

VISION

VIRTUAL INTEGRATED SUPPLY-CHAIN IMPROVEMENT WITH OPTIMIZED NETWORKING

D2.1 – Research on Net-zero and Sustainability Standards, Regulations, Carbon Markets and Trading Mechanisms



Project Identifier	Vision
Project Title	Virtual Integrated Supply-Chain Improvement with Optimized Networking
Document Version	V1.0
Planned Delivery Date	Feb 26
Document Title	Research on Net-zero and Sustainability Standards, Regulations, Carbon Markets and Trading Mechanisms
Work Package	WP2

Document History

Version	Date	Contributors	Changes/Updates
0.1	17/03/2026	Osman Tufan Dogan Firat Onar	Initial Version of Research on Net-Zero and Sustainability Standards, Regulations, Carbon Markets and Trading Mechanisms
1.0	18/08/2026	Osman Tufan Dogan Firat Onar	Final version. Research scope completed and implementation and research update approach aligned with WP2 requirements.

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1. Executive Summary

The transition to net-zero emissions is increasingly driven by an integrated system of greenhouse gas accounting standards, sustainability reporting frameworks, regulatory instruments, and carbon market mechanisms. These elements are converging into a coherent ecosystem that shapes investment decisions, operational strategies, and global value chains. Within this context, the European Union plays a leading role through instruments such as the EU Emissions Trading System (EU ETS), the Carbon Border Adjustment Mechanism (CBAM), and the Corporate Sustainability Reporting Directive (CSRD), which extend regulatory influence beyond EU borders via trade and supply chain dynamics.

Standardized emissions accounting methodologies, particularly the GHG Protocol and supporting ISO standards, form the foundation of this system. Their importance is reinforced by disclosure frameworks such as CSRD and IFRS S2, which require consistent and transparent reporting, including value-chain (Scope 3) emissions. As a result, emissions accounting is becoming a strategic capability linked to both regulatory compliance and financial reporting.

Carbon markets provide the economic dimension of decarbonization. Compliance systems such as the EU ETS, UK ETS, and Korea's K-ETS create binding incentives for emissions reduction, while CBAM extends carbon pricing to international trade. At the same time, voluntary carbon markets are becoming more structured through emerging integrity frameworks such as ICVCM and VCMI, with increasing alignment toward international mechanisms under Article 6 of the Paris Agreement.

Across jurisdictions, including the EU, United Kingdom, Republic of Korea, and Türkiye, a trend toward regulatory convergence is evident, although at different levels of maturity. The EU maintains the most comprehensive framework, while other regions are aligning through national systems and policy adaptations, often influenced by EU-driven mechanisms.

Sectoral impacts vary in complexity. Aviation operates under a hybrid regulatory model combining emissions trading, global offsetting schemes, and fuel mandates. Construction and mining are increasingly shaped by lifecycle and embodied carbon requirements, particularly under CBAM and EU Taxonomy. Logistics and warehousing are evolving toward more comprehensive Scope 3 emissions accounting across transport and distribution networks.

Overall, the regulatory landscape is shifting from fragmented approaches to an integrated system where standards, reporting, and carbon pricing reinforce each other. This creates both compliance challenges and strategic opportunities, requiring organizations to adopt integrated carbon management approaches supported by advanced monitoring, reporting, and digital capabilities.

2. Core Net-Zero and GHG Accounting Standards

Net-zero and greenhouse-gas (GHG) accounting increasingly rely on a combination of internationally recognized standards, calculation methodologies, target-setting frameworks and sustainability disclosure requirements. For the VISION project, these frameworks provide the methodological basis for defining reporting boundaries, identifying relevant activity data, selecting appropriate emission factors, calculating carbon footprints and ensuring that resulting carbon records remain transparent and traceable. The main standards and frameworks relevant to the VISION supply-chain context are summarized below.

Standard / Framework / Requirement	Scope / Purpose	Relevance to VISION
GHG Protocol Corporate Standard	Organization-level GHG accounting	Reporting boundaries and Scope 1/2 concepts
GHG Protocol Scope 3 Standard	Value-chain emissions	Supply-chain and logistics emissions
ISO 14064-1	Organizational GHG quantification and reporting	Traceable and auditable emissions accounting
ISO 14067	Product carbon footprint	Item/product-level embedded carbon
ISO 14083	Transport-chain GHG accounting	Shipment and transport emissions
GLEC Framework	Logistics emissions calculation	Freight and logistics activity calculations
SBTi Net-Zero Standard	Net-zero target-setting	Reduction targets and policy context

CSRD / IFRS S2	Sustainability/climate disclosure	Reporting and requirements	traceability
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Table 1 Overview of Core Net-Zero and GHG Accounting Standards and Frameworks

These standards and frameworks address complementary aspects of carbon management. The GHG Protocol and ISO standards primarily provide the accounting, quantification and reporting principles needed to determine how emissions should be measured, classified and attributed. ISO 14083 and the GLEC Framework provide more specific guidance for transport and logistics activities, which are particularly relevant to the VISION use cases. ISO 14067 extends the accounting perspective toward product-level carbon footprints, while the SBTi Net-Zero Standard provides a target-setting perspective by linking measured emissions to longer-term reduction objectives. Sustainability disclosure frameworks such as CSRD and IFRS S2 further increase the importance of transparent and traceable emissions information by connecting carbon accounting with organizational reporting and decision-making requirements.

Within VISION, these standards are not treated as isolated reporting references but as inputs to the design of the project's net-zero information structure. Their requirements are translated into concepts such as activity data, emission factors, calculation methods, reporting boundaries, data-quality indicators and carbon records. These concepts provide the methodological foundation for the Initial Net-zero Knowledge Model described in D2.2 and support interoperability between carbon calculations, supply-chain digital twins and subsequent decision-support and optimization activities within WP2. In this way, D2.1 establishes the standards and methodological baseline, while D2.2 translates that baseline into a reusable semantic structure suitable for different supply-chain contexts.

3. Carbon Markets and Trading Mechanisms

Carbon markets are increasingly positioned at the core of global decarbonization strategies, translating greenhouse gas emissions into economic signals that directly influence investment decisions, operational practices, and supply chain configurations. By assigning a price to carbon, these mechanisms incentivize emissions reduction, technological innovation, and resource efficiency. Compliance carbon markets—such as the European Union Emissions Trading System (EU ETS), the United Kingdom ETS (UK ETS), and Korea's Emissions Trading Scheme (K-ETS)—are based on cap-and-trade principles, whereby a finite number of emissions allowances are issued and traded among regulated entities (European Commission, 2023a; UK Government, 2023; ICAP, 2024). Through this approach, the cost of carbon is progressively internalized, creating a market-driven pathway toward emissions reduction.

The EU ETS remains the most mature and systemically influential carbon market, not only due to its scale but also because of its evolving design. Its tightening emissions cap, combined with the progressive reduction of free allowance allocations, is increasing carbon price signals across energy-intensive sectors (European Commission, 2023a). This internal strengthening is complemented by the introduction of the Carbon Border Adjustment Mechanism (CBAM), which represents a structural shift in how carbon pricing interacts with international trade. CBAM extends the logic of the EU ETS beyond European borders by requiring importers of carbon-intensive goods to account for embedded emissions and, from 2026 onwards, to purchase corresponding certificates (European Union, 2023b). This effectively aligns the carbon cost of imported products with that of EU domestic production, addressing the risk of carbon leakage while reinforcing global decarbonization incentives.

The implications of CBAM extend well beyond EU jurisdiction, driving regulatory convergence in neighboring and trading partner countries. Türkiye, for example, is advancing toward the establishment of a national emissions trading system partly in response to CBAM, aiming to retain carbon revenues domestically and maintain competitiveness in EU-facing sectors (Ministry of Environment, Urbanization and Climate Change, 2023). Similarly, industries such as mining and construction are experiencing a structural shift, as carbon pricing is increasingly applied to upstream materials such as steel, cement, and aluminum. This creates new requirements for accurate measurement of embedded emissions and strengthens the role of lifecycle-based accounting methodologies (European Commission, 2023b).

Aviation represents a distinct case within carbon market design, characterized by a hybrid regulatory architecture that combines regional compliance systems with global offsetting mechanisms. Airlines operating within Europe are subject to the EU ETS and UK ETS for intra-European flights, while international aviation emissions are addressed through the International Civil Aviation Organization's CORSIA scheme (ICAO, 2022). This dual structure introduces significant accounting and compliance complexity, as operators must ensure consistency in emissions reporting, credit

usage, and regulatory alignment across overlapping jurisdictions. The introduction of additional policy instruments, such as the ReFuelEU Aviation regulation, further expands this framework by mandating minimum shares of Sustainable Aviation Fuel (SAF) (European Union, 2023a). These fuel mandates interact with carbon pricing mechanisms, for instance through incentive multipliers within the ETS, thereby linking fuel transition policies with market-based instruments.

In parallel to compliance systems, voluntary carbon markets (VCMs) are undergoing a significant transformation toward greater standardization, transparency, and environmental integrity. Historically characterized by fragmentation and variable credit quality, these markets are now increasingly governed by emerging integrity frameworks such as the Core Carbon Principles (CCPs) developed by the Integrity Council for the Voluntary Carbon Market (ICVCM) and the Claims Code introduced by the Voluntary Carbon Markets Integrity Initiative (VCMI) (ICVCM, 2023; VCMI, 2023). These initiatives aim to define robust criteria for high-quality carbon credits and to ensure that corporate claims related to carbon neutrality or net-zero alignment are credible and verifiable.

The evolution of voluntary markets is also closely linked to developments under Article 6 of the Paris Agreement, which establishes mechanisms for international cooperation through the transfer of mitigation outcomes. The emergence of Internationally Transferred Mitigation Outcomes (ITMOs) introduces the potential for increased interoperability between compliance and voluntary markets, potentially leading to a more integrated global carbon market architecture over time (UNFCCC, 2021).

From a sectoral perspective, voluntary carbon markets play a particularly important role in addressing emissions that remain outside the scope of current compliance systems. For sectors such as logistics and warehousing, where a significant share of emissions arises from complex Scope 3 value chains, VCMs provide a complementary mechanism to address residual or hard-to-abate emissions. However, their use is increasingly expected to follow strict hierarchies, prioritizing direct emissions reductions and efficiency improvements before resorting to offsetting mechanisms (SBTi, 2021).

Overall, carbon markets are evolving from relatively isolated policy instruments into a multi-layered and interconnected system, where compliance mechanisms, voluntary markets, and international frameworks collectively shape the global trajectory toward net-zero. This evolution underscores the need for organizations to adopt integrated carbon management strategies that align regulatory compliance, market participation, and long-term decarbonization objectives.

4. Regulatory Landscape

A comparative analysis of the European Union, the United Kingdom, the Republic of Korea, and Türkiye highlights a clear trajectory toward regulatory convergence in climate governance, although each jurisdiction remains at a different stage of policy maturity and implementation. This convergence is driven by a combination of international climate commitments, particularly under the Paris Agreement, and increasing economic interdependencies through global trade and supply chains (UNFCCC, 2015). As a result, regulatory frameworks are evolving from fragmented and sector-specific approaches toward more integrated systems in which greenhouse gas accounting standards, disclosure obligations, and carbon pricing mechanisms are closely interconnected.

The European Union represents the most comprehensive and systemically influential regulatory environment, effectively setting a global benchmark for climate policy design. Its framework is characterized by the integration of multiple policy instruments under the European Green Deal, combining carbon pricing through the EU Emissions Trading System (EU ETS), mandatory sustainability disclosures under the Corporate Sustainability Reporting Directive (CSRD), and sector-specific regulations such as the EU Taxonomy and ReFuelEU Aviation (European Commission, 2019; European Union, 2022; European Union, 2023a). The introduction of the Carbon Border Adjustment Mechanism (CBAM) further extends the EU's regulatory reach into international trade, requiring importers to account for embedded emissions and thereby incentivizing non-EU producers to align with European standards (European Union, 2023b). This integrated approach creates a reinforcing system in which pricing, reporting, and investment criteria collectively drive decarbonization.

The United Kingdom, following its exit from the European Union, has maintained a high degree of regulatory alignment while progressively introducing independent policy mechanisms. The UK Emissions Trading Scheme (UK ETS) closely mirrors the structural principles of the EU ETS but allows for national adjustments in areas such as

allowance allocation, sectoral coverage, and market stability measures (UK Government, 2023). In addition, the UK is advancing its own regulatory agenda in areas such as sustainable aviation, where policy instruments related to Sustainable Aviation Fuel (SAF) mandates and incentives are being developed in parallel with, but not always identical to, EU regulations (Department for Transport, 2022). This approach reflects a balance between maintaining compatibility with EU markets and leveraging regulatory autonomy to pursue domestic priorities.

The Republic of Korea provides a mature example of a national emissions trading system within the Asian context. The Korea Emissions Trading Scheme (K-ETS), now operating through multiple implementation phases, demonstrates a high level of institutional stability and regulatory sophistication. Its design incorporates structured allocation mechanisms, sector-specific compliance requirements, and a gradual tightening of emissions caps in line with national carbon neutrality targets (ICAP, 2024). Korea's regulatory framework is closely linked to its industrial policy, with a strong focus on decarbonizing energy-intensive manufacturing sectors such as steel, petrochemicals, and electronics. Furthermore, Korea is exploring greater integration with international carbon markets, particularly through mechanisms aligned with Article 6 of the Paris Agreement (UNFCCC, 2021), positioning itself as a key player in the evolving global carbon market landscape.

Türkiye is currently in a transitional phase, developing the legal, technical, and institutional foundations required for a national emissions trading system. At the same time, it is significantly exposed to external regulatory pressures, most notably through the EU's CBAM, due to its strong trade relations with the European Union in carbon-intensive sectors such as steel, cement, aluminum, and electricity (European Union, 2023b; Ministry of Environment, Urbanization and Climate Change, 2023). This creates a dual dynamic in which domestic regulatory development and external compliance requirements progress simultaneously.

The establishment of Türkiye's ETS, including the development of monitoring, reporting, and verification (MRV) systems and the finalization of secondary legislation, is therefore critical not only for achieving national climate targets but also for maintaining competitiveness in EU-facing markets. In response to these pressures, Turkish industries are increasingly adopting international standards such as the GHG Protocol, ISO 14064, and ISO 14067, even ahead of mandatory enforcement (ISO, 2018a; ISO, 2018b). This early alignment reflects both a strategic adaptation to external regulatory drivers and a broader shift toward integration into global sustainability frameworks.

Overall, the comparative analysis underscores a broader global trend toward regulatory alignment, where differences in policy design are gradually narrowing under the combined influence of international agreements, market mechanisms, and cross-border regulatory instruments. While full harmonization remains unlikely in the short term, increasing interoperability between emissions trading systems, disclosure frameworks, and carbon accounting standards is reshaping the regulatory landscape. For organizations operating across multiple jurisdictions, this evolving environment necessitates integrated compliance strategies that account for both local regulatory requirements and the growing influence of global and EU-driven mechanisms.

5. Implementation Plan and Research Update Protocol

5.1 VISION Implementation Approach

Based on the standards, regulations, and carbon-market mechanisms reviewed in D2.1, VISION translates the research findings into the technical activities of WP2 rather than treating them solely as reporting references. In T2.2, the reviewed accounting standards and sustainability frameworks provide the baseline for the reporting boundaries, activity-data requirements, emission-factor metadata, calculation methods, regulatory references, and carbon records represented in the Net-zero Knowledge Model. The initial model described in D2.2 will be refined toward the final model in D2.3. T2.3 will use this information model together with BPMN-based supply-chain flows to support the design of the net-zero framework, optimization models, and carbon-policy recommendations, with the resulting software delivered in D2.4. T2.4/D2.5 will provide the APIs required for supply-chain users and other VISION components to interact with the net-zero framework.

Research Finding	VISION Implementation
GHG accounting standards	Reporting boundaries, Scope classification, calculation methods, and data requirements in T2.2.
Transport and product footprint standards	Activity data, emission-factor structures, allocation rules, and traceability for supply-chain calculations.
Sustainability and disclosure requirements	Regulatory-reference metadata and reporting traceability in the Net-zero Knowledge Model.
Carbon markets and trading mechanisms	Carbon-price and policy context for T2.3 optimization and carbon-policy recommendations.
Supply-chain use cases	Validation of model concepts, input-data needs, calculation outputs, and decision-support requirements.

Table 2 Translation of D2.1 Research Findings into VISION WP2 Implementation

5.2 Research and Regulatory Update Protocol

Since net-zero standards, regulations, and carbon-market mechanisms may evolve during the VISION project, WP2 will maintain a structured update process. Relevant local and global developments will be reviewed periodically and before major WP2 model or software releases. Significant changes will be assessed according to their potential impact on reporting boundaries, required activity data, emission factors, calculation methods, regulatory references, carbon-market assumptions, and policy parameters. Where a change is relevant to VISION, its impact and required action will be recorded and reflected, as appropriate, in D2.3, the T2.3/D2.4 framework and optimization outputs, and the T2.4/D2.5 APIs.

Update Item	Recorded Information
Standard, regulation, or market mechanism	Name and issuing body.
Jurisdiction	EU, UK, Republic of Korea, Türkiye, or international.
Publication / effective date	Date relevant to publication, entry into force, or applicability.
Change summary	New, revised, or withdrawn requirement, methodology, or guidance.
VISION impact	Potential impact on the model, calculation logic, optimization, policy assumptions, or APIs.
Required action	No action, model update, calculation update, policy update, or interface update.

Table 3 Research and Regulatory Update Information to Be Maintained During the Project

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