embodied carbon and natural aesthetics are desired. 2. Properties: Mineral mix of clay, sand, and plant fibres; vapour-open and hygroscopic, enabling moisture buffering; applied in one or more coats by trowel or spray. 3. Performance: Provides excellent indoor humidity regulation and repairability; avoid prolonged liquid-water exposure and detail or seal appropriately in splash zones.
249		Gypsum Plaster Board		**0.432**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: General-purpose lining for partitions, ceilings, and wall upgrades in dry interior spaces. 2. Properties: Paper-faced gypsum core board, typically available in multiple thicknesses and edge profiles, compatible with tape-and-joint or skim finishes. 3. Performance: Offers good fire and acoustic performance when detailed correctly; keep dry in storage and in use, and specify moisture- or mould-resistant variants for humid areas.
250		Plaster		**0.201**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Base or finish coat on masonry or board substrates for smooth, paint-ready surfaces. 2. Properties: Binder may be cement–lime or gypsum depending on region and project; aggregates are fine sands, with workability adjusted by additives. 3. Performance: Substrate preparation and controlled curing govern finish quality; manage setting time,

										thickness, and joint reinforcement to avoid cracking.
251		Plasterboard, 10 mm		**4.93**	kg CO2 eq./m2	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: 10 mm gypsum board for ceilings and wall linings where weight saving is helpful. 2. Properties: Light-gauge board paired with metal or timber framing; accepts tape-and-joint or skim coats and is supplied finish-ready. 3. Performance: Check deflection limits and fastener spacing due to reduced thickness; use moisture-resistant grades in bathrooms and kitchens.
252		Plasterboard, 10 mm		**4.71**	kg CO2 eq./m2	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Interior partitions and ceilings in dry conditions. 2. Properties: 10 mm paper-faced gypsum board compatible with standard joint compounds and skim coats. 3. Performance: Protect from water during transport and installation; use appropriate edge trims and jointing to limit cracking.
253		Skim Coat Mortar MU-257 AireSkimWall		**0.249**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL, ASIA	INDONESIA	1. Application: Thin finishing coat on plastered walls, interior or exterior, to achieve a smooth, paint-ready surface. 2. Properties: Factory-blended powder using recycled materials, cement, fillers, and additives; light grey and designed for easy trowel application and a fine finish. 3. Performance: Provides high coverage and a uniform finish with minimal sanding; check substrate flatness and priming, and protect from rapid drying and rain during curing.

254		Plaster		**1.67**	kg CO2 eq./ft2	Cradle to gate (Extraction to Manufacturing)	Engineering and Innovative Materials III (2014)	LOCAL, ASIA	MALAYSIA	1. Application: Traditional plaster finish for walls and ceilings, measured per square foot of coverage. 2. Properties: Typically a cement–lime or gypsum-based system applied in one to several coats over lath, masonry, or board. 3. Performance: Provides dense, durable surfaces with good acoustic mass; appropriate curing and joint reinforcement are key to minimising crazing and cracking.
255		Plastering Mortar MU-307		**0.0876**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL, ASIA	INDONESIA	1. Application: Bedding and plastering mortar for red-brick and AAC walls, typically 10–15 mm thick on interior and exterior surfaces. 2. Properties: Lightweight premix with recycled content, selected sand, cement, fillers, and lite particles, formulated for high coverage and easy application. 3. Performance: Offers up to roughly 50% more coverage than conventional mixes, supports faster application with reduced dead load, and requires proper curing to achieve bond and strength.
256		Plasterboard		**1.348**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	Wan Omar et al (2014)	LOCAL, ASIA	MALAYSIA	1. Application: Gypsum board for interior partitions and ceilings, reported per kilogram of product. 2. Properties: Paper-faced gypsum core with performance variants (fire-rated, moisture-resistant, or acoustic), compatible with metal framing and joint systems. 3. Performance: Requires dry storage, careful handling, and edge protection; select board type to suit fire, moisture, and acoustic requirements, and detail

										airtightness and jointing to meet performance targets.
257		Plaster (Gypsum Stone)		**9.06×10^{-5}**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	LOCAL, ASIA	MALAYSIA	1. Application: Gypsum stone is primarily used as a standard mineral product in the building industry, serving as a bonding agent in plaster and as a moulding material for construction and decorative purposes. 2. Properties: It consists of calcium sulphate dihydrate ($CaSO_4 \cdot 2H_2O$) with a density of about 2.31–2.33 g/cm^3, and is obtained from underground and open-pit mining followed by crushing, grinding, drying, and purification; extraction typically uses diesel-driven drilling equipment and ammonium nitrate/ANFO explosives. 3. Performance: Gypsum performs well as a binder because it sets and hardens when mixed with water, making it essential for plaster, wallboards, and mouldings; it is durable, fire-resistant, and recyclable, and the dataset you describe provides cradle-to-gate environmental information under Malaysian energy conditions for life-cycle assessment work.
258		Tiger Mortar General Plastering		**0.137**	kg CO_2 eq./kg	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2024)	GLOBAL, ASIA	THAILAND	Mortar for plastering is used for general wall plastering work, including plastering of ordinary bricks and blocks that require a smooth, uniform surface. It contains additives to increase water retention to reduce cracking and includes foaming agents to make the plaster smooth.
259		Tiger Mortar Lightweight		**0.148**	kg CO_2 eq./kg	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2024)	GLOBAL, ASIA	THAILAND	Mortar for plastering is specifically used for lightweight concrete block plastering work. It contains additives to increase water retention, making the mortar

		Block Plastering								cohesive and smooth and allowing it to dry at an appropriate rate.
260		SCG Mortar General Plastering 50 kg		**0.137**	kg CO_2 eq./kg	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2024)	GLOBAL, ASIA	THAILAND	Mortar for plastering is used for general wall plastering work, including plastering of ordinary bricks and blocks that require a smooth, uniform surface. It contains additives to increase water retention to reduce cracking and includes foaming agents to make the plaster smooth.
261		K Plastering Cement Bag 50 kg– Mixed Cement		**0.420**	kg CO_2 eq./kg	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL, ASIA	CAMBODIA	K Plastering Cement Bag 50 kg is a mixed cement suitable for masonry and plastering. K Plastering Cement Bag 50 kg includes special additives to provide a delicate texture and smooth, uninterrupted plastering for strong walls with a reduced chance of cracking.
262		Tiger Special Plastering Cement		**0.528**	kg CO_2 eq./kg	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2024)	GLOBAL, ASIA	THAILAND	Tiger Special Plastering Cement is a mixed cement with a special formula suitable for plastering bricks and concrete blocks. Its fine texture compared with regular cement results in smooth, attractive plastering work, and special plastering agents make plastering smooth, easy, and time-saving.
263		General Plaster (Gypsum)		**0.13**	kg CO_2 eq./kg	Cradle to gate (Extraction to Manufacturing)	BCA (2022)	GLOBAL	SINGAPORE	Gypsum plaster is a construction material made from calcium sulphate hemihydrate that hardens when mixed with water. It provides a smooth, quick-setting, fire-resistant finish for interior walls and ceilings. Lightweight, crack-resistant, and easy to apply, gypsum plaster offers excellent workability and a clean, durable surface for modern construction.
264		Plasterboard		**0.39**	kg CO_2 eq./kg	Cradle to gate (Extraction to Manufacturing)	BCA (2022)	GLOBAL	SINGAPORE	Plasterboard is a lightweight construction material made from a gypsum core sandwiched between durable paper liners. It provides smooth, fire-resistant, easy-to-install surfaces for interior walls and ceilings. Cost-effective

										and versatile, plasterboard supports rapid construction, good acoustic performance, and clean finishes in residential, commercial, and industrial buildings.
265	Sealants and adhesives	Epoxide Resin		**5.700**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Epoxy resins are used in the manufacture of adhesives, plastics, paints, coatings, primers, sealers, and flooring. 2. Properties: Epoxy resin has a modulus of about 3.42 GPa and a density of about 1,100 kg/m^3. 3. Performance: Epoxy resins provide strong bonds to a variety of substrates, for example concrete and wood.
266		Melamine Resin		**4.190**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Melamine resins are used for industrial coatings in decorative laminates, from countertops to laminate flooring. 2. Properties: Melamine resin has a density of about 1.5 g/cm^3. 3. Performance: Melamine resins are odourless and have good heat resistance.
267		Phenol Formaldehyde		**2.980**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Phenol–formaldehyde resin is used as a wood adhesive for plywood and particleboard. 2. Properties: Phenol–formaldehyde resin has a density of about 1.2–1.4 g/cm^3. 3. Performance: Phenol–formaldehyde (PF) resin is an excellent thermosetting resin with good mechanical properties and heat resistance, and it is used as a matrix for thermal-insulation, flame-retardant, and ablative materials.

268		Urea Formaldehyde		**2.76**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Urea–formaldehyde resins are generally used in adhesives, MDF, finishes, and moulded objects. 2. Properties: Urea–formaldehyde resins have a density of about 1.2–1.3 g/cm³. 3. Performance: Urea–formaldehyde resin's attributes include high tensile strength, high flexural modulus, high heat-distortion temperature, low water absorption, controlled mould shrinkage, high surface hardness, elongation at break, and high-volume resistivity.
269		Bitumen Sealing Alu80		**2.24**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Torch-on or self-adhesive bituminous waterproofing layer with aluminium-foil facing for roofs and detailing where solar reflectance and UV shielding are desired. 2. Properties: Oxidised or modified bitumen membrane reinforced with fibreglass or polyester and laminated to aluminium foil (about 80-micron class); provides vapour barrier and heat reflectance. 3. Performance: Good UV stability and fire-surface protection due to the foil; laps and penetrations must be detailed carefully; avoid mechanical damage and ensure compatible primers and substrates.
270		Bitumen Sealing V60		**0.962**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: General waterproofing membrane for flat roofs, terraces, and foundations under protection layers. 2. Properties: Bitumen membrane with penetration grade around 60 (stiffer binder), commonly reinforced with

										fibreglass and suited to warm climates and protected systems. 3. Performance: Requires controlled heating or adhesive application; should be protected from prolonged standing water and high movement; follow specified lap widths and torch-safety guidance.
271		Bitumen Sealing VA4		**1.73**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Heavy-duty bituminous sealing for roofing and below-grade works where higher resistance to deformation is needed. 2. Properties: Bituminous membrane typically with elastomer or plastomer modification, thicker mass per area than basic grades, and reinforced with polyester for tensile strength. 3. Performance: Improved fatigue and temperature-cycling performance; requires good substrate preparation, primer use, and correct torching to avoid voids and blistering.
272		Bitumen Sealing		**1.25**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Generic sheet or liquid-applied bituminous waterproofing for roofs, damp-proof courses, and foundations. 2. Properties: Petroleum-based bitumen binder with mineral fillers and reinforcements, available as torch-on sheets, cold adhesives, or emulsions. 3. Performance: Durable and cost-effective when protected from UV and mechanical damage; terminations and upstands must be detailed carefully; check compatibility with insulation and surfacing.

273		Bitumen Sealing, Polymer EP4 Flame Retardant		**1.17**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Polymer-modified flame-retardant membrane for roofing where fire performance and safer torch-on work are required. 2. Properties: SBS- or APP-modified bitumen with flame-retardant additives and EP4-class reinforcement (polyester, 4-mm class), offering enhanced flexibility and dimensional stability. 3. Performance: Better low-temperature flexibility and heat resistance than oxidised bitumen; follow specified lap treatment and heat control and combine with protection layers for long service life.
274		Plaster (Gypsum Stone)		**9.06×10^{-5}**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Gypsum stone is primarily used as a standard mineral product in the building industry, as a bonding agent in plaster and as a moulding material for construction and decorative purposes. 2. Properties: Composed of calcium sulphate dihydrate ($CaSO_4 \cdot 2H_2O$) with a density of about 2.31–2.33 g/cm^3; extracted by underground and open-pit mining, then crushed, ground, dried, and purified, typically using diesel-driven drilling and ANFO-type explosives. 3. Performance: Gypsum performs well as a binder due to its setting and hardening when mixed with water, and is essential in plaster, wallboards, and mouldings; it is durable, fire-resistant, and recyclable, supporting more sustainable construction.

275		Electronic Solder (Solder Paste SnAg2.6Cu 0.3)		**0.545**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Solder paste SnAg2.6Cu0.3 is used in the electronics industry for assembling printed wiring boards (PWBs), acting as the key joining material for surface-mounted components during reflow soldering. 2. Properties: The solder paste consists of a metal alloy blend containing about 96.1% tin (Sn), 2.6% silver (Ag), and 0.3% copper (Cu), combined with flux and filler; fine spherical alloy powder is produced by atomising the metals under controlled conditions and mixed with rosin-based flux, giving a lead-free alloy with relatively low melting point, strong metallurgical bonding, and reliable wetting behaviour. 3. Performance: Solder paste SnAg2.6Cu0.3 provides high mechanical strength and thermal-fatigue resistance in solder joints, ensuring long-term durability of electronic assemblies; its lead-free formulation complies with RoHS and is suitable for inclusion in life-cycle assessments when regional inventory data are available.
276		Electronic Solder (Solder Paste SnPb34Ag2)		**0.4302**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Solder paste SnPb34Ag2 is used in the electronics industry for assembling printed wiring boards (PWBs), acting as a joining material in surface-mount technology during reflow soldering. 2. Properties: It consists of about 64% tin (Sn), 34% lead (Pb), and 2% silver (Ag), produced by vacuum

										atomisation into spherical powder and mixed with rosin-based flux; it offers good wettability, strong metallurgical bonding, and a relatively low melting point but is non-RoHS-compliant because of its lead content. 3. Performance: Provides strong, durable solder joints with good thermal and mechanical stability, but its high lead content raises environmental and health concerns and restricts use under current directives; regional LCI data allow cradle-to-gate assessment in life-cycle studies of electronic products.
277		Bitumen, At Refinery		**0.691**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Base bituminous binder used for asphalt mixes, roofing membranes, and general waterproofing, and as feedstock for polymer-modified binders.
278	Aluminium	Aluminium, General*		**0.9335**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Aluminium is used for windows, roofing, cladding, curtain walling, structural glazing, prefabricated buildings, architectural hardware, HVAC, shopfitting, and partitions, and extensively in ladders, scaffolding, and plant; it is the second most used building metal after steel because it is lightweight and durable.
279		Aluminium Profile		**1.464**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	
280		Aluminium Cast		**1.3187**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	
281		Aluminium Sheet		**1.8508**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Aluminium sheet is used for interior and exterior design work, for example in constructing floors, ceilings, screens, sun-shades, and other architectural or decorative panels. 2. Properties: Aluminium sheets, also known as aluminium plates, are

										made by pressing and rolling basic aluminium stock into panel form under high pressure. 3. Performance: Aluminium sheet is generally manufactured to be very thin and lightweight, yet sturdy enough to offer high versatility and ease of installation and maintenance in construction.
282		Aluminium Foil		**1.7209**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Aluminium foil is widely used for insulation as a heat-insulating layer for pipes and ducts. In the construction industry it is also used as a top layer on insulating materials such as stone wool, foam insulation panels, and lamellar mats in building insulation. As a vapour barrier, the foil helps ensure that water vapour does not penetrate the insulation material and thus prevents mould formation and moisture damage.
283		Aluminium Alloy, $AlMg_3$		**8.3**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: General-purpose marine and architectural alloy (about 3% Mg) used for sheet, plate, and profiles requiring good corrosion resistance. 2. Properties: Medium-strength, non-heat-treatable Al–Mg alloy with good weldability and formability; density about 2.7 g/cm^3. 3. Performance: Strong corrosion resistance in marine and industrial atmospheres; avoid prolonged service above about 65–80 °C without checking temper stability; select surface treatment to suit exposure.
284		Aluminium Product Manufacturi		**5.34**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Generic downstream forming and fabrication of

		ng, Average Metal Working								aluminium products (cutting, bending, machining, assembly). 2. Properties: Represents average energy use and consumables across common metal-working steps applied to aluminium feedstock. 3. Performance: Embodied carbon depends on process mix and scrap recovery; increasing closed-loop recycling and optimising yields reduces impacts.
285		Aluminium Scrap, New		**0.027**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Clean industrial offcuts and turnings returned directly to remelters or foundries. 2. Properties: Known composition and low contamination enable efficient closed-loop recycling with minimal sorting. 3. Performance: Among the lowest impacts of scrap streams; segregate by alloy family and keep scrap dry to prevent explosions and oxidation during melting.
286		Aluminium Scrap, Old		**0.292**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Post-consumer scrap from end-of-life products (buildings, vehicles, packaging) used as feedstock for secondary aluminium. 2. Properties: Mixed alloys and coatings; requires collection, sorting, and decoating before melting. 3. Performance: Higher impacts than new scrap because of additional processing; input purity drives achievable alloy grades and yields.
287		Aluminium		**20.45**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Generic primary aluminium used across construction, transport, electrical, and packaging applications.

										2. Properties: Liquid primary aluminium cast into ingot, slab, or billet; properties vary by alloy and temper. 3. Performance: Embodied carbon is dominated by electricity for smelting; using low-carbon power and secondary content can greatly reduce impacts.
288		Aluminium, Primary, Liquid	20.28	**20.28**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Foundry and casting feedstock supplied as molten primary aluminium to adjacent casthouses. 2. Properties: Freshly smelted metal, typically above 99.5% Al before alloying, delivered hot to minimise remelt energy. 3. Performance: Similar impacts to primary aluminium; optimised logistics and thermal management reduce additional remelt losses.
289		Aluminium, Production Mix	14.19	**14.19**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Market-average aluminium reflecting the regional blend of primary and secondary routes. 2. Properties: Weighted mix of electrolytic primary and recycled secondary aluminium across products and alloys. 3. Performance: Actual project impacts depend on supplier mix and recycled content; request EPDs and scrap declarations where possible.
290		Aluminium, Production Mix, Cast Alloy		**4.88**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Casting alloys for die-casting, sand-casting, and permanent-mould components. 2. Properties: Typically higher silicon content for castability; often high secondary (recycled) content. 3. Performance: Lower embodied carbon than wrought mixes when

										recycled content is high; verify alloy limits and mechanical properties.
291		Aluminium, Production Mix, Wrought Alloy	18.45	**18.45**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Wrought products such as sheet, plate, extrusions, and forgings for structural and architectural uses. 2. Properties: Require upstream primary metal for tight composition control; properties shaped by alloy family (5xxx, 6xxx, 7xxx) and temper. 3. Performance: Higher impacts than cast mixes; use recycled billet and low-carbon power where feasible, and request supplier-specific data.
292		Aluminium, Secondary, From New Scrap		**0.502**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Secondary aluminium made primarily from clean industrial returns (new scrap). 2. Properties: Known composition enables precise alloying with minimal refining. 3. Performance: Very low embodied carbon; maintain closed-loop returns and minimise oxidation during melting to keep values at the low end.
293		Aluminium, Secondary, From Old Scrap		**1.68**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Secondary aluminium from post-consumer scrap streams. 2. Properties: Requires sorting, decoating, and refining to remove contaminants, with alloying additions used to meet specifications. 3. Performance: Impacts depend on scrap quality and yield; robust scrap segregation lowers energy use and improves alloy quality.
294		Cold Impact Extrusion,		**1.39**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Single-stroke cold-impact extrusion to form cups, cans, or shells from slug or wire.

		Aluminium, 1 Stroke								2. Properties: High-speed displacement forming at room temperature with minimal machining waste. 3. Performance: Energy use and die wear scale with part geometry and lubrication; recycle trim to reduce material losses.
295		Cold Impact Extrusion, Aluminium, 2 Strokes		**2.06**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Two-stroke forming sequence for deeper or more complex shapes. 2. Properties: Sequential extrusion passes with intermediate lubrication and possible annealing. 3. Performance: Requires more energy and tooling than a single stroke; maximise scrap recovery and die life.
296		Cold Impact Extrusion, Aluminium		**2.72**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Generic cold-impact extrusion covering a range of shapes and depths. 2. Properties: Uses high-pressure displacement to form near-net shapes without heating. 3. Performance: Embodied carbon varies with stroke count, part depth, and scrap rate; designing for manufacturability helps to reduce impacts.
297		Cold Impact Extrusion, Aluminium, 4 Strokes		**3.39**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Four-stroke sequence for long, thin-walled forms and precision housings. 2. Properties: Multiple passes with strict die alignment and lubrication control; potential inter-pass annealing. 3. Performance: Higher process energy and tooling wear; evaluate alternatives such as drawing or hydroforming for complex parts.

298		Cold Impact Extrusion, Aluminium, 5 Strokes		**4.05**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Five-stroke sequence for extreme draw ratios and complex cans or tubes. 2. Properties: Requires robust die sets, precise lubrication, and possibly intermediate heat treatment. 3. Performance: Highest energy and tooling among listed sequences; optimise geometry and stroke reduction to control impacts.
299		Aluminium Profile		**0.179**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Aluminium profiles are widely applied in the construction sector for façades, windows, doors, curtain walls, structural frames, and roofing systems. Their lightweight, durable, and corrosion-resistant nature makes them essential in modern architectural and structural applications. 2. Properties: Produced through extrusion of aluminium billets at 400–500 °C, these profiles have a density of 2.7 g/cm³ and are formed into precise shapes depending on design needs. Aluminium profiles combine low weight with high tensile strength, natural corrosion resistance due to the formation of an oxide layer, and excellent recyclability, making them a sustainable metal choice. 3. Performance: In practice, aluminium profiles deliver high performance through long service life, low maintenance needs, and adaptability in complex designs. Their favourable strength-to-weight ratio reduces overall structural loads, while their thermal and acoustic performance can be

										enhanced through insulation systems. Additionally, their recyclability supports circular economy strategies in the building industry.
300		Aluminium Secondary		**0.558**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Secondary aluminium is mainly applied in the provision of aluminium ingots that are subsequently used for sheet and profile making, as well as for a wide range of other industrial and construction applications. 2. Properties: This material has a density of about 2.7 g/cm³ and a molar mass of 26.98 g/mol. It is produced from aluminium scrap through rotary and reverbatory furnaces, with an assumed technology share of 64 % rotary and 36 % reverbatory based on European data. Being recycled aluminium, it retains the fundamental metallic properties of aluminium, such as low density, corrosion resistance, and high thermal and electrical conductivity. 3. Performance: From an environmental and performance perspective, secondary aluminium has a significantly lower embodied energy and greenhouse gas profile compared to primary aluminium, although the dataset cautions that Malaysia also imports primary aluminium, which has a higher environmental burden. The production route modelled here (rotary and reverbatory furnaces) allows efficient recovery of aluminium from scrap, making it a sustainable option for industrial use.

										Its consistent quality ensures that recycled ingots perform comparably to primary aluminium in downstream manufacturing.
301		Aluminium Sheet		**16.7**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Aluminium sheets are widely applied in multiple sectors, including packaging (such as cans and containers), the building industry (roofing and façade panels), transportation (closures and body-in-white components), engineering applications, and specialised uses like lithographic sheets. They can also be anodised or coated for enhanced durability and aesthetics. 2. Properties: The sheets are produced from aluminium alloys through hot rolling at about 400–500 °C followed by cold rolling, resulting in thicknesses ranging from 0.2 mm to 4 mm. The process uses ingots produced by direct chill (DC) casting, which may include both primary and recycled aluminium together with alloying elements such as magnesium and silicon. The sheets are lightweight, formable, and can be joined with other components for complex applications. 3. Performance: Aluminium sheets demonstrate high adaptability across sectors due to their combination of low weight, good mechanical strength, corrosion resistance, and compatibility with coatings and surface treatments. In structural and transport applications, they provide weight reduction and improved efficiency,

										while in packaging, they ensure product protection and recyclability. Their performance is further supported by regionalised production modelling, reflecting Malaysian energy mixes and import realities, ensuring environmental data reliability for life cycle assessments.
302		Aluminium Billet: CYCAL™ 80		**1.69**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	ASIA, LOCAL	MALAYSIA	The CYCAL™ 80 billet is produced with a high recycled aluminium content, consisting of at least 80 % scrap with a lower contribution of primary aluminium derived from renewable energy sources. The scrap is sourced from suppliers using advanced sorting technologies, as well as post-production scrap from PMBA's in-house manufacturing process.
303		Aluminium Virvin		**17.007**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	Wan Omar et al (2014)	ASIA, LOCAL	MALAYSIA	1. Application: Primary aluminium feedstock for casting, rolling, extrusion, and general manufacturing across construction, transport, and packaging. 2. Properties: Virgin smelter-produced aluminium (typically >99.5 % Al before alloying), cast into ingot, slab, or billet; properties then tailored by alloy family and temper. 3. Performance: Higher embodied carbon than secondary routes due to electrolytic smelting energy; mitigation options include specifying recycled content, sourcing from low-carbon power smelters, and requesting supplier EPDs and scrap declarations.
304		Aluminium Ingot G1		**3.75**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL, ASIA	INDONESIA	Aluminium ingot is the basic form of aluminium metal, produced through a smelting process and shaped into large bars. Its function is to serve as raw

										material for various industrial applications that use aluminium, such as automotive components, household appliances, electronic products, and construction materials.
305		Cast Aluminium Recycled		**4.631**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	Recycled aluminium is a construction material produced from reprocessed aluminium scrap, offering significant energy and carbon savings. It maintains a high strength-to-weight ratio, corrosion resistance, and excellent recyclability. Applications include façade systems, window frames, cladding, and structural components. Its performance is durable, lightweight, and environmentally efficient, supporting sustainable, long-lasting construction solutions.
306		Extruded Aluminium Recycled (e.g. Profiles)		**6.22**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	
307		Foil Aluminium Recycled		**10.35**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	
308		Sheet Aluminium Recycled (e.g. Composite Panel)		**3.35**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	
309		Sheet Aluminium Virgin (e.g. Composite Panel)		**9.05**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	Sheet aluminium virgin material — often used in composite panels — is produced from primary aluminium, offering superior purity, strength, and corrosion resistance. It is lightweight, formable, and highly durable. Applications include façades, roofing, cladding, signage, and architectural panels. Performance is consistent and long-lasting, with excellent weather resistance, structural stability, and aesthetic quality.
310		Extruded Aluminium Virgin (e.g. Profiles)		**18**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	
311		Other Virgin Aluminium		**16.6**	kg CO2 eq./KG	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	
312	Timber	Timber– Average of All Data*		**0.493**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Timber typically used in construction is hardwood. Hardwood is heavier and denser than softwood and is usually utilised for the construction of walls, ceilings, and floors.

313		Timber, Chipboard*		**0.400**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Chipboard, also known as particle board or low-density fibreboard (LDF), is used for cabinet applications, floor decking, shelving, and general building work.
314		Timber, Closed Panel Timber Frame System		**0.452**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Closed panel timber frames are used on the internal face of external panels as well as on both faces of internal walls.
315		Timber, CLT		**0.437**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Cross-laminated timber (CLT) is an engineered wood. CLT is a wood panel product made from gluing together layers of solid-sawn lumber across the wide faces of each board in a symmetric pattern.
316		Timber, Fibreboard		**0.715**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Fibreboard, particularly medium-density fibreboard, is heavily used in the furniture industry.
317		Timber, Glulam		**0.512**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Glue-laminated timber (glulam) is a structural engineered wood product commonly used for beams and columns in residential and commercial applications.
318		Timber, Hardboard		**0.815**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Hardboard is a high-density wood fibreboard and a standard material used in furniture making and interior furnishing and fitting. 2. Properties: Hardwood has a density above 800 kg/m³.
319		Timber, Hardwood		**0.306**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	
320		Timber, Laminate		**0.698**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Laminated timber is used for load-bearing structures in both horizontal and vertical directions, which are either left visible or clad. 2. Properties: Laminated timber is a structural wood product made from strips of wood glued together.

321		Timber, Laminated Strand Lumber		**0.504**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Laminated strand lumber is used as headers and beams, wall stud applications, roof beams and rafters, truss chords, rim boards, and stair stringers.
322		Timber, Laminated Veneer Lumber		**0.390**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Laminated veneer lumber uses multiple layers of thin wood assembled with adhesives, used for headers, beams, rim boards, and edge-forming materials.
323		Timber, MDF		**0.856**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: MDF is an excellent material that can be used as backing for shingles of any kind of roof. 2. Properties: MDF is an engineered wood-based sheet material made by bonding together wood fibres with a synthetic resin adhesive.
324		Timber, Parquet		**0.811**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Parquet is mainly used for flooring made from both solid and engineered wood. 2. Properties: Parquet has an appealing appearance, does not hold stains easily, does not absorb odours, is very durable, offers a long lifespan, and is allergen-free. 3. Performance: Parquet has fairly high durability and is resistant to general wear and tear.
325		Hardwood Poles		**378**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	Hardwood poles, made from dense species like *balau* or *keruing*, offer high strength, durability, and natural resistance to decay. Their performance is strong under heavy loads and in harsh environments, ensuring long service life and reliable stability in construction. Common applications include utility poles, structural supports, fencing, and rural infrastructure.

326		Hardwood Pulp Log, Low Quality		**49.86**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	Low-quality hardwood pulp logs are timber sections with limited structural strength, higher defects, and lower density. They are mainly used for paper and pulp production, biomass fuel, and low-grade composite boards. Their properties include poor durability and minimal load-bearing capacity, with performance adequate for processing applications but unsuitable for structural construction uses.
327		Hardwood Sawlog, High Quality		**138**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	High-quality hardwood sawlogs are dense, defect-free timber known for superior strength, durability, and fine grain. Common applications include structural beams, premium flooring, furniture, and joinery. Their excellent mechanical properties provide strong load-bearing performance, dimensional stability, and long service life, making them highly valued in high-end construction and woodworking industries.
328		Hardwood Sawlog, Low Quality		**57.41**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	Low-quality hardwood sawlogs contain knots, irregular grain, or defects that reduce strength and workability. They are typically used for pallets, low-grade furniture, packing materials, and non-structural components. Their properties include moderate durability and limited mechanical performance, providing adequate function for basic applications but being unsuitable for precision or high-load structural uses.
329		Hardwood Timber Production		**75.55**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	Hardwood timber production yields dense, durable wood from selected species. The material offers strong mechanical properties, good workability, and long service life. Applications include structural beams, flooring, furniture, and exterior works. Its

										performance is characterised by high strength, stability, and resistance to wear, making it suitable for demanding construction uses.
330		Hardwood Veneer Log		**212**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	Hardwood veneer logs are high-grade, straight-grained timber selected for peeling into thin decorative sheets. They feature uniform texture, minimal defects, and excellent workability. Common applications include plywood, laminated panels, furniture, and interior finishes. Their performance is marked by dimensional stability, aesthetic quality, and strong bonding properties, ensuring premium results in engineered wood products.
331		Hardwood, Stand Establishment / Tending / Site Development, Under Bark		**4.6**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	Hardwood from stand establishment, tending, or site development refers to young or early-stage timber harvested during thinning and land preparation. It has lower density, smaller diameter, and variable quality. Applications include biomass fuel, wood chips, and low-grade panels. Performance is modest, offering limited structural value but suitability for processing and energy-use purposes.
332		Plywood, Indoor Use	1040	**1040**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	Plywood is an engineered wood material made by bonding thin veneer layers with alternating grain directions for strength.
333		Plywood, Outdoor Use	1200	**1200**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	It is widely used in flooring, roofing, walls, furniture, and formwork. Its properties include high dimensional stability, good load-bearing capacity, and resistance to warping, delivering reliable performance in structural and interior applications.
334		Round Wood, Hardwood, Under Bark,		**138**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	Roundwood refers to raw, unprocessed tree trunks or branches used as construction or industrial material. It retains its natural shape and strength,

		u=70%, At Forest Road								offering durability, versatility, and good load-bearing capacity. Applications include utility poles, fencing, landscaping, and timber production. Performance varies by species and quality but generally provides a stable, cost-effective material for structural and processing uses.
335		Round Wood, Primary Forest, Clear-Cutting, At Forest Road		**8.32**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
336		Round Wood, Primary Forest, Clear-Cutting, At Forest Road		**8.32**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
337		Round Wood, Scandinavian Softwood, Under Bark, u=70% At Forest Road		**41.02**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
338		Round Wood, Softwood, Debarked, u=70% At Forest Road		**43.22**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
339		Round Wood, Softwood, Under Bark, u=70% At		**41.02**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	

		Forest Road								
340		Roundwood, Azobe (SFM), Debarked, u=30%, CM, At Maritime Harbour		**271**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
341		Roundwood, Azobe (SFM), Under Bark, u=30%, At Forest Road		**106**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
342		Roundwood, Eucalyptus Ssp. (SFM), Under Bark, u=50%, At Forest Road		**49.86**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
343		Roundwood, Meranti (SFM), Debarked, u=70%		**292**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
344		Roundwood, Meranti (SFM), Under Bark, u=70%, At Forest Road		**61.22**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
345		Roundwood, Paraná Pine (SFM), Under Bark,		**193**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	

		u=50%, At Forest Road								
346		Sawn Timber (SFM), Azobe, Planed, Air Dried, u=15%	524	**524**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	Sawn timber is wood cut into boards or planks with defined dimensions. It offers good strength, workability, and versatility depending on species and grade. Common applications include structural framing, flooring, furniture, joinery, and formwork. Its performance is characterised by reliable load-bearing capacity, durability, and stability when properly dried and maintained.
347		Sawn Timber, Hardwood, Planed, Air / Kiln Dried, u=10%	395	**395**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
348		Sawn Timber, Hardwood, Planed, Kiln Dried, u=10%	430	**430**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
349		Sawn Timber, Hardwood, Raw, Air / Kiln Dried, u=10%		**315**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
350		Sawn Timber, Hardwood, Raw, Air Dried, u=20%		**300**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
351		Sawn Timber, Hardwood, Raw, Kiln Dried, u=10%		**345**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	

352		Sawn Timber, Hardwood, Raw, Plant-Debarked, u=70%		**263**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
353		Sawn Timber, Paraná Pine (SFM), Kiln Dried, u=15%		**687**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
354		Sawn Timber, Paraná Pine (SFM), u=15%		**799**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
355		Sawn Timber, Scandinavian Softwood, Raw, Plant-Debarked, u=70%		**175**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
356		Sawn Timber, Softwood, Planed, Air Dried		**182**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
357		Sawn Timber, Softwood, Planed, Kiln Dried		**220**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
358		Sawn Timber, Softwood, Raw, Air Dried, u=20%		**128**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	

359		Sawn Timber, Softwood, Raw, Forest-Debarked, u=70%		**116**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
360		Sawn Timber, Softwood, Raw, Kiln Dried, u=10%		**161**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
361		Sawn Timber, Softwood, Raw, Kiln Dried, u=20%		**150**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
362		Sawn Timber, Softwood, Raw, Plant-Debarked, u=70%		**114**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
363		Softwood pole		**24.23**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	Softwood poles are construction elements made from species like pine or spruce, valued for their light weight, straight form, and good workability. Their applications include utility poles, fencing, landscaping, and temporary supports. Their performance offers moderate strength, easy handling, and cost-effectiveness, although they require treatment for improved durability and resistance to decay.
364		Softwood Pulp Log		**11.83**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
365		Softwood Sawlog, High Quality		**41.02**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
366		Softwood Sawlog, Low Quality		**29.06**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
367		Softwood Timber Production		**28.68**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	

368		Softwood, Stand Establishment / Tending / Site Development, Under Bark		**2.07**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
369		Softwood, Woodchips		**27.86**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
370		Particle Board Plant		**1.96**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Particle board is widely applied in the building and furniture industries, where it is used as a cost-effective wood-based construction part for panels, flooring, cabinetry, and interior fittings. 2. Properties: This material is manufactured by reducing wood into chips, drying them to a working moisture level of 8.5%, gluing, and pressing them under heat and pressure into boards. Subsequent processing includes trimming, sawing, and sanding, with residues reused for production or heat generation. Particle board is characterised by dimensional stability, uniform density, smooth surfaces for finishing, and efficient use of wood resources. 3. Performance: Particle board performs effectively as a lightweight, stable, and versatile construction material. It provides good machinability, uniformity, and surface quality, although it has lower strength compared to solid wood or plywood. Environmentally,

										the dataset reflects cradle-to-gate inventory with Malaysian-specific energy supply modelled largely from biomass, making it suitable for life cycle assessments and sustainable building evaluations.
371		Particle Board Producer		**1.97**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Particle board is commonly applied in the building and furniture industries as a cost-effective engineered wood product. It is used for panels, flooring, interior fittings, cabinetry, and other decorative or structural applications where smooth surfaces and machinability are required. 2. Properties: The board is produced by reducing different assortments of wood into chips, drying them to 8.5% moisture, gluing, and pressing them under heat and pressure into boards. The process involves trimming, sawing, and sanding, with production residues recycled for reuse or energy recovery. It has uniform density, smooth surfaces, dimensional stability, and consistent thickness, making it well suited for laminating and finishing. 3. Performance: Particle board performs effectively as a lightweight, stable, and versatile material. While it has lower strength than solid wood or plywood, it provides good machinability and surface quality, making it highly adaptable for interior and non-structural uses. From an environmental perspective, the dataset is cradle-to-gate and modelled with Malaysian-specific biomass energy supply, supporting

										its role in sustainable construction and life cycle assessments.
372		Plywood Board		**1.11**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Plywood is mainly applied in the construction and furniture industries, where it is used for making wood construction parts such as doors, walls, floors, and panels requiring strength, flexibility, and surface finish. 2. Properties: Plywood is produced by peeling dampened logwood into veneers, which are then glued and pressed crosswise in layers, with a minimum of three veneers required. The veneers are arranged symmetrically, each not exceeding 7 mm in thickness, to form boards with balanced mechanical properties. Depending on the adhesive used, plywood can be tailored for dry, damp, or outdoor environments. The dataset reflects boards with 5 % moisture content, manufactured under Malaysian-specific energy supply conditions, with energy primarily from biomass. 3. Performance: Plywood performs effectively as a versatile and durable engineered wood product, offering high strength-to-weight ratio, stability, and ease of machining. It provides flexibility for structural and decorative uses while maintaining resistance to warping and splitting. From an environmental perspective, the cradle-to-gate dataset reflects Malaysia's energy mix and transport conditions, making it reliable for life cycle assessments of construction and furniture applications.

373		Glued Laminated Timber	2080	**2080**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	A.T. Balasbaneh, A.K. 358 Bin Marsono (2017)	ASIA, LOCAL	MALAYSIA	Glued laminated timber (glulam) is an engineered wood product made by bonding multiple timber laminations with durable adhesives. It offers high strength, dimensional stability, and excellent load-bearing performance. Applications include beams, arches, bridges, and long-span structures. Glulam provides high durability, design flexibility, and consistent performance compared to solid timber, making it suitable for modern construction.
374		Timber Prefabricated	6250	**6250**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	A.T. Balasbaneh, A.K. 358 Bin Marsono, (2017)	ASIA, LOCAL	MALAYSIA	Timber prefabricated components are factory-produced structural or architectural elements made from engineered or solid wood. They offer high precision, fast installation, and reduced on-site labour. Applications include wall panels, roof trusses, floor cassettes, and modular units. Their performance features good strength, dimensional stability, and consistent quality, supporting efficient, reliable, and sustainable construction.
375		Plywood		**-118**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2024)	GLOBAL, ASIA	INDONESIA	Plywood is an engineered wood panel made by bonding cross-laminated veneer layers for strength and stability. Applications include flooring, roofing, wall sheathing, furniture, and formwork. Its properties include high dimensional stability, good load-bearing capacity, and resistance to warping. Performance is reliable, versatile, and durable across structural and interior construction uses.
376	Brass	General*		**2.64**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Brass is an alloy of copper and zinc commonly used in applications where corrosion resistance and low friction are required, such as locks, hinges, gears, bearings, ammunition
377		Virgin		**4.8**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	

378		Recycled		**1.2**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	casings, zippers, plumbing, hose couplings, valves, and electrical plugs and sockets. 2. Properties: More malleable than copper or zinc. Not as hard as steel. Corrosion resistant. Exposure to ammonia may produce stress cracking. Low melting point. 3. Performance: Known for its decorative attributes and bright gold appearance, brass also exhibits durability, corrosion resistance, and high electrical conductivity.
379		Nordic Brass		**1.46**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	EPD International (2017)	GLOBAL	FINLAND	1. Application: Used as façades, roofs, roof drainage systems, and other architectural elements of all shapes, as well as interior applications, decorations, ceilings, and wall claddings. 2. Properties: The Nordic Brass product is an alloy of copper and zinc (CuZn15) with a distinctive golden yellow colour. The copper (Cu) content is 84–86 % and the zinc (Zn) content is 14–16 %. Coefficient of thermal expansion $18 \times 10^{-6}\ K^{-1}$, tensile strength 310–370 N/mm², density 8 750 kg/m³, thermal conductivity (at 20 °C) 335 W/cm °C, specific heat 375 J/kg K, proof strength 200–290 N/mm², elongation min 10 %, hardness 80–115 HV. 3. Performance: The Nordic Brass product is an alloy of copper and zinc (CuZn15) with a distinctive golden yellow colour. When exposed to the atmosphere, the surface begins to darken within weeks and can change to a dark brown in around a year.

		Brass Bathroom Mixers			$kgCO_2e/kg$					
380		i) Bath Mixer		**9.20**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD International (2020)	GLOBAL	TURKEY	1. Application: Kitchen mixers are plumbing fixtures used to wash food, hands, and kitchen devices/accessories in a sink by mixing hot and cold water. Basin mixers are plumbing fixtures used to wash hands in lavatories and bathrooms by mixing hot and cold water. Bath and shower mixers are plumbing fixtures used to take showers by mixing hot and cold water. Taps are plumbing fixtures used to wash hands in lavatories and toilets by providing a flow of hot or cold water. Drain systems are plumbing fixtures used to discharge wastewater produced during washing of hands, washing of hair, taking showers, etc. Valves are plumbing fixtures used to control the flow of water to mixers, WC pans, bathrooms, and kitchens. 2. Properties: Maximum load temperature, permanent operation 65 °C. Maximum load temperature, temporary operation 90 °C. Flow rate (indications for pressure 0.54–1.2 m^3/h, range of 1–3 bar). Sound emissions ≤20 dB. 3. Performance: The Nordic Brass product is an alloy of copper and zinc (CuZn15) with a distinctive golden yellow colour. When exposed to the atmosphere, the surface begins to darken within weeks and can change to a dark brown in around a year.
		ii) Basin Mixer			$kgCO_2e/kg$					
		ii) Sink (Kitchen) Mixer			$kgCO_2e/kg$					
		iv) Shower Mixer			$kgCO_2e/kg$					
		v) Tap			$kgCO_2e/kg$					
		vi) valve			$kgCO_2e/kg$					
		vii) Drain System			$kgCO_2e/kg$					
381		Altech Brass and Chromated Brass Clamps		**0.50**	kg CO_2 eq./kg	Cradle to gate (Extraction to Manufacturing)	EPD International (2023)	GLOBAL	SWEDEN	Altech brass and chromated brass clamps (klämringskopplingar) are entirely made from brass and chromated brass respectively. The products are used to conduct and distribute hot and

										cold water in tap water installations, heating installations, and cooling installations. The chromated brass clamps are used for visible installations.
382		LK Rosette and Connections of Lead-Free Brass		**8.06**	kg CO_2 eq./kg	Cradle to gate (Extraction to Manufacturing)	EPD International (2025)	GLOBAL	SWEDEN	Chrome-plated rosette 80 mm to suit ½" connection couplings, launched in 2015. Supplied with foam. Olive Cu10 connection and LK UNI Adapter ECO for transition from G20 to G20 Play nut and flat seal. Fits LK UNI Distributor. Used with advantage against KV and VV meters in distribution cabinets. Nut is provided with a hole for sealing.
383	Zinc	General*		**3.09**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Zinc has been commonly used as a building material for covering roofs and façades, as well as for gutters and downpipes. 2. Properties: For construction applications, the zinc used is usually in sheet form of 99.9 %+ purity but with very small concentrations of titanium and copper. It is typically applied in sheet thicknesses of 0.7 mm. 3. Performance: When the zinc is to be laid on a continuous substrate (e.g. 18 mm plywood sheets with no ventilation gaps), contemporary practice typically installs a continuous, self-sealing vapour barrier and breather membrane to prevent moisture from condensing on the underside of the zinc.
384		Virgin*		**4.18**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	
385		Recycled		**0.52**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	
386		Hot Dip Galvanized Steel with Pure Zinc Coating		**2.56**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD International (2024)	GLOBAL	FRANCE	1. Application: The most common applications are: i) building – wide sections for roofing and cladding, doors and windows, door frames, metallic ceilings, partitions, structural members, etc.; ii) domestic appliances (white and

										brown goods); iii) tubular applications; iv) electrical equipment (electrical cabinets, cable trays); v) heat and ventilation equipment, air conditioners, road signals, etc. 2. Properties: The zinc coating process can apply various thicknesses of the zinc layer, up to 725 g/m² (total of both sides). Density 7 825 kg/m³. 3. Performance: Excellent corrosion resistance combined with very good forming properties.
387		Coated (on the Sub-Face) Preweathered Rolled Zinc		**4.3**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	IBU (2025)	GLOBAL	FRANCE	1. Application: The product can be used in buildings as roof, façade, or rainwater systems. 2. Properties: It is a copper and titanium zinc alloy in accordance with DIN EN 988, which has received a surface treatment on the sub-face. Coefficient of thermal expansion 22 × 10^{-6}/K; tensile strength 152 N/mm²; modulus of elasticity 9 000 N/mm²; melting point 420 °C; thermal conductivity 110 W/(mK); electrical conductivity at 20 °C 17 Ω^{-1} m^{-1}; density 7 200 kg/m³. 3. Performance: It has optimal mechanical and physical properties for applications in construction, in particular regarding mechanical resistance and resistance against creep deformation.
388		Natural Rolled Zinc		**3.80**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	IBU (2022)	GLOBAL	NETHERLAND	1. Application: The natural rolled zinc in sheets and coils is used in numerous building applications: roofing, façade applications, flashings, coverings, and roof drainage systems.

										2. Properties: Coefficient of thermal expansion 22 × 10^{-6} K^{-1}, tensile strength 152 N/mm², electrical conductivity at 20 °C 17 Ω^{-1} m^{-1}, compressive strength – N/mm², modulus of elasticity 9 000 N/mm², melting point 420 °C, thermal conductivity 110 W/(mK), density 7 200 kg/m³. 3. Performance: This alloy has optimal mechanical and physical properties for applications in construction, in particular regarding mechanical resistance and resistance against creep deformation.
389		Alu-Zinc Coated, Galvanised and Pre-Painted Steel Coil, Sheets and Profile		**3.51**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD International (2025)	GLOBAL	INDIA	1. Application: The textured and mattified rolled zinc in sheets and coils is used in numerous building applications: roofing, façade applications, flashings and coverings, and roof drainage systems. 2. Properties: Coefficient of thermal expansion 22 × 10^{-6} K^{-1}, tensile strength 152 N/mm², compressive strength – N/mm², modulus of elasticity 9 000 N/mm², melting point 420 °C. 3. Performance: This alloy contains mainly very high purity zinc in accordance with DIN EN 1179 (Grade Z1: 99.995 % purity) with very few alloy components (copper, titanium, and aluminium). It has optimal mechanical and physical properties for applications in construction, in particular regarding mechanical resistance and resistance against creep deformation. From an aesthetic point of view, textured and mattified

										rolled zinc is the lightest, most matt zinc and is distinguished by its heterogeneous surface punctuated with asperities.
390		Coated PreWeathered Rolled Zinc		**3.40**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD International (2025)	GLOBAL	FRANCE	1. Application: The coated preweathered rolled zinc in sheets and coils is used in numerous building applications: roofing, façade applications, flashings and coverings, and roof drainage systems. 2. Properties: Coefficient of thermal expansion $22 \times 10^{-6}\ K^{-1}$, tensile strength 152 N/mm^2, compressive strength – N/mm^2, modulus of elasticity 9 000 N/mm^2, melting point 420 °C, thermal conductivity 110 W/(mK), electrical conductivity at 20 °C 17 $\Omega^{-1}\ m^{-1}$, density 7 200 kg/m^3. 3. Performance: It has optimal mechanical and physical properties for applications in construction, in particular regarding mechanical resistance and resistance against creep deformation. From an aesthetic point of view, coated preweathered rolled zinc is less bright and darker than natural rolled zinc and is very lightly coloured.
391		Preweathered Rolled Zinc		**2.97**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD International (2025)	GLOBAL	CHILE	1. Application: The preweathered rolled zinc in sheets and coils is used in numerous building applications: roofing, façade applications, flashings and coverings, and roof drainage systems. 2. Properties: Coefficient of thermal expansion $22 \times 10^{-6}\ K^{-1}$, tensile strength 152 N/mm^2, compressive strength – N/mm^2, modulus of

										elasticity 9 000 N/mm², melting point 420 °C, thermal conductivity 110 W/(mK), electrical conductivity at 20 °C 17 Ω^{-1} m^{-1}, density 7 200 kg/m³. Product performance values are in line with EN 988 Zinc and Zinc Alloys – Requirements of Rolled Flat Products for Use in Construction. 3. Performance: It has optimal mechanical and physical properties for applications in construction, in particular regarding mechanical resistance and resistance against creep deformation. From an aesthetic point of view, preweathered rolled zinc is less bright and darker than natural rolled zinc.
392		Zinc, from Imperial Smelting Furnace		**3.43**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Zinc has been commonly used as a building material for covering roofs and façades, as well as for gutters and downpipes. 2. Properties: For construction applications, the zinc used is usually in sheet form of 99.9 %+ purity but with very small concentrations of titanium and copper. It is typically applied in sheet thicknesses of 0.7 mm. 3. Performance: When the zinc is to be laid on a continuous substrate (e.g. 18 mm plywood sheets with no ventilation gaps), contemporary practice typically installs a continuous, self-sealing vapour barrier and breather membrane to prevent moisture from condensing on the underside of the zinc.

393		Zinc Coating, Coils		**6.58 *(10.97 kgCO_2e/kg, Conv. Factor, thickness 0.3 mm=0.6 kg/m^2)**	kgCO_2e/m^2	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Zinc has a number of characteristics that make it a well-suited corrosion protective coating for iron and steel products in most environments. The coating provides corrosion protection for areas of exposed steel surfaces, such as cutting edges and areas where coating has been damaged (scratches, impacts, etc.). Full corrosion protection is also achieved in areas that have been heavily formed because the peeling tendency of the low-friction and tightly bonded coating is low. 2. Properties: Coating: hot-dip galvanizing (batch or continuous), electroplating, zinc plating – 43 µm thickness; metallizing (zinc spraying) – 48 µm thickness; mechanical plating – 55 µm thickness; zinc-rich paint – 75–150 µm thickness. 3. Performance: The excellent field performance of zinc coatings results from their ability to form dense, adherent corrosion product films and a rate of corrosion considerably below that of ferrous materials (some 10 to 100 times slower depending upon the environment). While a fresh zinc surface is quite reactive when exposed to the atmosphere, a thin film of corrosion products develops rapidly, greatly reducing the rate of further corrosion.
394		Zinc Coating, Pieces, Adjustment per um		**0.088115 *(1.47 kgCO_2e/kg, Conv. Factor, thickness 0.25 mm=0.06 kg/m^2)**	kgCO_2e/m^2	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
395		Zinc Coating, Pieces		**9.03 *(15.05 kgCO_2e/kg, Conv. Factor, thickness 0.3 mm=0.6 kg/m^2)**	kgCO_2e/m^2	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
396		Zinc, from Combined Metal Production,		**0.44**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: The natural rolled zinc in sheets and coils is used in numerous building applications: roofing, façade applications,

		at Beneficiation								flashings, coverings, roof drainage systems, and ornament. 2. Properties: Coefficient of thermal expansion 22 × 10^{-6} K^{-1}, tensile strength 152 N/mm², electrical conductivity at 20 °C 17 Ω^{-1} m^{-1}, compressive strength – N/mm², modulus of elasticity 9 000 N/mm², melting point 420 °C, thermal conductivity 110 W/(mK), density 7 200 kg/m³. 3. Performance: This alloy has optimal mechanical and physical properties for applications in construction, in particular regarding mechanical resistance and resistance against creep deformation.
397		Zinc, from Combined Metal Production, at Refinery		**1.02**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	
398		Zinc, Primary		**5.70**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Zinc has been commonly used as a building material for covering roofs and façades, as well as for gutters and downpipes. 2. Properties: For construction applications, the zinc used is usually in sheet form of 99.9 %+ purity but with very small concentrations of titanium and copper. It is typically applied in sheet thicknesses of 0.7 mm. 3. Performance: When the zinc is to be laid on a continuous substrate (e.g. 18 mm plywood sheets with no ventilation gaps), contemporary practice typically installs a continuous, self-sealing vapour barrier and breather membrane to prevent moisture from condensing on the underside of the zinc.
399		Zinc-Aluminium Alloy-		**16.10**	kg CO_2 eq./kg	Cradle to gate (Extraction to Manufacturing)	EPD International (2025)	GLOBAL	Chile	Zinc–aluminium coated steel panels are versatile solutions for roofing, façades, and cladding in construction and

		Coated Steel Panels								infrastructure projects. Designed in various geometries, they offer high strength, watertightness, and aesthetic appeal. Some models allow for natural lighting, while others stand out for their structural capacity and innovative architectural options, such as perforations. All the products evaluated have a nominal thickness of 0.5 mm and are coated with polyester paint.
400		Hot Dipped Aluminium-Zinc-Magnesium Alloy AM150 Coating		**13.50**	kg CO2 eq./m2	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL, ASIA	VIETNAM	It is coated to provide enhanced corrosion resistance and then further protected with a special surface treatment, passivated and resin coated. It is typically formed into roofing and walling, garage doors, structural sections, or other general manufactured articles. It suits a wide range of building designs, including a variety of commercial and industrial projects as well as rural sheds. It can also be used as an iconic design feature in residential applications.
401		Alu-Zinc Coated Galvalume, Galvanized and Pre-Painted Steel Coil, Sheets and Profile		**3.50**	kg CO_2 eq./kg	Cradle to gate (Extraction to Manufacturing)	EPD International (2025)	GLOBAL	INDIA	Pre-painted aluminium–zinc alloy metallic coated steel coil and sheet (plain) and hot-dip aluminium–zinc alloy metallic coated steel coil and sheet (plain).
402		Prepainted Hot Dip Zinc-Coated Steel in Coil (PPGI)		**3.37**	kg CO_2 eq./kg	Cradle to gate (Extraction to Manufacturing)	EPD International (2025)	GLOBAL	CHINA	Pre-painted hot-dip zinc-coated steel in coil (PPGI) is produced using galvanised steel coil as raw material, and paint is baked onto the surface. Therefore, in addition to excellent features such as good formability, impact resistance, abrasion resistance, chemical resistance, corrosion resistance, and weather resistance, it also has

										advantages such as easy processing and an appealing appearance.
403		Prime Pre-Painted Hot Dip Aluminium-Zinc Alloy Coated Steel Sheet (PPGL)		**2.79**	kg CO_2 eq./kg	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL, ASIA	VIETNAM	Produced using premium cold-rolled coils sourced from reputable manufacturers and processed with advanced NOF (Non-Oxidizing Furnace) technology, the prime pre-painted hot-dip aluminium–zinc alloy coated steel sheet of Hoa Sen Group ensures exceptional performance in both industrial and civil construction applications.
404		Prime Hot Dip Aluminium-Zinc Alloy Coated Steel Sheet (GL)		**2.75**	kg CO_2 eq./kg	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL, ASIA	VIETNAM	Produced using premium cold-rolled coils sourced from reputable manufacturers and processed with advanced NOF (Non-Oxidizing Furnace) technology, the prime hot-dip aluminium–zinc alloy coated steel sheet of Hoa Sen Group ensures exceptional performance in both industrial and civil construction applications.
405		Corrugated Steel Structures with Zinc Coating: Multi Plate, Nova Bridge 300 and Nova Bridge 500		**3.11**	kg CO_2 eq./kg	Cradle to gate (Extraction to Manufacturing)	EPD International (2025)	GLOBAL	LITHUANIA	Corrugated steel structures MultiPlate (MP), NovaBridge 300 (NB300), and NovaBridge 500 (NB500) have zinc coating. Corrugated steel structures are considered flexible structures. They take over the load and transfer it to the soil surrounding the structure. Most often, steel corrugated structures are used for tunnels or bridges for cars and railways, pedestrian, cyclist, or animal crossings, and water culverts. The corrugated steel structures can be adapted to strengthen and reconstruct existing culverts, bridges, or tunnels.
406		ZINCANNEAL® steel–ZF100–BMT 1.50		**32.60**	kg CO2 eq./m2	Cradle to gate (Extraction to Manufacturing)	EPD International (2024)	GLOBAL	AUSTRALIA	ZINCANNEAL® steel is a hot-dipped zinc/iron alloy-coated steel product designed for excellent bending, roll-forming, welding, and painting characteristics to meet fabrication performance requirements. With a

										spangle-free surface and suitable for post-painting and powder coating, ZINCANNEAL® steel is designed to accommodate many applications in the automotive and manufacturing segments. ZINCANNEAL® steel conforms to standard AS 1397:2021.
407		Zinc Mix		**2.42**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Zinc is widely applied as a coating material in galvanising to protect steel and iron from corrosion, in alloys such as brass and die-casting products, and in chemical compounds used for batteries, pigments, and fertilisers. 2. Properties: The dataset represents zinc produced through ore roasting, leaching, and electrowinning, supplied as a global production import mix to Malaysia. Zinc has a density of 7.14 g/cm^3 and a molar mass of 65.409 g/mol. The roasting process converts zinc sulphide to zinc oxide at 900–1000 °C, followed by leaching with sulphuric acid and electrowinning to deposit pure zinc metal at the cathode. The dataset is modelled under Malaysian energy supply conditions, though nearly 100 % of zinc is imported, making it a consumption mix rather than a local production dataset. 3. Performance: Zinc performs effectively by providing excellent corrosion resistance when applied as a protective coating, enhancing the durability and lifespan of steel structures. Its role in die-casting and alloys ensures good mechanical strength and versatility in manufacturing, while its use in chemical compounds supports

										essential industrial and agricultural applications. From a sustainability perspective, the Malaysian LCI confirms its cradle-to-gate inventory profile, allowing the integration of zinc's environmental impacts into life cycle assessments, with quantified resource use and emissions reflecting global import routes.
408		Zinc Building Profile		**2.35**	kg CO_2 eq./kg	Cradle to gate (Extraction to Manufacturing)	EPD International (2020)	GLOBAL	DENMARK	The profiles vary across a wide range of materials, designs, and surface treatments so that they suit the desired purpose with the accessories on the roof or façade. The building profiles are manufactured from a thin sheet of material in a wide range of dimensions and thicknesses. During manufacture, the raw material sheet is cut or punched out, after which the adapted item is bent so that it has the desired design for the building profile.
409		ZINCALUME® Ultra Steel. Substrate AM150 Coating at 0.48mm BMT		**13.50**	kg CO2 eq./m2	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2025)	GLOBAL, ASIA	VIETNAM	ZINCALUME® Ultra steel consists of a steel substrate with a metallic coating incorporating BlueScope's patented Activate™ technology (hot-dipped aluminium–zinc–magnesium alloy AM150 coating) to provide enhanced corrosion resistance and is then further protected with a special surface treatment, passivated and resin coated. Area density 3.9 kg/m³.
410	Lead	General*		**1.6681**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Lead was used for making water pipes, roofing and plumbing, cornices, tank linings, electrical conduits, cladding, flashing, gutters, and parapets. Lead was incorporated into soft solder, an alloy of lead and tin, and used for soldering tinplate and copper pipe joints. Lead-based
411		Virgin		**3.37**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	
412		Recycled		**0.58**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	

										paint inhibits the rusting and corrosion of iron and steel, and continues to be used on steel structures such as bridges, railways, and lighthouses. 2. Properties: Lead is still used for traditional buildings and conservation purposes. It is available in rolls in standard 3 m and 6 m lengths with a maximum width of 1 370 mm and in thicknesses from 1.32 mm (code 3) to 3.55 mm (code 8), although thicknesses up to 9 mm are available. 3. Performance: High density. Low melting point. Ductility. Resistance to oxidation. Abundance. Ease of extraction.
413		Lead Import		**0.14**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Lead is mainly applied for radiation protection, as an alloying element, and in various construction purposes. It is also widely used in batteries, shielding materials, and other industrial applications that benefit from its density and malleability. 2. Properties: The dataset represents 99.995 % pure lead, produced through smelting and refining of lead-bearing ores, with recovery of associated metals such as zinc, silver, or gold. The Malaysian mix is based entirely on imports, primarily from China (78.8 %), North America (11.6 %), and Australia (9.6 %), with an average seaway transport distance of about 5 500 km. The material is classified under metals and semimetals, with high density,

										corrosion resistance, and ease of processing. 3. Performance: Lead performs well in applications requiring high shielding effectiveness against radiation, structural malleability for shaping, and durability in alloys. While technically reliable, its production and use are associated with significant environmental and health concerns, necessitating strict management. The dataset provides cradle-to-gate inventory information under Malaysian energy and transport conditions, making it suitable for life cycle assessments of products incorporating lead.
414		Lead Secondary		**0.00604**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Secondary lead is mainly applied in the production of lead ingots used for manufacturing batteries, glass additives, electronics, and other industrial products. Recycling from scrap, particularly batteries, makes it a key resource for sustaining lead-dependent industries. 2. Properties: This dataset represents lead with a density of 11.3 g/cm^3 and a molar mass of 207 g/mol. The process involves remelting lead-containing scrap, especially from used batteries, in rotary furnaces with energy requirements between 5–8 GJ/t depending on furnace type and scrap quality. It is categorised under metals and semimetals, with high density, corrosion resistance, and ease of remelting, making it highly recyclable. 3. Performance: Secondary lead performs reliably in applications

										requiring durability, malleability, and radiation shielding. Compared with primary lead production, recycling significantly reduces energy demand and environmental burdens, though it still generates by-products such as slags and emissions. The dataset reflects Malaysian energy supply chains, making it suitable for life cycle assessments, while also highlighting that the environmental profile differs from primary lead production and must be interpreted accordingly.
415	Ceramic	**Fittings** i) Tube ii) Ceramic Gaskets iii) Elbows of 90-degree, 30-degree, 45-degree		**1.14**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: All pipe and fittings feature extremely wear-resistant ceramics that are also exceptionally corrosion-resistant. 2. Properties & Performance: High thermal strength and chemical resistance against acids and alkaline solutions.
416		**Sanitary Products** i) Toilet-Bowls ii) Bathtubs iii) Wash Basin iv) Shower-Plates,		**1.93**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Ceramic sanitaryware are plumbing fixtures that include shower plates, washbasins, toilet bowls, bathtubs, etc. 2. Properties & Performance: Highly cost-effective and easy to maintain, as they are abrasion resistant, corrosion resistant, and have a longer service life in comparison to their steel and iron counterparts. They are extremely durable, require low maintenance, and have high resistance to environmental conditions.
417		**Vitreous China Ceramic**		**0.815**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD International (2024)	GLOBAL	TURKEY	1. Application: Ceramic sanitaryware is a common term for washbasins, cisterns, bidets, shower trays,

		Sanitaryware:								squatting pans, and urinals utilised in bathrooms, kitchens, and toilets in glazed formation with a white or coloured outer surface. 2. Properties: Maximum water absorption 0.2–0.4 Vol. %; Harcord cracking test PASS; crazing test PASS; water absorption test PASS; resistance to chemicals and staining PASS; surface hardness test PASS; resistance to temperature change PASS. 3. Performance: Harcord cracking, crazing, resistance to strike, resistance to chemicals and staining agents, surface hardness, and resistance to temperature.
		i) Washbasins								
		ii) Cisterns								
		iii) Bidets								
		iv) Shower Trays, WC Pans								
		v) Squatting Pans								
		vi) Urinals								
418		**Fine Fireclay Ceramic Sanitaryware** i) Washbasins ii) Cisterns iii) Bidets iv) Kitchen Sinks vi) Urinals		**1.88**	kg CO_2e-/kg	Cradle to gate (Extraction to Manufacturing)	EPD International (2024)	GLOBAL	EGYPT	1. Application: Ceramic sanitaryware is a common term for washbasins, cisterns, bidets, shower trays, squatting pans, and urinals utilised in bathrooms, kitchens, and toilets in glazed formation with a white or coloured outer surface. 2. Properties: Maximum water absorption 8.5–9.5 Vol. %; Harcord cracking test PASS; crazing test PASS; water absorption test PASS; resistance to chemicals and staining PASS; surface hardness test PASS; resistance to temperature change 180 °C. 3. Performance: Harcord cracking, crazing, resistance to strike, resistance to chemicals and staining agents, surface hardness, and resistance to temperature.
419		Porcelain Tiles		**0.758**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Porcelain tiles are used for flooring, walls, and façades in both indoor and outdoor settings,

										especially in high-traffic and wet areas. 2. Properties: They have low water absorption, high density, and are available in various finishes with precise edges for a clean look. 3. Performance: Porcelain tiles offer excellent durability and resistance to water, stains, heat, and wear, making them long-lasting and easy to maintain.
420		Tiles		**0.796**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Ceramic tile is used from the interior to the exterior of a home, creating a flow-through effect of floor. Ceramic cladding resists perpetual changes in temperature and atmospheric attack from pollution, acid rain, and smog. 2. Properties & Performance: Highly versatile with exceptional mechanical characteristics, durable, enhances appearance, easy maintenance, good thermal insulation, environmentally friendly, easy availability, and inexpensive. Other term is stoneware.
421	Plastic	Plastics, General		**3.31**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: General plastics in construction are used for piping, insulation, window frames, roofing membranes, and wall panels. 2. Properties: They are lightweight, weather-resistant, moisture-proof, and easy to fabricate. 3. Performance: Plastics provide long-lasting durability, low maintenance, thermal insulation, and cost-effective solutions for various building components.
422		Plastics, ABS		**3.76**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Construction applications of acrylonitrile

										butadiene styrene (ABS) plastic are for pipes and fittings. 2. Properties: ABS plastic is sturdy and hard with a longer lifespan. 3. Performance: ABS plastic has a good balance of impact, heat, chemical and abrasion resistance, dimensional stability, tensile strength, surface hardness, rigidity, and electrical characteristics.
423		Plastics, Acrylic		**2.54**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Acrylic plastic is often used for light fixtures, LCD screens, windows, and other applications that call for transparent sheeting. 2. Properties: Acrylic plastic is strong yet lightweight, with an ultimate tensile strength of 70 MPa. 3. Performance: Acrylic plastic has great optical clarity, scratch resistance, and rigidity.
424		Plastics, General Polyethylene		**2.54**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Plastics are used in a broad range of building and construction applications, including insulation, piping, window frames, and interior design. 2. Properties: Plastics have low modulus of elasticity and are unsuitable for load-bearing applications. 3. Performance: Plastics have high durability and resistance to corrosion, making them ideal for applications such as window frames and pipes.
425		Plastics, High Density Polyethylene (HDPE)		**1.93**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: High-density polyethylene (HDPE) plastic is mainly used for piping systems. 2. Properties: HDPE is a durable, chemically resistant material.

										3. Performance: HDPE is weatherproof and has good low-temperature toughness.
426		Plastics, High Density Polyethylene (HDPE) Pipe		**2.52**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: HDPE pipes are used in construction for water supply, drainage, gas distribution, and underground conduit systems. 2. Properties: They are flexible, lightweight, corrosion-resistant, and have high chemical and impact resistance. 3. Performance: HDPE pipes offer excellent durability, leak-free joints, and long service life, making them ideal for demanding infrastructure applications.
427		Plastics, Low Density Polyethylene (LDPE) Resin		**2.08**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Low-density polyethylene (LDPE) plastic is used for drainpipes. 2. Properties: LDPE has high ductility but low tensile strength. 3. Performance: LDPE plastic is very tough, weatherproof, has good chemical resistance, low water absorption, and low cost.
428		Plastics, Low Density Polyethylene (LDPE) Film		**2.6**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: LDPE film is used in construction for vapour barriers, protective sheeting, damp-proof membranes, and temporary coverings. 2. Properties: It is flexible, lightweight, moisture-resistant, and has good chemical resistance. 3. Performance: LDPE film provides effective moisture protection, easy handling, and cost-efficiency for temporary and protective construction uses.
429		Plastics, Nylon	.	**9.14**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: – 2. Properties: Polyamide resin (PA) plastics have high strength and

		Polyamide 6 Polymer								3. stiffness at high temperature and good fatigue resistance. 3. Performance: PA is one of the engineering plastic materials with good mechanical properties and competitive price.
430		Plastics, Polycarbonate	.	**7.62**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Plastics in construction are mainly used for seals, profiles (windows and doors), pipes, cables, floor coverings, and insulation. 2. Properties: Polycarbonate can withstand extreme amounts of force and is nearly unbreakable. 3. Performance: Polycarbonate plastics are strong, stiff, hard, and tough.
431		Plastics, Polyester	.	**7.92**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Polyester plastics are used as plastic reinforcement. 2. Properties: The flexural strength ranges around 221 MPa. 3. Performance: Polyester plastics have high tensile strength, chemical resistance, thermal stability, flatness, clarity, high temperature resistance, and thermal and electrical insulation properties.
432		Plastics, Polypropylene, Orientated Film		**3.43**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Polypropylene oriented film is used in packaging, labelling, laminates, and textiles due to its clarity and strength. 2. Properties: It is lightweight, chemically resistant, moisture-proof, and has high tensile strength from its orientation process. 3. Performance: The film offers excellent durability, dimensional stability, and printability, with good barrier properties and low cost.
433		Plastics, Polypropylene,		**4.49**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	4. Application: Polypropylene for injection moulding is used in

		Injection Moulding								automotive parts, household goods, medical devices, and packaging. 5. Properties: It is lightweight, chemically resistant, impact resistant, and has good fatigue strength. 6. Performance: It offers excellent durability, flexibility, and processability, making it suitable for complex and high-volume moulded products.
434		Plastics, Polyethylterepthalate (PET)		**3.43**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Polyethylene terephthalate (PET) is one of the most produced thermoplastics in the world. Application of plastic waste as a modifier can reduce the quantity of cement and sand by its weight. 2. Properties: Flexural strength ranges around 221 MPa. 3. Performance: PET is a clear, strong, and lightweight plastic.
435		Plastics, Polypropylene		**4.49**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Polypropylene is used in a variety of building and construction applications, including siding, air and moisture barrier membranes, and carpet textiles. 2. Properties: Polypropylene plastics have tensile strength in the range between 0.95–1.30 N/mm^2. 3. Performance: Waterproof membranes made with polypropylene are used to create the drainage mats in vegetative roofing systems.
436		Plastics, Virgin Polypropylene Pellet		**1.64**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2024)	GLOBAL/ ASIA	INDONESIA	Plastic pellet is a virgin polypropylene material that has been through the melting process in a pelletising extruder.

437		Plastics, Expanded Polystyrene		**3.29**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Polystyrene plastics are used as insulation foam, panels, bath and shower units, and lighting and plumbing fixtures. 2. Properties: Flexural strength ranges around 83 MPa. 3. Performance: Polystyrene plastics are durable and resistant to water damage.
438		Plastics, General Purpose Polystyrene		**3.43**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: General purpose polystyrene (GPPS) is used in construction for insulation panels, light diffusers, and decorative elements. 2. Properties: It is rigid, lightweight, transparent or opaque, and easy to mould or cut. 3. Performance: GPPS offers good dimensional stability, ease of fabrication, and moderate impact resistance, suitable for non-structural interior applications.
439		Plastics, High Impact Polystyrene		**3.42**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: High-impact polystyrene (HIPS) is used in construction for wall linings, insulation facings, utility panels, and signage. 2. Properties: It is tough, impact resistant, lightweight, and easy to thermoform or fabricate. 3. Performance: HIPS provides good durability, strength, and ease of installation, making it suitable for interior and low-stress construction applications.
440		Plastics, Thermoformed Expanded Polystyrene		**4.39**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Thermoformed expanded polystyrene (EPS) is used in construction for thermal insulation, void filling, and lightweight structural panels.

										2. Properties: It is lightweight, rigid, moisture-resistant, and has good thermal insulation properties. 3. Performance: EPS offers excellent energy efficiency, compressive strength, and durability, making it ideal for insulating walls, roofs, and foundations.
441		Plastics, Polyurethane Flexible Foam		**4.84**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Polyurethane flexible foam is used in construction for cushioning in furniture, acoustic insulation, and sealing gaps. 2. Properties: It is soft, lightweight, resilient, and has good thermal and sound insulation properties. 3. Performance: The foam provides comfort, noise reduction, and energy efficiency, with excellent durability and flexibility for interior applications.
442		Plastics, Polyurethane Rigid Foam		**4.26**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Polyurethane plastic is used as a base component for various commercial applications and building materials. 2. Properties: Polyurethane plastic has high modulus, high tensile strength, and high elongation. 3. Performance: Polyurethane plastic is a resilient, flexible, and durable material.
443		Plastics, PVC General		**3.1**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: PVC is used in construction for pipe and in profile applications such as doors and windows. 2. Properties: PVC tensile stress is approximately 52 MPa. 3. Performance: PVC plastics are lightweight, cost-effective, and durable materials.

444		Plastics, PVC Pipe		**3.23**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: PVC pipes are widely used in water supply, drainage, irrigation, and electrical conduit systems. 2. Properties: They are lightweight, corrosion-resistant, chemically stable, and easy to install. 3. Performance: PVC pipes offer long service life, low maintenance, high pressure resistance, and good flow characteristics.
445		Plastics, Calendered Sheet PVC		**3.19**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Calendered PVC sheets are used in signage, wall coverings, automotive interiors, and flexible packaging. 2. Properties: They are smooth, flexible, chemically resistant, and available in various colours and finishes. 3. Performance: These sheets offer good dimensional stability, durability, printability, and ease of fabrication for various applications.
446		PVC Injection Moulding		**3.3**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: PVC injection moulding is used for fittings, valves, medical components, and electrical housings. 2. Properties: It offers good rigidity, chemical resistance, flame retardancy, and dimensional stability. 3. Performance: PVC provides reliable strength, durability, and precision in moulded parts, with good resistance to heat and impact.
447		UPVC Film		**3.16**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: UPVC film is used in window laminates, surface coatings, labels, and protective films. 2. Properties: It is rigid, UV-resistant, weatherproof, and offers good dimensional stability.

										3. Performance: UPVC film provides excellent durability, low maintenance, and long-term resistance to fading, moisture, and chemicals.
448		Plastics, Resin		**4.39**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Plastics are used in a broad range of building and construction applications, including insulation, piping, window frames, and interior design. 2. Properties: Plastics have low modulus of elasticity and are unsuitable for load-bearing applications. 3. Performance: Plastics have high durability and resistance to corrosion, making them ideal for applications such as window frames and pipes.
449		Plastics, UPVC*		**4.84**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
450		Plastics, Misc		**4.26**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
451		Plastics, Polyamide Nylon		**3.1**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
452		Plastic, Multi-Non-Plastic-Material		**3.23**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
453		Plastic, Multi-Plastic		**3.19**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
454		Plastic, Ethylene Tetrafluoro ethylene		**3.3**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
455		Plastic, Polyethylen e Vinyl Acetate		**3.16**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
456		Plastic, Hanit Mould Recycled		**0.235**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD International (2025)	GLOBAL	GERMANY	The declared products are construction and infrastructure elements made from hanit recycled plastic, used for ground reinforcement, structural landscaping, utility applications, and public space design. The range includes items such as paddock slabs, L-stones, palisades, boards, posts, benches, and technical

										components like biofilter flooring systems and tunnel blocks. These products are designed for long-term outdoor use, offering high durability, resistance to weather, chemicals, and mechanical stress, and are significantly lighter than conventional materials. Typical applications include soil stabilisation, slope retention, path and fence construction, raised beds, drainage systems, cable protection, and segment storage in tunnel construction. All components are made from durable recycled plastic (hanit), enabling low-maintenance, sustainable, and flexible use in agricultural, urban, and industrial environments.
457		Plastic, Wood Plastic Composite (WPC)		**0.396**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD International (2024)	GLOBAL, ASIA	CHINA	Wood plastic composite (WPC) is a decorative material made of wood powder and recycled plastic with extrusion and compression-moulding technologies. Its biggest advantage is turning waste into a resource, and it can be 100 % recycled with technology development. It can also decompose and will not cause “white pollution”, which is beneficial for environmental protection.
458		High Density Polyethylene (HDPE) Pipe		**2.52**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	HDPE pipe is a durable, flexible plastic piping with high chemical and corrosion resistance, widely used for water supply, drainage, and industrial applications.
459		Expanded Polystyrene		**3.29**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	Expanded polystyrene (EPS) is a lightweight, rigid foam made from expanded polystyrene beads, providing thermal insulation, impact resistance, and moisture resistance in construction applications.

460		PVC Pipe		**3.23**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	PVC pipe is durable plastic piping made from polyvinyl chloride, resistant to corrosion and chemicals, and widely used for water supply, drainage, and irrigation systems.
461		ABS		**3.76**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	ABS plastic is a tough, impact-resistant thermoplastic used in piping, fittings, and construction components, offering chemical resistance and dimensional stability.
462	Glass	Glass, General, per kg*		**1.44**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Glass is a transparent, hard material that can be easily moulded into desired shapes. It is produced by the application of heat to sand, so it can be blown, drawn, and pressed to any shape and thus used for general glazing purposes in buildings. 2. Properties: The main characteristics of glass are transparency, heat resistance, pressure and breakage resistance, and chemical resistance. 2.5 kg glass per mm thickness, per m^2.
463		Glass, Glazing, Double, per kg		**1.63**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: A double-glazing unit, also known as an insulated glass unit, consists of two or more panes of glass, separated by a desiccant-filled spacer and sealed with sealant. The main function of double glazing is to improve building occupants' comfort and reduce heating and cooling costs by reducing the flow of heat from the outside to the inside. 2. Properties: Double glazing units incorporating solar control products such as Low-E, Solar Low-E, and reflective glass significantly reduce solar heat gain, provide glare control, reduce air conditioning

										costs, improve noise reduction, and increase security. 2.5 kg glass per mm thickness, per m².
464		Glass, Glazing Triple, per kg		**1.75**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Triple glazing is a window that has three panes of glass separated by argon gas, which means it has an extra layer of glass to insulate a home over double glazing. This extra layer makes it more difficult for heat to escape, allowing the temperature to be maintained more easily. 2. Properties: Outstanding insulation values: Ug to 0.4 W/m²K, reduced heating costs, enhanced living comfort (warm surface, no draughts), optimised solar energy yield, high light transmission for natural light in the living area, and no visual difference to double glazing. 2.5 kg glass per mm thickness, per m².
465		Glass, Toughened, per kg		**1.67**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Toughened glass is a type of safety glass that is prepared to increase the strength of normal glass. The glass undergoes compression and tension through which it breaks down into small pieces. 2. Properties: Toughened glass has high withstanding capacity and is therefore suitable for uses where strength and thermal resistance are crucial. It is nearly four to five times stronger than annealed glass and three times as strong as heat-strengthened glass. Even during breakage, its relatively small pieces reduce the chances of injury. 2.5 kg glass per mm thickness, per m².

466		Glass, Multi Layer Safety, Filled Core, Fire Resistant, Toughened, per kg		**2.08**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Fire-resistant glass is specialist glass that has been proven to provide a period of protection against fire during a fire resistance test. Fire-resistant insulating glazing can be categorised in terms of its performance level (duration of the fire resistance and the method of insulation). 2. Properties: 2.5 kg glass per mm thickness, per m².
467		Glass, Multi Layer Safety, Unfilled, per kg		**1.56**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Laminated glass can both prevent bodily injury and protect the building envelope. Safety glazing incorporating PVB protective interlayers in a properly designed and installed system reduces the risk of injury from broken glass. Upon impact, the glass bonds firmly to the interlayer and remains in place, providing protection from dangerous flying or falling glass fragments. 2. Properties: 2.5 kg glass per mm thickness, per m².
468		Glass, Sky Light or Roof, with Frame, per kg		**3.1**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: A unit installed on a flat roof, or where installed on a pitched roof it is likely to be fitted out of plane with the level of the tiling. 2. Properties: The material choices available for skylights are safety glass, polycarbonate sheets, and FRP (fibre-reinforced polymer) panels. 2.5 kg glass per mm thickness, per m².
469		General Glass		**0.00396**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Glass is primarily applied as a construction material, particularly in the form of float flat glass for windows, façades, and security glass. Its use extends

										across buildings and transport infrastructure where transparency, aesthetics, and durability are required. 2. Properties: The glass consists of about 70 % silicon dioxide, produced from quartz sand and recovered glass with additives such as dolomite, kaolin, limestone, soda, and sodium sulphate. These additives improve melting performance, optimise durability, and enhance optical clarity. The float glass process produces flat, uniform sheets with smooth surfaces and stable mechanical and chemical properties. 3. Performance: Float glass demonstrates high performance in terms of structural stability, weather resistance, and adaptability for architectural and safety applications. The inclusion of recovered glass reduces raw material demand, making the process more resource efficient. With regionalised Malaysian-specific energy modelling, the production balances functionality with environmental considerations, ensuring compliance with building standards while maintaining lifecycle efficiency.
470		Coated Glass		**2.30**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	Coated glass is floating glass with a thin functional coating that improves how it controls light and heat. It is mainly used in building façades, windows, and skylights to reduce solar heat, protect against UV, and improve indoor comfort. Performance is usually measured by visible light transmission, solar heat gain coefficient, and U-value, where higher

										daylight and lower heat gain are preferred in hot climates like Malaysia.
471		Double Glazed Glass		**2.47**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	Double-glazed glass (also called an insulated glass unit, IGU) consists of two pieces of glass separated by an air or gas gap to improve thermal performance. The sealed gap reduces heat transfer and outside noise, making indoor spaces cooler and quieter. It is widely used in façades and windows for energy-efficient buildings, especially where air conditioning is used. Performance is indicated by a lower U-value and better sound insulation, helping to reduce cooling loads and increase comfort in hot climates.
472		Fiberglass		**3.75**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	Fibreglass is a material made from fine glass fibres formed into a strong and lightweight structure. It is commonly used for insulation, roofing components, wall panels, and ceilings because it resists heat, moisture, and corrosion. The fibres trap air, providing good thermal and acoustic insulation, which helps improve energy efficiency and indoor comfort in buildings.
473		Float Glass		**1.29**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	Float glass is standard flat glass produced by floating molten glass on a layer of molten metal to achieve a smooth and uniform surface. It is commonly used for windows, doors, partitions, and as a base glass for further processing such as tempering, laminating, or coating. It provides clear visibility and good strength and is the primary material for most architectural glass applications.
474		Laminated Glass		**1.55**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	Laminated glass is made by bonding two or more glass layers with a plastic interlayer, usually PVB, to hold the glass together if it breaks. It provides

										enhanced safety, security, and sound insulation, making it suitable for façades, skylights, and areas requiring impact resistance. It also offers improved UV protection and can reduce the risk of glass falling during breakage.
475		Skylight Glass		**4.65**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	Skylight glass is glass installed on roofs or overhead structures to bring natural daylight into a building. It is usually made as laminated or insulated glass for safety, heat protection, and weather resistance. Skylight glass helps improve indoor brightness while controlling heat, glare, and UV exposure from direct sunlight.
476		Tempered/ Annealed Glass		**2.98**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	Tempered glass is heat treated to increase its strength and safety, breaking into small blunt pieces rather than sharp shards. It is commonly used for façades, doors, and safety glazing where impact resistance is required.
477		Triple Glazed Glass		**2.51**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	Triple-glazed glass is a window unit consisting of three glass panes separated by insulating gas-filled spaces, offering enhanced thermal insulation, reduced heat loss, improved acoustic performance, and better energy efficiency compared with single or double glazing.
478	Insulation	General Insulation*		**1.86**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	Application: Insulation helps ensure maximum home efficiency by reducing heat flow. The primary purpose of insulation is to help keep a home's interior at the desired temperature while reducing the amount of energy used.
479		Woodwool (Board)		**0.98**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	Application: Insulating with wood wool is an ecological way of insulating, and the material comes from sustainably managed forests and is completely recyclable. Wood wool has a high heat storage capacity, is vapour permeable,

										and has good sound-insulating properties as well.
480		Cork		**0.19**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	Application: Cork insulation, which is much healthier than many other materials, can be used to protect buildings from noise, heat, cold, and excessive vibrations. Not only floors but also ceilings, concrete levelling elements, roofs, and inner and outer walls can be insulated using expanded cork.
481		Fibreglass (Glasswool)		**1.533**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Application: Typically manufactured in two different forms, pre-cut batts and rolls, and blown-in loose-fill, fibreglass building insulation is used primarily for thermal and acoustical purposes in wall cavities, attics, and other critical open spaces in building assemblies.
482		Flax (Insulation)		**1.7**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	Application: Flax insulation is made from flax with a polyester binder and treated for fire resistance. Flax insulation is used in breathing wall construction, ventilated pitched roofs, and in ceilings and floors. Flax is a renewable material.
483		Mineral Wool		**1.25**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Application: Mineral wool is any fibrous material formed by spinning or drawing molten mineral or rock materials such as slag and ceramics. Applications of mineral wool include thermal insulation (as both structural insulation and pipe insulation, though it is not as fire resistant as high-temperature insulation wool), filtration, soundproofing, and hydroponic growth medium.
484		Paper Wool		**0.63**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	Application: Cellulose insulation is made from recycled paper products, primarily newspapers, and has a very high recycled material content. The obtained cellulose fibres have a wool-like structure (therefore paper wool).

485		Polystyrene		**3.69**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Application: Lightweight polystyrene foam provides excellent thermal insulation in numerous applications, such as building walls and roofing, refrigerators and freezers, and industrial cold storage facilities. Polystyrene insulation is inert, durable, and resistant to water damage.
486		Polyisocyanurate (PIR)		**3.089**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Polyisocyanurate (PIR) insulation is used in walls, roofs, and cold storage for thermal insulation in buildings. 2. Properties: It has a closed-cell structure, low thermal conductivity, and high fire resistance. 3. Performance: PIR offers excellent insulation performance, energy efficiency, and dimensional stability, with strong resistance to moisture and heat.
487		Polyurethane Board		**4.532**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Polyurethane board insulation is used in walls, roofs, floors, and refrigeration systems for thermal insulation. 2. Properties: It features a closed-cell structure, low thermal conductivity, and is lightweight yet rigid. 3. Performance: The board provides excellent thermal insulation, energy efficiency, and moisture resistance, with good structural integrity and durability.
488		Polyurethane		**4.26-4.84**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	Application: Polyurethanes are a group of insulation materials based on PUR (polyurethane) or PIR (polyisocyanurate). The closed-cell structure and high crosslinking density give them the characteristics of good heat stability, high compressive strength, and excellent insulation properties.

489		Rockwool		**1.12**	$kgCO_2e/m$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	Application: Rock wool, which is also called mineral wool, comes in easy-to-install batts, similar to fibreglass. Rock-wool insulation can be installed with fibreglass or any other type of insulation in walls, floors, ceilings, attics, and crawlspaces.
490		Warm Edge Spacer, Seal Insulating Glass		**0.022 with a width of 12 mm**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2023) (Singapore)	GLOBAL, ASIA	SINGAPORE	Application: Technoform warm edge spacer is a thermally improved spacer, made of polypropylene and stainless steel, allowing it to substantially reduce heat transfer at the edge of the glass. Benefits of using a warm edge spacer include improving thermal performance at the edge of the glass while maintaining exceptional durability; reducing the risk of condensation at the edge of the glass; reducing building envelope heat gain; lowering electrical consumption and carbon emissions due to cooling and heating; improving indoor comfort; and increasing productivity during the fabrication of insulating glass units.
491		Polyurethane slab		**7.36**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	Uzan (2019)	GLOBAL, EUROPE	SWEDEN	Application: Polyurethane foam is a suitable solution for slab insulation. Unlike wool, the foam preserves its thermal and waterproofing properties for years. Foam is applied evenly, forming a uniform layer that retains heat in the building.
492		Cork slab		**0.81**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	Uzan (2019)	GLOBAL, EUROPE	SWEDEN	Application: Expanded insulation cork sheets are natural, balanced, and high-performance cork products that, with this special type of agglomerated cork, although comparable in terms of insulation properties to polystyrene or mineral wool, do not contain polyurethane or any other fillers or additives.

493		Polyurethane rigid foam		**6.78**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	Uzan (2019)	GLOBAL, EUROPE	SWEDEN	Application: Polyurethane rigid foam, also known as EPU, is a specific type of rigid foam insulation that is generally intended for insulated concrete forms. This allows for insulation for the full lifespan of the structure. It offers an average R-value of 5.9 per inch and is surprisingly durable.
494		Cellulose insulator		**1.83**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	Uzan (2019)	GLOBAL, EUROPE	SWEDEN	Application: Cellulose insulation is plant fibre used in wall and roof cavities to insulate, draught proof, and reduce free noise.
495		Sheep wool		**0.14**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	Uzan (2019)	GLOBAL, EUROPE	SWEDEN	Application: Wool insulation is made from sheep wool fibres that are either mechanically held together or bonded using between 5 % and 20 % recycled polyester adhesive to form insulating batts, rolls, and ropes. Natural wool insulation is effective for both thermal and acoustic insulation.
496		Glass Wool		**0.006759**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	LOCAL/ASIA	MALAYSIA	1. Properties: The material is produced by melting mineral glass at around 1 400 °C, defibrating it in hot airflow, and binding it at about 200 °C. It is available in different forms such as non-laminated felt (apparent density about 22 kg/m³, thickness 180 mm), wall panels (about 14 kg/m³, 60 mm), and hydrophobic insulation boards coated with yellow glass fleece (about 23 kg/m³, 60 mm). For some applications, densities can reach up to 100 kg/m³. 2. Performance: Glass wool provides effective thermal insulation and sound absorption, enhancing building energy efficiency and acoustic comfort. It is lightweight yet durable, with hydrophobic variants that resist moisture. The product is

										versatile for different insulation configurations and complies with cradle-to-gate environmental data quality standards under Malaysian energy and material supply conditions.
497		Mineral Fibre Board		**1.28**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	Mineral fibre board is a lightweight, rigid panel made from mineral fibres, offering excellent fire resistance and thermal and acoustic insulation for ceilings and partitions.
498	Tiles	Ceramic Tile*		**0.796**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Ceramic tile is used from the interior to the exterior of a home, creating a floor flow-through effect. 2. Properties: Water absorption as a mass percentage is >0.5 % to <10 %. Breaking load for tile thickness ≥ 7.5 mm: min. 600–1 300 N; breaking load for tile thickness < 7.5 mm: min. 200–600 N. Bending strength: min. 8–30 N/mm². 3. Performance: Long lifespan, versatility of use, and high resistance to scratches and abrasion.
499		Glazed porcelain tiles		**0.868**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD International	GLOBAL, EUROPE	EUROPE	1. Application: Glazed and unglazed tiles can be used in indoor and outdoor areas. Porcelain tiles are suitable for various domestic applications as well as some commercial ones with light foot traffic. They are also available in glazed forms, but they are less robust in this form. 2. Properties: Extremely low water absorption, no more than 0.05 %; waterproof and highly stain resistant, allowing different visual effects and colours. Porcelain tiles
500		Unglazed porcelain tiles		**0.868**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD International	GLOBAL, EUROPE		
501		Ecologic Porcelain Tiles		**0.632**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD International	GLOBAL, EUROPE		
502		Tech Porcelain Tiles		**0.881**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD International	GLOBAL, EUROPE		

										are manufactured from denser clay and treated at much higher temperatures than non-porcelain ceramic tiles. 3. Performance: More sturdy and resistant to damage than standard ceramic tiles. In contrast to standard ceramic tiles, porcelain tiles can be used outdoors because of their negligible porosity and better resistance to frost and extreme temperatures.
503		Cement Tile*		**1.44**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Cement tiles can be used on floors and walls in the kitchen, living room, foyer, dining room, bathroom, and laundry room; on the kitchen backsplash and underside of the island; on walls to add a unique work of art; on an outdoor patio; and in unique ways to create one-of-a-kind features like tile rugs. 2. Properties: Cement tiles have high thermal mass, acting as excellent insulators. The tiles are extremely porous, and a patina can develop over time to enhance the pattern. They can also be sanded and resealed, like wood floors, if they become discoloured over time. 3. Performance: Cement tiles are extremely versatile and can provide amazing patterns and colours. Cement is best used in low-traffic areas and in small quantities.
504		Marble Tile*		**0.21**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL, EUROPE	UK	1. Application: Marble tiles are a flooring option and are an ideal choice for adding aesthetic value and elegance to a house. 2. Properties & Performance: Marble is a natural and porous material, so

										it is more suitable for indoor use. Marble tiles are prone to stains and spillages because of their porous nature and are therefore hardly used outdoors. Marble is more resistant to cracking and chipping and will not easily give in to impact. As marble tiles are 100 % natural, they require regular maintenance.
505		Granite Tile		**0.146**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	Dong et al. (2010)	GLOBAL	AUSTRALIA	1. Application: Granite tiles are a good option to be installed in areas with heavy foot traffic. They are made from the dense and hard igneous rock, granite. 2. Properties: Granite tiles are highly porous and prone to stains, like marble tiles, but once polished, they perform well with respect to scratch resistance. 3. Performance: The natural and durable material used helps produce a scratch-resistant surface. Apart from being resistant to acids, granite tiles come in light and small forms, making them easy to work with.
506		Limestone Tile		**0.09**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Limestone is a classic architectural material and is suitable for a variety of applications from floors to walls to façades. Stone tiles can be used to create a walkway and bathroom that will significantly increase the property's market value. 2. Properties & Performance: Limestone is valued because of its sophisticated, rugged appearance, and its effect can improve a home's resale value. Because limestone is a naturally porous stone, it is susceptible to water damage; acidic

										products in particular can damage limestone.
507		Quarry Tile		**0.29**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	Uzan (2019)	GLOBAL, EUROPE	SWEDEN	1. Application: Quarry tile is extensively used for floors where a very durable material is required. It can be used either indoors or outdoors, although freeze-resistant grades of tile should be used outdoors in climates where freeze–thaw action occurs. 2. Properties: Quarry tile has exceptionally low absorption rates, as low as 0.5–3 %, and is often left unglazed, leaving a slightly rough texture better suited for high-moisture environments and better equipped to reduce slips and falls. 3. Performance: Hard flooring tile with low porosity that can be used both indoors and outdoors. Quarry tile is a cost-effective product suitable for indoor and outdoor flooring applications.
508		Terrazzo Tiles		**0.12**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Terrazzo can be applied to any interior wall or floor, including kitchens and bathrooms. Terrazzo retains warmth effectively, so it is a great choice for underfloor heating. 2. Properties: Terrazzo tiles are composed of multiple other material types that mainly include marble, granite, quartz, and glass. 3. Performance: The preparation process involves curing, grinding, and polishing. The resultant surface is long lasting, smooth, shiny, and attractive, making it ideal for public buildings. However, it is not the best tile material for installation in homes because of its slippery nature.

509		Slate Tiles		**0.075**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	Dong et al., (2010)	GLOBAL	AUSTRALIA	1. Application: Slate tiles are used not only for flooring but also for wall tiling, backsplashes, stepping stones, roofing, and a variety of other uses. Slate is probably the most common natural stone in general use. 2. Properties & Performance: Slate is an exceptionally durable tile and introduces natural beauty to give a floor a gorgeous look. The material can help keep the room warm, and its high slip resistance ensures a safe flooring option.
510		Vinyl Composite Tiles (VCT)		**3.19**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Vinyl flooring is resilient and sustainable and is a common choice in areas with high traffic. It is a flexible flooring type that comes in two varieties: sheet vinyl flooring and vinyl composite tile (VCT). VCT is known for its sturdiness and is highly preferred in commercial and institutional areas. 2. Properties & Performance: These tiles are easy to install and can be refinished and replaced without much physical effort. They are mostly made of inorganic filler that offers strength to the flooring to last for at least 15–20 years with minimal damage and fading. They also provide excellent noise absorption.
511		Vinyl tile (floor)*		**1.232**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	Dong et al., (2010)	GLOBAL	AUSTRALIA	1. Application: Vinyl flooring is a type of synthetic floor covering made from plastic or polyvinyl chloride. Self-adhesive vinyl is an easy-to-care-for option for bathrooms, kitchens, hallways, and children's rooms.

										2. Properties & Performance: Vinyl flooring is durable, comfortable underfoot, and reduces noise, which can be important for owners with children and pets. Compared with other flooring options, vinyl flooring is more economical, easy to install, and has low maintenance. It also comes in a wide range of colours and patterns to match every décor, including a variety of natural wood grain looks. It is termite proof, provides acoustic insulation, is waterproof, scratch resistant, odour free, suitable for hot/cold weather, easy to clean, anti-slip, impact resistant, stain resistant, and hassle free.
512		Sandstone Tiles		**0.095**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	Dong et al., (2010)	GLOBAL	AUSTRALIA	1. Application: Sandstone is a natural floor covering that is popular for its distinctive style. Homeowners choose sandstone tile especially in high-traffic areas. It is a popular tile for both indoors and outdoors, adding warmth to a room or outdoor space. 2. Properties: It is strong enough to last for decades and is relatively porous, with a water absorption rate of between 1 % and 6 %, which leaves it vulnerable to damage from liquid stains, mould, micro-organisms, and even warping in extreme cases. 3. Performance: Available in various colours, styles, and sizes, sandstone tiles provide a strong earthy appeal wherever they are used.

513		Cork Floor Tile		**0.578**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	Dong et al., (2010)	GLOBAL	AUSTRALIA	1. Application: Cork flooring has many merits, and its popularity has led to cork installation almost everywhere in the home. It provides sound control because it absorbs footfalls and noise. 2. Properties: The flooring material can be solid cork throughout the thickness or laminated around a fibreboard core. 3. Performance: This flooring is not as durable as some other flooring materials and is susceptible to several forms of damage. It provides a soft, cushioned surface, is a good insulator, hypoallergenic, antimicrobial, eco-friendly, and easy to install and maintain.
514		Carpet tile (tufted - 1200g/m^2, polyamine 6.6)		**3.148**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	EPD International	GLOBAL, EUROPE	EUROPE	1. Application: Carpet tiles are popular as a flooring option for commercial environments and other relatively uncomplicated projects. They are available in various shapes and sizes and are an alternative to wall-to-wall carpets. 2. Properties: Tufted carpet tiles with a pile material of solution-dyed polyamide 6.6 with a recycled content of 20 % and a polyester primary backing with recycled content. 3. Performance: Superior comfort, attractive acoustic and thermal qualities, and greater safety compared with hard surface alternatives. The colours and patterns of the carpet can convey a unique ambience.
515		Carpet tiles, nylon (Polyamide		**7.75 (GWP) per sqm**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)			1. Application: Carpet tiles are popular as a flooring option for commercial

		pile weight 300 g/m^2)								environments and other relatively uncomplicated projects.
516		Carpet tiles, nylon (Polyamide, pile weight 500 g/m^2)	.	**10.7 (GWP) per sqm**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)				2. Properties: (i) Surface pile weight 300 g/m² – total weight of this carpet 4 123 g/m²; (ii) surface pile weight 500 g/m² – total weight 4 373 g/m²; (iii) surface pile weight 700 g/m² – total weight 4 623 g/m²; (iv) surface pile weight 900 g/m² – total weight 4 873 g/m²; (v) pile weight 1 100 g/m² – total weight 5 123 g/m². 3. Performance: Easy installation and maintenance, easy replacement, stable and durable, acoustic, with good longevity and the same qualities as wall-to-wall carpet for creating a healthy, comfortable indoor environment. Carpet tiles offer considerable cost and time savings over wall-to-wall carpet, making them an ideal choice for projects on a tight budget or tight timeline.
517		Carpet tiles, nylon (Polyamide), pile weight 700 g/m^2)	.	**13.7 (GWP) per sqm**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)		GLOBAL	UK	
518		Carpet tiles, nylon (Polyamide, pile weight 900 g/m^2)	.	**16.7 (GWP) per sqm**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)				
519		Carpet tiles, nylon (Polyamide, pile weight 1100 g/m^2)	.	**19.7 (GWP) per sqm**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)				
520		Needled carpet tiles (pile material 700-800 g/m² PP, heavy backing bitumen based)		**1.17**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	EPD International	GLOBAL	EUROPE	1. Application: Carpet tiles are popular as a flooring option for commercial environments, such as bars and restaurants, and other relatively uncomplicated projects. They are available in various shapes and sizes and are an alternative to wall-to-wall carpets. Carpet tiles offer endless layout possibilities by allowing mixing and matching of colours, patterns, and textures. 2. Properties: Mass reference (average product) 3.68 kg/m². 3. Performance: Easy installation and maintenance, easy replacement, stable and durable, acoustic, with good longevity and the same qualities as wall-to-wall carpet for

										creating a healthy, comfortable indoor environment. Carpet tiles offer considerable cost and time savings over wall-to-wall carpet, making them an ideal choice for projects on a tight budget or tight timeline.
521		Hardwood Tiles		**0.586**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	Dong et al., (2010)	GLOBAL	AUSTRALIA	1. Application: Hardwood flooring tiles are widely known for increasing the value of homes. 2. Properties & Performance: Installation of hardwood on floors increases the value of the property owing to the non-depreciating value of wooden floors, which can last a lifetime. Hardwood floors are generally easier to care for compared with tile floors, although hardwood is less durable than tile in terms of resilience.
522		Clay Tile		**0.48**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Clay tiles are used in roofing, flooring, and wall cladding in both residential and commercial buildings. 2. Properties: Durable, fire resistant, weatherproof, eco-friendly, and available in various shapes and colours. They have low water absorption and good thermal insulation. 3. Performance: Long lasting (can exceed 50 years), resistant to decay and pests, and maintain their appearance over time with minimal maintenance. Suitable for both hot and cold climates.
523		Concrete Roof Tile*		**0.241**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Concrete tiles are an economical and durable roofing material. 2. Properties: Concrete roof tiles are extremely durable and can last a

										lifetime because concrete has the property of becoming stronger over time. Concrete roof tiles are designed to be walked on and are strong enough to withstand tough weather conditions. Even after heavy rain the weight of the tiles remains the same, as concrete roof tiles are dense and solid. 3. Performance: Just like concrete bridges and the structural elements of buildings, concrete tiles get stronger with age as they continue to harden in the sun. Concrete tiles withstand harsh elements well. The benefits of concrete tiles include colour longevity and flexibility.
524		Mineral Fibre Tile (roofing)		**2.7**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	Uzan (2019)	GLOBAL, EUROPE	SWEDEN	1. Application: Mineral fibre tiles come in a broad range of textures, sizes, and shapes with many different key performance features that make them suitable for use in any space. Mineral fibre tiles are the most common ceiling tile found in most offices, schools, and hospitals. 2. Properties: Mineral fibre tiles are made from a combination of natural, processed, and recycled content. Materials used include recycled newsprint, clay, perlite, starch, and fibreglass, with different quantities of each used depending on the characteristics and performance of the tile. 3. Performance: Mineral fibre tiles offer great value for money. Softer-textured mineral tiles absorb sound easily, while those with a denser composition offer better sound insulation.

525		Roof Tile		**1.63**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Roof tiles are designed mainly to keep out rain and are traditionally made from locally available materials such as terracotta or slate. 2. Properties & Performance: Modern materials such as concrete, metal, and plastic are also used, and some clay tiles have a waterproof glaze. Roof tiles can withstand harsh weather. Clay tiles are lighter and durable, but concrete tiles offer more designs and are cheaper.
526		Ceiling tile*		**1.32**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD International	GLOBAL	UK	1. Application: Products include acoustic ceiling tiles, baffles, islands, and wall applications. They are available with different coatings and facings in a variety of shapes, thicknesses, and densities and positively contribute to a healthy indoor environment. 2. Properties: Gross density 70–175 kg/m^3; sound absorption coefficient (αw) up to 1.00; susceptibility to the growth of harmful micro-organisms, as dampness according to EN 13964: A – not susceptible; thermal conductivity according to EN 13964 0.04 W/(mK); susceptibility to the growth of harmful micro-organisms, through thermal insulation according to EN 13964: A. 3. Performance: The acoustic ceiling tiles, baffles, islands, and wall applications are available with different coatings and facings in a variety of shapes, thicknesses, and densities and positively contribute to a healthy indoor environment.

527		Ceramic Tiles		**0.78**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	Ceramic tiles are durable fired clay tiles used for flooring and wall finishes, offering water resistance, easy maintenance, and aesthetic versatility.
528		Marble Tiles		**0.21**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	Marble tiles are natural stone tiles known for their elegance, durability, and polished finish, commonly used for flooring and wall cladding.
529		Granite Tiles		**0.7**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	Granite tiles are natural stone tiles prized for their strength, scratch resistance, and polished appearance, commonly used for flooring, countertops, and wall cladding.
530		Carpet Tiles		**9.8**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	Carpet tiles are modular textile floor coverings that are easy to install, replace, and maintain, providing comfort, sound absorption, and design flexibility.
531	Paint	General paint*		**2.91**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	Application: Paint is used to decorate, protect, and prolong the life of natural and synthetic materials, and acts as a barrier against environmental conditions.
532		Single coat (assuming 6.66 m^2 coverage per kg)		**0.44**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	Application: One-coat paint is a term used by paint manufacturers for heavy, thick acrylic-latex interior and exterior paint that builds up high.
533		Double coat (assuming 3.33 m^2 coverage per kg)		**0.87**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	Application: Two coats of paint are the minimum that should be applied when painting. Typically, one coat of paint will not give a solid full colour, and a second coat can usually be applied about four times as quickly as the first coat.
534		Triple coat (assuming 2.22 m^2 coverage per kg)		**1.31**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	Application: The tri-coat paint system consists of the following coats: the base coat, the middle coat, and the top clear coat. These separate coats layered on top of one another make this type of paint more difficult to repair but also give it greater depth and durability.

535		Waterborne paint		**2.152**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Application: Waterborne (or latex) paints are composed of synthetic resins and pigments that are kept dispersed in water by surfactants and also contain small amounts of coalescing solvents. Waterborne paints dry by evaporation of the water.
536		Solvent-borne paint		**3.76**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Application: A solvent-borne coating is a liquid protective layer that is primarily composed of organic compounds and applied to a material's surface to prevent corrosion. Solvent-borne coatings are typically more resilient than water-borne coatings during curing.
537		Intumescent paint (for steel work)		**2.31**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	Amoonn (2019)	GLOBAL	UK	Application: Intumescent coating, often referred to as intumescent paint, is one of the easiest and most efficient ways to protect load-bearing elements of buildings against fire. Intumescent coating delays the collapse of the structure by insulating the structural elements that support the building, thus helping achieve required fire resistance levels.
538		Emulsion paint (scouring proof)		**2.3427**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	Application: Emulsion paint consists of tiny polymer particles within which the pigments are trapped. The particles are suspended in water, then as the paint dries the particles fuse together, creating a film of paint on the wall.
539		Alkyd paint, 60% in H_2O		**2.96**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	Application: Waterborne acrylic coatings (also known as acrylic latex coatings) are more environmentally and user-friendly alternatives to solvent-based paints, for example alkyds.
540		Alkyd paint, 60% in solvent		**3.21**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	Application: Solvent-based coatings contain higher levels of organic compounds than water-based coatings. These solvents or compounds facilitate application, drying, and the formation of a durable, regular paint film.

541		Emulsion Paint		**2.6801**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: This emulsion paint is designed for use in the construction industry, primarily as exterior coatings on mineral or wooden surfaces. It serves as a scouring-proof paint suitable for both first coatings and protective finishes. 2. Properties: The paint is formulated as a water-based emulsion consisting of 33 % synthetic resin (acrylate binder), 20 % titanium dioxide as the main pigment, 25 % filler such as limestone and talcum, 17 % water, and additional additives to improve usability and performance. This composition provides durability, opacity, weather resistance, and ease of application. 3. Performance: The dataset reflects cradle-to-gate environmental performance, covering raw material extraction, energy supply, and production in Malaysia. The paint demonstrates good scouring resistance, stable adhesion on surfaces, and suitability under tropical climatic conditions, with an overall life cycle inventory that is representative of Malaysian energy and resource supply chains and shows good methodological consistency, completeness, and technological representativeness.
542		Solventborne		**3.76**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	Solventborne paint is a coating composed of pigments and binders dissolved in organic solvents, offering high durability, excellent adhesion, and resistance to weathering.
543		Waterborne		**2.54**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL, ASIA	SINGAPORE	Waterborne paint is paint in which water is the primary solvent, providing low VOC emissions, easy application, and

										good environmental and indoor air quality performance.
544	Pipe	Acrylonitrile Butadiene Styrene (ABS)		**3.76**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: This type of pipe is used for draining sewage and wastewater from households and is suitable for DWV (drainage and waste) systems. It is not flexible and is a solid pipe type. 2. Properties: Resists mechanical damage, even at low temperatures; performs at an operational temperature up to 140 °F (60 °C); is lightweight (one person can load and unload); and takes less time to rough in than metal DWV materials. 3. Performance: Easier and less expensive to install than metal piping. Features superior flow due to a smooth interior finish; does not rot, rust, corrode, or collect waste; withstands earth loads and shipping (with proper handling).
545		Brass		**2.64**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Brass pipe fittings are typically used for carrying water, chemicals, flammable gases, slurries, and other plumbing substances. Pipe fittings made of brass come in a wide range of shapes and thread sizes to connect, adapt, or control any liquid or gas in pipes. 2. Properties: Brass is an alloy of copper and zinc with high dimensional accuracy, good mechanical properties, easy cutting, excellent thermal conductivity, high strength, and good seawater corrosion resistance. 3. Performance: Strong structure, long service life, reliability, fine finish, and negligible maintenance needs.

546		Copper		**2.71**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Copper pipe is commonly used in the construction industry for water supply lines and refrigerant lines in heating, ventilation, and air-conditioning (HVAC) systems. The majority of copper tube applications are in the residential sector, where they are used to convey potable water in homes and offices; copper tubes are also used in refrigerator industries, firefighting systems, and medical and residential gas supplies. 2. Properties: It is light, strong, and corrosion resistant. 3. Performance: Versatility; variety of applications; wide range of sizes; problem-free performance; long lasting and maintenance free; corrosion resistance; high thermal conductivity; easy to join and install; and based on an abundant resource.
547		HDPE (High Density Polyethyline)		**2.52**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: HDPE pipe is a type of flexible plastic pipe used for fluid and gas transfer and is often used to replace ageing concrete or steel mains pipelines. HDPE pipe is used for applications such as water mains, gas mains, sewer mains, slurry transfer lines, rural irrigation, fire system supply lines, electrical and communications conduit, and stormwater and drainage pipes. 2. Properties: Temperature resistance −20 to 40 °C; non-toxic and tasteless; corrosion resistance; weathering resistance; simple installation; suitable as a water diversion pipe; cost effective.

										3. Performance: The toughness and resistance to chemicals of polyethylene, together with its corrosion resistance and low weight, contribute to its growing use where cost-effective and durable fluid and gas piping systems are required.
548		PVC*		**3.23**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: PVC pipes are used in a wide variety of piping applications, from transportation of drinking water to drainage solutions and advanced fire-sprinkler systems. 2. Properties: Unique combination of properties: safety, durability and cost efficiency, environmental performance, and recyclability. 3. Performance: PVC is not appropriate for hot water. As a low-carbon plastic, PVC pipes require less energy and fewer resources to manufacture. Due to their low weight, less energy is used for transport. PVC pipes last a long time with minimal maintenance and are easily recyclable. The ultra-smooth surface of PVC pipes reduces pumping costs and energy use, and their leak-free fittings eliminate water loss, which benefits both the environment and utility bills.
549		Steel, UO Pipe*		**3.02**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: UO pipe is usually large in diameter. Steel UO pipe is mainly used as line pipe for transporting petroleum and natural gas in large quantities over long distances. System expansion is used on the steel, for example for blast furnace slag and other co-products.

										2. Properties: Wall thickness up to 1.57 inch (40 mm); lengths up to 60 feet (18.3 m). 3. Performance: Strength, toughness, weldability, and corrosion resistance. The long pipes reduce the number of weld joints and inspections necessary on site, leading to faster construction and lower costs.
550		Steel pipe		**2.9**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD International	GLOBAL	EUROPE	1. Application: Steel pipe for water pipelines is used for transporting aqueous media such as wastewater, service water, cooling water, salt water, brines, and possibly drinking water. Steel pipes for oil and gas pipelines are used for conveying and transporting liquid and gaseous products under internal pressure. Steel pipe represents non-coated and coated steel pipes: 1) bare steel pipe (non-coated); 2) polyethylene-coated steel pipe; 3) polyurethane-coated steel pipe; 4) polypropylene-coated steel pipe; 5) fusion-bonded epoxy-coated steel pipe; 6) epoxy-coated steel pipe; 7) concrete-coated steel pipe. 2. Properties: Yield strength [ASTM A370] 235–555 N/mm^2; tensile strength [ASTM A370] 415–625 N/mm^2; elongation [ASTM A370] 15–26 %; hardness [ASTM E110] max. 275 HV10; notched-bar impact value [ASTM A370] 40 Joule; ductility [API RP 5L3] min. 85 %. 3. Performance: The use phase for steel pipe involves maintenance-free and generally durable products.

551		Vitrified clay pipe DN 100 & DN 150		**0.46**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Vitrified clay pipe (VCP) is made from a blend of clay and shale that has been subjected to high temperature to achieve vitrification, resulting in a hard, inert ceramic. VCP is commonly used in gravity sewer collection, drainage, and industrial and commercial applications. 2. Properties: Crushing strength (FN) – BS EN 295: DN100 and DN150 – 22, 28, 34 kN/m; DN200 – class no. 24, 32 kN/m; DN300 – class no. 35, 48 kN/m; DN500 – class no. 48, 60, 80 kN/m. 3. Performance: Long service life and resistance to almost all domestic and industrial sewage, particularly sulphuric acid generated by hydrogen sulphide, a common component of sewage. Only hydrofluoric acid and highly concentrated caustic wastes are known to attack VCP. It is economical to install, operate, and maintain due to the designed jointing system.
552		Vitrified clay pipe DN 200 & DN 300		**0.50**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	
553		Vitrified clay pipe DN 500		**0.55**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	
554	Asphalt	Asphalt General, 3% binder content*		**0.0501**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Asphalt is a mixture of aggregates, binder, and filler used for constructing and maintaining roads, parking areas, railway tracks, ports, airport runways, bicycle lanes, sidewalks, and play and sport areas. 2. Properties: Asphalt, also known as bitumen, is a sticky, black, highly viscous liquid or semi-solid form of petroleum.
555		Asphalt General, 3.5% binder content		**0.0511**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
556		Asphalt General, 4% binder content		**0.0522**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	

557		Asphalt General, 4.5% binder content		**0.0532**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	3. Performance: Asphalt is known for its durability and is often referred to as perpetual pavement because the top surface can be continuously replaced. A higher-designed asphalt content in the mixture can help guard against fatigue cracking.
558		Asphalt General, 5% binder content		**0.0542**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
559		Asphalt General, 5.5% binder content		**0.0553**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
560		Asphalt General, 6% binder content		**0.0563**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
561		Asphalt General, 6.5% binder content		**0.0573**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
562		Asphalt General, 7% binder content		**0.0584**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
563		Asphalt for road, 3% binder content		**0.0604**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
564		Asphalt for road, 3.5% binder content		**0.0615**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
565		Asphalt for road, 4% binder content		**0.0625**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
566		Asphalt for road, 4.5% binder content		**0.0635**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	

567		Asphalt for road, 5% binder content		**0.0646**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
568		Asphalt for road, 5.5% binder content		**0.0656**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
569		Asphalt for road, 6% binder content		**0.067**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
570		Asphalt for road, 6.5% binder content		**0.068**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
571		Asphalt for road, 7% binder content		**0.069**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
572		Mastic asphalt		**0.25**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	AUSTRALIA	1. Application: Mastic asphalt is used in footpath and road applications and for flooring or roof applications. In addition to the asphalt and aggregate, additives such as polymers and anti-stripping agents are added to improve the properties of the final product. 2. Properties: Mastic asphalt is a bituminous design mix containing bitumen, coarse aggregate, fine aggregate, and filler material. 3. Performance: It works as a waterproofing material and is used as a wearing course for a wide range of road and bridge construction works.
573	Bitumen	Bitumen, Straight-run		**0.19**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Straight-run bitumen is a by-product coming from the refinery.

										2. Properties: Bitumen has excellent adhesive qualities provided the conditions are favourable.
574		Polymer modified bitumen (PMB)		**0.33**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Polymer modified bitumen (PMB) is bitumen (asphalt) combined with one or more polymer materials. PMB is suitable for road pavements, particularly to withstand heavy-duty traffic and extreme weather conditions, and is also suitable for use as a sealant in residential roofing applications. 2. Properties: This modification of PMB is to enhance the mechanical properties of the bitumen material.
575		Bitumen emulsion		**0.22**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Bitumen emulsions are a dispersion of bitumen in an aqueous continuous phase, stabilised by the addition of an emulsifier. The emulsifier makes the emulsion stable for transport and storage and allows it to break during use. Bitumen emulsions are suitable for pavement preservation techniques such as chip seal, fog seal, and microsurfacing. 2. Properties: They are used to maintain the surface properties of the road while preserving the structural layers beneath.
576	Copper	Virgin		**3.81**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Copper is used in electrical wiring, roofing, plumbing, cladding, and HVAC systems. 2. Properties: Pure copper is highly conductive (electrically and thermally), corrosion resistant, malleable, and antimicrobial. 3. Performance: It offers excellent durability, long service life, and efficiency in electrical and thermal systems. Copper maintains

										appearance and function with minimal maintenance and is recyclable without losing its properties.
577		Recycled		**0.84**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Recycled copper is used in electrical wiring, plumbing, roofing, and cladding, similar to virgin copper. 2. Properties: It retains key properties of virgin copper—high conductivity, corrosion resistance, and durability—and is environmentally friendly with lower energy use in production. 3. Performance: It performs nearly identically to virgin copper in most construction applications. It is reliable, cost effective, and supports sustainable building practices.
578		Copper Blister		**3.31**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Blister copper (98 % purity) is mainly applied as an intermediate material for electrolytic refining into cathode copper, which is then used in electrical conductors, electronics, construction, transport, and industrial machinery. 2. Properties: Blister copper has a density of 8.92 g/cm^3 and a molar mass of 64 g/mol. It contains about 98 % copper, with the balance being sulphur, oxygen, and trace metals. The dataset models global production routes, including Outokumpu (Chile), ISA smelt (Australia), and Mitsubishi process (Indonesia), with an average transport distance of about 14 600 km to Malaysia. 3. Performance: Blister copper delivers high electrical and thermal

										conductivity after refining, making it essential for efficient energy transmission and durable infrastructure. From a sustainability perspective, its cradle-to-gate production results in notable embodied emissions due to ore mining, smelting, and global shipping, but it also offers long-term recyclability with minimal degradation of material quality, supporting circular economy principles.
579		Copper Domestic		**0.1199**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: This copper is mainly applied in electronics and construction industries, where its high purity ensures reliability in conductors, wiring, and structural components. 2. Properties: The product is 99.999 % pure electrolytic copper, produced through electrolysis and refining processes. It has a density of about 8.92 g/cm^3, offering excellent electrical and thermal conductivity. It is processed into wire, billets, strips, or shaped wires, depending on the intended industrial use. 3. Performance: Under cradle-to-gate boundaries (A1–A3), the dataset quantifies copper production with Malaysian-specific energy and transport conditions. The inventory covers all relevant energy, thermal processes, and emissions, ensuring representativeness. Performance-wise, the material supports high electrical efficiency, corrosion resistance, and durability, making it indispensable for sustainable

										infrastructure and advanced technologies.
580		Copper Import		**0.1302**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Copper imported into Malaysia at 99.999 % purity is primarily applied in the manufacture of copper parts such as pipes, electrical conductors, strips, wires, and billets. These products are essential in the construction, energy, and electronics sectors, where high conductivity and reliability are critical. 2. Properties: The dataset specifies electrolytic copper with 99.999 % purity, produced through electrolysis and global mining supply chains. The material is refined into electrodes, then processed into strips, wires, billets, or shaped components. The copper exhibits excellent electrical and thermal conductivity, high ductility, and corrosion resistance, which underpin its wide range of industrial uses. 3. Performance: From a life cycle perspective, the dataset represents a cradle-to-gate (A1–A3) inventory with country-specific energy and transportation conditions. The foreground system accounts for global ore processing and Malaysian electricity and thermal energy inputs, while the background system incorporates detailed power mix, refinery, and transport modelling. The copper demonstrates reliable performance in high-demand applications but also embodies significant environmental burdens due to the energy-intensive refining and

										transport processes, making it important for LCAs and embodied carbon studies in Malaysia.
581		Copper Pipe		**2.71**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL	SINGAPORE	Copper pipe is durable metal piping used for plumbing, heating, and cooling systems, resistant to corrosion and high temperatures, ensuring long service life.
582		Copper Pipe (Virgin)		**3.81**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	GLOBAL	SINGAPORE	Virgin copper pipe is high-purity, unrecycled copper piping used in plumbing and HVAC systems, offering excellent corrosion resistance, durability, and thermal conductivity.
583		Copper Pipe (Recycled)		**0.84**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	Recycled copper pipe is piping manufactured from recovered copper, providing good corrosion resistance and durability while reducing environmental impact compared with virgin copper.
584	Iron	General		**2.03**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Commonly used in structural frameworks, reinforcement bars (rebar), beams, columns, and gates. 2. Properties: Strong, hard, dense, and ductile; can be cast or forged. Susceptible to corrosion without protective treatment. 3. Performance: Provides high structural strength and load-bearing capacity. Reliable and long lasting when properly maintained or coated to resist rust. Widely available and cost effective.
585	Lime	General		**0.78**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Used in mortar, plaster, whitewash, soil stabilisation, and as a binder in masonry work. 2. Properties: Made from limestone (calcium carbonate), lime is breathable, workable, and sets slowly. It can be hydraulic (sets with water) or non-hydraulic (sets with air).

										3. Performance: Provides good bonding, flexibility, and resistance to cracking. Enhances breathability and durability of walls. Ideal for restoration and eco-friendly construction.
586	Vinyl	Sheet		**2.40**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Used for flooring, wall coverings, and waterproofing layers in residential, commercial, and healthcare buildings. 2. Properties: Made from polyvinyl chloride (PVC); flexible, water resistant, easy to clean, and available in various colours and textures. 3. Performance: Durable, low maintenance, and resistant to moisture, stains, and wear. Offers good aesthetics and comfort underfoot, with a long service life in high-traffic areas.
587		Tiles		**1.74**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Commonly used as flooring in residential, commercial, and institutional buildings. 2. Properties: Made from PVC; durable, lightweight, water resistant, and available in various designs and finishes, including wood and stone looks. 3. Performance: Easy to install and replace; provides good wear resistance, comfort, and sound insulation. Ideal for high-traffic areas due to its resilience and low maintenance needs.
588	Alloying Additive	Ferrochrome		**6.59**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Ferrochrome is primarily applied in the steel industry as an alloying element to produce stainless steel and special steels. Its high chromium content (about 60 %) and carbon level

										enhance corrosion resistance, hardness, and durability in steel products. 2. Properties: The material consists of a high-carbon ferrochrome alloy produced from chromite ore through mining, beneficiation, and smelting in an open electric arc furnace. It contains approximately 60 % chromium and exhibits high hardness, wear resistance, and strong oxidation resistance at elevated temperatures. 3. Performance: From a life cycle perspective, the dataset represents a cradle-to-gate inventory for Malaysia, modelled as a global consumption mix since ferrochrome is not produced domestically but imported. The performance includes environmental considerations, with total embodied carbon calculated at about 6.59 kg CO_2e per kg of ferrochrome under IPCC AR6 GWP100 factors, reflecting emissions from mining, beneficiation, smelting, energy use, and international transport.
589		Ferronickel		**0.302**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Ferronickel (FeNi) is primarily used as a raw material in the production of stainless steel and other specialty alloys, where it provides nickel content that enhances corrosion resistance, durability, and high-temperature strength. 2. Properties: The dataset represents ferronickel with about 32 % nickel content. It is produced from open-cast and underground nickel ore mining, followed by mechanical beneficiation (grinding, flotation,

										magnetic separation) to generate a copper–nickel concentrate. Smelting occurs in an open electric arc furnace, where nickel is separated from copper during matte refining. The process reflects Malaysian energy conditions, using both imported and domestic fuel mixes. 3. Performance: Ferronickel delivers excellent metallurgical performance in alloying, significantly improving corrosion resistance and mechanical stability in stainless steel applications. Its production is energy intensive, but the dataset provides cradle-to-gate inventory information to assess environmental performance, with LCI data confirming good methodological quality and consistency for life cycle and carbon footprint studies.
590	Precious Metal Alloy	Gold Mix		**351.9**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Gold is predominantly used in the manufacture of jewellery, with the remainder serving essential roles in electronics, medicine, and optics due to its excellent conductivity, biocompatibility, and resistance to corrosion. 2. Properties: Gold has a density of 19.32 g/cm^3 and a molar mass of 196.97 g/mol. It is chemically stable, highly malleable, and ductile, making it suitable for intricate designs and precision applications. In industrial contexts, its electrical and thermal conductivity, along with its inertness, enable critical uses in circuit boards, medical implants, and high-performance optical devices.

										3. Performance: The performance of gold is linked to its durability, recyclability, and unique functional properties such as resistance to tarnish and excellent bonding with other metals. From a production standpoint, the dataset covers cradle-to-gate impacts of underground mining and hydrometallurgical leaching using sodium cyanide, with recovery via activated carbon or zinc precipitation. While energy and resource intensive, the dataset provides robust methodological quality for evaluating environmental performance and supporting life cycle assessments.
591	Electronic Solder	Solder Paste SnAg2.6Cu 0.3		**0.545**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Solder paste SnAg2.6Cu0.3 is primarily applied in the electronics industry for assembling printed wiring boards (PWBs), where it serves as the key joining material for surface-mounted components during reflow soldering processes. 2. Properties: The solder paste consists of a metal alloy blend containing 96.1 % tin (Sn), 2.6 % silver (Ag), and 0.3 % copper (Cu), combined with flux and filler materials. The alloy is produced by atomising the metals under vacuum conditions to form fine spherical powders, which are then mixed with rosin-based flux. This composition provides a lead-free alternative with a relatively low melting point, strong metallurgical bonding, and reliable wetting behaviour essential for electronics manufacturing.

										3. Performance: Solder paste SnAg2.6Cu0.3 performs effectively by delivering high mechanical strength and thermal fatigue resistance in solder joints, ensuring long-term durability of electronic assemblies. Its lead-free formulation meets RoHS directives, enhancing environmental compliance. The Malaysian LCI dataset confirms its cradle-to-gate performance under regionalised energy supply conditions, making it suitable for integration into life cycle assessments of electronic products.
592		Solder Paste SnPb34Ag2		**0.4302**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Solder paste SnPb34Ag2 is primarily applied in the electronics industry for assembling printed wiring boards (PWBs), where it is used as a joining material in surface-mount technology to create reliable electrical and mechanical connections during reflow soldering. 2. Properties: This solder paste is composed of 64 % tin (Sn), 34 % lead (Pb), and 2 % silver (Ag), produced by vacuum atomisation of metals into spherical powders and subsequently mixed with rosin-based flux. The alloy provides good wettability, strong metallurgical bonding, and a relatively low melting point, although its lead content categorises it as non-RoHS compliant. The dataset is regionalised for Malaysia, reflecting the country-specific energy mix and supply chain conditions. 3. Performance: Solder paste SnPb34Ag2 performs reliably in

										providing strong and durable solder joints with good thermal and mechanical stability, ensuring long service life of electronic assemblies. However, due to its high lead content, it poses environmental and health concerns, limiting its use under current environmental directives. The Malaysian LCI confirms its cradle-to-gate performance profile, quantifying energy and emission flows under regional conditions, making it suitable for integration into life cycle assessments of electronic products.
593	Non-ferrous Metal	Copper Blister		**3.31**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Blister copper (98 % purity) is mainly applied as an intermediate material for electrolytic refining into cathode copper, which is then used in electrical conductors, electronics, construction, transport, and industrial machinery. 2. Properties: Blister copper has a density of 8.92 g/cm³ and a molar mass of 64 g/mol. It contains about 98 % copper, with the balance being sulphur, oxygen, and trace metals. The dataset models global production routes, including Outokumpu (Chile), ISA smelt (Australia), and Mitsubishi process (Indonesia), with an average transport distance of about 14 600 km to Malaysia. 3. Performance: Blister copper delivers high electrical and thermal conductivity after refining, making it essential for efficient energy transmission and durable infrastructure. From a sustainability

										perspective, its cradle-to-gate production results in notable embodied emissions due to ore mining, smelting, and global shipping, but it also offers long-term recyclability with minimal degradation of material quality, supporting circular economy principles.
594		Copper Domestic		**0.1199**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: This copper is mainly applied in the electronics and construction industries, where its high purity ensures reliability in conductors, wiring, and structural components. 2. Properties: The product is 99.999 % pure electrolytic copper, produced through electrolysis and refining processes. It has a density of about 8.92 g/cm^3, offering excellent electrical and thermal conductivity. It is processed into wire, billets, strips, or shaped wires, depending on the intended industrial use. 3. Performance: Under cradle-to-gate boundaries (A1–A3), the dataset quantifies copper production with Malaysian-specific energy and transport conditions. The inventory covers all relevant energy, thermal processes, and emissions, ensuring representativeness. Performance-wise, the material supports high electrical efficiency, corrosion resistance, and durability, making it indispensable for sustainable infrastructure and advanced technologies.
595		Copper Import		**0.1302**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Copper imported into Malaysia at 99.999 % purity is primarily applied in the manufacture

										of copper parts such as pipes, electrical conductors, strips, wires, and billets. These products are essential in the construction, energy, and electronics sectors, where high conductivity and reliability are critical. 2. Properties: The dataset specifies electrolytic copper with 99.999 % purity, produced through electrolysis and global mining supply chains. The material is refined into electrodes, then processed into strips, wires, billets, or shaped components. The copper exhibits excellent electrical and thermal conductivity, high ductility, and corrosion resistance, which underpin its wide range of industrial uses. 3. Performance: From a life cycle perspective, the dataset represents a cradle-to-gate (A1–A3) inventory with country-specific energy and transportation conditions. The foreground system accounts for global ore processing and Malaysian electricity and thermal energy inputs, while the background system incorporates detailed power mix, refinery, and transport modelling. The copper demonstrates reliable performance in high-demand applications but also embodies significant environmental burdens due to the energy-intensive refining and transport processes, making it important for LCAs and embodied carbon studies in Malaysia.

596		Tin		**0.0223**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (MYLCID)	ASIA, LOCAL	MALAYSIA	1. Application: Tin is widely applied as a solder material in electronics, for tin plating to protect other metals from corrosion, and as an alloying element in bronze, pewter, and other specialty alloys. It is also used in decorative applications such as artwork. 2. Properties: This dataset represents tin produced via dredging of offshore tin sand (about 25 % Sn), followed by beneficiation through electrostatic and magnetic separation, and subsequent smelting at about 1 000 °C using coke as a reducing agent. The refined product achieves a purity of 99.92 % tin metal, with a molar mass of 118.71 g/mol. The process is modelled under Malaysian boundary conditions, including local energy supply chains and import statistics, ensuring regional representativeness. 3. Performance: Tin performs effectively by providing excellent corrosion resistance, good malleability, and low toxicity compared with many other metals, which makes it especially valuable in food-safe coatings, electronic soldering, and alloy production. Its role in solder ensures strong electrical connectivity and mechanical bonding in electronic circuits, while tin plating extends the life of steel products by protecting against rust. From a sustainability perspective, the Malaysian LCI confirms its cradle-to-gate inventory profile, enabling integration into life


cycle assessments for industries
relying on tin as a key input.

EMBODIED CARBON INVENTORY DATA (BUILDING ELEMENTS)

NO	ELEMENTS	TYPES	EMBODIED-CARBON INDICATOR	EMBODIED-CARBON FACTOR	UNIT	BOUNDARY	SOURCE OF EMBODIED CARBON	VALUE USED	COUNTRY OF OWNER	DESCRIPTIONS
1	Footing	Stone		**0.079**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Stone is extracted from natural deposits by quarrying. Stone is mainly used as coarse aggregate in cement concrete. 2. Properties: The density of stone is 1602 kg/m³. 3. Performance: Stone is a highly durable, low-maintenance building material with high thermal mass.
2		Concrete		**0.1034**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Concrete is an important material in construction and is used in many applications. 2. Properties: Total density is generally 2380 kg/m³. 3. Performance: Concrete is inexpensive and widely available. The amount of energy required for concrete production is low compared with steel. Additionally, concrete can withstand high temperatures better than wood and steel.
3		Cement		**0.832**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Cement is suitable for use as a binder. 2. Properties: There are various types of cement used in concrete construction. Each type of cement has its properties, uses, and advantages based on the composition materials used during its manufacture. Cement provides strength to structures, has excellent binding ability, is workable, and has good resistance to moisture. 3. Performance: Cement is a hydraulic binder and a finely ground inorganic material which, when mixed with water, forms a paste that sets and hardens through hydration reactions and processes.
4		44525T-50 Footings		**174**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	EPD International (2025)	GLOBAL	ITALY	1. Ready-mix concrete for footings. 2. Gross density of product: 1820 kg/m³.

5		34527T-50 Footings (Ready Mix Concrete)		**211**	kg CO2 eq./m3	Cradle to gate (Extraction to Manufacturing)	EPD International (2025)	GLOBAL	ITALY	1. Ready-mix concrete for footings. 2. Gross density of product: 1770 kg/m³.
6		Hot Rolled Stainless Steel		**2.3**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD International (2024)	GLOBAL	ITALY	1. Application: Hot-rolled products are used in a wide range of applications in building and construction. Typical uses include load-bearing structures such as heavy transport, bridges and floodgates, building fixings, traffic barriers, and façade components. 2. Properties: Density 7900 kg/m³; Coefficient of thermal expansion 14 × 10^{-6} K^{-1}; Thermal conductivity 19 W/(m·K); Modulus of elasticity 205 GPa; Melting point 1450 °C; Proof strength Rp0.2 200–530 MPa; Tensile strength Rm 450–950 MPa; Elongation A 18–45%; Impact strength KV 40–90 (transverse). 3. Performance: Hot-rolled products are supplied as coil or plate. Hot-rolled stainless steel has excellent durability and strength. A range of sheet and plate widths, lengths, and thicknesses are available to meet various design requirements.
7		Steel Deformed Bars for Concrete Reinforcement		**0.527**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD International (2011)	GLOBAL	ITALY	1. Application: Hot-rolled deformed bars are the most commonly used steel reinforcement for R.C.C. structures. As the name indicates, the reinforcement undergoes hot rolling, leaving surface deformations in the form of ribs. 2. Properties: Adherence and surface geometry fR or fP: – for Ø ≤ 8 mm, fR or fP ≥ 0.035; – for 8 < Ø ≤ 12 mm, fR or fP ≥ 0.040; – for Ø > 12 mm, fR or fP ≥ 0.056. Weldability: Ceq < 0.52. Typical yield stress Cv: 400 ≤ Cv ≤ 600 MPa. Elongation Agt: ≥ 5%. Successful bend and rebend tests. Recycled material content ≥ 98%. Successful strength and oligocyclic strength tests. 3. Performance: These ribs help form a bond with the concrete. The typical yield strength of hot-rolled deformed bars is 60,000 psi.

8		Cold Rolled Stainless Steel		**3.39**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD International (2024)	GLOBAL	ITALY	1. Application: Cold-rolled products are used in a wide range of applications in building and construction. Typical uses include building envelopes, interior cladding and panelling, heating, cooling and ventilation systems, lifts, and elevators. 2. Properties: Density 7900 kg/m³; Coefficient of thermal expansion 14 × 10^{-6} K^{-1}; Thermal conductivity 19 W/(m·K); Modulus of elasticity 205 GPa; Melting point 1450 °C; Proof strength Rp0.2 200–530 MPa; Tensile strength Rm 420–950 MPa; Elongation A 18–45%. 3. Performance: Cold-rolled stainless steel has excellent dimensional tolerances and high surface quality. A range of sheet widths and heights are available to meet various design specifications and requirements. Service life depends on the physical and mechanical service conditions. Correct alloy designation can ensure a required service life.
9		Reinforcing Steel*		**1.99**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2019)	GLOBAL	UK	1. Application: Reinforcing steel bars (rebar) are steel rods used as a tension device in concrete. Typical applications include the construction of buildings, bridges, roads, and other civil works (infrastructure, superstructures, etc.). 2. Properties: Tensile strength (CA25) 30 N/mm²; Weldability (max) 0.55 Ceq; Yield strength (CA25) 250 N/mm²; Yield strength (CA50/AP 500/AH 500) 500 N/mm². 3. Performance: Plain concrete is weak in tension but strong in compression. Tensile properties for concrete structures are achieved by incorporating steel reinforcement, which is strong in both tension and compression. The tensile property provided by the steel reinforcement prevents and minimises concrete cracks under tensile loads. The coefficient of thermal expansion of steel reinforcement and concrete are similar, ensuring minimal stress during temperature

										variations. The patterned surface of reinforcement bars provides a proper bond with the surrounding concrete material.
10		Steel CA60 Rebar, Welded Mesh and Truss		**1.67**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD International (2022)	GLOBAL	AUSTRALIA	1. Application: Steel rebar, short for reinforcing steel, is used for the reinforcement of concrete and is also the material used to produce CA60 rebar, welded mesh, and trusses. Welded mesh offers high resistance and is used in the manufacture of slabs and concrete floors. Trusses are used in prefabricated slab joists, concrete floor slabs, and transfer bar supports for concrete floors. Typical applications include the construction of buildings, bridges, roads, and other civil works (infrastructure, superstructures, etc.). 2. Properties: Density 7850 kg/m^3. 3. Performance: Reinforcing steel CA60 rebar, welded mesh, and trusses are used in concrete to provide additional mechanical resistance. The lifetime of CA60 reinforcing steel, welded mesh, and trusses is therefore limited by the service life of the building.
11		Stainless Steel Reinforcing Bar		**4.99**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD International (2024)	GLOBAL	SPAIN	1. Application: Stainless steel rebar is used as reinforcement in concrete. It replaces ordinary carbon steel rebar where non-magnetic reinforcement is required or as a durability solution for long-life design buildings or structures in aggressive environments (marine or other construction sites exposed to high chloride concentrations). 2. Properties: Density 7900 kg/m^3; Modulus of elasticity 205,000 N/mm^2; Coefficient of thermal expansion $14 \times 10^{-6}\ K^{-1}$; Thermal conductivity 19 $W/(m \cdot K)$; Melting point 1450 °C. 3. Performance: Stainless rebar provides corrosion resistance against both carbonation-induced and chloride-induced corrosion. For carbonation-induced corrosion, the environment is not aggressive, and the

										service life of the reinforced structure can reach up to 1000 years. For chloride-induced corrosion, service life depends on grade selection, which must ensure a critical chloride threshold level (CCTL) higher than the predicted chloride concentration at the rebar depth for the intended design life.
12		Reinforcement Bar*		**0.684**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD International (2021)	GLOBAL	UK	1. Application: This is the most common type of rebar. Rebar is commonly used as a tensioning device in reinforced concrete and reinforced masonry structures, holding the concrete in compression. 2. Properties: Rebar is typically used within concrete to provide improved tensile strength. It is easily bent and formed. 3. Performance: It is extremely versatile but corrodes more easily than other types, making it unsuitable in areas with high humidity or structures frequently exposed to water. Carbon steel rebars are considered the best option for most other construction types.
13		Cold-Rolled Reinforcing Steel and Electrowelded Mesh		**0.772**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD International (2017)	GLOBAL	ITALY	1. Application: Coils: Cold-formed steel, particularly in thin-gauge sheet form, is commonly used in the construction industry for structural or non-structural elements such as columns, beams, joists, studs, floor decking, built-up sections, and other components. Electro-welded wire mesh (WWM) is mainly used to reinforce slabs and retaining or shear walls. 2. Properties: Diameters: 6–12 mm; Weight: 2100–5000 kg. Electrowelded mesh: Diameters 4.5–12 mm; Length 2.00–2.40 m; Width 3–6 m; Weight 9.24–177.70 kg. Typical yield stress: 400 MPa ≤ Cv ≤ 600 MPa; Elongation Agt > 5%; Successful bend and rebend tests; Recycled material content ≥ 97% (Certificate IGQ n. C057 under ISO 14021).

										3. Performance: Key properties of cold-formed steel include lightness in weight, high strength and stiffness, ease of prefabrication and mass production, and fast, simple erection and installation. Other advantages are reduced weather delays, accurate detailing, non-shrinking and non-creeping behaviour at ambient temperatures, no formwork requirement, termite and rot resistance, uniform quality, easy transport and handling, non-combustibility, recyclability, and the potential for enclosed conduit cells within panels and decks.
14		Structural Steel: Sections and Plates		**1.13**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD International (2018)	GLOBAL	GERMANY	1. Application: Structural steels are intended for bolted, welded, or otherwise connected constructions such as buildings, bridges, and other structures, including composite steel and concrete systems. Examples include: • Single-storey buildings (industrial, storage, halls, etc.) • Multi-storey buildings (offices, residential, shops, car parks, high-rise, etc.) • Bridges (railway, road, pedestrian, etc.) • Other structures (power plants, stadiums, convention centres, airports, stations, etc.) 2. Properties: Density 7850 kg/m³; Modulus of elasticity 210,000 N/mm²; Coefficient of thermal expansion $12 \times 10^{-6}\ K^{-1}$; Thermal conductivity at 20 °C: 48 W/(m·K); Melting point up to 1536 °C (depending on alloy composition); Shear modulus 81,000 N/mm². 3. Performance: The chemical composition of structural steel is highly regulated and critically important, as it defines the material's mechanical properties.
15		Rebar		**0.739**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2024)	ASIA	VIETNAM	Steel rebar, or reinforcing bar, is a critical material in reinforced concrete structures, providing tensile strength for buildings, bridges, and infrastructure. VAS Rebars are produced from high-quality

										materials to meet rigorous standards, including TCVN 1651-1:2008, TCVN 1651-2:2018, JIS G 3112:2010, ASTM A615/A615M-20, BS 4449:1997, and CS02:2012. Specifications such as dimensions and mechanical properties vary by grade and size. Rebars are bundled with double wire ties for safe handling, painted on both ends for lot identification, and labelled at both ends with detailed product and origin information.
16		Deformed Bar, Wire Rod, Deformed Bar in Coil		**1.01**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2024)	ASIA	VIETNAM	Deformed bars, wire rods, and deformed bars in coils are widely used in building structures, public construction works, and various industrial structures, providing essential reinforcement and strength for concrete applications.
17		Steel Bar		**2.61**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	EPD Southeast Asia (2024)	ASIA	INDONESIA	Steel bars manufactured by PT Putra Baja Deli, Indonesia, meet AS/NZS 4671:2019, MS 146:2014, SNI 2052:2017, and SS 560:2016 standards, with sizes ranging from 8 mm to 50 mm. Produced from high-quality billet using advanced NCO machinery and a fully automated rolling line with horizontal and vertical configurations, in-line thermo-mechanical processing, high-speed delivery, automatic cooling, packing, tying, and weighing systems. Designed with advanced automation/HMI technology and environmentally friendly water treatment systems. Commonly used in reinforced concrete structures, high-rise buildings, bridges, flyovers, industrial and commercial facilities, foundations, slabs, beams, retaining walls, columns, and pillars.
18		Aggregates and Sand, General UK, Mixture of Land Won, Marine, Secondary and Recycled, Bulk, Loose		**0.007**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Aggregates are the most basic materials used in construction. They form the foundation for roads, bridges, and buildings, comprising over 90% of asphalt pavement and up to 80% of concrete mixes. Aggregates are raw materials produced from natural sources and extracted from pits and quarries, including gravel, crushed stone, and sand.

19		Aggregates and Sand, General, Virgin Mixture of Land Won and Marine, Bulk, Loose		**0.009**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	2. Properties: The density of aggregate ranges around 1600 kg/m³.
20		Aggregates and Sand, from Virgin Land Won Resources, Bulk, Loose		**0.006**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
21		Aggregates and Sand, from Virgin Marine Resources, Bulk, Loose		**0.119**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
22		Aggregates and Sand, from Recycled Resources, No Heat Treatment, Bulk, Loose		**0.063**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
23		Aggregates and Sand, from Recycled Resources, with Heat Treatment, Bulk, Loose		**0.014**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
24		Aggregates and Sand, Expanded Clay, Bulk, Loose		**0.013**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
25		Aggregates, Expanded Foamed Glass, Bulk, Loose		**0.007**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
26		Aggregates and Sand, From Secondary Resources, Bulk, Loose		**0.005**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	

27		Aggregates and Sand, Mixture of Recycled and Secondary Resources, Bulk, Loose		**0.006**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
28		Sand-Lime Brick		**0.15**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	UK	
29		Sand		**0.005**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICM (2019)	GLOBAL	UK	
30		Aggregates		**0.007**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Weighted average of aggregates represents consolidated environmental impact data for various aggregate types, calculated as a weighted average based on production volumes and usage proportions.
31		Limestone		**0.016**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Crushed stone 0/2 (grain size 0/2) is a fine aggregate used in construction applications requiring precise particle grading. Its consistent quality makes it suitable for high-performance mixes in both structural and finishing works.
32		Limestone Fines		**0.016**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Crushed stone 0/2 (grain size 0/2), sourced from Ökobaudat, is a fine aggregate material with uniform grading, ideal for use in various cementitious applications and construction projects.
33		Lime, Hydrated		**0.891**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Fine crushed stone 0/2 (grain size 0/2) is generally used in mortar production. It provides good workability and strength in masonry and plastering applications.
34		Lime, Quicklime		**1.136**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Fine crushed stone 0/2 (grain size 0/2) is generally used in cement production. It contributes to the overall strength, stability, and durability of cement-based products.
35		Aggregates, General, Virgin Mixture of Land Won and Marine, Bulk, Loose		**0.005**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Excludes recycled and secondary aggregates. The model comprises 89% land-won and 11% marine-won aggregates. Consumption statistics are sourced from the British Marine Aggregates Producers Association, a member of the Mineral Products Association (MPA) [Tenth Sustainable

										Development Report for the British Marine Aggregate Industry, Dec 2016]. Marine aggregate consumption is assumed to equal total marine aggregate production, with 68% used in the GB market, 11% exported to the European market, and 21% utilised for beach replenishment or fill.
36		Aggregates, From Virgin Land Won Resources, Bulk, Loose		**0.004**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	
37		Aggregates, from Virgin Marine Resources, Bulk, Loose		**0.009**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Marine-won aggregates are used in a variety of construction applications, including concrete production, road building, and coastal protection works. In the UK, they are also applied for beach replenishment and fill, with significant volumes supplied to both domestic and European markets. Their usage supports infrastructure development, residential and commercial projects, and environmental restoration works in marine and coastal zones.
38		Aggregates, From Recycled Resources, No Heat Treatment, Bulk, Loose		**0.006**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Recycled aggregates (no heat treatment) are sourced from construction and demolition waste, excluding secondary aggregates such as blast furnace slag or bottom ash. They are used in various construction applications, though data variability adds uncertainty to embodied impact assessments.
39		Aggregates, from Recycled Resources, with Heat Treatment, Bulk, Loose		**0.119**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Recycled aggregates (heat treated) originate from construction and demolition waste, excluding secondary aggregates such as blast furnace slag or bottom ash. They are used in construction works where heat treatment enhances material properties, though data variability remains high.
40		Aggregates, Expanded Clay, Bulk, Loose		**0.335**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Expanded clay aggregates, based on ICE Database averages, are lightweight aggregates used in structural and geotechnical applications, providing thermal insulation, low density, and high strength-to-weight performance.
41		Aggregates, Expanded		**0.274**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Expanded foamed glass aggregates, based on ICE Database averages, are lightweight aggregates typically used in civil engineering,

		Foamed Glass, Bulk, Loose								insulation, and drainage applications, offering low density, durability, and resistance to moisture and chemicals.
42		Aggregates, From Secondary Resources, Bulk, Loose		**0.063**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Secondary aggregates include blast furnace slag, bottom ash, road plannings, mining spoil, and other by-products from secondary resources. They are applied in road construction, concrete production, and bulk fill, with composition and data derived from UK regional surveys.
43		Aggregates, Mixture of Recycled and Secondary Resources, Bulk, Loose		**0.014**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	Mixed recycled and secondary aggregates are composed of approximately 33% secondary and 67% recycled materials. They are used in concrete, road base, and general construction, combining the benefits of resource recovery with performance in structural and non-structural applications.
44		Concrete, General		**0.103**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Generic ready-mixed concrete baseline. 2. Properties: From BRMCA/MPA EPD-RMC-20180095-CBG1-EN; indicative recipe ≈200 kg CEM I, 95 kg GGBS, 15 kg fly ash, 1915 kg aggregates, 139 kg water, 1.55 kg admixture per m^3. 3. Performance: Use only as a placeholder. Strongly recommended to switch to a strength-class entry or an actual cement-content record/EPD for accuracy.
45		Concrete, GEN 0 (6/8 MPa)		**0.063**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Very low-strength concrete for kerb bedding/backing and blinding layers. 2. Properties: Assumed mix for class C6/8 (28-day cube 8 MPa; cylinder 6 MPa); low binder content relative to aggregates. 3. Performance: Cradle-to-gate only; confirm project mix ticket. Maintain early curing to avoid dusting and weak surfaces.
46		Concrete, GEN 1 (8/10 MPa)		**0.087**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Mass concrete, mass fill, trench foundations, blinding, strip footing. 2. Properties: Assumed mix for C8/10 with low cement factor; high aggregate proportion; high-workability variants are common.

										3. Performance: Use actual cement content where possible; moisture-retentive curing helps surface integrity.
47		Concrete, GEN 2 (12/15 MPa)		**0.094**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Very low-strength concrete for kerb bedding/backing and blinding layers. 2. Properties: Assumed mix for class C6/8 (28-day cube 8 MPa; cylinder 6 MPa); low binder content relative to aggregates. 3. Performance: Cradle-to-gate only; confirm project mix ticket. Maintain early curing to avoid dusting and weak surfaces.
48		Concrete, GEN 3 (16/20 MPa)		**0.101**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Garage floors and similar ground-bearing slabs. 2. Properties: Assumed mix for C16/20; may include plasticiser; finish and air content tailored to wear and freeze–thaw exposure. 3. Performance: Ensure level control, compaction, and curing; check slip and abrasion requirements when used as the final surface.
49		Concrete, 20/25 MPa		**0.109**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Structural concrete C20/25 for slabs, beams, and foundations. 2. Properties: Assumed strength-class recipe; binder can be CEM I or blended (FA/GGBS/PLC). 3. Performance: Prefer project-specific mix/EPD; coordinate cover and exposure class for durability.
50		Concrete, 25/30 MPa		**0.115**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Structural C25/30, common in foundations and RC frames. 2. Properties: Assumed strength-class design; admixtures used to manage workability and finish. 3. Performance: Align binder and W/C with exposure class; use SCMs if programme allows for lower embodied carbon.
51		Concrete, 28/35 MPa		**0.122**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Structural C28/35 for ground floors and frames. 2. Properties: Assumed mix; may require air entrainment and finishing control for abrasion and freeze–thaw.

										3. Performance: Check exposure class; ensure curing to meet characteristic strength.
52		Concrete, 32/40 MPa		**0.134**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Structural C32/40; in situ floors, walls, superstructure. 2. Properties: Assumed strength-class composition; higher binder intensity than lower grades. 3. Performance: Control temperature rise, shrinkage, and curing to meet strength and deflection targets.
53		Concrete, 35/45 MPa		**0.144**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Structural C35/45 in more demanding RC elements. 2. Properties: Assumed mix with increased binder; admixtures often used for workability without raising W/C. 3. Performance: Confirm reinforcement cover and curing regime to satisfy durability requirements.
54		Concrete, 40/50 MPa		**0.154**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: High-strength C40/50; often for precast or heavily loaded members. 2. Properties: Assumed high-binder recipe; heat of hydration and early-age behaviour require management. 3. Performance: Consider SCMs for heat control and durability; adopt thermal control and robust curing.
55		Concrete, PAV1		**0.122**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Domestic parking and outdoor paving (PAV1). 2. Properties: Assumed paving mix; finish, air content, and jointing tailored to abrasion and freeze–thaw. 3. Performance: Ensure finishing and curing for surface durability; coordinate joint layout and load transfer.
56		Concrete, PAV2		**0.134**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Heavy-duty outdoor paving (higher wheel loads). 2. Properties: Assumed paving mix with higher performance requirements; dowels and joint spacing are key. 3. Performance: Verify jointing, load transfer, and curing to resist scaling and abrasion.

57		Concrete, GEN 0 (6/8 MPa)–with CEM I		**0.065**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Kerb bedding/backing and blinding (GEN 0). 2. Properties: Class C6/8 with CEM I binder; faster early strength; higher clinker content. 3. Performance: Cradle-to-gate only; confirm actual cement content; maintain moisture to avoid dusting.
58		Concrete, GEN 1 (8/10 MPa)–with CEM I		**0.09**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Mass concrete, mass fill, trench foundations, blinding, strip footing. 2. Properties: C8/10 using CEM I; low cement factor but quicker early set than blends. 3. Performance: Use actual mix data where available; manage curing for surface quality.
59		Concrete, GEN 2 (12/15 MPa)–with CEM I		**0.097**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: General foundations and fill to C12/15. 2. Properties: CEM I binder; moderate cement factor; good workability with plasticiser. 3. Performance: Verify curing and finish; control shrinkage cracking in hot or dry weather.
60		Concrete, GEN 3 (16/20 MPa)–with CEM I		**0.104**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Garage floors and similar slabs. 2. Properties: CEM I mix to C16/20; may include fibres or air depending on exposure. 3. Performance: Plan jointing, finishing, and curing aligned with abrasion and slip demands.
61		Concrete, RC 20/25–with CEM I		**0.112**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Reinforced concrete C20/25 (slabs, beams, footings). 2. Properties: CEM I binder; increased binder intensity versus GEN grades; admixtures for placement around reinforcement. 3. Performance: Ensure reinforcement detailing and cover; consider SCM substitution for aggressive exposures.
62		Concrete, RC 25/30–with CEM I		**0.119**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Reinforced foundations and RC elements. 2. Properties: CEM I structural mix to C25/30; control W/C and slump for durability. 3. Performance: Confirm exposure class and admixture selection; maintain curing continuity.

63		Concrete, RC 28/35–with CEM I		**0.126**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Reinforced foundations and ground floors. 2. Properties: CEM I to C28/35; higher binder and admixture control for finish and performance. 3. Performance: Compact well in congested reinforcement and protect against early drying.
64		Concrete, RC 32/40–with CEM I		**0.138**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Structural RC; in situ floors, walls, superstructure. 2. Properties: CEM I mix with elevated binder; temperature rise and shrinkage require attention. 3. Performance: Control temperature and shrinkage; consider SCMs for durability and heat-reduction benefits.
65		Concrete, RC 35/45–with CEM I		**0.148**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: C35/45 structural members. 2. Properties: CEM I; high strength; admixtures for rheology without raising W/C. 3. Performance: Tight cover and curing regimes for durability; manage thermal gradients in thicker sections.
66		Concrete, RC 40/50–with CEM I		**0.159**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: High-strength RC and precast. 2. Properties: CEM I high-binder mix; fast early strength; higher heat of hydration. 3. Performance: Manage early-age cracking and temperature; where feasible, introduce SCMs to moderate heat and CO_2.
67		Concrete, PAV1–with CEM I		**0.126**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Domestic parking and outdoor paving. 2. Properties: CEM I paving mix; air content and finishing adapted to abrasion and freeze–thaw risks. 3. Performance: Finish and curing to abrasion requirements; verify jointing and sub-base quality.
68		Concrete, PAV2–with CEM I		**0.138**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Heavy-duty paving. 2. Properties: CEM I paving mix with higher performance demands; dowel and load-transfer design is critical.

										3. Performance: Ensure proper curing and surface texture to resist scaling and abrasion.
69		Portland Limestone Concrete 14%, GEN 0 (6/8 MPa)		**0.057**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Low-strength works (C6/8) such as bedding and blinding. 2. Properties: Portland limestone cement with about 14% limestone reduces clinker content and CO_2 while maintaining familiar workability. 3. Performance: Early strength can be marginally slower than CEM I; extend curing and stripping where needed.
70		Portland Limestone Concrete 14%, GEN 1 (8/10 MPa)		**0.078**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Mass fill, foundations, blinding. 2. Properties: PLC (about 14% limestone) binder; lower clinker share than CEM I. 3. Performance: Confirm programme tolerates slightly slower early strength gain.
71		Portland Limestone Concrete 14%, GEN 2 (12/15 MPa)		**0.084**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: General foundations (C12/15). 2. Properties: PLC 14% assumed recipe; workable and lower CO_2 intensity versus CEM I. 3. Performance: Ensure curing and moisture retention for target strength and surface quality.
72		Portland Limestone Concrete 14%, GEN 3 (16/20 MPa)		**0.089**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Slabs and garage floors (C16/20). 2. Properties: PLC 14% assumed mix; finishing and air content tuned to surface demands. 3. Performance: Plan curing and finishing consistent with abrasion and slip-resistance requirements.
73		Portland Limestone Concrete 14%, RC 20/25		**0.096**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Reinforced concrete C20/25 for beams, slabs, and foundations. 2. Properties: PLC 14% binder reduces clinker and embodied carbon while retaining mainstream mix practice. 3. Performance: Confirm compliance with durability class; observe cover, W/C, compaction, and curing for service life.
74		Portland Limestone		**0.102**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Reinforced foundations and RC members (C25/30).

		Concrete 14%, RC 25/30								2. Properties: Portland limestone cement with about 14% limestone lowers clinker and carbon versus CEM I; assumed strength-class mix. 3. Performance: Expect slightly slower early strength than CEM I; verify cover, water–cement ratio, and curing for durability.
75		Portland Limestone Concrete 14%, RC 28/35		**0.108**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Reinforced foundations and ground floors (C28/35). 2. Properties: PLC 14% binder; assumed strength-class composition with admixtures as needed. 3. Performance: Plan curing and compaction to meet characteristic strength and abrasion requirements.
76		Portland Limestone Concrete 14%, RC 32/40		**0.119**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Structural in-situ floors, walls, and superstructure (C32/40). 2. Properties: PLC 14% binder reduces clinker share; higher binder intensity than lower grades. 3. Performance: Control temperature rise, shrinkage, and curing to achieve target strength.
77		Portland Limestone Concrete 14%, RC 35/45		**0.13**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Structural C35/45. 2. Properties: PLC 14% binder with assumed strength-class mix; admixtures for workability without raising water–cement ratio. 3. Performance: Confirm durability class and cover; manage thermal gradients in thicker pours.
78		Portland Limestone Concrete 14%, RC 40/50		**0.141**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: High-strength structural and precast members (C40/50). 2. Properties: PLC 14% high-binder mix; early strength may be slower than CEM I. 3. Performance: Use thermal control and robust curing; verify stripping times with site trials.
79		Portland Limestone Concrete 14%, PAV1		**0.108**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Domestic parking and outdoor paving. 2. Properties: PLC 14% paving mix; air content and finish tuned for abrasion and freeze–thaw.

										3. Performance: Ensure finishing quality, curing, and joint layout for service life.
80		Portland Limestone Concrete 14%, PAV2		**0.119**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Heavy-duty paving with higher wheel loads. 2. Properties: PLC 14% paving mix with higher performance demands; dowel and load-transfer design are critical. 3. Performance: Verify jointing, base quality, surface texture, and curing to resist scaling and abrasion.
81		Natural Pozzolanic Ash 35%, GEN 0 (6/8 MPa)		**0.052**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: C6/8 bedding, backing, and blinding. 2. Properties: About 35% natural pozzolanic ash replaces cement; assumed GEN 0 recipe. 3. Performance: Pozzolanic reactions improve long-term durability; early strength develops more slowly, so extend curing and protect surfaces.
82		Concrete with 35% Natural Pozzolanic Ash GEN 1 (8/10 MPa)		**0.07**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Mass fill and foundations (C8/10). 2. Properties: About 35% natural pozzolanic ash; low cement factor; high aggregate proportion. 3. Performance: Account for slower early strength; maintain moisture-retentive curing.
83		Concrete with 35% Natural Pozzolanic Ash GEN 2 (12/15 MPa)		**0.075**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: General foundations and fills (C12/15). 2. Properties: Assumed recipe with 35% pozzolanic ash replacing cement. 3. Performance: Verify batching, compaction, and curing to achieve target strengths.
84		Concrete with 35% Natural Pozzolanic Ash GEN 3 (16/20 MPa)		**0.081**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Garage slabs and ground-bearing slabs (C16/20). 2. Properties: Assumed GEN 3 mix with 35% natural pozzolanic ash. 3. Performance: Plan finishing and extended curing periods to manage slower early strength.
85		Concrete with 35% Natural Pozzolanic Ash		**0.087**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Reinforced concrete C20/25 for slabs, beams, and foundations.

		RC 20/25								2. Properties: 35% pozzolanic ash reduces clinker and carbon; assumed strength-class composition. 3. Performance: Coordinate cover and exposure class; allow for longer curing and stripping.
86		Concrete with 35% Natural Pozzolanic Ash RC 25/30		**0.092**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Reinforced foundations and RC members (C25/30). 2. Properties: Around 35% pozzolanic ash; admixtures as needed for workability. 3. Performance: Monitor early-age strength and adjust programme as required.
87		Concrete with 35% Natural Pozzolanic Ash RC 28/35		**0.098**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: RC foundations and ground floors (C28/35). 2. Properties: Strength-class recipe with 35% pozzolanic ash. 3. Performance: Ensure compaction around reinforcement and maintain curing continuity.
88		Concrete with 35% Natural Pozzolanic Ash RC 32/40		**0.108**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Structural in-situ floors, walls, and superstructure (C32/40). 2. Properties: 35% pozzolanic ash; higher binder intensity than lower grades. 3. Performance: Control temperature rise and shrinkage; plan extended curing.
89		Concrete with 35% Natural Pozzolanic Ash RC 35/45		**0.115**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Structural C35/45. 2. Properties: Assumed mix with 35% pozzolanic ash; admixtures for placement around congested steel. 3. Performance: Manage thermal gradients; confirm durability class and cover.
90		Concrete with 35% Natural Pozzolanic Ash RC 40/50		**0.122**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: High-strength RC and precast (C40/50). 2. Properties: High-binder mix with 35% pozzolanic ash; early strength slower than CEM I. 3. Performance: Use thermal control; confirm stripping times via site trials.
91		Concrete with 35% Natural Pozzolanic Ash PAV1		**0.098**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Domestic parking and outdoor paving. 2. Properties: Paving mix with 35% pozzolanic ash; adjust air content and finish for abrasion and freeze–thaw.

										3. Performance: Ensure curing, jointing, and sub-base preparation.
92		Concrete with 35% Natural Pozzolanic Ash PAV2		**0.108**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Heavy-duty paving. 2. Properties: Paving mix with 35% pozzolanic ash; higher performance demands for load transfer. 3. Performance: Verify jointing and dowel design; maintain moisture-retentive curing.
93		Fly Ash 15%–GEN 0 (6/8 MPa)		**0.059**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: C6/8 bedding, backing, and blinding. 2. Properties: About 15% fly ash replaces cement; low binder, high aggregate proportion. 3. Performance: Expect slower early strength; plan curing to avoid weak surfaces.
94		Fly Ash 30%–GEN 0 (6/8 MPa)		**0.053**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: C6/8 bedding, backing, and blinding. 2. Properties: About 15% fly ash replaces cement; low binder, high aggregate proportion. 3. Performance: Expect slower early strength; plan curing to avoid weak surfaces.
95		Fly Ash 40%–GEN 0 (6/8 MPa)		**0.049**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: C6/8 bedding, backing, and blinding. 2. Properties: About 40% fly ash; lowest clinker among these FA options. 3. Performance: Longest early strength development; plan conservative stripping times.
96		Fly Ash 15%–GEN 1 (8/10 MPa)		**0.082**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Mass fill and trench foundations (C8/10). 2. Properties: About 15% fly ash; low cement factor. 3. Performance: Maintain moisture-retentive curing for surface integrity.
97		Fly Ash 30%–GEN 1 (8/10 MPa)		**0.073**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Mass fill and trench foundations (C8/10). 2. Properties: About 30% fly ash replacement; improves long-term durability. 3. Performance: Expect slower early strength; adjust programme accordingly.

98		Fly Ash 40%–GEN 1 (8/10 MPa)		**0.066**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Mass fill and trench foundations (C8/10). 2. Properties: About 40% fly ash; lowest clinker among these GEN 1 options. 3. Performance: Extend curing and stripping; protect against early-age drying.
99		Fly Ash 15%–GEN 2 (12/15 MPa)		**0.089**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: General foundations and fills (C12/15). 2. Properties: About 15% fly ash in an assumed GEN 2 mix. 3. Performance: Verify batching, compaction, and curing to meet design strength.
100		Fly Ash 30%–GEN 2 (12/15 MPa)		**0.079**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: General foundations and fills (C12/15). 2. Properties: About 30% fly ash; reduces clinker and carbon. 3. Performance: Longer early-age strength development; plan for extended curing.
101		Fly Ash 40%–GEN 2 (12/15 MPa)		**0.07**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: General foundations and fills (C12/15). 2. Properties: About 40% fly ash; highest SCM level among these GEN 2 options. 3. Performance: Use conservative strip times; maintain moisture to avoid plastic shrinkage.
102		Fly Ash 15%–GEN 3 (16/20 MPa)		**0.095**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Garage slabs and ground floors (C16/20). 2. Properties: About 15% fly ash in a GEN 3 mix; finish and air content tuned to surface demands. 3. Performance: Ensure compaction, finishing, and curing to achieve abrasion and slip requirements.
103		Fly Ash 30%–GEN 3 (16/20 MPa)		**0.085**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Garage slabs and ground floors (C16/20). 2. Properties: About 30% fly ash; lowers clinker and carbon versus 15% option. 3. Performance: Early strength gain slower; plan finishing and curing windows accordingly.
104		Fly Ash 40%–GEN 3 (16/20 MPa)		**0.075**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Garage slabs and ground floors (C16/20).

										2. Properties: About 40% fly ash replacement; lowest clinker among these GEN 3 options. 3. Performance: Slowest early strength; plan conservative finishing and stripping windows; maintain moisture-retentive curing.
105		Fly Ash 15%–RC 20/25		**0.103**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Reinforced concrete C20/25 for slabs, beams, and foundations. 2. Properties: Around 15% fly ash; improves workability and long-term durability versus neat CEM I. 3. Performance: Early strength gain slower; verify cover, water–cement ratio, and curing for durability.
106		Fly Ash 30%–RC 20/25		**0.091**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Reinforced C20/25 elements. 2. Properties: About 30% fly ash; reduced clinker and embodied carbon. 3. Performance: Allow longer curing and conservative formwork striking.
107		Fly Ash 40%–RC 20/25		**0.081**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Reinforced C20/25 elements. 2. Properties: About 40% fly ash; highest SCM level among these C20/25 options. 3. Performance: Longest early-age strength development; protect against early drying and thermal cracking.
108		Fly Ash 15%–RC 25/30		**0.109**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Reinforced foundations and RC members (C25/30). 2. Properties: About 15% fly ash with assumed strength-class composition. 3. Performance: Confirm exposure class, admixtures, and curing for target performance.
109		Fly Ash 30%–RC 25/30		**0.097**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: RC members and footings (C25/30). 2. Properties: About 30% fly ash; lower clinker and CO_2 than 15% option. 3. Performance: Expect slower early strength; plan formwork and stripping accordingly.
110		Fly Ash 40%–RC 25/30		**0.086**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: RC members and footings (C25/30). 2. Properties: About 40% fly ash; highest SCM content here.

										3. Performance: Use robust curing; extend strip times; monitor temperature and shrinkage.
111		Fly Ash 15%–RC 28/35		**0.116**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: RC foundations and ground floors (C28/35). 2. Properties: About 15% fly ash; workability improved with plasticiser. 3. Performance: Maintain compaction around congested reinforcement; ensure curing continuity.
112		Fly Ash 30%–RC 28/35		**0.104**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: RC foundations and floors (C28/35). 2. Properties: About 30% fly ash; reduces clinker and CO_2 while supporting durability. 3. Performance: Plan for slower early strength; adjust programme and curing.
113		Fly Ash 40%–RC 28/35		**0.091**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: RC foundations and floors (C28/35). 2. Properties: About 40% fly ash; highest SCM fraction for this class. 3. Performance: Longest early-age development; use moisture-retentive coverings and conservative strip times.
114		Fly Ash 15%–RC 32/40		**0.128**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Structural in-situ floors, walls, and superstructure (C32/40). 2. Properties: About 15% fly ash in a higher-strength recipe. 3. Performance: Control temperature rise and shrinkage; ensure curing to reach characteristic strength.
115		Fly Ash 30%–RC 32/40		**0.116**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Structural RC (C32/40). 2. Properties: About 30% fly ash; lowers heat of hydration versus neat CEM I. 3. Performance: Plan extended curing and measured formwork turnover.
116		Fly Ash 40%–RC 32/40		**0.101**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Structural RC (C32/40). 2. Properties: About 40% fly ash; highest SCM fraction here. 3. Performance: Manage early-age strength expectations; protect against plastic shrinkage and thermal gradients.

117		Fly Ash 15%–RC 35/45		**0.137**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Higher-strength RC members (C35/45). 2. Properties: About 15% fly ash with high-binder content. 3. Performance: Tighten curing and cover control; consider temperature monitoring on thicker pours.
118		Fly Ash 30%–RC 35/45		**0.123**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Higher-strength RC members (C35/45). 2. Properties: About 30% fly ash; reduces clinker and peak hydration temperature. 3. Performance: Allow for slower early strength and longer curing.
119		Fly Ash 40%–RC 35/45		**0.107**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Higher-strength RC members (C35/45). 2. Properties: About 40% fly ash; highest SCM fraction. 3. Performance: Conservative programme for stripping; robust curing to control cracking.
120		Fly Ash 15%–RC 40/50		**0.147**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: High-strength RC and precast (C40/50). 2. Properties: About 15% fly ash in a high-binder mix. 3. Performance: Use thermal control plans; confirm demould times with site trials.
121		Fly Ash 30%–RC 40/50		**0.131**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: High-strength RC and precast (C40/50). 2. Properties: About 30% fly ash; reduces clinker and heat of hydration. 3. Performance: Longer early-age timeline; maintain curing and temperature monitoring.
122		Fly Ash 40%–RC 40/50		**0.114**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: High-strength RC and precast (C40/50). 2. Properties: About 40% fly ash; highest SCM fraction with largest early-strength slowdown. 3. Performance: Plan conservative stripping; protect against early-age thermal and shrinkage cracking.
123		Fly Ash 15%–PAV1		**0.116**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Domestic parking and outdoor paving.

										2. Properties: PAV1 paving mix with about 15% fly ash; air content and finish tailored to abrasion and freeze–thaw. 3. Performance: Ensure finishing, curing, and jointing for surface durability.
124		Fly Ash 30%–PAV1		**0.104**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Domestic parking and outdoor paving. 2. Properties: About 30% fly ash; lowers clinker and improves long-term durability. 3. Performance: Maintain moisture-retentive curing; verify surface texture and slip requirements.
125		Fly Ash 40%–PAV1		**0.091**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Domestic parking and outdoor paving. 2. Properties: About 40% fly ash; highest SCM fraction here. 3. Performance: Expect slower early strength; plan finishing and opening to traffic accordingly.
126		Fly Ash 15%–PAV2		**0.129**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Heavy-duty paving with higher wheel loads. 2. Properties: PAV2 paving mix with about 15% fly ash; dowel and joint spacing are critical. 3. Performance: Verify jointing, load transfer, surface texture, and curing to resist scaling and abrasion.
127		Fly Ash 30%–PAV2		**0.116**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Heavy-duty paving. 2. Properties: About 30% fly ash; reduces clinker and CO_2 while supporting durability. 3. Performance: Use robust curing and quality sub-base preparation for long service life.
128		Fly Ash 40%–PAV2		**0.101**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Heavy-duty paving. 2. Properties: About 40% fly ash; highest SCM fraction with the most conservative early-age schedule. 3. Performance: Maintain moisture-retentive curing and confirm load-transfer design.
129		GGBS 25%–GEN 0 (6/8 MPa)		**0.052**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: C6/8 bedding, backing, and blinding.

										2. Properties: About 25% ground granulated blastfurnace slag replaces cement; improves durability and reduces heat. 3. Performance: Early strength slower than CEM I; maintain curing for surface quality.
130		GGBS 50%–GEN 0 (6/8 MPa)		**0.039**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: C6/8 bedding, backing, and blinding. 2. Properties: About 50% GGBS; significant clinker reduction and lower CO_2. 3. Performance: Longer early-age strength development; plan conservative strip times.
131		GGBS 70%–GEN 0 (6/8 MPa)		**0.034**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: C6/8 bedding, backing, and blinding. 2. Properties: About 70% GGBS; very low clinker share and heat of hydration. 3. Performance: Slowest early strength of the three; extend curing and protect against early drying.
132		GGBS 25%–GEN 1 (8/10 MPa)		**0.069**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Mass fill and trench foundations (C8/10). 2. Properties: About 25% GGBS; improves sulphate and chloride resistance long term. 3. Performance: Expect slower early strength; maintain moisture and plan formwork removal accordingly.
133		GGBS 50%–GEN 1 (8/10 MPa)		**0.051**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Mass fill and trench foundations (C8/10). 2. Properties: About 50% GGBS; further clinker reduction versus 25%. 3. Performance: Longer early-age development; keep curing continuous and adjust programme.
134		GGBS 70%–GEN 1 (8/10 MPa)		**0.044**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Mass fill and trench foundations (C8/10). 2. Properties: About 70% ground granulated blastfurnace slag replaces cement; very low clinker and heat of hydration. 3. Performance: Slow early strength; maintain moisture-retentive curing and plan conservative strip times.

135		GGBS 25%–GEN 2 (12/15 MPa)		**0.076**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: General foundations and fills (C12/15). 2. Properties: About 25% GGBS; improves durability and lowers peak hydration temperature. 3. Performance: Early strength slower than neat CEM I; ensure compaction and curing continuity.
136		GGBS 50%–GEN 2 (12/15 MPa)		**0.056**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: General foundations and fills (C12/15). 2. Properties: About 50% GGBS; substantial clinker reduction and CO_2 savings. 3. Performance: Plan for slower early strength; adjust programme and formwork removal.
137		GGBS 70%–GEN 2 (12/15 MPa)		**0.047**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: General foundations and fills (C12/15). 2. Properties: About 70% GGBS; very low clinker and heat of hydration. 3. Performance: Longest early-age development; use robust moisture curing and conservative stripping.
138		GGBS 25%–GEN 3 (16/20 MPa)		**0.082**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Garage slabs and ground floors (C16/20). 2. Properties: About 25% GGBS; supports durability with moderate clinker reduction. 3. Performance: Manage finishing windows; maintain curing to achieve abrasion and slip requirements.
139		GGBS 50%–GEN 3 (16/20 MPa)		**0.06**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Garage slabs and ground floors (C16/20). 2. Properties: About 50% GGBS; lower heat of hydration and CO_2. 3. Performance: Early strength slower than 25%; plan conservative opening to traffic.
140		GGBS 70%–GEN 3 (16/20 MPa)		**0.05**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Garage slabs and ground floors (C16/20). 2. Properties: About 70% GGBS; highest SCM fraction here; very low heat of hydration. 3. Performance: Slowest early strength; maintain moisture and extend stripping and finishing windows.

141		GGBS 25%–RC 20/25		**0.088**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Reinforced concrete C20/25 for slabs, beams, and foundations. 2. Properties: About 25% GGBS; improves chloride and sulphate resistance. 3. Performance: Ensure cover, water–cement ratio, and curing for durability.
142		GGBS 50%–RC 20/25		**0.065**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Reinforced C20/25 elements. 2. Properties: About 50% GGBS; large clinker reduction and CO_2 savings. 3. Performance: Allow longer curing and conservative formwork striking.
143		GGBS 70%–RC 20/25		**0.053**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Reinforced C20/25 elements. 2. Properties: About 70% GGBS; very low clinker and heat of hydration. 3. Performance: Plan extended curing and stripping; protect against early-age drying.
144		GGBS 25%–RC 25/30		**0.094**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Reinforced foundations and RC members (C25/30). 2. Properties: About 25% GGBS; supports workability with plasticiser. 3. Performance: Confirm exposure class and curing regime.
145		GGBS 50%–RC 25/30		**0.069**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: RC members and footings (C25/30). 2. Properties: About 50% GGBS; lowers clinker and peak hydration temperature. 3. Performance: Expect slower early strength; adjust programme accordingly.
146		GGBS 70%–RC 25/30		**0.056**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: RC members and footings (C25/30). 2. Properties: About 70% GGBS; highest SCM fraction here. 3. Performance: Use robust curing; extend strip times; monitor temperature and shrinkage.
147		GGBS 25%–RC 28/35		**0.101**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: RC foundations and ground floors (C28/35). 2. Properties: About 25% GGBS; improves durability and surface finish with proper curing. 3. Performance: Ensure compaction around reinforcement and maintain curing continuity.

148		GGBS 50%–RC 28/35		**0.075**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: RC foundations and floors (C28/35). 2. Properties: About 50% GGBS; reduces clinker and CO_2 while supporting durability. 3. Performance: Plan for slower early strength; adjust programme and curing.
149		GGBS 70%–RC 28/35		**0.059**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: RC foundations and floors (C28/35). 2. Properties: About 70% GGBS; very low heat of hydration; aids mass pours. 3. Performance: Longest early-age development; use moisture-retentive coverings and conservative strip times.
150		GGBS 25%–RC 32/40		**0.113**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Structural in-situ floors, walls, and superstructure (C32/40). 2. Properties: About 25% GGBS in a higher-strength recipe. 3. Performance: Control temperature rise and shrinkage; ensure curing to reach characteristic strength.
151		GGBS 50%–RC 32/40		**0.085**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Structural RC (C32/40). 2. Properties: About 50% GGBS; lowers heat of hydration versus neat CEM I. 3. Performance: Plan extended curing and measured formwork turnover.
152		GGBS 70%–RC 32/40		**0.064**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Structural RC (C32/40). 2. Properties: About 70% GGBS; highest SCM fraction here. 3. Performance: Manage early-age strength expectations; protect against plastic shrinkage and thermal gradients.
153		GGBS 25%–RC 35/45		**0.121**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Higher-strength RC members (C35/45). 2. Properties: About 25% GGBS with high-binder content. 3. Performance: Tighten curing and cover control; consider temperature monitoring on thicker pours.
154		GGBS 50%–RC 35/45		**0.092**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Higher-strength RC members (C35/45).

										2. Properties: About 50% GGBS; reduces clinker and peak hydration temperature. 3. Performance: Allow for slower early strength and longer curing.
155		GGBS 70%–RC 35/45		**0.068**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Higher-strength RC members (C35/45). 2. Properties: About 70% GGBS; highest SCM fraction. 3. Performance: Conservative programme for stripping; robust curing to control cracking.
156		GGBS 25%–RC 40/50		**0.13**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: High-strength RC and precast (C40/50). 2. Properties: About 25% GGBS in a high-binder mix. 3. Performance: Use thermal control plans; confirm demould times with site trials.
157		GGBS 50%–RC 40/50		**0.098**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: High-strength RC and precast (C40/50). 2. Properties: About 50% GGBS; reduces clinker and heat of hydration. 3. Performance: Longer early-age timeline; maintain curing and temperature monitoring.
158		GGBS 70%–RC 40/50		**0.072**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: High-strength RC and precast (C40/50). 2. Properties: About 70% GGBS; highest SCM fraction with largest early-strength slowdown. 3. Performance: Plan conservative stripping; protect against early-age thermal and shrinkage cracking.
159		GGBS 25%–PAV1		**0.101**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Domestic parking and outdoor paving. 2. Properties: PAV1 paving mix with about 25% GGBS; air content and finish tailored to abrasion and freeze–thaw. 3. Performance: Ensure finishing, curing, and jointing for surface durability.
160		GGBS 50%–PAV1		**0.075**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Domestic parking and outdoor paving. 2. Properties: About 50% GGBS; lowers clinker and improves long-term durability.

										3. Performance: Maintain moisture-retentive curing; verify surface texture and slip requirements.
161		GGBS 70%–PAV1		**0.059**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Domestic parking and outdoor paving. 2. Properties: About 70% GGBS; highest SCM fraction here. 3. Performance: Expect slower early strength; plan finishing and opening to traffic accordingly.
162		GGBS 25%–PAV2		**0.113**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Heavy-duty paving with higher wheel loads. 2. Properties: PAV2 paving mix with about 25% GGBS; dowel and joint spacing are critical. 3. Performance: Verify jointing, load transfer, surface texture, and curing to resist scaling and abrasion.
163		GGBS 50%–PAV2		**0.085**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Heavy-duty paving. 2. Properties: About 50% GGBS; reduces clinker and CO_2 while supporting durability. 3. Performance: Use robust curing and quality sub-base preparation for long service life.
164		GGBS 70%–PAV2		**0.064**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Heavy-duty paving with higher wheel loads. 2. Properties: About 70% GGBS; highest SCM fraction for PAV2, with very low clinker and heat of hydration. 3. Performance: Slowest early strength among PAV2 options; maintain moisture-retentive curing and confirm load-transfer design.
165		In-situ, 1:1:2 (Cement:Sand:Aggregate)–with CEM I		**0.193**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: High-strength concrete for heavy-duty structural elements. 2. Properties: Nominal volume proportions 1:1:2; CEM I binder with typical UK cementitious additions; high binder intensity. 3. Performance: Verify actual cement content and water–cement ratio; prefer project mix or cement-content tables for accuracy.
166		In-situ, 1:1.5:3–with CEM I		**0.144**	kgCO_2e/kg	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Floor slabs, columns, and load-bearing structure.

										2. Properties: Nominal volume mix 1:1.5:3 using CEM I; balanced binder-to-aggregate ratio. 3. Performance: Confirm W/C, placement, and curing; use project-specific mix where available.
167		In-situ, 1:2:4–with CEM I		**0.116**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: General structural concrete, buildings up to about three storeys. 2. Properties: Nominal volume mix 1:2:4 with CEM I; widespread, easy to batch. 3. Performance: Strength and durability depend on compaction and curing; check exposure class requirements.
168		In-situ, 1:2.5:5–with CEM I		**0.097**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: General purpose concrete for moderate loads. 2. Properties: Nominal volume mix 1:2.5:5 with CEM I; lower binder intensity. 3. Performance: Ensure adequate curing and verify target strength for intended use.
169		In-situ, 1:3:6–with CEM I		**0.085**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Non-structural mass concrete and fills. 2. Properties: Nominal volume mix 1:3:6 with CEM I; lower binder and higher aggregate proportion. 3. Performance: Suitable where strength demand is low; maintain curing to avoid surface dusting.
170		In-situ, 1:4:8–with CEM I		**0.069**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Very low-strength mass concrete and simple blinding. 2. Properties: Nominal volume mix 1:4:8 with CEM I; minimal binder content. 3. Performance: Not intended for structural members; protect during early age to prevent weak surfaces.
171		In-situ, 1:1:2–with Average UK cement		**0.186**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: High-strength concrete for heavily loaded elements. 2. Properties: Nominal volume mix 1:1:2 using Average UK cement dataset; includes typical cementitious additions. 3. Performance: Use project-specific cement content for accuracy; control W/C and curing.

172		In-situ, 1:1.5:3– with Average UK cement		**0.139**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Floor slabs, columns, and load-bearing structure. 2. Properties: Nominal volume mix 1:1.5:3 with Average UK cement; moderate binder intensity. 3. Performance: Verify exposure class and curing regime; compact adequately.
173		In-situ, 1:2:4– with Average UK cement		**0.112**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: General structural concrete for buildings up to about three storeys. 2. Properties: Nominal volume mix 1:2:4 with Average UK cement. 3. Performance: Strength depends on W/C, compaction, and curing; check durability requirements.
174		In-situ, 1:2.5:5– with Average UK cement		**0.083**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: General purpose concrete under moderate loads. 2. Properties: Nominal volume mix 1:2.5:5 with Average UK cement; lower binder content. 3. Performance: Ensure curing to achieve target strength and surface quality.
175		In-situ, 1:3:6– with Average UK cement		**0.083**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Non-structural mass concrete and fills. 2. Properties: Nominal volume mix 1:3:6 with Average UK cement; lower binder, higher aggregate. 3. Performance: Maintain moisture to avoid plastic shrinkage and surface dusting.
176		In-situ, 1:4:8– with Average UK cement		**0.067**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Very low-strength mass concrete and blinding. 2. Properties: Nominal volume mix 1:4:8 with Average UK cement; minimal binder intensity. 3. Performance: Not for structural elements; protect during early age and provide adequate curing.
177		Concrete, 100 kg Average cement per m^3		**0.047**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Any class where very low cement content is acceptable. 2. Properties: Modelled with General UK Average cement for the full cementitious content at 100 kg per m^3; aggregates, water, and admixture typical of ready-mix.

										3. Performance: Lower uncertainty than strength-class method; verify against project mix ticket.
178		Concrete, 120 kg Average cement per m³		**0.054**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Any class where low cement content is acceptable. 2. Properties: 120 kg per m³ Average UK cement; balance of aggregates, water, and admixture. 3. Performance: Use project cement-content records for best accuracy; curing remains critical.
179		Concrete, 140 kg Average cement per m³		**0.061**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: General purpose mixes with low to moderate strength demand. 2. Properties: 140 kg per m³ Average UK cement basis. 3. Performance: Coordinate W/C and curing with target strength and durability.
180		Concrete, 160 kg Average cement per m³		**0.068**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: General purpose structural or slab-on-grade where moderate strength is needed. 2. Properties: 160 kg per m³ Average UK cement; typical aggregates and admixture. 3. Performance: Prefer project EPD or mix ticket; maintain curing continuity.
181		Concrete, 180 kg Average cement per m³		**0.075**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Conventional structural elements at moderate strength levels. 2. Properties: 180 kg per m³ Average UK cement. 3. Performance: Monitor W/C to meet exposure class; ensure adequate compaction and curing.
182		Concrete, 200 kg Average cement per m³		**0.081**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Widely used structural mixes for slabs, beams, and footings. 2. Properties: 200 kg per m³ Average UK cement. 3. Performance: Strength and carbon scale with cement content; consider SCMs where feasible.
183		Concrete, 220 kg Average cement per m³		**0.088**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Structural concrete requiring moderate to higher capacity.

										2. Properties: 220 kg per m³ Average UK cement. 3. Performance: Verify cover and exposure class; manage early-age temperature and shrinkage.
184		Concrete, 240 kg Average cement per m³		**0.095**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Structural elements and slabs where higher characteristic strength is desired. 2. Properties: 240 kg per m³ Average UK cement. 3. Performance: Ensure curing and compaction; confirm admixture selection for rheology.
185		Concrete, 260 kg Average cement per m³		**0.102**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Structural members with increased strength and durability requirements. 2. Properties: 260 kg per m³ Average UK cement. 3. Performance: Use thermal control and curing to reduce cracking risk.
186		Concrete, 280 kg Average cement per m³		**0.109**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Higher-strength structural elements and slabs. 2. Properties: 280 kg per m³ Average UK cement. 3. Performance: Plan for higher heat of hydration; monitor early-age behaviour.
187		Concrete, 300 kg Average cement per m³		**0.116**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Higher-strength RC and demanding structural applications. 2. Properties: 300 kg per m³ Average UK cement. 3. Performance: Control W/C and temperature; adopt robust curing.
188		Concrete, 320 kg Average cement per m³		**0.123**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: High-strength RC where early capacity is important. 2. Properties: 320 kg per m³ Average UK cement. 3. Performance: Thermal management and shrinkage control become more important; ensure curing continuity.
189		Concrete, 340 kg Average cement per m³		**0.13**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: High-strength members and precast elements.

										2. Properties: 340 kg per m³ Average UK cement. 3. Performance: Expect increased heat of hydration; use admixtures and curing plans to manage.
190		Concrete, 360 kg Average cement per m³		**0.137**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: High-strength structural and precast components. 2. Properties: 360 kg per m³ Average UK cement. 3. Performance: Assess thermal gradients in thick sections; consider SCMs for heat moderation.
191		Concrete, 380 kg Average cement per m³		**0.144**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Very high-strength elements and precast sections. 2. Properties: 380 kg per m³ Average UK cement. 3. Performance: Use thermal control plans; apply robust curing to mitigate early-age cracking.
192		Concrete, 400 kg Average cement per m³		**0.151**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Very high-strength RC and precast members with demanding performance. 2. Properties: 400 kg per m³ Average UK cement. 3. Performance: Highest heat of hydration to this point; adopt strict temperature and curing controls.
193		Concrete, 420 kg Average cement per m³		**0.158**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Very high-strength concrete and precast where early capacity and durability are paramount. 2. Properties: 420 kg per m³ Average UK cement. 3. Performance: Elevated risk of early-age thermal cracking; consider SCMs or staged pours and enforce curing discipline.
194		Concrete, 440 kg Average cement per m³		**0.164**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Very high-strength RC and precast members. 2. Properties: 440 kg per m³ Average UK cement; high binder intensity and heat of hydration.

										3. Performance: Use thermal control and strict curing; consider SCMs to moderate heat.
195		Concrete, 460 kg Average cement per m³		**0.171**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Very high-strength structural and precast elements with demanding early capacity. 2. Properties: 460 kg per m³ Average UK cement; elevated binder content. 3. Performance: Monitor thermal gradients; apply robust curing and shrinkage control.
196		Concrete, 480 kg Average cement per m³		**0.178**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Ultra-high binder content for speciality structural applications. 2. Properties: 480 kg per m³ Average UK cement; increased heat of hydration and shrinkage potential. 3. Performance: Thermal modelling recommended; consider SCMs or staged pours; enforce curing continuity.
197		Concrete, 500 kg Average cement per m³		**0.185**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	ICE (2024)	GLOBAL	UK	1. Application: Very high-strength concrete and precast requiring rapid capacity and durability. 2. Properties: 500 kg per m³ Average UK cement; highest binder range in this set. 3. Performance: Highest cracking risk; apply temperature control, low W/C, and rigorous curing.
198		Concrete C20/25; strength class C20/25		**0.142**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (2013)	LOCAL	MALAYSIA	1. Application: General structural works for slabs, beams, columns, and foundations at about 20 MPa cylinder strength. 2. Properties: Ready-mix concrete produced in Malaysia; cement, water, and mineral aggregates; reflects 2013 local energy and supply chains. 3. Performance: Suitable for typical RC elements; align cover, exposure class, and curing to meet durability.
199		Concrete C30/37; Strength Class 30/37		**0.109**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (2013)	LOCAL	MALAYSIA	1. Application: Structural elements requiring higher capacity such as beams, columns, and floors. 2. Properties: Malaysian ready-mix C30/37; cement, water, aggregates; dataset represents cradle-to-gate conditions in 2013.

										3. Performance: Provides higher compressive strength; ensure compaction and steady curing, especially in hot climates.
200		Concrete C8/10; Strength Class 8/10		**0.108**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (2013)	LOCAL	MALAYSIA	1. Application: Non-structural works including blinding layers, pathways, and simple foundations. 2. Properties: Low-strength, normal-weight concrete prepared at plant; designed for about 8 MPa cylinder strength. 3. Performance: Adequate for bedding and fill; maintain curing to prevent surface weakness or dusting.
201		Concrete Masonry Unit; Concrete Masonry; Site Specific, At Plant		**0.137**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	SIRIM (2013)	LOCAL	MALAYSIA	1. Application: Masonry blocks for walls and partitions with thermal mass and fire resistance. 2. Properties: Plant-produced CMU using cement, water, and aggregates; Malaysian cradle-to-gate inventory. 3. Performance: Durable and dimensionally stable when properly cured; use appropriate mortar and reinforcement details.
202		Ordinary Portland Cement (OPC)		**0.923**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	OPC is the most widely used hydraulic binder in construction, offering high early strength, durability, and reliable performance. Applications include concrete, mortar, grouting, and precast elements. Its properties include good workability and predictable setting. OPC delivers strong compressive performance but has a high carbon footprint relative to blended cements.
203		Fly Ash		**0.055972**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Fly ash is a pozzolanic by-product from coal combustion used as a supplementary cementitious material. It improves concrete workability, durability, and resistance to sulphate attack. Applications include blended cement, eco-concrete, and mass pours. Performance enhances long-term strength and reduces heat of hydration while lowering environmental impact.
204		Ground-Granulated Blast-Furnace Slag (GGBS)		**0.07888**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	GGBS is a high-performance SCM produced from molten iron slag. It enhances concrete durability, reduces permeability, and improves sulphate and chloride resistance. Applications include blended

										binders, high-durability structures, and eco-concrete. Performance features improved long-term strength and lower embodied carbon compared to OPC, supporting sustainable construction.
205		Limestones		**0.10188**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Limestone is a sedimentary rock used in cement production, aggregates, road base, and building blocks. It offers good workability, durability, and natural availability. Performance includes moderate strength and stability, making it suitable for general construction and cement manufacturing, with advantages in cost efficiency and reduced embodied energy.
206		Limestones Fines		**0.08688**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Limestone fines are finely ground particles used as filler in concrete and asphalt. They improve particle packing, workability, and finish quality. Applications include blended cement, precast products, and pavement layers. Performance enhances early strength and surface smoothness, supporting sustainable mix designs with reduced clinker content.
207		Recycled Concrete Aggregates (RCA)		**0.00667**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	RCA is produced by crushing demolished concrete, offering a sustainable substitute for natural aggregates. Applications include road base, structural concrete (with proper grading), and precast elements. Properties include lower density and higher absorption. Performance varies but can achieve good strength with proper mix design while reducing waste and embodied carbon.
208		Granite		**0.00743**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Granite is a dense, durable igneous rock commonly used as coarse aggregate, flooring, tiles, and cladding. It offers high strength, abrasion resistance, and weather durability. Performance is excellent in high-load and outdoor applications, providing long service life and structural reliability.
209		Aggregates		**0.0048**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Aggregates are granular materials such as sand, gravel, and crushed stone used as the backbone of concrete and asphalt. They provide strength, volume, and stability. Applications include

										structural concrete, road layers, drainage, and foundations. Performance depends on grading and hardness, ensuring load distribution and long-term durability.
210		Washed Copper Slag (WCS)		**0.28185**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	WCS is an industrial by-product used as a sand replacement in concrete and abrasive blasting. It offers good particle hardness, density, and low water absorption. Performance improves concrete strength and durability while reducing natural sand consumption, making it a sustainable alternative for selected structural and non-structural applications.
211		Sand		**0.00438**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Sand is a fine aggregate essential for concrete, mortar, plaster, and bedding layers. It provides workability, compactibility, and surface finishing qualities. Applications range from masonry to structural concrete. Performance depends on grain size and cleanliness, ensuring proper bonding and strength development in construction materials.
212		Concrete (Natural) Grade 20		**0.121**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Grade 20 natural concrete is a low-strength mix suitable for non-structural applications such as pathways, drains, blinding layers, and minor foundations. It provides adequate workability and durability for light loads. Performance is modest, offering reliable service in low-stress environments with cost-effective material use.
213		Concrete (Natural) Grade 25		**0.129**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Grade 25 concrete is widely used in residential slabs, beams, and columns. It provides balanced strength, workability, and durability for general structural applications. Performance includes good compressive strength and moderate load-bearing capacity, making it a standard choice for housing and small-scale commercial construction.
214		Concrete (Natural) Grade 30		**0.149**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Grade 30 concrete is suitable for medium structural elements such as suspended slabs, beams, and foundations. It offers improved mechanical strength, durability, and resistance to cracking. Performance is reliable under moderate loads, making it common in commercial buildings, infrastructure, and multi-storey structures.

215		Concrete (Natural) Grade 35		**0.161**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Grade 35 concrete is used in heavier structural applications including shear walls, columns, and industrial floors. It provides higher compressive strength, durability, and good resistance to aggressive environments. Performance supports long-term structural stability and reduced maintenance in medium- to high-load designs.
216		Concrete (Natural) Grade 40		**0.172**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Grade 40 concrete is designed for demanding structural elements such as heavily loaded beams, high-rise columns, and bridge components. It offers strong compressive performance, low permeability, and good crack resistance. Performance delivers high durability and reliability under significant stresses and challenging environmental conditions.
217		Concrete (Natural) Grade 50		**0.19**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Grade 50 concrete is a high-strength mix used for critical elements in tall buildings, pre-stressed structures, and infrastructure. It offers excellent compressive strength, low shrinkage, and enhanced durability. Performance ensures long service life in heavily loaded or high-performance engineering applications.
218		Concrete (Natural) Grade 80		**0.2325**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Grade 80 concrete is ultra-high-strength material used in high-rise cores, long-span bridges, and specialised infrastructure. It provides exceptional load-bearing capacity, stiffness, and resistance to environmental degradation. Performance supports advanced engineering designs requiring superior strength and durability.
219		Concrete (Natural) Grade 100		**0.227**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Grade 100 concrete is an advanced ultra-high-strength mix used for mega-structural applications such as high-rise superstructures, deep foundations, and pre-stressed segments. It offers outstanding compressive strength, minimal permeability, and excellent durability. Performance enables cutting-edge construction with reduced member size and enhanced structural efficiency.
220		Eco Concrete (15% Fly Ash		**0.111**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	This Grade 20 mix incorporates 15% fly ash to improve workability and sustainability. Applications include non-structural works,

		Replacement) Grade 20								pavements, and blinding layers. Its properties provide reduced heat of hydration and improved long-term durability. Performance is adequate for light loads, delivering lower environmental impact compared to standard Grade 20 concrete.
221		Eco Concrete (15% Fly Ash Replacement) Grade 25		**0.118**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	A Grade 25 mix with 15% fly ash offers better workability and enhanced durability. Applications include residential slabs, beams, and general structural elements. It reduces carbon footprint while supporting moderate strength requirements. Performance improves resistance to sulphate attack and cracking, making it suitable for typical building construction.
222		Eco Concrete (15% Fly Ash Replacement) Grade 30		**0.139**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Grade 30 eco concrete with 15% fly ash provides improved cohesiveness and long-term strength. Used in medium structural applications like beams, suspended slabs, and foundations. Its properties include reduced permeability and improved finishing. Performance is reliable under moderate loads with enhanced durability and environmental benefits.
223		Eco Concrete (15% Fly Ash Replacement) Grade 35		**0.149**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	This Grade 35 mix increases sustainability through 15% fly ash substitution. Applications include industrial floors, columns, and medium- to high-load elements. It offers good strength gain, reduced heat release, and improved durability. Performance enhances structural stability and service life while lowering embodied carbon.
224		Eco Concrete (15% Fly Ash Replacement) Grade 40		**0.159**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Grade 40 eco concrete with 15% fly ash supports demanding structural applications such as high-rise columns, heavy beams, and bridge components. Properties include lower permeability, improved chemical resistance, and good long-term strength. Performance remains strong and durable in aggressive environments while reducing environmental impact.
225		Eco Concrete (15% Fly Ash Replacement) Grade 50		**0.174**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	This Grade 50 mix incorporates 15% fly ash to enhance sustainability and durability in high-strength applications. It is ideal for heavily loaded structures, precast elements, and high-rise buildings. It offers improved workability and

										reduced cracking. Performance ensures long service life with strong mechanical and environmental performance.
226		Eco Concrete (30% Fly Ash Replacement) Grade 20		**0.099**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Grade 20 eco concrete with 30% fly ash reduces cement content significantly, improving sustainability. Applications include non-structural elements and pavements. Properties include enhanced workability and reduced heat of hydration. Performance is suitable for light loads with improved long-term durability but slower early strength development.
227		Eco Concrete (30% Fly Ash Replacement) Grade 25		**0.105**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	This mix increases fly ash to 30%, improving cohesiveness and sustainability. Used in residential slabs and general structures. Properties include lower permeability and improved finishing quality. Performance achieves adequate strength with enhanced durability, making it a greener alternative to normal Grade 25 concrete.
228		Eco Concrete (30% Fly Ash Replacement) Grade 30		**0.125**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Grade 30 concrete with 30% fly ash delivers improved chemical resistance and durability. Applications include beams, slabs, and foundations requiring moderate strength. Its properties involve slower strength gain but superior long-term performance. It provides reliable structural behaviour with reduced environmental footprint.
229		Eco Concrete (30% Fly Ash Replacement) Grade 35		**0.133**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	This Grade 35 mix with 30% fly ash suits industrial flooring, medium-load structures, and infrastructure. Properties include enhanced sulphate resistance and durability. Performance offers strong long-term strength, reduced cracking, and improved environmental efficiency compared to conventional mixes.
230		Eco Concrete (30% Fly Ash Replacement) Grade 40		**0.142**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Grade 40 eco concrete with 30% fly ash provides excellent long-term chemical resistance and durability. It is used for heavy-duty elements, high-rise structures, and bridge components. Properties include lower permeability and reduced heat. Performance supports demanding applications while reducing carbon footprint.

231		Eco Concrete (30% Fly Ash Replacement) Grade 50		**0.155**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	This high-strength Grade 50 concrete incorporates 30% fly ash, improving sustainability and durability while moderating hydration heat. Applications include high-rise columns, precast components, and long-span beams. Performance delivers excellent long-term strength, reduced shrinkage, and better resistance to aggressive environments.
232		Eco Concrete (25% GGBS Replacement) Grade 20		**0.094**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Grade 20 eco concrete with 25% GGBS improves durability and reduces carbon impact. Applications include pavements, drains, and light-load elements. Properties include better sulphate resistance and smooth finishing. Performance is adequate for low-stress uses with enhanced long-term stability.
233		Eco Concrete (25% GGBS Replacement) Grade 25		**0.1**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	This Grade 25 mix uses 25% GGBS to enhance durability and sustainability. Applications include residential structures and general elements. Properties include improved workability and reduced permeability. Performance provides strong long-term strength and environmental benefits compared to traditional concrete.
234		Eco Concrete (25% GGBS Replacement) Grade 30		**0.12**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Grade 30 concrete with 25% GGBS offers strong chemical durability and lower heat of hydration. It is used in medium structural systems such as slabs and beams. Performance includes improved long-term strength and resistance to aggressive environments, enhancing service life.
235		Eco Concrete (25% GGBS Replacement) Grade 35		**0.129**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	This Grade 35 mix strengthens structural durability with 25% GGBS. Applications include industrial floors, foundations, and moderate-load columns. Properties feature reduced permeability and improved chemical resistance. Performance is strong and stable, providing better sustainability and long-term service.
236		Eco Concrete (25% GGBS Replacement) Grade 40		**0.138**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Grade 40 eco concrete with 25% GGBS is used for high-demand structures such as columns, bridge components, and heavy beams. It offers enhanced durability, reduced chloride ingress, and improved long-term performance. Overall, it supports high-strength, sustainable construction.

237		Eco Concrete (25% GGBS Replacement) Grade 50		**0.153**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	This mix combines high strength with sustainability through 25% GGBS replacement. Applications include high-rise buildings, precast systems, and heavily loaded members. Properties include high durability and reduced environmental impact. Performance offers excellent structural reliability and long-term resistance.
238		Eco Concrete (50% GGBS Replacement) Grade 20		**0.068**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Grade 20 concrete with 50% GGBS greatly reduces cement usage and improves durability. Applications include non-structural elements and pavements. Properties include low permeability and enhanced sulphate resistance. Performance is adequate for light loads with strong environmental benefits.
239		Eco Concrete (50% GGBS Replacement) Grade 25		**0.072**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	This Grade 25 mix significantly improves sustainability using 50% GGBS. Applications include residential slabs and beams. Properties include high durability and reduced heat of hydration. Performance provides strong long-term strength and enhanced durability compared to standard concrete.
240		Eco Concrete (50% GGBS Replacement) Grade 30		**0.089**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Grade 30 eco concrete with 50% GGBS offers excellent long-term strength and chloride resistance. Applications include foundations, beams, and slabs. Performance supports durable construction in moderately aggressive environments with significant carbon reduction.
241		Eco Concrete (50% GGBS Replacement) Grade 35		**0.095**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	This Grade 35 mix improves chemical durability using 50% GGBS. Applications include industrial floors and medium-load structures. Properties include low permeability and reduced cracking. Performance ensures strong service life and sustainability.
242		Eco Concrete (50% GGBS Replacement) Grade 40		**0.102**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Grade 40 concrete with 50% GGBS suits demanding structures requiring durability, such as bridge piers and marine components. Properties include excellent chloride resistance and reduced thermal cracking. Performance is robust with high long-term strength.

243		Eco Concrete (50% GGBS Replacement) Grade 50		**0.115**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	This high-strength Grade 50 eco mix maximises sustainability with 50% GGBS. Applications include high-rise structures, heavily loaded columns, and precast elements. Performance includes superior durability, minimal permeability, and strong long-term strength, enabling advanced structural efficiency.
244		Precast Concrete (Natural) Grade 20		**0.139**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Precast Grade 20 concrete is used for light-duty elements such as small panels, drains, and boundary components. It offers good workability and consistent factory-controlled quality. Performance is adequate for low-load applications, providing uniformity, ease of installation, and improved durability compared to cast-in-place systems.
245		Precast Concrete (Natural) Grade 25		**0.147**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Precast Grade 25 is suitable for residential wall panels, slabs, and minor structural elements. It offers better strength, dimensional accuracy, and faster site assembly. Performance ensures reliable load-bearing capacity with improved curing control, enhancing durability and reducing construction time.
246		Precast Concrete (Natural) Grade 30		**0.168**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Precast Grade 30 is widely used in beams, columns, façade panels, and floor systems. It offers good mechanical strength and improved surface finish. Performance includes consistent quality, reduced on-site labour, and enhanced structural reliability for medium-load applications.
247		Precast Concrete (Natural) Grade 35		**0.179**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Precast Grade 35 supports heavier applications such as industrial panels, structural members, and multi-storey components. Properties include high strength and reduced permeability. Performance ensures long-term durability, faster project delivery, and excellent load-bearing stability due to controlled factory production.
248		Precast Concrete (Natural) Grade 40		**0.191**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Precast Grade 40 is used in high-rise building components, bridge elements, and heavy structural systems. It offers strong compressive strength and improved resistance to cracking. Performance provides long service life, reduced maintenance, and superior precision.

249		Precast Concrete (Natural) Grade 50		**0.208**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Precast Grade 50 is designed for demanding applications such as prestressed beams, large-span elements, and infrastructure. Its high strength, dense microstructure, and durability ensure excellent performance under heavy loads, offering precision fabrication and long-term structural resilience.
250		Precast Eco Concrete (15% Fly Ash Replacement) Grade 20		**0.13**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	This sustainable precast Grade 20 mix improves environmental performance with 15% fly ash. It is used for drains, lightweight panels, and non-structural components. Properties include better workability and reduced heat generation. Performance is adequate for light loads with improved durability and eco-efficiency.
251		Precast Eco Concrete (15% Fly Ash Replacement) Grade 25		**0.137**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Precast Grade 25 with 15% fly ash is used for housing components, small beams, and wall panels. It offers smoother finishes and enhanced durability. Performance includes good strength development and reduced environmental footprint, ensuring practical application in standard precast systems.
252		Precast Eco Concrete (15% Fly Ash Replacement) Grade 30		**0.158**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	This Grade 30 precast mix incorporates 15% fly ash to improve cohesiveness and long-term performance. Applications include structural panels, slabs, and moderate-load beams. Performance ensures strong durability, reduced permeability, and cost-effective sustainability.
253		Precast Eco Concrete (15% Fly Ash Replacement) Grade 35		**0.167**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Grade 35 precast elements using 15% fly ash support industrial components and structural framing. Properties include improved sulphate resistance and crack control. Performance delivers reliable strength, durable service life, and reduced embodied carbon.
254		Precast Eco Concrete (15% Fly Ash Replacement) Grade 40		**0.177**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	This Grade 40 mix enhances durability using 15% fly ash, suitable for high-rise precast systems and heavy-load structural components. It offers lower permeability and good long-term strength. Performance supports robust, sustainable construction with enhanced service life.

255		Precast Eco Concrete (15% Fly Ash Replacement) Grade 50		**0.203**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	High-strength precast components using 15% fly ash provide excellent durability and reduced hydration heat. Applications include prestressed beams, high-rise panels, and long-span precast systems. Performance ensures exceptional structural capacity with reduced environmental impact.
256		Precast Eco Concrete (30% Fly Ash Replacement) Grade 20		**0.117**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	This Grade 20 precast mix incorporates 30% fly ash to reduce cement use and improve sustainability. It is suitable for drains, kerbs, and low-load precast items. Properties include improved workability and moderate early strength. Performance emphasises durability and eco-benefits over load-bearing capacity.
257		Precast Eco Concrete (30% Fly Ash Replacement) Grade 25		**0.124**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Grade 25 precast concrete with 30% fly ash suits residential panels and general building components. It offers enhanced durability and reduced permeability. Performance provides adequate structural strength with improved environmental efficiency.
258		Precast Eco Concrete (30% Fly Ash Replacement) Grade 30		**0.144**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	This Grade 30 precast mix delivers strong long-term performance with improved chemical resistance. Applications include structural panels, beams, slabs, and columns. Performance improves durability and serviceability, especially in aggressive environments.
259		Precast Eco Concrete (30% Fly Ash Replacement) Grade 35		**0.151**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Precast Grade 35 with 30% fly ash supports medium- to heavy-load components. It features improved durability, reduced shrinkage, and enhanced chemical resistance. Performance ensures long-term strength and sustainability.
260		Precast Eco Concrete (30% Fly Ash Replacement) Grade 40		**0.16**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	This mix offers high durability for demanding precast systems including high-rise panels and bridge components. Properties include low permeability and improved resistance to chloride ingress. Performance is strong, stable, and environmentally efficient.
261		Precast Eco Concrete (30% Fly Ash		**0.184**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	High-strength precast Grade 50 with 30% fly ash provides excellent durability and long-term performance. It is suitable for prestressed beams and high-load structural elements. Performance

		Replacement) Grade 50								offers significant sustainability gains while maintaining superior strength.
262		Precast Eco Concrete (25% GGBS Replacement) Grade 20		**0.113**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	This Grade 20 precast mix with 25% GGBS improves durability and reduces carbon footprint. It is suitable for drains, kerbs, and lightweight components. Performance enhances long-term stability and resistance to deterioration.
263		Precast Eco Concrete (25% GGBS Replacement) Grade 25		**0.119**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Precast Grade 25 with 25% GGBS is used for building panels, slabs, and structural components. It offers improved workability and durability. Performance ensures reliable strength with reduced environmental impact.
264		Precast Eco Concrete (25% GGBS Replacement) Grade 30		**0.139**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	This Grade 30 mix enhances chemical resistance and long-term strength through 25% GGBS. It is used in structural precast applications. Performance supports durable construction with reduced permeability.
265		Precast Eco Concrete (25% GGBS Replacement) Grade 35		**0.148**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Grade 35 precast concrete using 25% GGBS suits industrial floors, structural beams, and load-bearing components. Performance delivers excellent durability, strength, and sustainability.
266		Precast Eco Concrete (25% GGBS Replacement) Grade 40		**0.157**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	This Grade 40 mix improves long-term durability and resistance to aggressive environments. Applications include high-rise elements and bridge components. Performance is robust with enhanced service life.
267		Precast Eco Concrete (25% GGBS Replacement) Grade 50		**0.182**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	High-strength Grade 50 precast with 25% GGBS is used for prestressed beams and heavy-load structures. It offers excellent durability and long-term performance with significant carbon reduction.
268		Precast Eco Concrete (50% GGBS Replacement) Grade 20		**0.086**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	This sustainable Grade 20 mix uses 50% GGBS, enhancing durability and reducing cement use. It is ideal for non-structural precast components. Performance emphasises environmental benefits and long-term stability.
269		Precast Eco Concrete (50% GGBS		**0.09**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Grade 25 precast with 50% GGBS is suitable for panels and light structural elements. It provides low permeability and improved durability.

		Replacement) Grade 25								Performance is reliable with strong sustainability advantages.
270		Precast Eco Concrete (50% GGBS Replacement) Grade 30		**0.107**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	This Grade 30 mix enhances chemical durability and strength development. It is used in structural panels and beams. Performance ensures excellent durability for long-term applications.
271		Precast Eco Concrete (50% GGBS Replacement) Grade 35		**0.114**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Precast Grade 35 with 50% GGBS supports moderate- to high-load components. Properties include superior resistance to chloride and sulphate attack. Performance ensures strong durability and reduced carbon impact.
272		Precast Eco Concrete (50% GGBS Replacement) Grade 40		**0.12**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	This Grade 40 mix suits demanding precast systems requiring high durability. Performance features excellent long-term strength and resilience in harsh conditions.
273		Precast Eco Concrete (50% GGBS Replacement) Grade 50		**0.144**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	High-strength precast Grade 50 with 50% GGBS is used for prestressed beams and heavily loaded systems. It offers outstanding durability, low permeability, and significant environmental savings.
274		Primary Cold Rolled Coil		**2.34**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Primary cold-rolled coil is steel processed through cold reduction for superior surface finish, tight tolerances, and improved strength. Applications include automotive panels, appliances, and precision-formed components. Its properties offer excellent formability and smoothness. Performance ensures reliable dimensional accuracy and high-quality finishing for demanding manufacturing and construction needs.
275		Recycled Cold Rolled Coil		**1.07**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Recycled cold-rolled coil is produced from recovered steel, offering similar strength and surface finish to primary material while reducing environmental impact. Applications include building panels, furniture, and fabricated components. Properties include good formability and dimensional consistency. Performance is reliable, cost-effective, and sustainable, supporting circular-economy construction.

276		Primary Hot Rolled Coil		**2.23**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Primary hot-rolled coil is steel processed at high temperature, offering good strength, weldability, and versatility. Applications include structural components, pipes, general fabrication, and heavy machinery. Its properties include high ductility and robust mechanical performance. It delivers stable structural behaviour for load-bearing and manufacturing applications.
277		Recycled Hot Rolled Coil		**1.053**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Recycled hot-rolled coil uses remelted scrap steel to achieve strong, ductile, and weldable material suitable for structural fabrication. Applications include beams, channels, and general construction steelwork. Properties provide good toughness and mechanical reliability. Performance is structurally sound and environmentally efficient, reducing embodied carbon compared to primary steel.
278		Primary Electrogalvanized		**2.98459**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Primary electrogalvanised steel is coated with a uniform zinc layer for enhanced corrosion resistance and a smooth finish. Applications include HVAC ducts, electrical enclosures, wall systems, and automotive parts. Properties include excellent paintability and surface quality. Performance ensures long service life in corrosive or humid environments.
279		Recycled Electrogalvanized		**1.79**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Recycled electrogalvanised steel offers corrosion resistance and good surface quality while reducing environmental footprint through scrap-based production. Applications include interior panels, appliances, ducts, and enclosures. Properties include good adhesion for coatings and stable mechanical strength. Performance is durable, sustainable, and reliable for general construction uses.
280		Primary Plate		**2.6**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Primary steel plate is thick, high-strength material used for heavy structural applications such as bridges, industrial floors, tanks, and offshore platforms. Its properties include excellent weldability, toughness, and load-bearing capacity. Performance ensures long-term structural stability and resistance to deformation under high stress.

281		Recycled Plate		**1.73**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Recycled steel plate provides strong, thick structural material with reduced environmental impact. Applications include building frames, industrial equipment, and marine structures. Properties include good weldability and high toughness. Performance delivers dependable strength and durability, supporting sustainable heavy construction.
282		Primary Wire Rod		**2.41**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Primary wire rod is hot-rolled steel used for drawing into wires, fences, fasteners, springs, and reinforcement products. Properties include high ductility, tensile strength, and consistent quality. Performance enables reliable forming and long-term functionality in structural and manufacturing applications.
283		Recycled Wire Rod		**0.87477**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Recycled wire rod is produced from scrap steel and used in fencing, mesh, nails, and reinforcement wires. Properties include good workability and strong tensile performance. It provides sustainable, cost-efficient material with dependable mechanical behaviour for construction and industrial applications.
284		Primary Steel		**1.73**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Primary steel is produced from virgin iron ore, offering high purity, strength, and durability. Applications include structural beams, columns, plates, and reinforcement systems. Properties feature excellent mechanical performance and weldability. Performance ensures long-term reliability and high load-bearing capacity across major construction and infrastructure works.
285		Recycled Steel		**1.06**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Recycled steel is manufactured from scrap, delivering strong, durable, and versatile material with significantly lower embodied carbon. Applications include structural sections, roofing, reinforcement, and mechanical components. Properties include good weldability and toughness. Performance is reliable and sustainable, matching many primary steel applications.

286		Primary Reinforcement Bar and Rod		**2.51**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Primary reinforcement bars provide high-strength steel for concrete reinforcement, ensuring tensile resistance and crack control. Applications include slabs, beams, columns, and foundations. Properties include high yield strength, weldability, and surface ribs for bond adherence. Performance ensures excellent structural integrity and long-term reliability in load-bearing concrete.
287		Recycled Reinforcement Bar and Rod		**0.86204**	$kgCO_2e/kg$	Cradle to gate (Extraction to Manufacturing)	BECC, SINGAPORE	ASIA	SINGAPORE	Recycled reinforcement bars are produced from scrap steel, offering strong tensile capacity and good bonding with concrete. Applications include general reinforced concrete works in buildings and infrastructure. Properties include durable ribbed surfaces and reliable mechanical strength. Performance is cost-effective, sustainable, and structurally dependable for standard reinforcement needs.

EMBODIED CARBON DIGITAL CALCULATOR

EMBODIED CARBON DIGITAL CALCULATOR

This chapter describes the development of a digital embodied carbon calculator for building elements. The calculator is designed to estimate embodied carbon by integrating updated embodied carbon inventory data and providing multiple material and building-element options. It enables users to calculate embodied carbon at the building-element level by selecting relevant materials, quantities, and data sources, supporting more consistent and data-driven assessment of embodied carbon in construction projects.

1.1 Background and Rationale

The construction sector is a significant contributor to greenhouse gas (GHG) emissions, particularly through the consumption of construction materials, transportation activities, and on-site construction processes. In response to increasing national and global commitments towards climate change mitigation, there is a growing need for practical tools that enable the quantification, analysis, and management of embodied carbon associated with building projects.

Embodied carbon refers to the total greenhouse gas emissions generated throughout the life cycle stages of construction materials and processes, including raw material extraction, manufacturing, transportation, and construction activities. Accurate assessment of embodied carbon at the project level is essential to support informed decision-making, sustainable material selection, and policy development.

1.2 Purpose of the Embodied Carbon Digital Calculator

The embodied carbon digital calculator is developed as a technical decision-support tool to assist users in estimating and analysing embodied carbon emissions associated with building projects. The calculator provides a structured and transparent approach for quantifying embodied carbon based on user-defined project inputs, material quantities, transportation parameters, and construction-related data.

The primary purposes of the calculator are to:

- Support industry practitioners in evaluating and comparing embodied carbon impacts during planning, design, and implementation stages;
- Facilitate research and academic studies related to life cycle assessment (LCA), low-carbon construction, and sustainability performance;
- Provide a technical reference platform to inform policy development, benchmarking, and future regulatory frameworks; and
- Enhance awareness and understanding of embodied carbon concepts among students and the general public.

1.3 Scope and System Boundary

The embodied carbon digital calculator adopts a life cycle–based assessment framework, focusing on embodied carbon emissions associated with building construction. The scope of assessment is defined in accordance with established life cycle assessment principles and is structured to be compatible with future CIDB guidelines and national standards.

The calculator is designed to evaluate embodied carbon contributions from:

- Construction materials associated with life cycle stages A1-A3; and
- Transportation of materials to the construction site under stage A4.

The system boundary and calculation logic are explicitly defined within the calculator to ensure transparency, reproducibility, and consistency of results. Any exclusions or assumptions adopted in the assessment are clearly stated to avoid misinterpretation of outputs. Construction installation activities (A5), use-stage impacts, and end-of-life stages are currently outside the scope of the calculator unless otherwise specified.

1.4 Intended Users

The calculator is designed for use by a broad range of stakeholders, including:

- Construction industry practitioners (consultants, contractors, developers);
- Researchers and academic institutions;
- Policymakers, regulators, and technical agencies; and
- The public with an interest in sustainable construction.

The accompanying instruction manual is written to ensure that users with varying levels of technical expertise can understand the calculator's methodology, data requirements, and output interpretation, while maintaining a level of rigour suitable for professional and regulatory applications.

2.0 Overview of the Embodied Carbon Digital Calculator

2.1 Calculator Architecture and Platform

The embodied carbon digital calculator is developed as a digital-based assessment tool that enables systematic estimation of embodied carbon emissions for building projects. The calculator operates through a structured workflow, guiding users from project information input to detailed embodied carbon outputs.

The digital architecture of the calculator is designed to:

- Ensure consistency in data input and calculation procedures,
- Minimise user error through predefined input fields and logical data flow, and
- Support scalability for future enhancement, integration, or standardisation.

The calculator may be accessed through a digital interface, allowing efficient data entry, review, and output generation for both professional and educational applications.

2.2 System Boundary and Life Cycle Stages Considered

The calculator adopts a life cycle–based assessment framework covering life cycle stages A1 to A4, in alignment with recognised embodied carbon accounting practices.

The life cycle stages considered in the calculator are as follows:

1. **A1: Raw Material Supply**

- Emissions arising from the extraction and processing of raw materials used in the production of construction materials.

2. **A2: Transport to Manufacturing**

- Emissions associated with the transportation of raw materials to manufacturing facilities.

3. **A3: Manufacturing**

- Emissions generated during the manufacturing and fabrication of construction materials and products.

4. **A4: Transport to Construction Site**

- Emissions resulting from the transportation of construction materials from manufacturing facilities or distribution points to the construction site.

By explicitly addressing stages A1 to A4, the calculator enables a consistent and transparent evaluation of embodied carbon associated with material production and supply chains. This scope aligns with commonly adopted embodied carbon reporting boundaries and supports future harmonisation with CIDB guidelines and national assessment frameworks. Life cycle stages beyond A4, including construction installation activities (A5), use stage, and end-of-life stages, are currently outside the scope of the calculator unless otherwise stated. Any such exclusions are clearly communicated to ensure appropriate interpretation of results.

2.3 Input–Output Logic and Calculation Transparency

The calculator operates on a clear input–process–output logic, whereby user provided data are systematically processed to generate embodied carbon results.

Key characteristics of the calculation logic include:

- Automatic computation based on validated formulas,
- Structured aggregation of embodied carbon contributions from material production (A1-A3) and transportation (A4); and
- Transparent reporting of embodied carbon factor source classification (Local / Asia / Global).

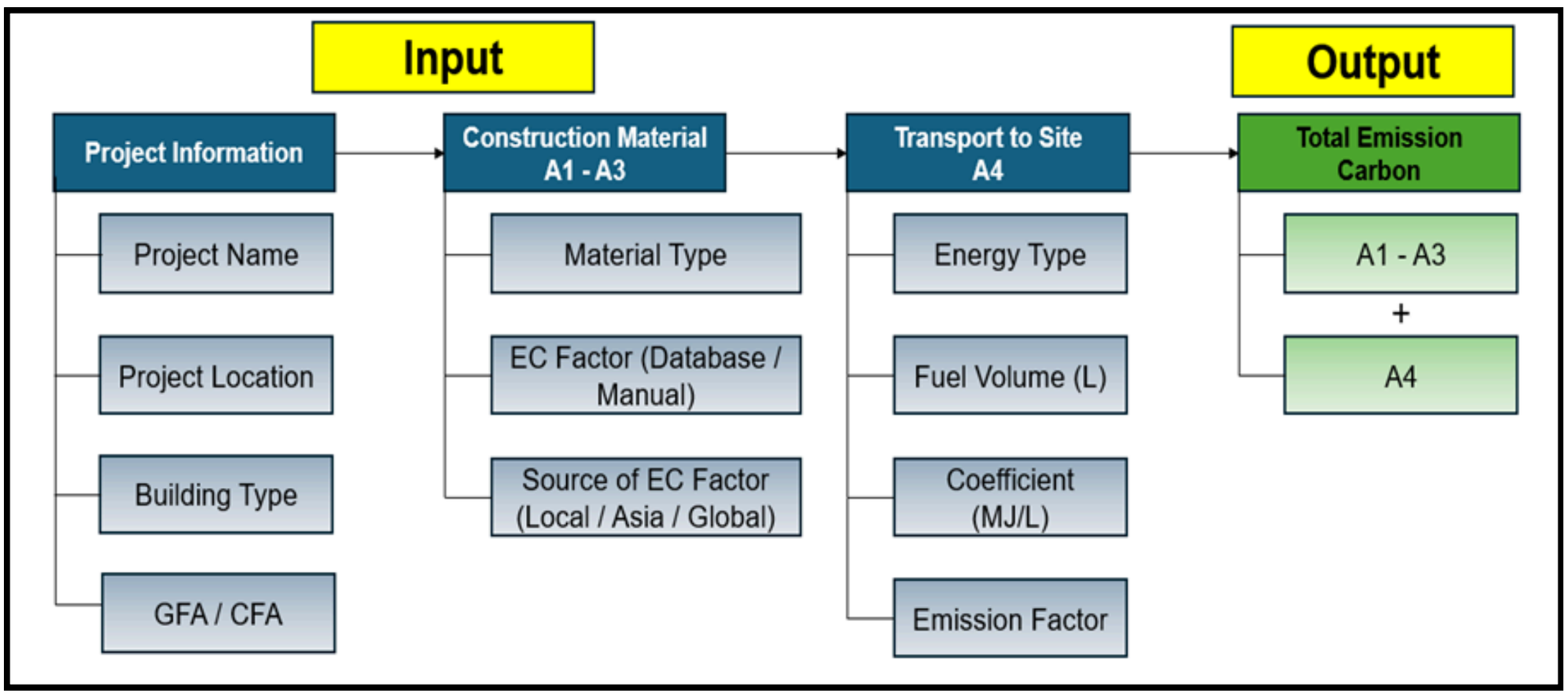


Figure 8: Development of Embodied Carbon Calculator

INPUT	The calculator requires inputs on project information, selected construction materials, embodied carbon (EC) factors, source classification, and transportation parameters to estimate embodied carbon for the defined project scope.
OUTPUT	Displays the calculated embodied carbon emissions for material production stages (A1–A3), transportation to site (A4), and the aggregated total embodied carbon (A1–A4), enabling users to review and analyse overall project emissions.
PROJECT INFORMATION	Project information includes essential project details such as project name, project address/location, building type, and gross floor area (GFA) or construction floor area (CFA), which provide contextual reference for the embodied carbon assessment.
BUILDING ELEMENT (A1-A3)	Building Element A1–A3 refers to the product stage of the life cycle, covering raw material supply (A1), transport to manufacturing (A2), and manufacturing processes (A3) associated with the building element.
TRANSPORT TO SITE (A4)	This stage represents the embodied carbon associated with transporting materials from the production site to the construction site, including energy type and fuel volume.
CONSTRUCTION MATERIAL INPUT	Users select the relevant construction material and material type from predefined lists. The calculator provides default embodied carbon factors from the inventory database (local, regional, or global), while allowing users to manually input project-specific EC factors where applicable.
EC FACTOR INPUT	Indicates the embodied carbon factor ($kgCO_2e/kg$) applied to the selected material. Users may choose: • From database; or • Manual input.
SOURCE OF EMISSIONS FACTOR INPUT	Indicates the geographical classification of the embodied carbon factor (Local / Asia / Global), ensuring transparency and traceability of data origin.
ENERGY TYPE INPUT	Users select the type of energy used during transportation, including diesel, petrol, kerosene, fuel oil, LPG, or LNG
FUEL USED INPUT	Users enter the amount of fuel consumed (in litres) for transportation, which is used to calculate the associated embodied carbon.
COEFFICIENT (MJ/L) INPUT	The coefficient field indicates the energy content of the fuel in megajoules per litre, which is used to convert fuel volume into energy for embodied carbon calculations.
TOTAL EMISSIONS OUTPUT	Displays the calculated embodied carbon emissions ($kgCO_2e$) for: • Material production (A1–A3); • Transportation to site (A4); and • Total embodied carbon (A1–A4).

3.0 Navigating the Embodied Carbon Digital Calculator Interface

3.1 General Navigation Structure

The Embodied Carbon Digital Calculator is designed with a structured and sequential interface to guide users through the embodied carbon assessment process. The navigation flow reflects the practical workflow of a construction project, beginning with project information input, followed by material specification for life cycle stages A1–A3, transportation inputs under stage A4, and concluding with automatic calculation and result display.

The calculator adopts a life cycle–based framework covering:

- A1–A3: Raw material supply, transport to manufacturing, and manufacturing processes; and
- A4: Transportation of materials to the construction site.

3.2 Calculator Overview

Upon accessing the Embodied Carbon Digital Calculator, users are presented with the main working interface comprising three principal sections.

- Project Information
- Construction Material Detail (A1–A3)
- Transport to Site (A4)

These sections collectively define the system boundary for embodied carbon assessment under life cycle stages A1–A4. The layout is structured to support systematic data entry and clear differentiation between material-related emissions and transportation-related emissions.

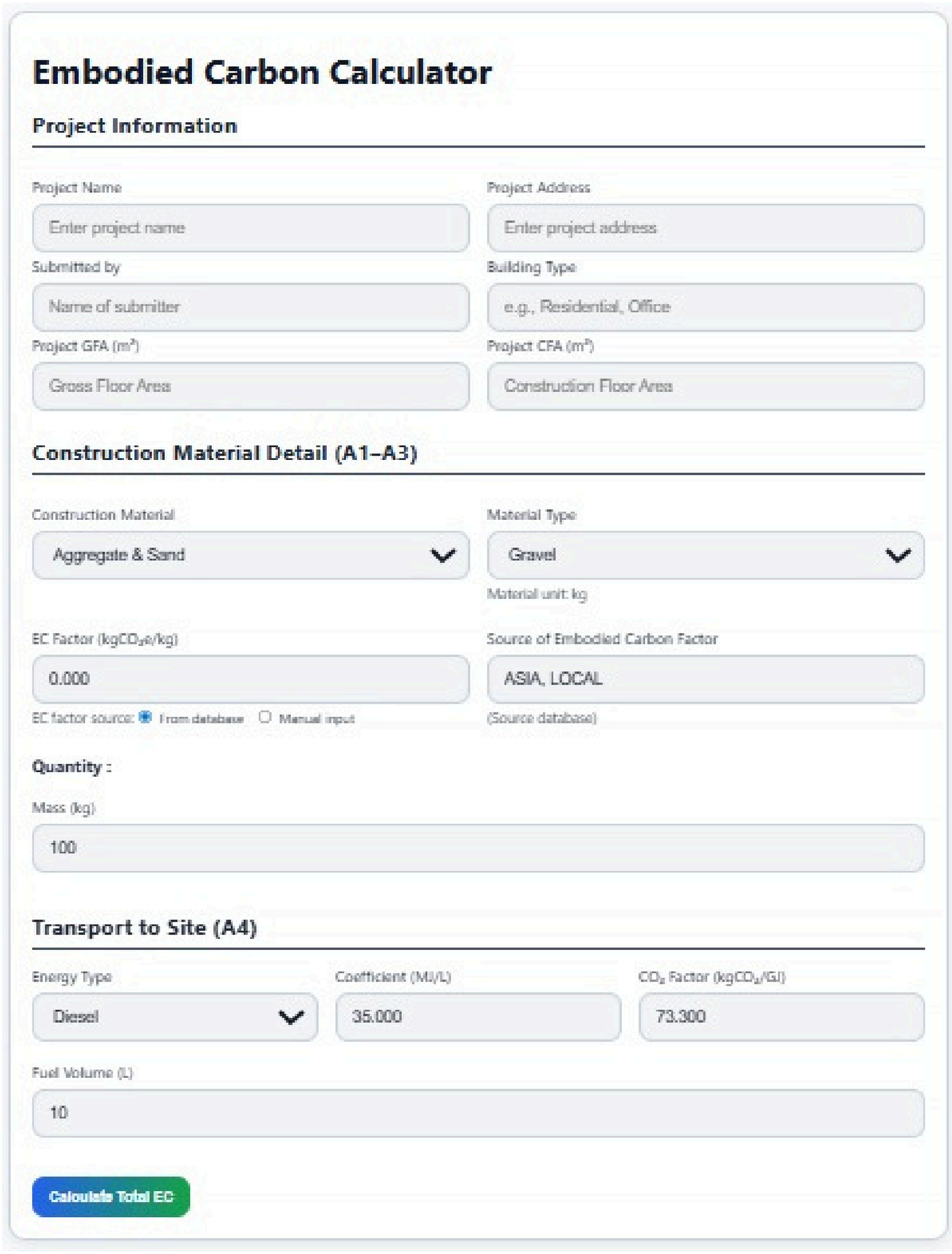


Figure 9: Overall interface of the Embodied Carbon Digital Calculator, showing Project Information, Construction Material Detail (A1–A3), and Transport to Site (A4) modules within the A1–A4 life cycle boundary.

3.3 Calculator Material and Material Input Interface (A1–A3)

The Construction Material Detail (A1–A3) section enables users to define material-specific parameters associated with life cycle stages A1 to A3, covering raw material supply, transport to manufacturing, and manufacturing processes.

Users begin by selecting a Construction Material from the predefined dropdown list. This list contains major material categories such as cement, concrete, steel, lime, aluminium, and others.

For materials such as Cement, the system provides a second dropdown under Material Type, which contains specific product variants or sub-material classifications (e.g., CEM I 32.5, CEM II/A-M, clinker product, plant-specific production data).

This hierarchical structure allows:

- Selection of the main material category; and
- Selection of a specific material type or production source to improve accuracy of embodied carbon estimation.

Upon selection of a Construction Material and corresponding Material Type, the system automatically populates:

- The EC Factor ($kgCO_2e/kg$); and
- The Source of EC Factor (Local / Asia / Global).

based on the integrated embodied carbon database.

By default, the EC factor is retrieved from the database. However, users may alternatively select the “Manual input” option to override the default value and enter project-specific embodied carbon data, such as those obtained from Environmental Product Declarations (EPDs) or verified manufacturer information.

Once the material selection is completed, the Quantity (Mass in kg) input field becomes active. Users are required to enter the material mass to enable calculation of embodied carbon emissions for stages A1–A3.

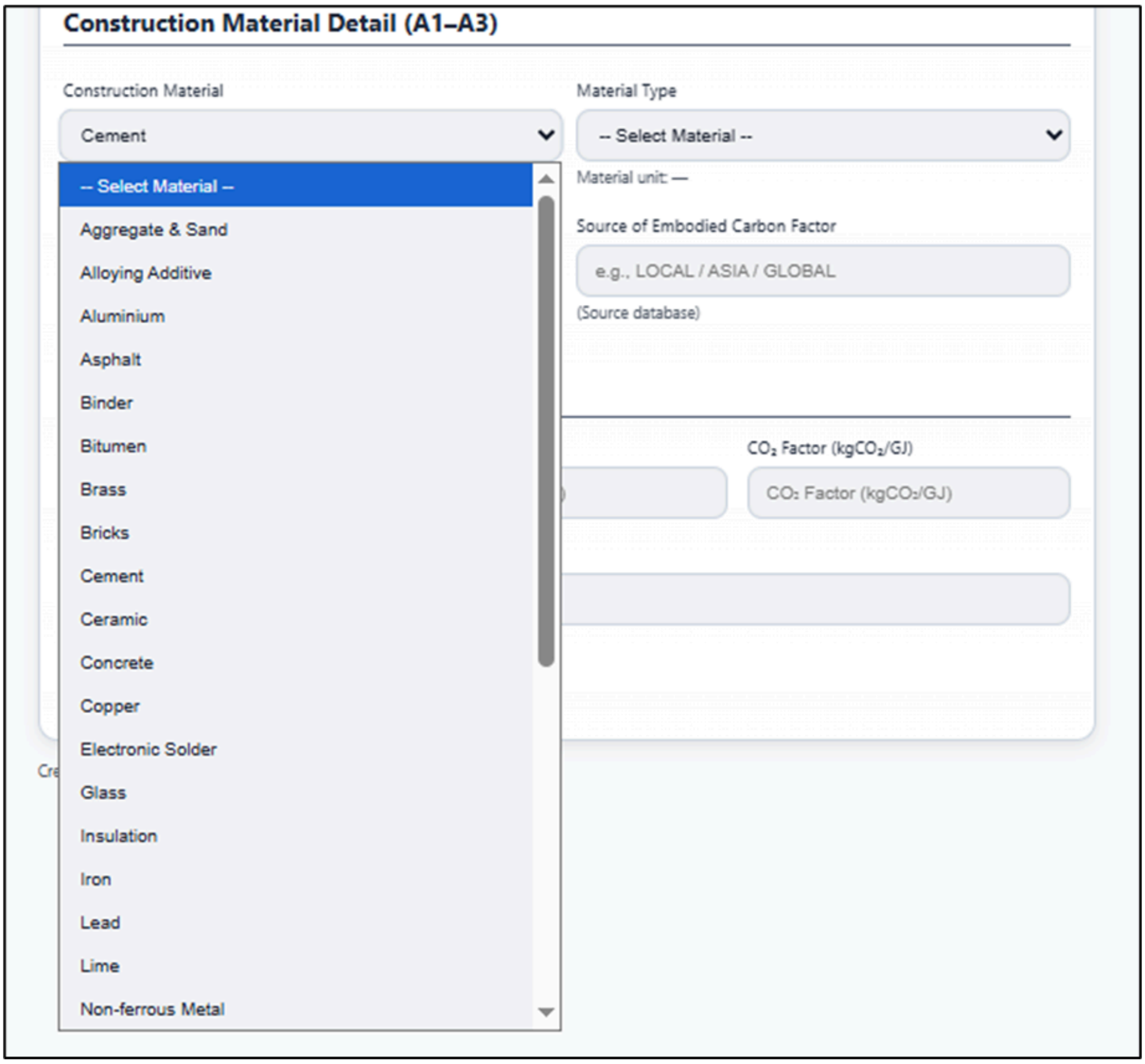


Figure 10: Construction Material Detail (A1–A3) interface showing selection of the main construction material category from the predefined material list within the embodied carbon inventory database.

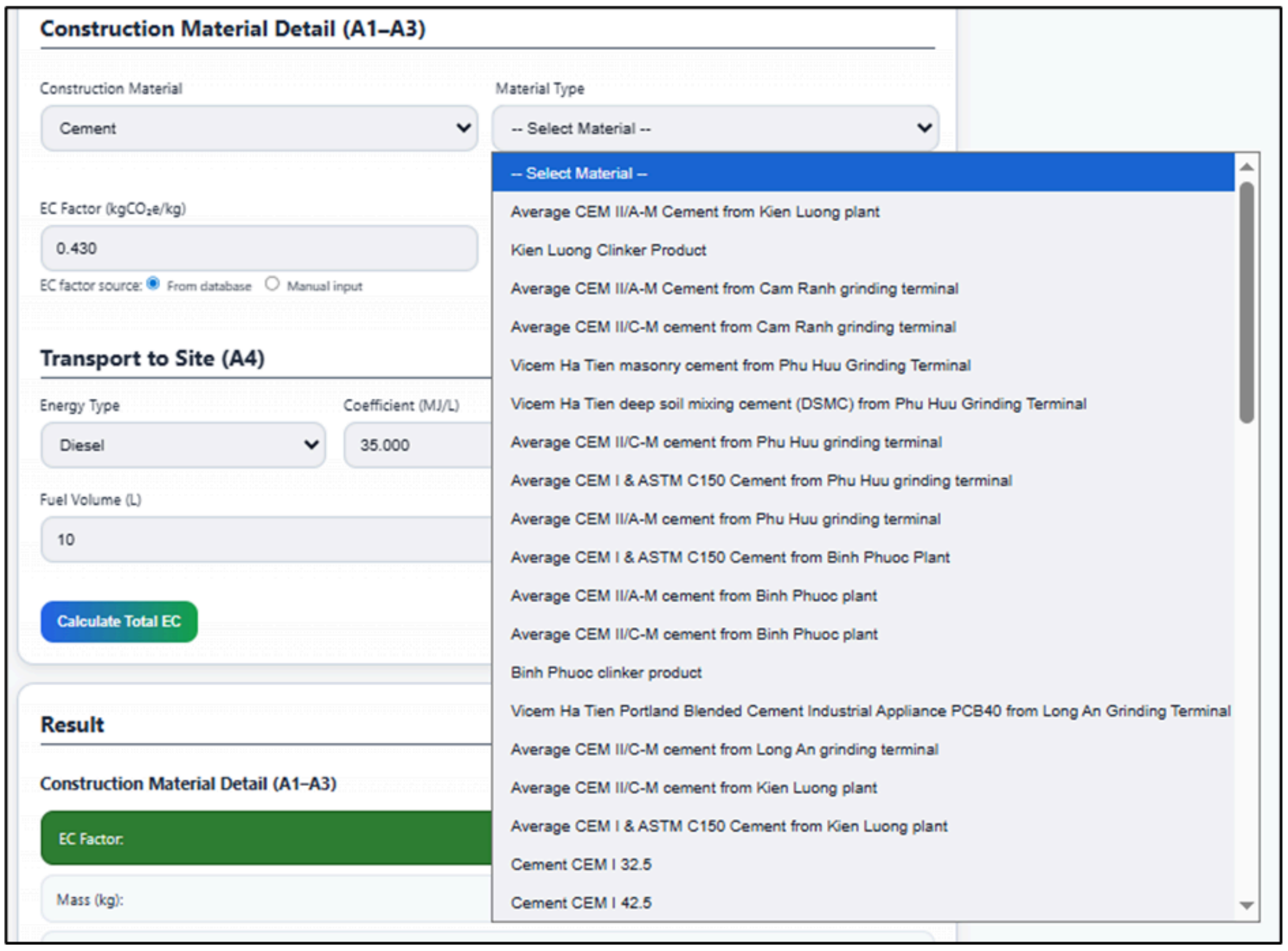


Figure 11: Construction Material Detail (A1–A3) interface illustrating selection of specific material types under the Cement category, including plant-specific and grade-specific variants for improved embodied carbon accuracy.

Mass Input for Embodied Carbon Calculation

After the construction material and material type have been selected, the Mass (kg) input field becomes active. Users are required to enter the material quantity in kilograms. The system calculates embodied carbon emissions for stages A1–A3 by multiplying the entered mass by the applicable EC factor.

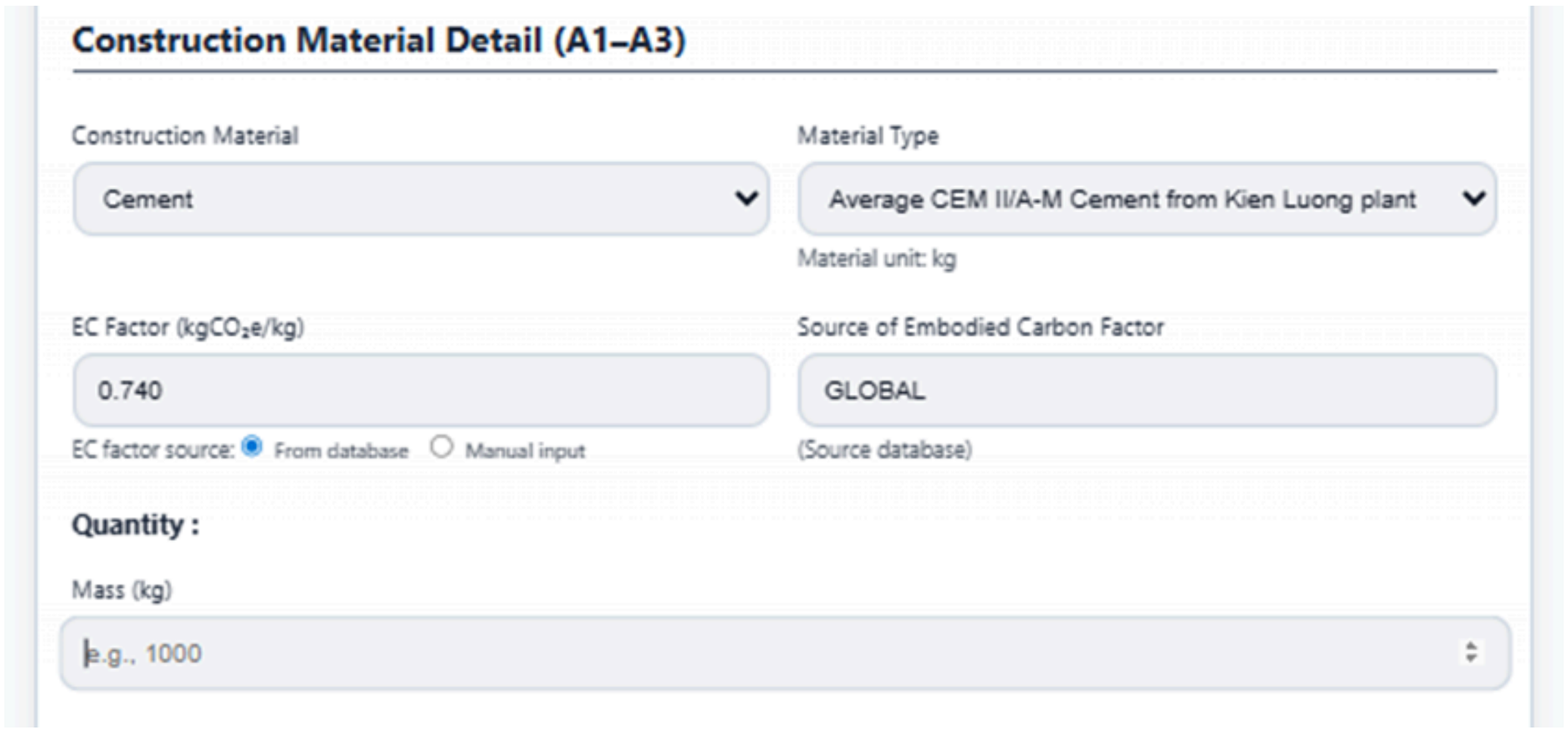


Figure 12: Construction Material Detail (A1–A3) interface showing activation of the Mass (kg) input field following material selection, enabling calculation of embodied carbon emissions based on user-defined material quantity.

3.4 Transportation to Site Input for Embodied Carbon Calculation (A4)

The Transport to Site (A4) section quantifies embodied carbon emissions associated with transporting construction materials from the production or distribution point to the construction site.

Users are first required to select the Energy Type (e.g., diesel, petrol, kerosene, fuel oil, LPG, LNG) from the dropdown menu. Upon selection of the energy type, the system automatically populates:

- The Energy Coefficient (MJ/L); and
- The CO_2 Emission Factor ($kgCO_2/GJ$)

based on predefined emission data within the integrated database. Users are then required to input the Fuel Volume (L) corresponding to the transportation activity. The system applies the automatically populated energy coefficient and emission factor together with the user-defined fuel volume to calculate transportation-related embodied carbon emissions under life cycle stage A4.

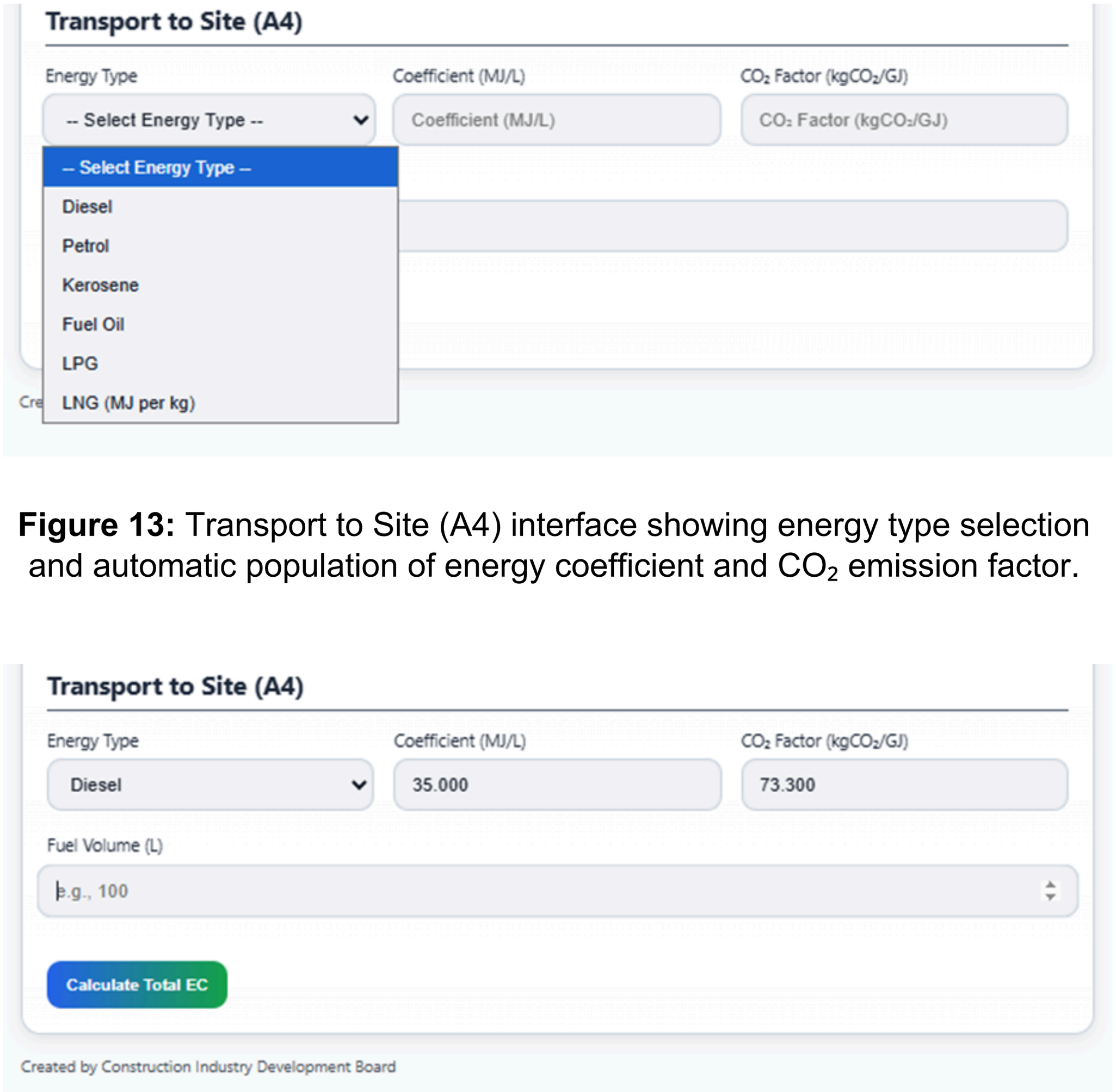


Figure 13: Transport to Site (A4) interface showing energy type selection and automatic population of energy coefficient and CO_2 emission factor.

Figure 14: Transport to Site (A4) interface illustrating the fuel volume input field required for calculation of transportation-related emissions.

3.5 Embodied Carbon Results and Output Summary (A1–A4)

Upon completion of inputs under Construction Material Detail (A1–A3) and Transport to Site (A4), users activate the “Calculate Total EC” button to generate the embodied carbon results.

The system automatically computes emissions based on:

- Selected construction material and material type;
- Applied EC Factor ($kgCO_2e/kg$);
- Entered material mass (kg); and
- Defined transportation parameters (energy type and fuel volume).

The results are displayed in the Result section in a structured and clearly separated format. The output interface presents:

- EC Factor applied to the selected material, including qualitative indicator (e.g., Very Low / Low);
- Mass (kg) used in the calculation;
- Embodied Carbon for material production (A1–A3);
- Material Embodied CO_2 Emission (A1–A3) shown as a consolidated value;
- Energy CO_2 Emission (A4) representing transport-related emissions; and
- Total CO_2 Emission (A1–A4) representing the aggregated embodied carbon across both stages.

The results section visually distinguishes between:

- Material-related emissions (A1–A3);
- Transportation-related emissions (A4); and
- The final aggregated total.

All results are presented in $kgCO_2e$, ensuring consistency in reporting and supporting benchmarking, comparison, and documentation for project-level assessment.

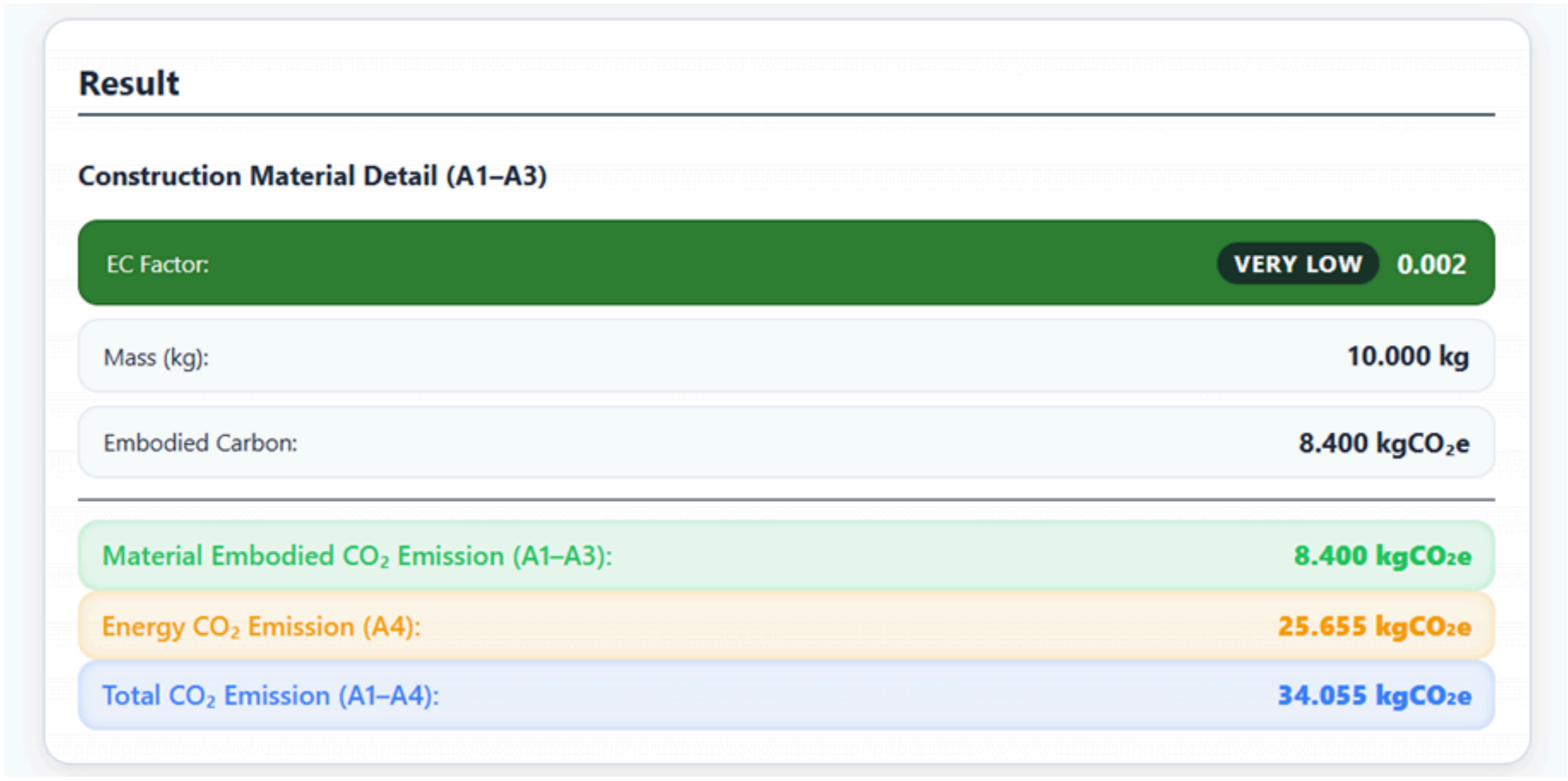


Figure 16: Embodied carbon results interface of the Embodied Carbon Digital Calculator, showing EC factor classification, material mass input, material embodied carbon (A1–A3), transport emissions (A4), and total embodied carbon emissions (A1–A4).

CONCLUSION AND WAY FORWARD

CONCLUSION AND WAY FORWARD

This chapter summarises the key findings of the study and provides recommendations to support long-term reduction of embodied carbon in the Malaysian construction industry. The study highlights the importance of updated and locally relevant embodied carbon data and the practical utility of the digital calculator for building-element-level assessment.

KEY CONCLUSIONS

Enhanced Embodied Carbon Inventory

- The 2025 Inventory 2.0 significantly expands coverage, with **600 construction material records** and **583 building element records,** compared to 301 and 200 in the 2021 Inventory 1.0.

Data Quality and Methodological Rigour

- The inventory prioritises data quality and regional relevance, with all datasets conforming to ISO 14040/14044 standards and verified EPDs.

Locality Prioritisation

- Data follow a hierarchy: **local Malaysian sources first, Southeast Asian regional data second, and international data when necessary.**

Hybrid Data Integration

- Combining local, regional, and international data ensures comprehensive coverage while maintaining regional accuracy.

Practical Application

- The updated inventory and digital calculator provide a **data-driven** tool for assessing and reducing embodied carbon in construction projects.

WAY FORWARD : STRATEGIC ACTION TOWARDS DECARBONISATION CONSTRUCTION 2050

Leverage Established Expertise

- Organise **knowledge-sharing sessions with leading embodied carbon international institutions (e.g., ICE, CLF, WGBC, BRE) to share best practices in developing embodied carbon programmes**. Facilitate workshops to transfer practical experience in establishing local embodied carbon initiatives.

Mandate Carbon Accountability to Regulations

- Integrate embodied carbon considerations into **regulations**, ensuring contractors and consultants adopt sustainable practices. Include **embodied carbon requirements in government infrastructure procurement**; contractors must obtain certification and fully comply to qualify for projects

Build Guidelines and Local Carbon Intelligence Data Reporting

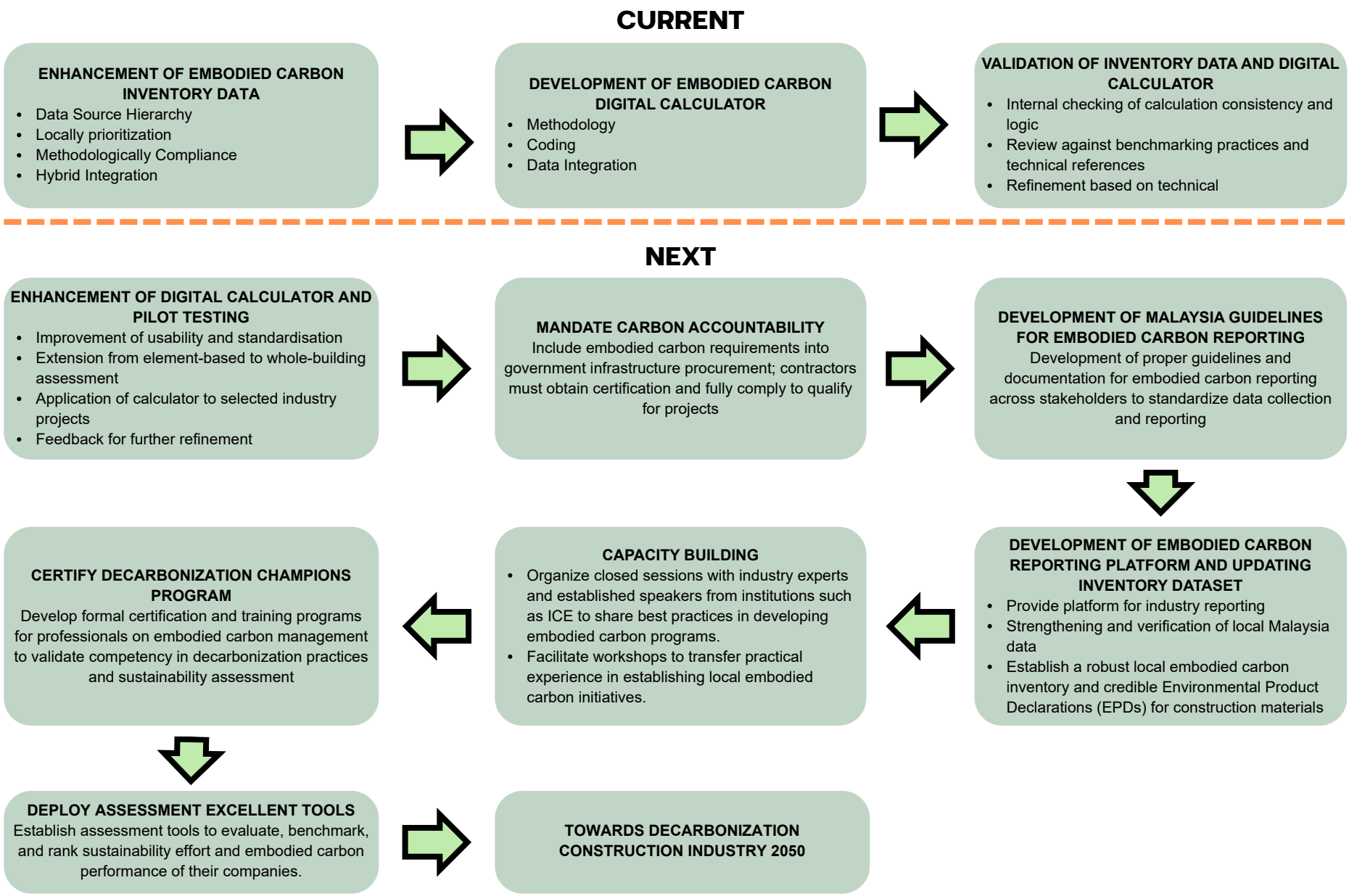
- Develop proper guidelines and documentation for embodied carbon reporting across stakeholders to **standardise data collection and reporting.**
- Establish a robust **local embodied carbon inventory and credible Environmental Product Declarations (EPDs)** for construction materials.

Certify Decarbonisation Champions Programme

- Develop **formal certification and training programmes** for professionals on embodied carbon management, issued by recognised bodies such as CIDB and relevant international institutions to validate competency in decarbonisation practices and sustainability assessment.

Deploy Assessment Excellence Tools

- Establish assessment tools to evaluate, benchmark, and rank the sustainability efforts and embodied carbon performance of their companies.


CURRENT
ENHANCEMENT OF EMBODIED CARBON INVENTORY DATA
Data Source Hierarchy
Locally prioritization
Methodologically Compliance
Hybrid Integration
DEVELOPMENT OF EMBODIED CARBON DIGITAL CALCULATOR
Methodology
Coding
Data Integration
VALIDATION OF INVENTORY DATA AND DIGITAL CALCULATOR
Internal checking of calculation consistency and logic
Review against benchmarking practices and technical references
Refinement based on technical
NEXT
ENHANCEMENT OF DIGITAL CALCULATOR AND PILOT TESTING
Improvement of usability and standardisation
Extension from element-based to whole-building assessment
Application of calculator to selected industry projects
Feedback for further refinement
MANDATE CARBON ACCOUNTABILITY
Include embodied carbon requirements into government infrastructure procurement; contractors must obtain certification and fully comply to qualify for projects
DEVELOPMENT OF MALAYSIA GUIDELINES FOR EMBODIED CARBON REPORTING
Development of proper guidelines and documentation for embodied carbon reporting across stakeholders to standardize data collection and reporting
DEVELOPMENT OF EMBODIED CARBON REPORTING PLATFORM AND UPDATING INVENTORY DATASET
Provide platform for industry reporting
Strengthening and verification of local Malaysia data
Establish a robust local embodied carbon inventory and credible Environmental Product Declarations (EPDs) for construction materials
CAPACITY BUILDING
Organize closed sessions with industry experts and established speakers from institutions such as ICE to share best practices in developing embodied carbon programs.
Facilitate workshops to transfer practical experience in establishing local embodied carbon initiatives.
CERTIFY DECARBONIZATION CHAMPIONS PROGRAM
Develop formal certification and training programs for professionals on embodied carbon management to validate competency in decarbonization practices and sustainability assessment
DEPLOY ASSESSMENT EXCELLENT TOOLS
Establish assessment tools to evaluate, benchmark, and rank sustainability effort and embodied carbon performance of their companies.
TOWARDS DECARBONIZATION CONSTRUCTION INDUSTRY 2050

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