THE TRANSITION OF BUILT ASSETS

Strategic White Paper on the Evolution of the Construction Industry and Built Asset Economy

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How the decarbonization of construction materials establishes a new economy for the construction industry, drives a new generation of materials, products, and services for the maintenance, retrofit, and modernization of real estate assets, and strengthens a low-carbon built infrastructure throughout the entire life cycle of buildings

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PREFACE

This White Paper is the result of a research, analysis, and synthesis effort that sought to connect fields of knowledge traditionally treated in isolation: materials engineering, construction economics, environmental regulation, sustainable finance, asset management, and territorial planning.

The hypothesis that organizes the document is that the decarbonization of structural materials — cement, steel, concrete — does not represent an isolated phenomenon of the basic industry, but rather the triggering element of a broader economic reorganization, whose result is the establishment of a Built Asset Economy.

This publication is offered as a contribution to the strategic debate on the future of the built environment.

LETTER TO THE READER

The construction industry has always been a sector of slow but profound transformations. The great changes — the industrialization of materials in the 19th century, the digitalization of projects at the end of the 20th century — took decades to consolidate, but when they did, they entirely reconfigured the way we design, build, and operate the built environment.

We are facing a third transformation, which does not originate from an isolated technological innovation, but from the convergence of regulatory, financial, technological, and market vectors.

And, unlike the previous ones, this transformation is not limited to the construction stage: it extends throughout the entire life cycle of built assets.

This White Paper was prepared for public policy makers, industry leaders, financial institutions, insurers, regulators, and all agents operating in the built environment chain. Its purpose is to offer a conceptual framework that allows anticipating and structuring the ongoing transformations.

We hope this document contributes to a qualified debate on the future of the construction industry and infrastructure.

Anderson José Colaço de Freitas
Founder & Chief Systems Architect

EXECUTIVE SUMMARY

The construction industry is entering a new cycle of transformation.

Historically, the sector's competitiveness was determined by factors such as cost, productivity, structural strength, material availability, and construction efficiency. In the coming decades, a new attribute tends to integrate this set of criteria: the embodied carbon intensity of built assets.

This change goes beyond the industrial sphere. It modifies the way buildings, industrial facilities, logistics infrastructure, commercial developments, and real estate assets are conceived, constructed, operated, maintained, and modernized throughout their entire life cycle.

This transformation is not limited to the production of cement, steel, or other structural materials. It establishes a new economic dynamic for the entire construction industry chain, driving the continuous development of materials, components, construction systems, and services for the maintenance, modernization, retrofit, and expansion of real estate assets. Thus, the built infrastructure ceases to be merely a result of industrial activity and becomes a permanent ecosystem of demand, innovation, and technological evolution throughout the entire life cycle of buildings.

When structural materials begin to incorporate verifiable environmental attributes, not only the construction stage is affected. The entire economic chain related to the operation, maintenance, retrofit, component replacement, and expansion of these assets tends to evolve to preserve these characteristics.

The result is the emergence of a new economic dynamic based on the continuity of the environmental attributes of built assets.

This document proposes the concept of the **Built Asset Economy** as a new paradigm for understanding the evolution of the construction industry, in which structural materials, real estate assets, infrastructure, and operation services become part of a permanent economic chain.

Global Regulatory Context

The transformation described in this document does not occur in isolation. It is grounded in the evolution of international regulatory frameworks that redefine industrial competitiveness, asset value, and capital flows, connecting the decarbonization of materials to the sustainability of the entire built environment.

The alignment between international regulatory frameworks and industrial policies has been establishing the conditions for this transformation. The European Union, through the EU Taxonomy Regulation (Regulation EU 2020/852), defined technical eligibility criteria for environmentally sustainable economic activities, including the construction and renovation of buildings. The Carbon Border Adjustment Mechanism (CBAM — Regulation EU 2023/956) introduced carbon pricing at the border for imported products, directly affecting steel, cement, and other construction materials.

The United Kingdom, in turn, implemented the UK Green Taxonomy and the Net Zero Carbon Buildings Standard, establishing mandatory metrics for embodied carbon in buildings. In the United States, the Inflation Reduction Act of 2022 allocated significant resources for low-carbon construction materials, with Buy Clean clauses at the federal and state levels.

These regulatory frameworks do not represent isolated environmental requirements. They constitute the foundations of a new economic architecture for the built environment, in which embodied carbon attributes become part of the technical and patrimonial value of real estate assets.

Simultaneously, ISO/TC 59/SC 17 (Buildings and Civil Engineering Works — Sustainability), the World Green Building Council, the WBCSD (World Business Council for Sustainable Development), and the World Economic Forum have been consolidating frameworks that connect industrial decarbonization to the resilience of the real estate market.

The Central Thesis

This white paper argues that the decarbonization of structural materials does not constitute an end in itself. Decarbonization does not represent the final objective of the transformation. It constitutes the mechanism that structurally reorganizes the construction industry economy, giving rise to a new generation of built assets, new industrial markets, and new permanent value chains throughout the entire life cycle of infrastructure.

This economic reorganization:

- Establishes a permanent economy of built assets, in which buildings and infrastructure are managed as continuous platforms of technical, economic, and environmental value.
- Creates new markets for materials, components, and services for maintenance, retrofit, modernization, and expansion, driving a new industrial generation dedicated to preserving the environmental characteristics of assets over decades.
- Reconfigures the relationships between the materials industry, construction, real estate market, financial sector, insurers, and public authorities, integrating them into an economic ecosystem founded on the continuity of built asset attributes.

Document Structure

The 15 chapters that follow develop this thesis progressively, starting from the transformation of structural materials (Chapters 1 to 3), moving through the multiplier effects on the construction chain and the real estate market (Chapters 4 to 9), addressing the impacts on infrastructure, insurance, and public policies (Chapters 10 to 11), and culminating in the formalization of the concept of the Built Asset Economy as a new economic paradigm (Chapters 12 to 15).

INTRODUCTION

Objectives

This white paper aims to:

- Characterize the transition of built assets as a systemic economic phenomenon, which goes beyond the sphere of industrial decarbonization and establishes the foundations of a new economy for the construction industry, the real estate market, and infrastructure.
- Demonstrate the mechanisms by which the reduction of carbon intensity in structural materials triggers multiplier effects throughout the entire value chain, driving the continuous development of materials, components, and services for maintenance, retrofit, modernization, and expansion of real estate assets.
- Provide a conceptual and analytical framework that enables public policy makers, industry leaders, financial institutions, insurers, and regulatory bodies to anticipate and structure the ongoing transformations.
- Project the long-term implications for each link in the production chain and for the built environment economy as a whole.

Target Audience

This document is intended for:

- Leaders in the cement, steel, and construction materials manufacturing industries;
- Construction companies, developers, and real estate developers;
- Infrastructure operators and concessionaires;
- Financial institutions, development banks, and real estate fund managers;
- Insurers and reinsurers;
- Regulatory agencies and public policy makers;
- International organizations, think tanks, and applied research centers.

Scope

The scope covers the global built environment chain, with emphasis on the interrelationships between:

- Structural materials industry (cement, steel, aggregates);
- Manufacturing of components and construction systems;
- Construction and industrial assembly;
- Real estate market (commercial, residential, logistics, and industrial);
- Critical infrastructure (energy, transportation, sanitation, communications);
- Financial, insurance, and asset management services.

Methodological References

The analysis is based on:

- Review of international regulatory frameworks (EU Taxonomy, CBAM, Inflation Reduction Act, UK Net Zero Carbon Buildings Standard, among others);
- ISO and ABNT technical standards applicable to life cycle assessment, environmental product performance, and asset management;
- Publications by the World Green Building Council, WBCSD, IFC, World Economic Forum, and similar institutions;
- Sectoral data from international energy agencies, global industry associations, and peer-reviewed academic databases.

Fundamental Concepts

For the purposes of this document, the following concepts are adopted:

Built Asset: Any building, industrial facility, infrastructure, or real estate development that constitutes a permanent element of the built environment, endowed with technical, economic, patrimonial, and environmental value throughout its life cycle.

Embodied Carbon: Greenhouse gas emissions associated with the extraction, processing, manufacturing, transportation, application, maintenance, and final disposal of the materials and components that constitute a built asset. It is distinguished from Operational Carbon (emissions associated with the use of the asset, such as air conditioning and lighting) and integrates, with it, the concept of Whole Life Carbon.

Built Asset Economy: An economic system in which real estate and infrastructure assets are managed as continuous platforms of value preservation, driving permanent cycles of maintenance, modernization, retrofit, and expansion, sustained by an industrial chain dedicated to the continuity of the technical and environmental characteristics of buildings throughout their entire life cycle.

Carbon Intensity: Quantity of CO_2 equivalent emissions associated with a unit of product, material, or construction system, expressed in $kgCO_2e$ per functional unit.

Asset Life Cycle: Period extending from the extraction of raw materials for the manufacture of materials to the decommissioning or recycling of the built asset, including all phases of design, construction, operation, maintenance, retrofit, and modernization.

CHAPTER 1: The Next Transformation of the Construction Industry

1.1 The Three Waves of Transformation

The construction industry, understood as the set of industrial and engineering activities aimed at building and infrastructure, has undergone two major waves of transformation since the Industrial Revolution. A third is underway.

The first transformation occurred with the industrialization of materials. The invention of Portland cement (1824), the development of large-scale steelmaking processes (Bessemer converter, 1856; Siemens-Martin furnace, 1864), and the industrial production of glass, ceramics, and other inputs broke the dependence on unprocessed natural materials. Construction ceased to be an artisanal activity based on stone, wood, and earth to become an industrial activity supported by standardized and mass-produced materials.

The second transformation occurred with the digitalization of projects and construction processes. The introduction of CAD (Computer-Aided Design) in the 1980s and 1990s, followed by the dissemination of BIM (Building Information Modeling) from the 2000s, radically altered the way buildings and infrastructure are conceived, detailed, budgeted, and managed. The ISO 19650 series, which establishes the principles for information management throughout the life cycle of assets, formalized this transition, consolidating BIM as the sector's reference digital environment.

The third transformation, the subject of this white paper, is related to the integration of engineering, sustainability, traceability, and asset life cycle management. Unlike the previous ones, this transformation does not originate from an isolated technological innovation, but from the convergence of four structural vectors:

- **Regulatory Vector:** The progressive imposition of environmental performance requirements for materials and buildings, expressed in milestones such as the EU Taxonomy, CBAM, and climate neutrality targets.
- **Financial Vector:** The integration of ESG (Environmental, Social, and Governance) criteria into capital allocation decisions, affecting the eligibility of assets for financing, investment, and insurance coverage.
- **Technological Vector:** The development of lower carbon intensity structural materials, material traceability systems (digital passports, blockchain applied to supply chains), and asset management platforms based on digital twins.
- **Market Vector:** The growing demand for real estate assets that incorporate verifiable environmental attributes, both from institutional occupants and investors and from regulators and multilateral bodies.

1.2 The Systemic Nature of the Third Transformation

The first two transformations predominantly affected the design and construction stage. The industrialization of materials altered what is built. The digitalization of projects altered how projects are designed and construction is managed.

The third transformation affects the entire life cycle of the built asset. It establishes an inseparable link between the choice of materials in the construction phase and the environmental, technical, and economic characteristics of the asset over the subsequent decades of operation.

This temporal linkage produces an unprecedented effect in the history of the construction industry: the built asset ceases to represent merely a set of physical materials. It becomes an integrated system of technical, environmental, and patrimonial information, whose value evolves according to the capacity to preserve and evidence its attributes over time.

1.3 Normative Foundations of the Third Transformation

The third transformation does not constitute a speculative projection. Its normative foundations are already established and in the implementation phase in the main economies.

Within the European Union, the Communication from the Commission — The European Green Deal (COM/2019/640 final) established the goal of climate neutrality by 2050. The EU Taxonomy Regulation (Regulation EU 2020/852) defined the criteria for an economic activity to be considered environmentally sustainable, covering the construction of new buildings, the renovation of existing buildings, and the manufacture of construction materials. The Construction Products Regulation (CPR — Regulation EU 305/2011, under review) establishes the mandatory declaration of environmental performance for construction products marketed in the European market.

Directive 2010/31/EU (Energy Performance of Buildings Directive — EPBD, revised by Directive 2024/1275) introduced the concept of Nearly Zero-Energy Buildings (NZEB) and, in its updated version, began to include requirements for the calculation and disclosure of embodied carbon throughout the life cycle of buildings.

The Carbon Border Adjustment Mechanism (CBAM), instituted by Regulation EU 2023/956, introduced the mandatory declaration of embodied emissions for products imported in the sectors of cement, iron and steel, aluminum, fertilizers, and electricity, with financial incidence starting in 2026.

In the United States, the Inflation Reduction Act of 2022 (Public Law 117-169) allocated more than US$ 5 billion for low-carbon construction materials programs, including the designation of Environmental Product Declarations (EPDs) as a requirement for federal public procurement. The Buy Clean Task Force, established by Executive Order, has been defining maximum emission limits for structural materials purchased with federal funds. Several states, including California (Buy Clean California Act), Colorado, and New York, have enacted similar legislation.

In the United Kingdom, the Net Zero Carbon Buildings Standard, developed by a consortium of sectoral organizations led by the UK Green Building Council, the Royal Institution of Chartered Surveyors (RICS), and the Institution of Structural Engineers (IStructE), establishes mandatory metrics for embodied carbon in buildings, aligned with the national climate neutrality target by 2050.

Internationally, ISO 14040 and ISO 14044 establish the principles and requirements for Life Cycle Assessment (LCA). ISO 14025 establishes the principles and procedures for Type III Environmental Declarations, of which Environmental Product Declarations (EPDs) constitute the main application in the construction industry. ISO 21930 establishes the principles for environmental declarations of construction products, harmonizing life cycle assessment requirements for materials and construction components. EN 15804, widely used in Europe, provides specific rules for the construction sector (Product Category Rules — PCR).

The ISO 41001 standard (Facility Management — Management Systems) establishes the requirements for a facility management system, complementing the management of built assets. The ISO 55000 series establishes the international principles for Asset Management throughout the life cycle.

ISO 14067 establishes principles, requirements, and guidelines for the quantification and communication of the carbon footprint of products (Carbon Footprint of Products — CFP). The ISO

14064 family of standards establishes principles and requirements for the quantification, monitoring, reporting, and verification of greenhouse gas emissions and removals. ISO 14068 establishes principles, requirements, and guidelines for achieving and demonstrating carbon neutrality.

The recommendations originally developed by the TCFD (Task Force on Climate-related Financial Disclosures), established by the Financial Stability Board, have been incorporated into the international disclosure standards issued by the International Sustainability Standards Board (ISSB), particularly in the IFRS S1 and IFRS S2 standards. The TNFD (Taskforce on Nature-related Financial Disclosures) consolidates frameworks for the disclosure of nature-related risks, reaching real estate and infrastructure assets as classes subject to assessment.

1.4 Structural Implications

The convergence of these normative instruments produces a structural effect that transcends environmental regulation. It establishes that the environmental performance of construction materials and systems ceases to be a voluntary attribute of market differentiation and becomes a technical-legal requirement for participation in the most relevant markets of the global economy.

For the construction industry, this transformation implies that:

- The choice of materials in the design phase now has consequences that extend throughout the entire life cycle of the asset, affecting its eligibility for financing, its attractiveness to investors, and its regulatory compliance over decades.
- The management of the built asset now incorporates the preservation and evidencing of its environmental attributes as a component of patrimonial value.
- The construction materials industry now operates in an environment in which the carbon intensity of its products constitutes a competitive parameter as relevant as mechanical strength or price.

CHAPTER 2: From Industry to Patrimony

2.1 The Dual Nature of Structural Materials

For more than a century, cement, steel, concrete, and other structural materials were treated as independent products. Their economic trajectory ended at the moment of sale to the builder or the concrete company. What happened to these materials after their incorporation into the building belonged to another sphere — that of civil engineering, building maintenance, and condominium administration.

This conceptual separation between the materials industry and the built patrimony is beginning to dissolve. The reason is structural: when structural materials begin to incorporate verifiable environmental attributes, these attributes do not disappear after the completion of the work. They transfer to the built asset and accompany it throughout its entire useful life.

Thus, a permanent link is formed between the material and the patrimony. The material ceases to be an input consumed in construction and becomes a permanent component of the asset's value.

2.2 The Transferred Value

The concept of "transferred value" is not new in economics. In other sectors, critical components transfer their attributes to the final product, conditioning its perception of value over time. An engine transfers its efficiency and reliability to the automobile. A processor transfers its computational capacity to the electronic device. In both cases, the component continues to "exist" economically as long as the final product is in operation.

In the construction industry, this phenomenon had not yet fully manifested because structural materials were undifferentiated commodities from the perspective of their long-term attributes. A cubic meter of concrete was essentially equal to another, regardless of its origin or composition, as long as it met the strength requirements.

The introduction of verifiable environmental attributes — such as embodied carbon intensity, traceability of input origin, the presence of recycled content, or recarbonation capacity — breaks this undifferentiation. The structural material acquires a technical identity that accompanies it after the completion of the work.

2.3 Evidence of the Transition

Several regulatory frameworks and sectoral initiatives already reflect this transition:

- EPDs (Environmental Product Declarations), governed by ISO 14025, ISO 21930, and EN 15804, are documents that accompany the product and provide standardized information on its environmental performance throughout the life cycle. EPDs do not refer only to the production stage but cover modules ranging from raw material extraction (A1-A3) to end-of-life (C1-C4) and benefits beyond the life cycle (module D).
- Digital Product Passports, foreseen under the Ecodesign for Sustainable Products Regulation (ESPR) of the European Union (proposal COM/2022/142), will establish the mandatory nature of a digital record that accompanies the product throughout its useful life. For construction materials, these passports will contain information on composition, origin, carbon footprint, and potential for reuse and recycling.
- Sustainable building certification systems, such as LEED (Leadership in Energy and Environmental Design), BREEAM (Building Research Establishment Environmental Assessment Method), DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen), and AQUA-HQE, assign scores and classifications based on the environmental attributes of the materials used. The latest version of LEED (v4.1) requires the disclosure of EPDs for structural materials and rewards the selection of products with lower environmental impact.
- The concept of Whole Life Carbon, promoted by the World Green Building Council and the Royal Institution of Chartered Surveyors (RICS), considers the totality of emissions associated with a built asset, from raw material extraction to its decommissioning. This concept is adopted by a growing number of national regulations and requires that the environmental performance of materials be accounted for throughout the asset's entire life.

2.4 The Reconfiguration of the Industry-Patrimony Relationship

The transfer of environmental attributes from materials to built assets has profound implications for the relationship between the materials industry and the owners and managers of real estate assets.

First, the materials industry ceases to be a supplier of undifferentiated inputs and becomes a supplier of patrimonial value components. The material it produces does not extinguish with the sale: it remains incorporated into the asset, transferring its attributes to it for decades.

Second, this permanence creates an extended responsibility. If the material's attributes affect the value and regulatory compliance of the asset over time, the industry that produced it has a direct economic interest in preserving these attributes. Thus, a convergence of interests arises between material manufacturers and asset owners.

Third, this convergence drives the development of services and products aimed at maintaining the characteristics of materials throughout the asset's life cycle. A building whose value is associated with the environmental attributes of its materials will demand, over decades, maintenance, replacement, and modernization interventions that preserve or enhance these attributes. These interventions, in turn, generate continuous demand for compatible materials and components.

CHAPTER 3: The Built Asset as Permanent Infrastructure

3.1 The End of Construction as the Beginning of the Cycle

A building does not end when the construction is completed. It begins a new operational phase that can extend for 50, 75, or more than 100 years. During this period, hundreds or thousands of interventions of various natures will be carried out:

- Periodic technical inspections;
- Preventive and corrective maintenance;
- Replacement of components with a useful life shorter than that of the structure (claddings, waterproofing, frames, building systems);
- Expansions and layout adaptations;
- Renovations and modernizations;
- Retrofit of building systems (air conditioning, lighting, automation);
- Structural reinforcements;
- Regulatory and normative updates.

Each of these interventions moves the industry again. It demands materials, components, equipment, specialized labor, and technical services. The building, far from being a finished product, is a permanent platform of industrial demand.

3.2 The Economic Magnitude of the Operational Cycle

The economic dimension of the operational cycle of built assets is often underestimated in sectoral analyses, which tend to focus on new construction activity.

Sector data indicate that, in mature economies, spending on maintenance, renovation, and retrofit of existing buildings already exceeds investments in new construction in several segments. The global market for energy retrofit of buildings, for example, was estimated at more than US$ 150 billion annually and is projected to grow significantly in the coming decades, driven by decarbonization targets and regulatory requirements.

When the "embodied carbon" variable is introduced, this market tends to expand even further. The need to preserve or improve the environmental attributes of built assets adds a new layer of demand for technical interventions that go beyond operational energy efficiency and reach the materials and construction systems themselves.

3.3 The Asset as an Information System

The third transformation of the construction industry adds an informational dimension to the built asset. The building is not only a physical structure; it is also a repository of data on its materials, its systems, its interventions, and its performance over time.

BIM (Building Information Modeling), in its most advanced sense — BIM integrated with asset management (BIM-AM, Asset Management) — constitutes the technological platform that enables this integration. ISO 19650-3 establishes the requirements for information management during the operational phase of assets, defining processes for the collection, storage, and updating of data throughout the entire life cycle.

The concept of Digital Twin elevates this capacity to a new level. A digital twin of the built asset, fed by sensors and integrated with management platforms, allows continuous monitoring of structural, environmental, and operational parameters. This monitoring generates data that feed back into the asset's information model, creating a continuous cycle of updating and refinement.

3.4 Implications for the Industrial Chain

The understanding of the built asset as permanent infrastructure has direct implications for the materials industry:

- Demand is no longer exclusively for new construction. The industry also begins to serve — and increasingly — the demand generated by the operational cycle of existing assets: maintenance, retrofit, modernization, and expansion.
- The materials and components supplied need to be compatible with the environmental attributes of the asset. A building conceived with low-carbon materials will demand, throughout its life, replacement materials and modernization components that preserve or enhance this environmental profile.
- Traceability becomes an economic requirement. For the environmental attributes of the asset to be evidenced and valued over time, it is necessary that the materials and components be traceable from their origin. This traceability, which begins in the materials industry, runs through the entire chain and is consolidated in the asset's information system.
- A new market for industrial services emerges. In addition to supplying materials, the industry begins to offer technical support services, documentation, extended warranties, and customized solutions for interventions in built assets.

CHAPTER 4: The Multiplier Effect of Decarbonization

4.1 Mechanism of the Multiplier Effect

The adoption of lower carbon intensity structural materials is not an isolated phenomenon. It triggers a multiplier effect that tends to propagate throughout the entire construction supply chain.

The mechanism is as follows: once the building structure — responsible for the largest share of embodied carbon — is conceived with low-carbon materials, technical and economic pressure is created for the other components and construction systems to present compatible environmental performance.

This pressure stems from two convergent factors:

- **Regulatory Factor:** Environmental performance standards for buildings (such as the revised EPBD and national Net Zero Carbon Buildings standards) assess the total embodied carbon of the asset, not just that of the structure. For the building to reach the required thresholds, all its components need to contribute.
- **Market Factor:** A development that invested in a low-carbon structure will seek to evidence this attribute as a competitive differentiator. The presence of components with high embodied carbon would dilute this differentiator and compromise the asset's sustainability narrative.

4.2 Scope of the Multiplier Effect

The multiplier effect tends to progressively reach all building subsystems:

- Metal structures and connections: profiles, plates, bolts, and fastening systems;
- Sealing systems: masonry, prefabricated panels, façade systems;
- Claddings: mortars, tiles, ceramics, natural stones, textile coverings;
- Frames: doors, windows, curtain wall systems;
- Roofs: tiles, membranes, insulation systems;
- Industrialized components: precast elements, structural panels, modules;
- Building installations: pipes, ducts, trays, electrical and hydraulic systems;
- Technical furniture: countertops, cabinets, partitions, ceilings;
- Finishing elements: paints, textures, sealants, adhesives.

The transformation, therefore, ceases to be localized and begins to encompass the construction ecosystem as a whole.

4.3 Impacts for Component Manufacturers and Maintenance Material Suppliers

The multiplier effect creates an environment of opportunity for component manufacturers and maintenance material suppliers that anticipate the transition.

For component manufacturers, the demand for products with verified EPDs and low carbon intensity tends to grow significantly. This includes everything from metal structural components to façade systems, frames, and roof elements. Manufacturers that develop the capacity to quantify and communicate the environmental performance of their products will be positioned to capture this demand.

For maintenance material suppliers, the opportunity is equally relevant. As built assets will demand maintenance interventions over decades, the materials used in these interventions will need to be compatible with the asset's environmental attributes. This opens a continuous market for:

- Repair mortars with a low carbon footprint;
- Claddings and finishes with verified EPDs;
- Sealants, adhesives, and waterproofing agents with lower environmental impact;
- Replacement components with guaranteed traceability.

4.4 The Building Retrofit and Modernization Industry

The multiplier effect drives the development of a specific building retrofit and modernization industry focused on preserving and improving the environmental attributes of assets.

Unlike traditional retrofit — focused predominantly on operational energy efficiency — retrofit oriented towards the preservation of embodied carbon also considers materials and construction systems. This includes:

- Replacement of components with high embodied carbon with lower-impact alternatives;
- Structural reinforcement with materials compatible with the asset's environmental profile;
- Modernization of building systems with equipment and materials of lower carbon intensity;
- Documentation and traceability of interventions for updating the asset's environmental profile.

This retrofit industry represents a new economic segment, which integrates knowledge of civil engineering, architecture, materials science, facility management, and life cycle assessment. Its development will depend on:

- Technical training of designers and installers;
- Availability of materials and components with verified environmental performance;
- Embodied carbon modeling and simulation tools;
- Standardized intervention and documentation protocols.

4.5 Market Evidence

The multiplier effect is already manifesting in various segments of the global market:

- Large real estate developers have been establishing embodied carbon targets for their developments, covering not only the structure but also façades, installations, and finishes.
- Hotel chains and corporate buildings of large occupants (big techs, financial institutions) require EPDs from all material and component suppliers.

- Certifications such as LEED v4.1 and BREEAM New Construction assign specific credits for the selection of products with EPDs and for the reduction of embodied carbon in multiple material categories.
- Real estate investment funds and REITs have been incorporating embodied carbon metrics into their asset acquisition and management policies.

CHAPTER 5: The Birth of a New Category of Real Estate Assets

5.1 The Emergence of the Category

The convergence of the factors described in the previous chapters — regulation, finance, technology, and market — is generating the conditions for the emergence of a new economic category: Low Carbon Intensity Real Estate Assets.

This category is not defined by a seal, a certification, or an isolated attribute. It is defined by the systematic presence of characteristics that allow a built asset to evidence, throughout its life cycle, an embodied emissions profile below a certain reference threshold, and to demonstrate the continued preservation of this profile through management, maintenance, and documentation practices.

5.2 Characterizing Attributes

The assets that integrate this new category share a set of attributes that go beyond their structural and functional function:

- **Structural materials with verified carbon intensity:** use of cement, steel, concrete, and other structural materials whose carbon footprint has been quantified and communicated through EPDs in accordance with ISO 14025, ISO 21930, and EN 15804.
- **Supply chain traceability:** ability to identify the origin of the main materials and components, the industrial processes employed, and the respective emission profiles.
- **Asset information model:** existence of a registration system — typically a BIM model or an asset management platform — that consolidates information on the materials, components, and construction systems used, including their environmental attributes.
- **Documented intervention history:** record of maintenance, repair, replacement, and modernization operations carried out throughout the life cycle, with the respective updating of the asset's environmental profile.
- **Plan for the preservation of environmental attributes:** existence of a plan that guides future interventions in the asset, ensuring that the materials and components used are compatible with the environmental profile established in the original construction.

5.3 Asset Valuation through its Environmental Attributes

The incorporation of environmental attributes into the profile of the real estate asset has consequences for its economic valuation.

Traditionally, the valuation of a real estate asset was based on parameters such as location, built area, finishing standard, apparent age, and revenue generation potential. These parameters remain relevant, but are supplemented by a new dimension: the environmental attributes embodied in the materials and construction systems.

This new dimension affects the asset's valuation through at least three channels:

- **Regulatory Channel:** Assets that meet the criteria of the EU Taxonomy or equivalent national taxonomies qualify for tax benefits, differentiated financing lines, and inclusion in Article 8 or Article 9 funds of the SFDR (Sustainable Finance Disclosure Regulation). Assets that do not meet these criteria may face increasing restrictions.
- **Market Channel:** Institutional investors, pension funds, and insurers, increasingly subject to ESG disclosure requirements, including the IFRS S1 and IFRS S2 standards issued by the ISSB, tend to favor assets that contribute to their emission reduction targets. The embodied carbon of the real estate portfolio becomes a relevant metric.
- **Occupancy Channel:** Corporate occupants with sustainability targets (Net Zero, Science Based Targets) tend to prefer buildings whose environmental profile is compatible with their public commitments, including embodied carbon.

5.4 Implications for the Real Estate Market

The emergence of the category of Low Carbon Intensity Real Estate Assets tends to produce a segmentation in the market, analogous to what occurred with energy efficiency in the last two decades.

Buildings that cannot evidence an environmental profile compatible with regulatory and market requirements may face:

- Relative devaluation (brown discount);
- Financing and insurance coverage restrictions;
- Difficulty in attracting corporate occupants;
- Increasing regulatory adaptation costs.

Buildings that integrate the new category, on the other hand, tend to benefit from:

- Relative appreciation (green premium);
- Access to differentiated financing lines (green bonds, sustainability-linked loans);
- Greater attractiveness for institutional investors;
- Lower regulatory and transition risk.

5.5 Evidence of Segmentation

Recent studies in the real estate sector have been documenting the emergence of this segmentation:

- The JLL "Sustainability in Real Estate" report (2023) identified a green premium of 5% to 15% in office assets with sustainability certification in the main European and North American markets.

- The CRREM (Carbon Risk Real Estate Monitor), supported by the European Union, developed decarbonization trajectories for different building typologies, establishing emission thresholds (operational and embodied) that assets will need to meet to maintain their investment eligibility.
- The GRESB (Global Real Estate Sustainability Benchmark), which evaluates the ESG performance of real estate portfolios, has included embodied carbon metrics in its assessment methodology.

CHAPTER 6: The New Role of the Cement Industry

6.1 The Dimension of the Cement Sector in the Global Context

The cement industry occupies a unique position in the global economy. With an annual production of over 4 billion tons, cement is the most consumed manufactured material by humanity, surpassed in volume only by water. Its ubiquity in construction — from foundation to finishing, from popular housing to critical infrastructure — makes it an unavoidable vector of any transformation of the built environment.

The sector is also responsible for approximately 7% to 8% of global anthropogenic CO_2 emissions, which places it at the center of decarbonization policies. Of this total, about 60% to 65% of emissions result from the chemical process of limestone calcination (process emissions), and the remainder comes from fuel consumption for clinkerization kilns (combustion emissions).

This dual source of emissions — chemical and thermal — makes cement decarbonization particularly complex, distinguishing it from other industrial sectors in which emissions stem exclusively from energy consumption. It is not enough to decarbonize the energy source; it is necessary to act on the very chemistry of the material.

6.2 Technological Routes for Reducing Carbon Intensity

Strategies for reducing the carbon intensity of cement have been the subject of intense research, development, and industrial implementation. They can be grouped into five complementary axes:

Axis 1 — Thermal Efficiency and Fuel Substitution: Reduction of energy consumption per ton of clinker produced and substitution of fossil fuels with biomass, industrial waste, and waste-derived fuels (WDF). This axis is already at an advanced stage of implementation in the main global cement companies.

Axis 2 — Clinker Substitution (Reduction of the Clinker/Cement Factor): Incorporation of Supplementary Cementitious Materials (SCMs) to reduce the proportion of clinker in cement. The future availability of the more traditional SCMs — granulated blast furnace slag and fly ash — is intrinsically linked to industrial processes (coal-based steelmaking and coal-fired power plants) that the very decarbonization policies seek to discontinue. This creates a supply paradox in the construction chain: the decarbonization of the steel industry and the energy matrix tends to drastically reduce the supply of the by-products that today substitute clinker. This industrial mass balance constraint makes it imperative to research and develop alternative SCMs of primary source, such as calcined clays, natural pozzolans, and finely ground limestone, whose geological availability and large-scale processing feasibility will dictate the real ceiling for clinker substitution in the coming decades.

Axis 3 — Carbon Capture, Utilization, and Storage (CCUS): Technologies aimed at capturing the CO_2 emitted during cement production, either for permanent geological storage (Carbon Capture and Storage — CCS) or for use in other industrial processes (Carbon Capture and Utilization — CCU). The International Energy Agency (IEA) and the Global Cement and Concrete Association (GCCA) identify CCUS as an unavoidable route for the sector's carbon neutrality by 2050.

Axis 4 — Accelerated Carbonation and CO_2 Mineralization: Processes in which CO_2 reacts with calcium- or magnesium-based minerals to form stable carbonates. This route includes the curing of concretes and precast elements in CO_2-enriched atmospheres, the incorporation of carbonated recycled aggregates, and the production of cementitious materials through the direct mineralization of CO_2.

Axis 5 — Disruptive Innovations in Binders: Development of alternative binders to traditional Portland clinker, including cements based on alkali-activated aluminosilicates (geopolymers), precipitated calcium carbonate cements, synthetic hydrated calcium silicate cements, and other low processing temperature binders.

Regardless of the technological route adopted, the most relevant transformation is not limited to the industrial process. It alters the technical characteristics incorporated into the built patrimony, allowing structural materials to become part of assets with verifiable environmental attributes potentially preserved for decades.

6.3 Carbonation as a Driver of Patrimonial Value

Among the different technological routes, those capable of incorporating permanent environmental attributes into structural materials have the potential to influence not only the reduction of industrial emissions but also the economic evolution of built assets throughout their life cycle.

The phenomenon of natural concrete carbonation has been known for decades by civil engineering, traditionally associated with the reduction of the pH of the cementitious matrix and the risk of reinforcement corrosion. However, when properly managed — through specific formulations, controlled environments, and technical monitoring — the carbonation process can be converted into a permanent CO_2 sequestration mechanism.

Accelerated carbonation in precast elements and concrete elements, for example, allows the material to incorporate significant amounts of CO_2 already in the production phase. The CO_2 reacts with calcium hydroxide and hydrated calcium silicates to form stable calcium carbonate, which remains chemically fixed in the material matrix indefinitely.

The technical literature indicates that the natural carbonation of concrete can, under ideal atmospheric exposure conditions, reabsorb between 15% and 25% of process CO_2 over decades. It is crucial, however, to understand the kinetic-chemical balance inherent in this phenomenon. For this reabsorption to occur, a cementitious matrix with open porosity that allows CO_2 diffusion is necessary. High-performance structures, characterized by very low permeability, exhibit extremely slow carbonation kinetics, limiting capture to very superficial layers during the asset's useful life. There exists, therefore, an engineering paradox: the maximization of structural durability restricts the carbonation rate. The highest reabsorption rates are typically expected in concretes with greater porosity, in controlled relative humidity environments, or after the crushing of the material in the decommissioning phase, and not in the structural element in service. This distinction is fundamental to avoid overestimated carbon sequestration projections in life cycle inventories.

6.4 Cement as a Component of Asset Value

The strategic implication of this evolution is profound: cement ceases to represent merely a construction input. It begins to directly participate in the formation of patrimonial assets with long-term environmental attributes.

This new position redefines the relationship of the cement industry with the other links in the chain:

- The cement company ceases to be a commodity supplier and becomes a supplier of solutions for the patrimonial value of the asset. The cement it produces is no longer evaluated only by its compressive strength or its price per ton, but also by its contribution to the building's environmental profile over decades.
- The quality of cement now includes its carbonation capacity. Formulations that maximize CO_2 absorption over the asset's useful life add value to the material and, by extension, to the building.
- Traceability becomes a commercial asset. The ability to document the origin, composition, and carbon footprint of each batch of cement — and to link this information to the asset's digital model — becomes a competitive differentiator.
- The cement company develops a long-term economic interest in the built asset. If the environmental performance of the building depends, in part, on the characteristics of the cement used, the cement company that supplied that cement has a direct interest in ensuring that the asset is properly maintained and that its future interventions use compatible materials.

Upon entering buildings, infrastructure, or industrial facilities, these materials cease to represent merely an industrial product. They become part of assets that will demand maintenance, retrofit, expansion, and component replacement throughout their life cycle, continuously stimulating the chain of compatible materials, products, and services.

6.5 Evidence and Reference Milestones

The transformation of the cement industry's role already has international reference milestones:

- The Global Cement and Concrete Association (GCCA) published in 2021 the Concrete Future: The GCCA 2050 Cement and Concrete Industry Roadmap for Net Zero Concrete, establishing the commitment to achieve carbon neutrality in concrete by 2050. The roadmap identifies carbonation as one of the pillars of the strategy, alongside CCUS, energy efficiency, and new binders.
- The IEA Technology Roadmap — Cement (updated in 2023) projects that carbon capture (including carbonation) will represent about 36% of the emission reductions needed for the sector to reach the Net Zero scenario by 2050.

- The EN 16757 standard establishes the rules for accounting for concrete carbonation within the scope of EPDs, allowing the CO_2 reabsorbed during the material's useful life to be accounted for in module B1 (use) and module D (benefits beyond the life cycle).
- The Global Carbon Project and the IPCC have been incorporating concrete carbonation into their CO_2 emission and removal inventories, recognizing the role of the built environment as a carbon sink.
- Several global cement companies have been launching product lines with verified EPDs and low carbon intensity attributes, specifically aimed at developments seeking certifications such as LEED, BREEAM, and DGNB.

Thus, the technological evolution of the cement industry ceases to produce effects exclusively in manufacturing and begins to influence the development of the real estate market, built infrastructure, and the Built Asset Economy as a whole.

Synthesis Table — The Transformation of the Cement Industry's Role

Traditional View	New Proposed View
Sale of cement	Formation of built assets
Construction material	Patrimonial component
Emissions in production	Environmental attributes throughout the life cycle
Construction market	Permanent Built Asset Economy
Industrial chain	Integrated ecosystem between industry, construction, infrastructure, and real estate market

CHAPTER 7: The Transformation of the Steel Industry

7.1 Steel in Construction

Steel is the second most consumed structural material by the global construction industry, with applications ranging from reinforced concrete reinforcement to metal structures, profiles, plates, pipes, roofs, and fastening systems. Global crude steel production reached approximately 1.9 billion tons in 2023, of which about 50% to 55% was destined for construction and infrastructure.

Steelmaking emissions represent between 7% and 9% of global anthropogenic CO_2 emissions, positioning the sector, alongside cement, as one of the main focuses of industrial decarbonization policies.

7.2 Technological Decarbonization Routes

The steel industry has multiple routes for reducing its carbon intensity, at different stages of technological maturity and commercial viability:

Route 1 — Blast Furnace with Carbon Capture: Installation of CO_2 capture systems (CCS/CCUS) in blast furnace top gases, allowing the continuity of the integrated route (iron ore +

coal) with drastically reduced emissions. Large-scale industrial projects in different regions explore this pathway.

Route 2 — Direct Reduction with Green Hydrogen (H_2-DRI): Substitution of coal with green hydrogen as the reducing agent for iron ore, eliminating process emissions from the integrated route. This route presents the greatest theoretical long-term emission reduction potential. However, its macroeconomic-scale viability is conditioned by a fundamental thermodynamic requirement: the production of green hydrogen would demand an increase in renewable energy of a magnitude equivalent to a significant fraction of current global capacity. The transition to this route, therefore, is not a simple technological substitution, but a challenge of massive expansion of clean energy generation infrastructure. Its implementation will be necessarily progressive and geographically heterogeneous, concentrating, in the next 15 years, in regions with access to low-cost renewable energy surpluses.

Route 3 — Electric Arc Furnaces (EAF) with Renewable Energy: Use of metal scrap as raw material in electric furnaces powered by renewable sources. This route is already widely employed (about 28% of global steel production) and its expansion potential is associated with the availability of quality scrap and access to clean energy.

Route 4 — Direct Electrolysis of Iron Ore (Electrowinning): Technology at the research and development stage, in which iron ore is reduced by electrolysis in an alkaline medium or in molten salts. Various research and development programs have been advancing on this front.

Route 5 — Increase in Recycled Content: Maximization of the proportion of scrap in the metallic charge, reducing dependence on virgin iron ore and, consequently, emissions associated with chemical reduction.

Regardless of the technological route adopted, the most relevant transformation is not limited to the industrial process. It alters the technical characteristics incorporated into the built patrimony, allowing structural materials to become part of assets with verifiable environmental attributes potentially preserved for decades.

7.3 Steel as a Component of the Environmental Integrity of the Asset

Similar to cement, steel experiences a transformation of its economic role. Its function ceases to be exclusively structural. It also begins to integrate construction systems whose composition influences the environmental characteristics of the asset throughout its entire useful life.

This transformation manifests in multiple dimensions:

Traceability Dimension: The steel used in a building — whether in concrete reinforcement, structural profiles, or façade systems — can be traced back to its origin, with identification of the production route, the associated carbon intensity, and the recycled content. This traceability feeds the asset's information model and composes its environmental documentation.

Circularity Dimension: Steel is intrinsically recyclable. At the end of the building's useful life, steel can be recovered and reintegrated into the production chain without loss of quality. This characteristic confers on the asset an attribute of circularity that contributes to its environmental profile. The documentation of the steel used — including its composition, coatings, and surface treatments — is essential to enable this circularity.

Durability Dimension: Steel contributes to the longevity of the built asset. Properly designed and protected metal structures can remain in service for more than a century. This durability is a relevant environmental attribute, as it distributes the embodied carbon of construction over a longer period, reducing the annual emission intensity.

Upon entering buildings, infrastructure, or industrial facilities, these materials cease to represent merely an industrial product. They become part of assets that will demand maintenance, retrofit, expansion, and component replacement throughout their life cycle, continuously stimulating the chain of compatible materials, products, and services.

7.4 Implications for the Steel Industry

The transformation of steel's role in construction brings strategic implications for the steel industry:

- The demand for low-carbon steels tends to grow structurally, driven by regulations (CBAM, Buy Clean), building certification requirements (LEED, BREEAM, DGNB), and institutional investor requirements.
- Differentiation by environmental attributes ceases to be a niche strategy and becomes a market requirement. Plants that cannot evidence the carbon intensity of their products through EPDs may lose access to relevant demand segments.
- Traceability becomes an added value. The ability to supply steel with documented identity — origin of scrap or ore, production route, carbon intensity, recycled content — will be increasingly demanded by builders and developers.
- A new dialogue emerges between steel companies and asset managers. As in the case of cement, steel companies begin to have an interest in preserving the attributes of the assets that use their products, opening space for technical support services, extended warranties, and the supply of compatible steels for maintenance and modernization interventions.

7.5 Reference Milestones

- The World Steel Association annually publishes the Sustainability Indicators Report, with data on carbon intensity and energy efficiency of the global steel industry.
- The ResponsibleSteel Standard establishes criteria for the certification of steel plants regarding ESG practices, including greenhouse gas emissions, water resource management, and labor rights.
- The ISO 20915 standard establishes the requirements for the life cycle assessment of steel products, providing the methodological basis for the preparation of sectoral EPDs.
- SteelZero, an initiative of the Climate Group in partnership with ResponsibleSteel, brings together companies that have committed to using 50% drastically reduced emission steel by 2030 and 100% by 2050.
- The Inflation Reduction Act (USA) and the CBAM (European Union) establish financial incentives and emission declaration requirements that directly affect the competitiveness of steels marketed in these markets.

Thus, the technological evolution of the steel industry ceases to produce effects exclusively in manufacturing and begins to influence the development of the real estate market, built infrastructure, and the Built Asset Economy as a whole.

Synthesis Table — The Transformation of the Steel Industry's Role

Traditional View	New Proposed View
Sale of steel	Formation of built assets
Construction material	Patrimonial component
Emissions in production	Environmental attributes throughout the life cycle
Construction market	Permanent Built Asset Economy
Industrial chain	Integrated ecosystem between industry, construction, infrastructure, and real estate market

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CHAPTER 8: The Evolution of the Real Estate Market

8.1 The New Valuation Paradigm

The global real estate market — which annually moves trillions of dollars in purchase and sale, leasing, financing, and development transactions — is in the process of incorporating environmental parameters into its asset valuation matrix.

This incorporation is not a passing trend. It stems from structural transformations in regulatory frameworks, institutional investor requirements, and corporate occupant preferences. As argued in the previous chapters, the embodied carbon of materials and construction systems emerges as one of the central parameters of this new matrix.

8.2 The Transmission Mechanisms

The integration of environmental attributes into the market value of real estate assets operates through multiple transmission mechanisms, whose potency tends to increase as regulations consolidate and environmental performance data become more accessible and standardized.

Mechanism 1 — Regulatory Compliance as a Liquidity Condition: Assets that do not meet the minimum environmental performance requirements defined by taxonomies and national regulations may face restrictions on their commercialization, leasing, or financing. Regulatory compliance ceases to be a desirable attribute and becomes a liquidity condition for the asset.

Mechanism 2 — Institutional Investor Preference: Pension funds, insurers, and asset managers that adopt investment policies aligned with ESG principles or that are subject to disclosure requirements (such as the SFDR in the European Union and the IFRS S1 and IFRS S2 standards issued by the ISSB) tend to favor assets with a documented environmental profile. This preference directly affects demand and, consequently, market value.

Mechanism 3 — Corporate Occupant Requirements: Large corporations that have made public commitments to climate neutrality (Net Zero) or that have joined initiatives such as the Science Based Targets (SBTi) need their facilities — owned or leased — to present environmental performance compatible with these targets. Scope 3 of the GHG Protocol, which includes value chain emissions, covers the properties occupied by the company.

Mechanism 4 — Differentiated Cost of Capital: Financial institutions have been developing specific products for low-carbon assets, such as green bonds, sustainability-linked loans, and green mortgages. These products offer more favorable conditions (reduced interest rates, extended terms) for assets that meet predefined environmental performance criteria.

Mechanism 5 — Transparency and Comparability: The dissemination of EPDs, building certifications, and benchmark platforms (such as CRREM and GRESB) increases the transparency and comparability of the environmental performance of assets, allowing buyers, tenants, and investors to incorporate this information into their decisions.

8.3 Continuous Demand for Compatible Materials and Components

A particularly relevant aspect for the Built Asset Economy thesis is the effect that the new valuation matrix produces on the demand for materials and components throughout the operational life of the asset.

If the value of the real estate asset comes to be influenced by its environmental attributes — including embodied carbon — any maintenance, repair, replacement, or modernization intervention will need to be carried out with materials and components that preserve or enhance these attributes. Otherwise, the asset's environmental profile degrades and, with it, its market value and regulatory compliance.

This creates continuous and structural demand for:

- Maintenance materials with verified EPDs: Repair mortars, grouts, filling concretes, sealants, and adhesives with a documented carbon footprint.
- Compatible replacement components: Frames, claddings, façade systems, roofs, and building installations whose environmental profile is compatible with that of the original asset.
- Low-carbon modernization products: Air conditioning, lighting, automation, and electrical and hydraulic systems with reduced carbon intensity.
- Technical documentation and environmental profile updating services: Capacity to record the interventions carried out and update the asset's information model (BIM, Digital Twin) with the new environmental performance data.

8.4 The Permanent Demand Cycle

The permanent demand cycle generated by the new real estate market valuation matrix can be described in the following stages:

Stage 1 — Original Construction: The asset is conceived with low carbon intensity structural materials, documented by EPDs, and integrated into the development's BIM model.

Stage 2 — Initial Valuation: The asset is valued considering its environmental attributes, obtaining a green premium and access to differentiated financing.

Stage 3 — Operation and Maintenance: Throughout the operational life, maintenance interventions are carried out with materials and components compatible with the asset's environmental profile.

Stage 4 — Documentary Update: Each intervention is recorded in the asset's information model, updating its environmental profile.

Stage 5 — Retrofit and Modernization: When necessary, retrofit and modernization interventions are carried out with materials and systems that preserve or enhance the asset's environmental attributes.

Stage 6 — Continuous Revaluation: The asset is periodically revalued, and the preservation of its environmental attributes contributes to maintaining its market value and attractiveness for investors and occupants.

Stage 7 — Continuous Industrial Demand: Each intervention in stages 3 and 5 generates demand for new materials, components, and services, feeding back into the industry.

8.5 Evidence and Trends

- The Carbon Risk Real Estate Monitor (CRREM), supported by the European Union, establishes decarbonization trajectories for the real estate sector, defining the maximum carbon intensity levels (operational and embodied) that assets must reach each year to remain aligned with the Paris Agreement.
- The Global Real Estate Sustainability Benchmark (GRESB) annually evaluates the ESG performance of more than US$ 7 trillion in real estate and infrastructure assets, including embodied carbon metrics.
- The Royal Institution of Chartered Surveyors (RICS) published the Whole Life Carbon Assessment for the Built Environment, a professional standard for assessing the embodied and operational carbon of built assets.
- Large global real estate fund managers have been setting emission reduction targets for their portfolios, covering embodied carbon.
- The EU Taxonomy Regulation, the SFDR, and the EPBD revision provide the regulatory framework that makes these trends mandatory.

CHAPTER 9: The Evolution of Financing

9.1 The Financial System as a Transformation Driver

The financial system plays a central role in the transition of built assets. Through capital allocation, risk pricing, and the definition of eligibility criteria for credit and investment, financial institutions have the capacity to accelerate — or delay — the incorporation of environmental attributes into the built environment.

The integration of environmental, social, and governance (ESG) criteria into real estate financing and investment decisions is no longer a voluntary initiative of a restricted market segment. It has been progressively codified into regulatory frameworks that establish due diligence, transparency, and disclosure obligations for financial institutions.

9.2 Regulatory Frameworks for ESG Integration

European Union: The SFDR Regulation (Sustainable Finance Disclosure Regulation — Regulation EU 2019/2088) requires financial market participants to disclose how sustainability risks are integrated into their investment decision processes. Funds classified as Article 8 (which promote environmental or social characteristics) and Article 9 (which have sustainable investment as their objective) need to demonstrate the alignment of their assets with the EU Taxonomy.

The EU Taxonomy Regulation (Regulation EU 2020/852) establishes the technical criteria for an economic activity — including the acquisition and ownership of buildings, as well as the renovation of existing buildings — to be considered environmentally sustainable. Assets that meet these criteria qualify for green bonds and other sustainable financing modalities.

The European Union Green Bond Standard (Regulation EU 2023/2631) establishes a voluntary high-quality standard for green bonds, requiring that the funds raised be fully allocated to activities that meet the EU Taxonomy criteria.

Global: The Equator Principles, adopted by more than 130 financial institutions in 38 countries, establish standards for assessing socio-environmental risks in large-scale projects, including real estate and infrastructure developments.

The IFRS S1 and IFRS S2 standards, issued by the International Sustainability Standards Board (ISSB), establish the global requirements for the disclosure of sustainability and climate-related financial information, incorporating and updating the recommendations originally developed by the TCFD. Financial institutions in jurisdictions that adopt these standards will need to report their exposure to climate risks, including the risks associated with real estate and infrastructure assets in their portfolios.

The Network for Greening the Financial System (NGFS), which brings together more than 100 central banks and financial supervisors, has been developing scenarios and methodologies for assessing climate risks in the financial system.

9.3 Financial Mechanisms for Low Carbon Intensity Assets

Various financial instruments have been developed or adapted for low carbon intensity real estate assets:

Green Bonds: Debt securities whose funds are exclusively destined for projects with environmental benefits, including green buildings and building retrofits. The global green bond market surpassed US$ 500 billion in annual issuances in 2023, with a significant share destined for the real estate sector.

Sustainability-Linked Loans (SLLs): Loans whose conditions (interest rate, term) are linked to the borrower's performance on predefined sustainability metrics, such as reducing the carbon intensity of the asset portfolio.

Green Mortgages: Real estate financing with differentiated conditions for buildings that meet energy efficiency criteria and, increasingly, low embodied carbon criteria.

Green Real Estate Investment Trusts (REITs): Funds that select assets based on sustainability criteria and disclose environmental performance metrics, including the embodied carbon intensity of their portfolios.

Sustainability-Linked Bonds: Securities whose financial characteristics are tied to the issuer's fulfillment of sustainability targets.

9.4 The Role of Development Banks and Multilateral Organizations

Institutions such as the World Bank, the International Finance Corporation (IFC), the European Investment Bank (EIB), and the Inter-American Development Bank (IDB) play a catalytic role in integrating environmental criteria into the financing of built assets.

The IFC, through its EDGE (Excellence in Design for Greater Efficiencies) program, provides a green building certification platform aimed at emerging markets. The program has already certified more than 250 million square meters in over 150 countries.

The EIB, as the European Union's financial arm, conditions its financing on compliance with the EU Taxonomy criteria and requires the disclosure of embodied carbon metrics for construction and infrastructure projects.

9.5 Implications for the Construction Industry Chain

The evolution of real estate financing has direct implications for the entire construction industry chain:

- Builders and developers will need to demonstrate the environmental performance of the materials and construction systems used so that their developments are eligible for differentiated financing.
- Material manufacturers that do not have verified EPDs may see their products excluded from developments seeking green financing.
- Investors and developers will need to incorporate embodied carbon metrics into their due diligence processes and capital allocation decisions.
- Financial institutions will need to develop technical capacity to assess the environmental performance of real estate assets, including the analysis of EPDs and life cycle reports.

Chapter 10

Traceability and Integrity of Built Assets

10.1 From Material Traceability to Asset Traceability

Historically, traceability systems in the construction industry have focused on the identification of materials, components, and production batches. This information plays an important role in quality control, technical compliance, and product certification; however, it represents only one part of the infrastructure life cycle.

As buildings, bridges, dams, highways, ports, airports, and other infrastructure assets increasingly incorporate environmental attributes and long-term performance requirements, it becomes necessary to extend traceability beyond individual construction materials.

In this context, the unit of management is no longer limited to the construction component itself, but evolves to encompass the built asset as a whole.

10.2 The Asset as a Permanent Management Unit

Each built asset may be understood as a patrimonial infrastructure composed of multiple structural, mechanical, electrical, hydraulic, and operational systems.

Throughout its service life, this asset accumulates information related to:

- Executive design;
- Technical specifications;
- Materials employed;
- Origin and documentation of components;
- Periodic inspections;
- Structural testing;
- Maintenance interventions;
- Component replacements;
- Expansions;
- Retrofits;
- Operational monitoring;
- Performance history.

Together, these records constitute a continuous technical history of the asset.

10.3 Information Continuity

The management of built infrastructure evolves from reliance on dispersed documentation toward an integrated framework of technical information.

This continuity enables the evolution of the asset to be monitored over decades while preserving records and evidence related to its structural condition, operational condition, and intervention history.

Among the information that may compose this technical history are:

- Composition of structural systems;
- Embodied carbon intensity of materials;
- Design service life of components;

- Inspection records;
- Test results;
- Photographic records;
- Instrumentation monitoring;
- Intervention history;
- Associated technical documentation.

10.4 Critical Infrastructure and Monitoring

For assets classified as critical infrastructure, traceability may be integrated with permanent monitoring systems.

Among the parameters that may be monitored are:

- Structural deformation;
- Displacements;
- Vibrations;
- Corrosion;
- Carbonation;
- Cracking;
- Temperature;
- Humidity;
- Mechanical stresses;
- Load cycles;
- Operational performance.

These data support inspection processes, maintenance planning, and intervention strategies throughout the asset life cycle.

10.5 The Evolution of Maintenance

The continuous availability of information enables maintenance practices to evolve from predominantly calendar-based approaches toward condition-based strategies.

This approach may contribute to:

- Greater precision in intervention planning;
- Technical prioritization of investments;
- Reduced operational downtime;

- Improved asset management;
- Better support for decisions related to operational continuity.

10.6 Traceability and Long-Term Infrastructure Finance

Infrastructure financed by development banks, multilateral institutions, or public organizations frequently remains in operation for many decades.

The existence of a structured technical history enhances the ability to monitor asset performance throughout the financing period.

Among the aspects that may be monitored are:

- Structural condition;
- Maintenance interventions;
- Component replacement;
- Evolution of technical indicators;
- Inspection documentation;
- Compliance evidence.

These records strengthen asset management, patrimonial management, and technical assessment processes throughout the infrastructure life cycle.

10.7 The Asset Integrity Economy

Traceability evolves beyond a documentary control mechanism and becomes an integral component of infrastructure life-cycle management.

In this context, materials, components, inspections, maintenance, retrofits, and modernization become part of a continuous flow of information accompanying the asset throughout its entire existence.

This evolution strengthens the integration among industry, construction, infrastructure operators, the real estate sector, financial institutions, and public authorities, consolidating an economy based not only on the construction of new developments but also on the long-term preservation, modernization, and management of built assets.

CHAPTER 11: Public Infrastructure and Territorial Planning

11.1 The State as a Transformation Driver

The public authorities — in their multiple spheres: national, regional, and local — play a triple role in the transition of built assets. They are, simultaneously, regulator (establishing the norms and standards that guide private activity), contractor (accounting for a significant share of the demand for construction and infrastructure), and planner (defining the territorial occupation and urban development guidelines that condition the built environment for decades).

In this triple condition, the State has the capacity to accelerate the transition through instruments that go far beyond direct environmental regulation. Public procurement, master plans, building codes, infrastructure concessions, and public-private partnerships are transformation drivers with long-term impact on the entire construction industry chain.

11.2 Public Procurement as a Market Lever

Government procurement represents a significant share of the demand for construction materials and engineering services. It is estimated that public spending on infrastructure and buildings corresponds to 15% to 25% of the construction sector's GDP in most countries, reaching even higher percentages in developing economies.

The introduction of sustainability criteria — and, more specifically, carbon intensity — in public bids has the potential to create an initial market of scale for low-carbon materials, enabling learning curves and economies of scale that will later benefit the private market.

Several jurisdictions already implement sustainable public procurement policies focused on construction materials:

European Union: Directive 2014/24/EU (Public Procurement) expressly authorizes the inclusion of environmental criteria in public bids, including the requirement for EPDs and emission limits for construction materials. The European Commission's Green Public Procurement (GPP) establishes voluntary criteria that have been adopted by a growing number of Member States.

United States: The Buy Clean Task Force, established by Executive Order in 2021, defined maximum emission limits for structural materials (steel, concrete, glass, asphalt) purchased with federal funds. The Inflation Reduction Act of 2022 allocated US$ 4.5 billion for the General Services Administration (GSA) and the Department of Transportation to prioritize low-carbon materials in their procurement. States such as California (Buy Clean California Act, 2017), Colorado, New York, and Oregon have enacted similar legislation.

United Kingdom: Procurement Policy Note (PPN) 06/21, issued by the Cabinet Office, requires all central government bids to include carbon emission reduction criteria, covering embodied carbon in construction materials.

Canada: The Standard on Embodied Carbon in Construction, published by the Treasury Board of Canada Secretariat, establishes the mandatory disclosure of embodied carbon in federal construction projects starting in 2023, with progressive limits in subsequent years.

11.3 Urban Planning and Building Codes

Municipal master plans and building codes are territorial planning instruments with direct impact on the characteristics of the built environment. Traditionally focused on parameters such as building height, floor area ratio, setbacks, and occupancy rate, these instruments have been progressively incorporating environmental performance requirements.

Cities such as Vancouver (Green Buildings Policy for Rezonings), Oslo (FutureBuilt), Copenhagen (CPH 2025 Climate Plan), San Francisco, and Singapore have established carbon neutrality targets for the built environment and require the disclosure of embodied carbon metrics for new developments. These municipal requirements create a regulatory environment that anticipates and, in many cases, exceeds national requirements.

The inclusion of embodied carbon parameters in building codes has the effect of:

- Internalizing the environmental cost of construction in design and material selection decisions;
- Creating a local market for low-carbon materials, stimulating supply from manufacturers;
- Generating a municipal database on the environmental performance of the built stock, allowing the monitoring of emission reduction targets;
- Influencing the technical culture of designers, builders, and developers, who begin to consider embodied carbon as a design variable as relevant as cost or time.

11.4 Critical Infrastructure and Concessions

The State is the main contractor and regulator of critical infrastructure projects — highways, railways, ports, airports, water supply systems, sanitation, energy generation and transmission, telecommunications. These projects, due to their scale, mobilize significant volumes of structural materials — concrete, steel, asphalt — and operate for decades under concession or public management.

The introduction of embodied carbon criteria in concession bidding documents and public-private partnership (PPP) contracts can:

- Establish a large-scale captive market for low-carbon materials;
- Create a documentary history of environmental performance that feeds back into technical standards and regulatory parameters;
- Reduce transition risk for concessionaires, who begin to operate assets aligned with long-term regulatory expectations;
- Contribute to the fulfillment of national emission reduction targets (NDCs) assumed under the Paris Agreement.

11.5 Territorial Planning and Climate Resilience

The transition of built assets also connects to climate adaptation and resilience policies. The choice of materials and construction systems directly influences the vulnerability of buildings and infrastructure to extreme weather events — floods, storms, heat waves, sea level rise.

Construction materials with greater durability, lower permeability, greater resistance to humidity and temperature cycles, and self-healing capacity (such as concretes that benefit from controlled carbonation) contribute to the resilience of the built environment. This contribution adds to the emission reduction benefits, creating a virtuous circle between climate mitigation and adaptation.

11.6 Reference Milestones

- UNFCCC — Paris Agreement (2015): The Nationally Determined Contributions (NDCs) of several countries include sectoral targets for the construction and infrastructure industry.

- UN Sustainable Development Goals (SDGs): SDG 9 (Industry, Innovation, and Infrastructure), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action) provide the global framework for built environment policies.
- World Bank — Infrastructure Sustainability Framework: The World Bank has developed a framework for assessing the sustainability of infrastructure projects, incorporating embodied carbon metrics.
- C40 Cities: The network of megacities committed to climate action includes specific targets for the decarbonization of the built environment, covering embodied carbon.
- Global Alliance for Buildings and Construction (GlobalABC): An initiative of UNEP (United Nations Environment Programme) that brings together governments, the private sector, and civil society organizations to promote sustainability in the construction sector.

CHAPTER 12: The Permanent Economic Cycle

12.1 Construction as an Inaugural Event

The built environment economy has traditionally been conceived as a project economy. The economic cycle of a building — from the perspective of the materials industry and the construction industry — began with the decision to build and ended with the completion of the work. What occurred afterwards — operation, maintenance, renovations — belonged to another economic universe, that of facility services and condominium administration.

The transition of built assets breaks this compartmentalization. Construction ceases to be the main economic event around which maintenance activities orbit in an accessory manner. Construction becomes the inaugural event of an economic cycle that will extend throughout the asset's entire life and will mobilize, continuously and recurrently, the industry of materials, components, and specialized services.

12.2 The Phases of the Economic Cycle

The permanent economic cycle of a built asset can be broken down into the following phases, each generating specific demand for materials, components, and services:

Phase 1 — Original Construction: Demand for structural materials (cement, steel, concrete), components (frames, claddings, installations), and engineering and construction services. This phase establishes the asset's reference environmental profile.

Phase 2 — Initial Operation (years 1 to 5): Building stabilization period, with punctual adjustment interventions and correction of non-conformities. Demand for repair materials, sealants, waterproofing agents, and replacement components.

Phase 3 — Scheduled Maintenance (years 5 to 15): Regular cycles of preventive and corrective maintenance. Replacement of short-life components (claddings, waterproofing, paint systems). Continuous demand for maintenance materials compatible with the asset's environmental profile.

Phase 4 — First Retrofit (years 15 to 25): Significant modernization intervention. Replacement of building systems (air conditioning, electrical, hydraulic, automation), updating of façades and roofs.

Significant demand for materials and components with environmental performance equal to or greater than that of the original construction.

Phase 5 — Mature Operation (years 25 to 50): Continuity of maintenance cycles, with localized structural reinforcement and modernization interventions. Demand for high-performance materials and customized technical solutions.

Phase 6 — Second Retrofit or Expansion (years 50 to 75): Comprehensive intervention that may include expansion of built area, integral modernization, and structural reinforcement. Demand for large volumes of materials, potentially with even more stringent environmental specifications than those of the original construction, due to regulatory evolution.

Phase 7 — Decommissioning or Recycling (after 75 or 100 years): Demand for selective demolition, sorting, processing, and material recycling services. Steel can be fully recycled; concrete can be crushed and reused as aggregate, with additional carbonation potential.

12.3 Construction as a Permanent Platform of Industrial Demand

The central implication of this cycle is that construction represents only the beginning. Over decades, the asset will continue to demand materials, components, equipment, and specialized services. Each intervention generates new economic activity. The asset transforms into a permanent platform of industrial demand.

This platform has characteristics that distinguish it from the traditional new construction market:

- **Recurrence:** Demand is not punctual but continuous and recurrent throughout the asset's entire life.
- **Compatibility:** The materials and components demanded need to be compatible with the asset's environmental profile, creating a captive market for products with verified EPDs and low carbon intensity.
- **Traceability:** Interventions need to be documented and integrated into the asset's information model, generating demand for specialized technical services.
- **Customization:** Interventions in existing assets often require customized technical solutions, opening space for high value-added engineering services.

12.4 Economic Magnitude of the Cycle

The economic magnitude of the permanent cycle is substantial. Sector data suggest that, in mature economies, the accumulated expenses with maintenance, renovation, retrofit, and modernization over the life of a building can equal or exceed the cost of the original construction.

For a typical commercial building with a 60-year useful life, it is estimated that:

- The original construction cost represents 30% to 40% of the total expense throughout the life cycle;
- Maintenance and minor renovation costs represent 20% to 30%;
- Retrofit and modernization costs represent 25% to 35%;
- Decommissioning costs represent 5% to 10%.

When the "embodied carbon" variable is added, these expenses tend to grow in absolute terms (lower carbon intensity materials and components may have a higher initial cost) and in relative terms (the need to preserve the asset's environmental profile may anticipate or intensify retrofit interventions).

12.5 Implications for Industrial Strategy

For the materials industry, the permanent economic cycle implies a strategic reorientation:

- **From product to cycle:** The business unit ceases to be the punctual sale of a volume of material and becomes the continuous supply of materials and solutions throughout the asset's life.
- **From commodity to system:** The material ceases to be sold as an undifferentiated commodity and becomes part of documented construction systems, with verifiable environmental attributes.
- **From single client to ecosystem:** The industry begins to relate not only with builders but with an expanded chain that includes developers, property managers, retrofit companies, asset managers, and insurers.
- **From anonymity to identity:** The material acquires identity — origin, composition, carbon footprint, production date, batch — and this identity is preserved throughout the asset's entire life cycle.

CHAPTER 13: A New Value Chain

13.1 The Reconfiguration of Sectoral Relations

The transition of built assets does not only affect materials or construction techniques. It reconfigures the relationships between the economic agents that make up the built environment chain.

The traditional model — linear and segmented — organized the chain into sequential and relatively watertight stages:

- Raw material extraction
- Material manufacturing (cement, steel, glass, ceramics)
- Component and system production (precast elements, frames, installations)
- Design (architecture, engineering)
- Construction (builders, contractors)
- Commercialization (developers, brokers)
- Operation and maintenance (property managers, facilities)
- Decommissioning (demolition companies, recyclers)

In this model, each stage operated with relative autonomy. Information flowed in a limited way between stages, and each agent optimized its own activity without considering the impacts on subsequent stages.

The transition of built assets imposes network integration. The asset's environmental attribute — embodied carbon — is the result of the sum of the contributions of all stages of the chain, and its preservation over time requires coordination among agents that, in the traditional model, operated independently.

13.2 The Agents of the New Value Chain

The new built environment value chain integrates an expanded spectrum of economic agents:

1. Structural Materials Industry:
Cement companies, steelmakers, aggregate producers, and concrete companies. They supply the materials that determine the largest share of the asset's embodied carbon and that establish its reference environmental profile.

2. Component and System Manufacturers:
Producers of precast elements, sealing panels, frames, façade systems, roofs, building installations, and finishing elements. They must supply products with verified EPDs and environmental performance compatible with that of the structural materials.

3. Builders and Developers:
Responsible for the execution of the work and the commercialization of the development. They act as integrators of the supply chain, selecting materials and construction systems that meet the project's environmental requirements. They are the guardians of the asset's construction documentation.

4. Building Maintenance Companies:
They carry out preventive and corrective maintenance interventions throughout the asset's operational life. In the new value chain, they need to use materials and components compatible with the asset's environmental profile and document the interventions carried out.

5. Retrofit and Modernization Companies:
Specialized in large-scale interventions in existing assets — updating building systems, modernizing façades, structural reinforcement. They represent an expanding market segment, driven by regulatory requirements and decarbonization targets.

6. Infrastructure Operators:
Concessionaires of highways, railways, ports, airports, water and energy systems. They manage long-term assets in which operational continuity and resilience are critical. The traceability and environmental performance of the materials used are relevant for risk management and regulatory compliance.

7. Financial Sector:
Banks, investment funds, asset managers, and development agencies. Through the definition of eligibility criteria for financing and investment, they influence the decisions of all other agents in the chain. The integration of embodied carbon metrics into due diligence processes and portfolio management is a consolidated trend.

8. Insurers and Reinsurers:
They assess and price risks associated with built assets. In the new value chain, they have more detailed information on materials and construction systems, allowing for more accurate actuarial assessment and the development of differentiated products.

9. Property and Facility Managers:
Responsible for the daily administration of assets and the execution of maintenance plans. In the new value chain, they act as guardians of the asset's environmental integrity, ensuring that interventions preserve its attributes and that documentation is kept up to date.

10. Public Authorities and Regulatory Agencies:
They define the rules that guide the activity of all other agents. Through regulations, incentives, public procurement, and territorial planning, the State establishes the boundary conditions of the new Built Asset Economy.

13.3 Integration as a Competitiveness Factor

In the new value chain, the capacity for integration among agents becomes a competitiveness factor. Builders that can articulate suppliers of materials with verified EPDs, developers that can evidence the environmental profile of their projects for investors and financiers, infrastructure operators that can document the resilience of their assets for insurers — all these agents tend to obtain competitive advantages in the new economic environment.

Integration is not limited to the exchange of commercial information. It involves:

- **Documentation system compatibility:** The data generated by each agent need to be compatible with the systems of the others, allowing the consolidation of the asset's environmental profile.
- **Metric standardization:** Carbon intensity, durability, and other attributes need to be measured and communicated based on common standards (ISO, EN, ABNT), ensuring comparability and reliability.
- **End-to-end traceability:** From the origin of the materials to the most recent maintenance intervention, the asset's history needs to be traceable and auditable.
- **Contractual and documentary continuity:** Performance warranties, EPDs, and intervention records need to be preserved and transferred in the event of sale or change of control of the asset.

13.4 Digital Platforms and Integration

Digital platforms — BIM, Digital Twins, distributed ledger technologies (blockchain/DLT) for supply chain traceability, and asset management platforms — are the technological enablers of integration.

BIM (Building Information Modeling), in particular, constitutes the digital environment in which the information generated by all agents in the chain can be consolidated, visualized, and analyzed. The ISO 19650 series establishes the principles for information management throughout the life cycle of assets, defining processes and responsibilities for the production, exchange, and maintenance of information.

The Digital Twin extends this capacity, integrating sensor data and monitoring systems into the asset's digital model, allowing real-time monitoring of structural, environmental, and operational parameters.

It is essential, however, to recognize the limitation known as the "Oracle Problem" in decentralized systems: distributed ledger technology guarantees the immutability of data once inserted, but does not attest to the physical-chemical veracity of the material that the data represents. The effectiveness of an end-to-end traceability system depends, ultimately, on a robust bridge between the physical asset and its digital twin, built through rigorous governance, audit, and verification processes at the point of application. Without this layer of trust, the digitalization of environmental performance runs the risk of becoming a vector of "digitalized greenwashing," where immutable data perpetuates materially false sustainability claims.

CHAPTER 14: The Built Asset Economy

14.1 Formalization of the Concept

The previous chapters have provided the necessary elements for the formalization of the concept that constitutes the central thesis of this white paper: the Built Asset Economy.

The Built Asset Economy is defined as the economic system in which:

- Real estate and infrastructure assets are managed as continuous platforms for the preservation of technical, economic, and environmental value;
- The environmental attributes of materials and construction systems — in particular, embodied carbon — integrate the patrimonial value of assets and influence their eligibility for financing, their attractiveness to investors, and their regulatory compliance;
- The preservation and improvement of these attributes throughout the life cycle drive permanent cycles of maintenance, retrofit, modernization, and expansion;
- These cycles generate continuous demand for materials, components, and industrial services, feeding back into the construction industry and related sectors;
- Construction ceases to be an isolated event and becomes the inaugural event of an economic cycle that extends throughout the asset's entire life.

14.2 Structural Characteristics

The Built Asset Economy is distinguished from the traditional construction industry model by a set of structural characteristics:

1. Extended Temporality: The relevant economic horizon is not the construction period (2 to 5 years) but the asset's complete life cycle (50 to 100 years or more). Decisions made in the design and construction phase have economic consequences that unfold over decades.

2. Embodied Value: The asset's value is not determined solely by its location and physical characteristics but also by the environmental attributes embodied in its materials and construction systems. These attributes are transferred from the material to the asset and accompany it throughout its entire useful life.

3. Recurrent Demand: The demand for materials, components, and services is not concentrated in the construction phase but is distributed throughout the asset's entire life cycle, with peaks associated with retrofit and modernization interventions.

4. Network Integration: The value chain ceases to be linear and segmented and begins to operate as an integrated network, in which information on the attributes of materials and systems flows among all agents.

5. Normative and Documentary Basis: The Built Asset Economy rests on a normative framework (technical standards, environmental regulations, financial requirements) and documentary framework (EPDs, BIM models, intervention records) that ensures the verifiability and comparability of asset attributes.

14.3 The Self-Feeding Dynamic

A distinctive characteristic of the Built Asset Economy is its self-feeding dynamic. With each maintenance or retrofit intervention that preserves or enhances the asset's environmental attributes:

- The asset's value is preserved or increased, maintaining its attractiveness for investors and occupants;
- Regulatory compliance is renewed, ensuring the asset's liquidity;
- New industrial demand is generated, feeding back into the materials and components industry;
- The cycle restarts, with the asset demanding new interventions in the future.

This dynamic creates a virtuous circle in which the preservation of asset value, regulatory compliance, and industrial activity mutually reinforce each other. The built asset ceases to be a depreciating asset and becomes a continuously evolving asset.

14.4 The Connection between Industry, Construction, Real Estate Market, and Infrastructure

The Built Asset Economy connects sectors that, in the traditional model, operated with independent logics:

- The materials industry ceases to sell products for a construction site and begins to supply value components for an asset that will operate for decades.
- The construction industry ceases to be a project activity and becomes the origin of a continuous flow of demand for maintenance and modernization services.
- The real estate market ceases to transact square meters and begins to transact assets whose value is influenced by documented environmental attributes.
- Infrastructure ceases to be a stock of public works and becomes a portfolio of assets managed with long-term sustainability and resilience criteria.

This connection redefines the very economic nature of the built environment. It ceases to be a sector of the economy and becomes a transversal economic platform that integrates industry, services, finance, and regulation in a continuous cycle of value creation and preservation.

14.5 Macroeconomic Implications

Although a detailed macroeconomic analysis goes beyond the scope of this white paper, it is possible to identify some far-reaching implications:

- The gross fixed capital formation (GFCF) of the construction sector tends to stabilize at higher levels, sustained by the recurrent demand for maintenance, retrofit, and modernization, even in mature economies with lower population growth.
- Employment in the sector tends to shift from new construction to maintenance, retrofit, and asset management services, with impacts on professional qualification and sector productivity.
- The construction materials industry tends to become more sophisticated, incorporating differentiation attributes (EPDs, traceability, environmental performance) into products traditionally considered commodities.
- The financial system tends to develop new instruments and markets (green bonds, sustainability-linked loans, green mortgages) backed by the environmental performance of built assets.
- International trade in construction materials tends to be influenced by carbon barriers (such as the European CBAM), affecting the relative competitiveness of exporting countries.

CHAPTER 15: Conclusion and Perspectives

15.1 Thesis Synthesis

This white paper has argued that the decarbonization of structural materials does not constitute an end in itself, nor is it limited to a sectoral industrial innovation. It represents the triggering element of a wide-ranging economic transformation that reorganizes the construction industry chain, establishes a permanent economy of built assets, and drives the continuous development of materials, products, and services aimed at preserving the environmental characteristics of infrastructure throughout its entire life cycle.

The 15 chapters of this document have covered the complete arc of this transformation:

- Chapters 1 to 3 established the conceptual foundations, characterizing the third transformation of the construction industry, the link between industry and patrimony, and the built asset as permanent infrastructure.
- Chapters 4 and 5 demonstrated the multiplier effect of decarbonization on the entire supply chain and the birth of a new category of real estate assets, also valued for their environmental attributes.

- Chapters 6 and 7 analyzed the specific implications for the cement and steel industries, which cease to be commodity suppliers and become suppliers of patrimonial value components.
- Chapters 8 to 11 examined the impacts on the real estate market, the financial system, the insurance sector, and public authorities, evidencing the convergence of interests among agents that traditionally operated independently.
- Chapters 12 to 14 formalized the concepts of permanent economic cycle, new value chain, and Built Asset Economy, providing the analytical framework for understanding the transformation in its entirety.

15.2 The Central Hypothesis Confirmed

The central hypothesis presented in the Introduction was developed and substantiated throughout the document:

The decarbonization of structural materials triggers an economic transformation that reorganizes the entire construction industry chain, establishes a permanent economy of built assets, and drives the continuous development of materials, products, and services aimed at preserving the environmental characteristics of infrastructure throughout its entire life cycle.

The normative, technical, and economic foundations presented throughout the 15 chapters provide robust evidence to support this hypothesis.

15.3 Perspectives for the Coming Decades

Projecting the development of the Built Asset Economy in the coming decades involves significant uncertainties, associated with the evolution of regulations, technologies, and global macroeconomic conditions. Nevertheless, it is possible to identify trends with a high probability of consolidation:

Decade 2025-2035 — Regulatory and Market Consolidation:

- Entry into force of the main regulatory frameworks (CBAM, EU Taxonomy, Buy Clean, EPBD updates), establishing mandatory requirements for embodied carbon.
- Consolidation of EPDs as the standard for communicating the environmental performance of construction materials.
- Growth of the green bond and sustainability-linked loan market backed by real estate assets.
- Price differentiation (green premium / brown discount) becoming observable in the main real estate markets.
- First generations of low carbon intensity real estate assets completing their first scheduled maintenance cycle.

Decade 2035-2050 — Maturation of the Built Asset Economy:

- Carbon neutrality in the production of the main structural materials (cement, steel) in an advanced implementation process, with commercial scale CCUS and H_2-DRI.
- Retrofit and modernization cycle of assets built in the 1990s to 2020s driving industrial demand.

- Digital Twins and integrated BIM as standard built asset management platforms.
- Secondary market for construction materials (from decommissioning) established and operating with quality and traceability standards.
- Convergence between asset information systems and public property registries, creating a global database on the environmental performance of the built environment.

Beyond 2050 — The Built Asset Economy as the Dominant Paradigm:

- Carbon-neutral or carbon-negative buildings (which capture more CO_2 than they emit over their life cycle) as the market standard.
- Continuous maintenance, retrofit, and modernization cycles operating as permanent drivers of industrial activity.
- Full integration between asset management systems, financial markets, and regulation, with dynamic pricing of embodied carbon.
- The construction industry operating as a service and solution economy, more than a product and project economy.

15.4 Strategic Recommendations

Based on the analysis developed, strategic recommendations are presented for the main agents in the chain:

For the Materials Industry (Cement, Steel, Components):

- Develop and publish EPDs for the entire product portfolio, in compliance with ISO 14025, ISO 21930, and EN 15804.
- Invest in traceability systems (digital passports, blockchain) that allow documenting the origin and composition of materials.
- Develop specific product lines for maintenance, retrofit, and modernization, compatible with the environmental profile of built assets.
- Establish partnerships with builders, developers, and asset managers for the continuous supply of materials throughout the life cycle.

For Builders and Developers:

- Train design and supply teams for the analysis of EPDs and the selection of materials based on embodied carbon criteria.
- Implement documentation systems (BIM) that consolidate the environmental information of the materials used and transfer them to the asset managers.
- Anticipate regulatory requirements (EU Taxonomy, CBAM, Buy Clean) in current projects, positioning themselves as leaders in the supply of low-carbon assets.

For the Financial Sector and Insurers:

- Develop technical capacity for the assessment of the environmental performance of real estate assets, including the analysis of EPDs and life cycle reports.

- Structure differentiated financial and insurance products for low-carbon assets (green bonds, sustainability-linked loans, green mortgages, policies with special conditions).
- Incorporate embodied carbon metrics into due diligence, portfolio management, and risk underwriting processes, in compliance with the IFRS S1 and IFRS S2 standards issued by the ISSB.

For Public Authorities and Regulators:

- Include embodied carbon criteria in public procurement for construction works and engineering services (sustainable public procurement).
- Update building codes and master plans to incorporate environmental performance requirements, including embodied carbon limits.
- Foster technical training and applied research in low-carbon materials, life cycle assessment, and built asset management.
- Align national construction and infrastructure policies with international frameworks (EU Taxonomy, Paris Agreement, SDGs).

15.5 Limitations and Future Research Agenda

This white paper does not exhaust the topic. Several questions remain open and constitute a future research agenda:

- Precise quantification of multiplier effects: What is the elasticity of demand for low-carbon materials in other building components as a function of the adoption of low carbon intensity structural materials?
- Cost-benefit analysis of the complete cycle: What is the total cost of ownership (TCO) of a low carbon intensity asset, including maintenance, retrofit, and modernization costs, compared to a conventional asset?
- Distributive and social impacts: How does the transition affect access to housing, the cost of popular construction, and urban inequality?
- International standardization of metrics: How to harmonize the different national and regional methodologies for life cycle assessment and embodied carbon calculation?
- Incentive and pricing mechanisms: What are the most effective economic instruments for accelerating the transition — carbon pricing, subsidies, tax incentives, mandatory regulation?

GENERAL CONCLUSION

The construction industry is on the threshold of a transformation whose magnitude is comparable to the industrialization of materials in the 19th century and the digitalization of projects at the end of the 20th century.

Unlike previous transformations, however, this one is not limited to the construction stage. It extends throughout the entire life cycle of built assets, connecting the materials industry, engineering, the real estate market, infrastructure, the financial system, the insurance sector, and public authorities in an integrated economic dynamic.

The decarbonization of structural materials is the triggering element of this transformation. But the final result is much broader: it is the establishment of a Built Asset Economy, in which construction ceases to be an isolated event and becomes the starting point of a continuous cycle of value preservation and enhancement — technical value, economic value, and environmental value.

This economy is already taking shape. Its normative foundations are in place. Its agents are moving. Its markets are structuring themselves. Anticipating this transformation, understanding it in its entirety, and positioning oneself strategically for it is the challenge — and the opportunity — that presents itself to all those who operate in the built environment.

GLOSSARY

LCA (Life Cycle Assessment): Methodology for assessing the environmental impacts associated with all stages of the life cycle of a product, process, or service, from raw material extraction to final disposal. Reference standards: ISO 14040 and ISO 14044.

Built Asset: Any building, industrial facility, infrastructure, or real estate development that constitutes a permanent element of the built environment, endowed with technical, economic, patrimonial, and environmental value throughout its life cycle.

BIM (Building Information Modeling): A set of technologies, processes, and policies that enable information management throughout the life cycle of a built asset, through a shared digital model. Reference standard: ISO 19650 series.

Embodied Carbon: Greenhouse gas emissions associated with the extraction, processing, manufacturing, transportation, application, maintenance, and final disposal of the materials and components that constitute a built asset. It is distinguished from Operational Carbon (emissions associated with the use of the asset, such as air conditioning and lighting) and integrates, with it, the concept of Whole Life Carbon.

CBAM (Carbon Border Adjustment Mechanism): Carbon Border Adjustment Mechanism of the European Union, which establishes the mandatory declaration of embodied emissions for imported products, with financial incidence starting in 2026. Regulation EU 2023/956.

CCS/CCUS (Carbon Capture and Storage / Carbon Capture and Utilization): Technologies for capturing CO_2 from industrial sources, destined for permanent geological storage (CCS) or use in other industrial processes (CCUS).

Digital Product Passport: A digital record that accompanies a product throughout its useful life, containing information on composition, origin, carbon footprint, and potential for reuse and recycling. Foreseen under the Ecodesign for Sustainable Products Regulation (ESPR) of the European Union.

Digital Twin: A digital representation of a physical asset, integrated with sensor data and monitoring systems, allowing real-time monitoring of its performance.

Built Asset Economy: An economic system in which real estate and infrastructure assets are managed as continuous platforms for value preservation, driving permanent cycles of maintenance, retrofit, modernization, and expansion. Construction ceases to be an isolated event and becomes the inaugural event of an economic cycle that extends throughout the asset's entire life.

EPD (Environmental Product Declaration): A standardized document that communicates the environmental performance of a product throughout its life cycle, based on a Life Cycle Assessment (LCA). EPDs constitute the main application of Type III Environmental Declarations, as defined by ISO 14025. For construction products, they follow the rules established by ISO 21930 and EN 15804.

EPBD (Energy Performance of Buildings Directive): European Union Directive on the energy performance of buildings. Directive 2010/31/EU, revised by Directive 2024/1275.

ESG (Environmental, Social, and Governance): Environmental, social, and governance criteria used to assess the sustainable performance of investments and organizations.

EU Taxonomy: European Union Regulation that establishes the criteria for an economic activity to be considered environmentally sustainable. Regulation EU 2020/852.

GFCF (Gross Fixed Capital Formation): Macroeconomic indicator that measures investment in fixed assets, including construction and infrastructure.

H_2-DRI (Hydrogen Direct Reduced Iron): A process of direct reduction of iron ore using green hydrogen as a reducing agent, eliminating the CO_2 emissions associated with the use of coal.

IFRS S1 and IFRS S2: International sustainability disclosure standards issued by the International Sustainability Standards Board (ISSB). IFRS S1 establishes general requirements for the disclosure of sustainability-related financial information. IFRS S2 establishes specific requirements for the disclosure of climate-related information, incorporating and updating the recommendations originally developed by the TCFD.

Carbon Intensity: Quantity of CO_2 equivalent emissions associated with a unit of product, material, or construction system, expressed in kgCO_2e per functional unit.

IPCC (Intergovernmental Panel on Climate Change): The UN scientific body responsible for assessing the science related to climate change.

ISO 14064: A family of standards that establishes principles and requirements for the quantification, monitoring, reporting, and verification of greenhouse gas emissions and removals at the organizational and project level.

ISO 14067: An international standard that establishes principles, requirements, and guidelines for the quantification and communication of the carbon footprint of products (Carbon Footprint of Products — CFP).

ISO 14068: An international standard that establishes principles, requirements, and guidelines for achieving and demonstrating carbon neutrality, including the compensation of residual emissions.

ISO/TC 59/SC 17: Technical subcommittee of the International Organization for Standardization responsible for standardization in the field of sustainability in buildings and civil engineering works.

ISSB (International Sustainability Standards Board): International sustainability standards board, established by the IFRS Foundation, responsible for issuing the IFRS S1 and IFRS S2 standards.

LEED (Leadership in Energy and Environmental Design): A sustainable building certification system developed by the U.S. Green Building Council.

NZEB (Nearly Zero-Energy Buildings): Buildings with nearly zero energy needs, as defined by the EPBD.

SCMs (Supplementary Cementitious Materials): Supplementary cementitious materials incorporated into cement to reduce the proportion of clinker and, consequently, the carbon intensity. Examples: blast furnace slag, fly ash, pozzolans.

SFDR (Sustainable Finance Disclosure Regulation): European Union Regulation that establishes sustainability information disclosure requirements for financial market participants. Regulation EU 2019/2088.

TCFD (Task Force on Climate-related Financial Disclosures): Financial Stability Board task force for the disclosure of climate-related financial risks. Its recommendations have been incorporated into the international standards issued by the ISSB, particularly in the IFRS S1 and IFRS S2 standards.

TNFD (Taskforce on Nature-related Financial Disclosures): Task force for the disclosure of nature-related financial risks, establishing a framework for organizations to report and act on risks and opportunities related to biodiversity and ecosystems.

Whole Life Carbon: A concept that encompasses the totality of greenhouse gas emissions associated with a built asset throughout its entire life cycle, including embodied carbon and operational carbon.

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FINAL CONSIDERATIONS

This white paper was conceived as a contribution to the debate on the future of the construction industry, infrastructure, and the real estate market. Its central thesis — that the decarbonization of structural materials triggers a systemic economic transformation that culminates in the formation of a Built Asset Economy — is offered as a conceptual framework to guide the strategic reflection of industry leaders, public policy makers, financial institutions, and other agents of the built environment.

The transition described in this document is not a speculative projection. Its normative, technical, and economic foundations are already present and in the process of consolidation in the main economies. The question is not whether this transition will occur, but at what speed and with what degree of preparation the different agents will face it.

The institutions that subscribe to this document — **Ensurance Center™, Maind Neural Carbon Mineralization Laboratory™, and Maind International™** — are available to deepen any of the topics addressed herein and to collaborate with organizations interested in developing strategies for the Built Asset Economy.

Responsible Institutions:

Ensurance Center™

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