Greening Tools In Transport And Logistics Operations: A Policy-Instrument Classification And Governance Assessment

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Abstract.

The decarbonisation of transport and logistics is not only a technological challenge but also a problem of policy design, investment sequencing, institutional capacity, and corporate implementation. This article develops a five-part classification of greening tools used in transport and logistics operations and interprets them as a coordinated policy-instrument portfolio. The framework distinguishes legal and regulatory instruments, technical and technological solutions, economic instruments, organisational-managerial tools, and informational-analytical mechanisms. The study uses a structured integrative review of the literature cited in the manuscript, comparative analysis of European Union and Ukrainian regulatory sources, and qualitative evidence synthesis. It deliberately avoids pooled effect-size estimates because the underlying studies use heterogeneous units, baselines, technologies, and system boundaries. The analysis shows that the five instrument families are complementary: regulation establishes minimum requirements, economic instruments alter investment incentives, infrastructure and technology enable compliance, organisational measures improve operational efficiency, and information systems make performance measurable and auditable. For Ukraine, the central challenge is to combine EU-alignment obligations with wartime resilience and reconstruction priorities. The article therefore proposes a governance sequence based on measurement, regulatory alignment, infrastructure planning, targeted finance, implementation, and verification. The contribution is a transparent classification and decision framework rather than a claim that a single universal emissions-reduction percentage can be assigned to an integrated portfolio.

Keywords: *green logistics; transport decarbonisation; policy instruments; environmental regulation; sustainable governance; Ukraine.*

1.Introduction

Transport and logistics sit at the intersection of economic connectivity and climate policy. Freight movement supports trade, industrial production, food security, e-commerce, and post-crisis recovery, but it also depends heavily on energy-intensive vehicles, terminals, warehouses, and supporting infrastructure. The resulting policy problem is therefore two-sided: governments and firms must preserve the reliability and affordability of logistics while progressively reducing its environmental burden. In this setting, greening cannot be reduced to the purchase of cleaner vehicles. It requires a coordinated set of rules, incentives, infrastructure investments, management practices, and information systems.

The concept of green logistics has developed as part of the broader literature on green supply chain management. Early work emphasised the integration of environmental considerations into procurement, production, distribution, reverse flows, and end-of-life management (Srivastava, 2007). Subsequent research has shown that environmental performance is shaped by institutional pressure, managerial commitment, collaboration, operational design, and technological capability rather than by a single intervention (Sarkis et al., 2011; Zhu et al., 2013; Centobelli et al., 2017). This makes classification important: policy makers and managers need to understand not only what tools exist, but what function each tool performs and how tools interact.

For the European Union, the governance architecture for transport decarbonisation has become more concrete. Revised CO2 standards for new heavy-duty vehicles set fleet-wide reduction targets relative to the 2019 baseline of 45% from 2030, 65% from 2035, and 90% from 2040 for the relevant vehicle groups (European Parliament and Council of the European Union, 2024). Regulation (EU) 2023/1804 on alternative fuels infrastructure establishes mandatory deployment requirements for recharging and refuelling infrastructure and places particular emphasis on the progressive coverage of the trans-European transport network. A separate emissions trading system for buildings, road transport and additional sectors (ETS2) is also part of the policy mix; it regulates fuel suppliers upstream and is scheduled to become fully operational in 2028 (European Commission, 2026a). These measures illustrate a central point of this article: technology adoption is conditioned by the surrounding regulatory and infrastructure environment.

For Ukraine, the same issue is intensified by the simultaneous demands of European integration, wartime resilience, and reconstruction. Ukraine completed the bilateral screening process with the European Union in 2025 and continues to align national law and administrative capacity with the EU acquis (European Commission, 2025). At the same time, transport and energy infrastructure remain among the sectors most affected by the war and among the largest areas of reconstruction need (European Commission, 2026b). The policy challenge is therefore not to copy isolated European instruments, but to sequence legal approximation, investment, financing, infrastructure renewal, and verification in a way that remains feasible under severe fiscal and security constraints.

This article addresses three research problems. First, existing green-logistics literature uses overlapping classifications, which makes it difficult to distinguish policy instruments from the operational objects on which they act. Second, environmental-effectiveness claims are often transferred across technologies and contexts even though studies use different baselines, functional units, time horizons, and system boundaries. Third, the Ukrainian context requires an explicit governance interpretation that connects corporate greening with accession-driven regulatory change and reconstruction policy.

The aim is to develop a transparent classification of greening tools in transport and logistics operations and to assess their role within a coordinated governance framework. The objectives are: (1) to distinguish five principal instrument families; (2) to clarify the mechanism through which each family can influence environmental performance; (3) to update the EU and Ukrainian regulatory context; (4) to identify the limits of quantitative comparison across heterogeneous evidence; and (5) to formulate a practical sequencing framework for Ukraine. The article does not claim to provide a meta-analysis or a universal pooled emissions-reduction estimate.

2. Literature Review

2.1. Green supply chain management and logistics decarbonisation

Green supply chain management provides the broad theoretical foundation for analysing transport and logistics greening. Srivastava (2007) framed the field as the integration of environmental thinking into supply-chain management across product design, sourcing, manufacturing, delivery, and end-of-life management. Sarkis et al. (2011) and Zhu et al. (2013) further emphasised that organisational and institutional pressures shape the adoption of green practices. This literature is important because it explains why the environmental performance of logistics is not determined solely by vehicle technology: supplier relationships, management systems, regulation, and information all influence implementation.

Environmental measures in transport and logistics can be grouped by the part of the system they seek to change. Technical interventions include vehicle electrification, alternative powertrains, energy-efficient buildings, and charging or refuelling infrastructure. Operational interventions include routing, consolidation, load-factor improvement, modal choice, and reverse logistics. Governance interventions include standards, taxes, subsidies, carbon pricing, public procurement, disclosure, and environmental management systems. The analytical difficulty is that these categories operate at different levels and are therefore not directly comparable in a single effect-size table.

2.2. Technology and infrastructure

The literature on freight technology shows substantial decarbonisation potential from electrification, but the practical result depends on route characteristics, payload, vehicle duty cycle, charging availability, electricity generation, and capital cost. Liimatainen et al. (2019), for example, demonstrate that the feasibility of electric trucks varies markedly across freight tasks. The implication is that a percentage taken from one vehicle class or electricity mix cannot be transferred automatically to another.

Infrastructure is equally important. Alternative-fuel vehicles create little system-level value if the necessary charging or refuelling network is absent or unreliable. Regulation (EU) 2023/1804 reflects this complementarity by setting infrastructure deployment requirements alongside vehicle decarbonisation policy. In warehouse operations, studies such as Meneghetti and Monti (2015) illustrate the potential of energy-aware facility design, but the magnitude of savings depends on warehouse type, climate, refrigeration demand, automation, and baseline technology. Such evidence supports the direction of greening, not a universal percentage applicable to every logistics facility.

2.3. Organisational and digital tools

Operational efficiency remains one of the most accessible routes to lower emissions intensity. Better vehicle utilisation, freight consolidation, route design, and modal optimisation can reduce unnecessary vehicle-kilometres and energy use. Piecyk and McKinnon (2010) show that the carbon footprint of road freight is sensitive to logistics parameters such as vehicle utilisation and operational efficiency. Digital transport management systems can support these decisions, but digitalisation should be treated as an enabling capability rather than an emissions-reduction measure in itself.

Recent work on digital technologies and sustainable supply chains reinforces this distinction. Winkelmann et al. (2024) discuss how digital tools can support resilience and sustainability through improved information, coordination, and decision-making. The actual environmental outcome, however, depends on the operational decision that follows from the information. A routing algorithm has no direct climate value if it is not integrated into dispatching practice; a carbon dashboard has limited value if no management target or investment decision is linked to it.

2.4. Economic, informational, and institutional drivers

Institutional research consistently identifies regulation, customer requirements, competitive pressure, and managerial commitment as drivers of environmental practice (Zhu et al., 2013; Chatzoudes et al., 2024). Economic instruments change the relative cost of high- and low-emission choices, while informational instruments make performance visible to regulators, investors, customers, and managers. Rao and Holt (2005) connect green supply-chain practices with competitiveness and economic performance, although the relationship is context-dependent and should not be read as proof that every environmental investment generates a short payback period.

Carbon accounting, environmental management systems, sustainability reporting, and audit mechanisms are especially important from a governance perspective. They do not necessarily reduce emissions directly, but they establish baselines, define accountability, and allow policy makers or investors to assess whether operational claims are credible. This evidentiary function is essential in a field where effect estimates can otherwise be detached from their original scope and reused as if they were universally comparable.

2.5. Ukrainian context and research gap

Ukrainian scholarship has examined the ecologisation of logistics systems and the relationship between economic, environmental, and social goals (Velychko & Velychko, 2023). The Ukrainian context nevertheless differs from stable-market settings in three respects:

war-related infrastructure damage, constrained access to long-term capital, and rapid regulatory approximation associated with EU accession. These conditions increase the importance of sequencing and institutional capacity.

The remaining gap is therefore not simply a shortage of lists of green technologies. What is needed is an analytical framework that separates types of instruments, specifies their governance role, and avoids false precision when the underlying evidence is heterogeneous. The present study addresses that gap by combining a five-part typology with an evidence hierarchy and a governance sequence for implementation.

3. Materials And Methods

The study uses a structured integrative review and comparative regulatory analysis. It is conceptual and evidence-synthetic rather than experimental. The source base consists of the peer-reviewed works cited in the manuscript on green logistics, green supply chain management, transport technology, circular supply chains, and institutional drivers, supplemented by authoritative legal and policy sources required to update the regulatory context through 2026. No primary survey, company questionnaire, field experiment, or proprietary emissions dataset was used.

The review process was organised around three analytical questions: what greening instrument is being described; through what mechanism can it influence emissions or environmental performance; and what kind of evidence supports the claimed effect? Sources were coded into five instrument families: legal and regulatory; technical and technological; economic; organisational-managerial; and informational-analytical. The categories are functional rather than mutually exclusive. For example, an electric truck is a technical instrument, while the subsidy that lowers its purchase cost is an economic instrument and the charging-network obligation that makes its operation feasible is a regulatory-infrastructure measure.

The regulatory analysis compares current EU transport-decarbonisation instruments with the policy and institutional challenges relevant to Ukraine. Particular attention is given to the revised heavy-duty vehicle CO2 standards, alternative-fuels infrastructure regulation, ETS2, Ukraine-EU regulatory alignment, and Ukraine's National Renewable Energy Action Plan to 2030. The analysis does not assume that EU measures are automatically transferable; instead, it asks which administrative, financial, and infrastructure capacities are required for implementation.

The article deliberately does not present a PRISMA flow diagram, a pooled effect estimate, or a standardised cross-study gCO2e/tkm meta-analysis. The cited evidence differs in functional units, system boundaries, baselines, technologies, geographic contexts, and time horizons. Combining such values into a single range would create a level of statistical comparability that the source base does not support. Numerical values are retained only where they are directly traceable to authoritative legal targets or clearly scoped source-specific evidence.

The principal limitation is therefore also a design choice: this study evaluates the role, complementarity, and governance relevance of instruments rather than estimating a causal average treatment effect. Corporate sustainability disclosures are treated as illustrative evidence of organisational practice and not as independently verified sector-wide performance data. This distinction is particularly important for Ukraine, where wartime conditions constrain data availability and comparability.

4. Results And Discussion

4.1. A five-category classification of greening instruments

The synthesis supports a five-category classification. The categories are best interpreted as parts of an instrument portfolio rather than as competing alternatives. Each category addresses a different implementation problem: authority, technology, incentives, operations, or information.

Table 1. Five-category classification of greening tools and their governance function

Category	Representative instruments	Primary mechanism	Governance function
Legal and regulatory	Vehicle emission and CO2 standards; environmental assessment; access rules; procurement requirements; carbon-market rules	Defines mandatory or permitted behaviour	Creates minimum standards and enforceable obligations
Technical and technological	Battery-electric and fuel-cell vehicles; charging and refuelling infrastructure; efficient warehouses; low-carbon energy systems	Changes the physical emissions profile of assets	Provides the technical means to comply with policy goals
Economic	Taxes and charges; grants; purchase incentives; concessional finance; carbon pricing; green bonds	Changes relative costs and investment returns	Makes cleaner investment more or less financially attractive
Organisational-managerial	TMS/WMS; consolidation; load-factor improvement; modal shift; reverse logistics; ISO 14001 systems	Changes how assets and flows are managed	Reduces avoidable activity and embeds continuous improvement
Informational-analytical	GHG accounting; carbon audits; ESG reporting; eco-labelling; digital traceability; performance dashboards	Makes impacts measurable and visible	Supports accountability, verification, and policy learning

The classification clarifies an important conceptual distinction. Technical and organisational measures are the objects through which emissions can be reduced operationally, while legal, economic, and informational instruments often shape whether those measures are adopted. A regulator may set a CO2 standard, create a fiscal incentive, and require disclosure; the firm then responds through fleet, route, warehouse, or energy decisions. The categories therefore operate at different causal levels.

This distinction also explains why an effectiveness table that assigns one percentage range to each category can be misleading. A legal standard does not have a stable direct percentage effect independent of enforcement and technology response. Similarly, an information instrument can be decisive for accountability without reducing one tonne of CO2 by itself. The meaningful unit of analysis is therefore the instrument mix and the implementation pathway.

4.2. The EU regulatory architecture as an instrument mix

The European Union provides a clear example of coordinated instrument design. Regulation (EU) 2024/1610 revised the CO2 performance standards for new heavy-duty vehicles. For the relevant vehicle groups, the fleet-wide targets require reductions of 45% from 2030, 65% from 2035, and 90% from 2040 relative to the 2019 baseline. These are manufacturer fleet targets, not direct claims about the life-cycle emissions of every individual truck. This legal distinction matters when translating EU targets into operational or corporate indicators.

Regulation (EU) 2023/1804 addresses a complementary bottleneck: alternative-fuels infrastructure. It establishes mandatory national targets and common requirements for publicly accessible recharging and refuelling infrastructure and provides for progressive heavy-duty vehicle infrastructure coverage along the TEN-T network. The policy logic is complementary: vehicle standards create demand for cleaner powertrains, while infrastructure rules reduce the risk that insufficient charging or refuelling capacity prevents adoption.

ETS2 adds an economic signal. The system covers emissions from fuels supplied to buildings, road transport, and additional sectors, with regulated fuel suppliers rather than end users responsible for monitoring and surrendering allowances. According to the European Commission's current implementation information, ETS2 is to become fully operational in 2028 (European Commission, 2026a). The important governance point is that carbon pricing does not replace standards or infrastructure policy; it changes the economics within which firms respond to them.

Together, these measures illustrate the logic of an instrument portfolio: standards define the trajectory, infrastructure regulation removes physical bottlenecks, carbon pricing changes operating incentives, and reporting obligations enable verification. The framework developed here uses this logic as a reference point for analysing Ukraine, while recognising that administrative and fiscal capacity differs significantly.

4.3. Ukraine: regulatory alignment, reconstruction, and implementation capacity

Ukraine's transport greening agenda is increasingly connected to EU accession rather than only to the Association Agreement. The European Commission reported the completion of bilateral screening in 2025, creating a technical basis for continued alignment with the acquis. Transport policy and environment and climate change are separate negotiation chapters, but in practice decarbonising logistics requires interaction between both: vehicle rules, infrastructure planning, energy policy, environmental enforcement, statistics, and investment governance.

The domestic policy framework also continues to evolve. In August 2024, the Cabinet of Ministers approved the National Renewable Energy Action Plan for the period to 2030. This is more relevant to the current energy-transition context than the obsolete 2021-2025 formulation previously used in some policy discussions. For logistics, renewable-energy policy matters because the climate value and operating resilience of electrified transport depend increasingly on the electricity system, storage, and grid capacity.

Wartime damage adds a further governance layer. The 2026 update of the joint recovery and reconstruction needs assessment identifies transport and energy among the most heavily affected sectors and shows that transport reconstruction needs remain exceptionally high (European Commission, 2026b). Reconstruction therefore creates both a constraint and a sequencing opportunity: infrastructure that must be rebuilt can be designed for future low-carbon mobility, but only if green standards, financing conditions, interoperability, and maintenance capacity are incorporated at the planning stage.

Table 2. Regulatory and policy architecture relevant to greening transport and logistics

Instrument / framework	Verified role	Implication for logistics governance
EU Regulation 2024/1610 on heavy-duty vehicle CO_2 standards	Sets manufacturer fleet CO_2 reduction targets for new heavy-duty vehicles: 45% from 2030, 65% from 2035, 90% from 2040 versus 2019 for relevant groups	Creates a predictable long-term technology trajectory for new fleets
EU Regulation 2023/1804 on alternative fuels infrastructure	Sets mandatory deployment requirements for alternative-fuels infrastructure, including heavy-duty vehicle charging along the TEN-T network	Links vehicle transition to infrastructure availability and interoperability
EU ETS2	Applies upstream carbon pricing to fuels used in road transport, buildings, and additional sectors; current EU implementation information points to full operation in 2028	Adds an economic signal alongside standards and infrastructure policy
Ukraine - National Renewable Energy Action Plan to 2030 (2024)	Updates national renewable-energy planning through 2030	Connects transport electrification with grid, renewable energy, and storage policy
EU accession / Ukraine Report 2025	Requires continued alignment with the transport, environment, climate, energy, and administrative acquis	Makes institutional capacity and enforcement part of the greening agenda
Recovery and reconstruction planning	Rebuilding transport and energy assets after war damage	Creates a window to integrate low-carbon standards before infrastructure is locked in

4.4. Technical and technological instruments

Technical measures have the most visible relationship with emissions because they change vehicles, energy systems, or buildings directly. Battery-electric heavy-duty vehicles can eliminate tailpipe CO_2 emissions at the point of use, but life-cycle performance depends on electricity generation, battery production, vehicle utilisation, payload, and replacement cycles. Fuel-cell vehicles may provide advantages in particular long-haul applications, but their environmental performance depends heavily on hydrogen production and infrastructure. These dependencies make technology assessment scenario-specific.

The revised EU policy framework increasingly favours zero-emission powertrains while treating gaseous fossil fuels as limited or transitional options. Regulation (EU) 2023/1804 itself notes a limited long-term role for gaseous fuels in heavy-duty road transport. Accordingly, LNG should not be presented as equivalent to zero-emission technology. It may provide operational advantages in certain contexts, but investment decisions must consider methane leakage, infrastructure lock-in, and the trajectory of EU regulation.

Warehouses and terminals form a second technical domain. Energy-efficient lighting, building envelopes, heat pumps, rooftop photovoltaics, energy management, and automation can lower facility energy use. The relevant metric, however, is facility-specific energy and emissions intensity rather than a universal reduction percentage. The design principle is to establish a baseline, identify high-consumption systems, and evaluate each measure through life-cycle and operational data.

4.5. Economic instruments and finance

Economic instruments determine whether technically feasible options are investable. Taxes, carbon pricing, grants, accelerated depreciation, concessional loans, guarantees, and green bonds can alter the balance between cleaner and conventional assets. The appropriate mix depends on the policy objective. Carbon pricing rewards lower operating emissions but may be insufficient to overcome high up-front capital costs; purchase support or concessional finance can address the capital barrier; public procurement can create early demand.

For Ukraine, financial design is particularly important because war-risk premiums and damaged infrastructure shorten corporate planning horizons. A credible greening strategy must therefore connect environmental requirements with financing channels. International financial institutions and the Ukraine Investment Framework can play a role, but environmental conditionality should be designed so that it supports implementation rather than simply adding compliance costs to firms with limited capital.

4.6. Organisational-managerial instruments

Organisational measures are often less capital-intensive than fleet replacement and can be implemented incrementally. Freight consolidation, improved load factors, dynamic routing, intermodal planning, reverse-logistics integration, and maintenance management can reduce avoidable activity and improve resource use. Their effect is nevertheless highly dependent on baseline inefficiency. A company with severe empty running may obtain large gains from planning improvements; a highly optimised network will have less remaining potential.

Digital TMS and WMS platforms should therefore be evaluated through operational indicators rather than assumed emissions percentages. Useful indicators include vehicle-kilometres per shipment, empty-running share, load factor, energy use per tonne-kilometre, on-time performance, and the carbon intensity of alternative routing choices. Digitalisation becomes a greening instrument only when it changes these decisions measurably.

4.7. Informational-analytical instruments and verification

Carbon accounting and sustainability reporting are the evidence infrastructure of greening. A firm cannot manage a reduction target credibly without defining organisational boundaries, operational boundaries, a base year, data sources, and calculation methods. GHG Protocol or ISO-based systems can support this process. External assurance, where feasible, improves comparability and reduces the risk that environmental claims are based on changing boundaries or selective indicators.

Corporate disclosures can illustrate organisational commitment but should not automatically be treated as independently verified evidence of national-sector performance. For example, Raben Group, which operates in Ukraine, reports group-level progress on emissions and sustainability targets. Such disclosure is useful evidence that formal ESG systems are being implemented in logistics, but group-level results should not be reassigned to Raben Ukraine or used as a proxy for the Ukrainian logistics sector unless country-specific data are published (Raben Group, 2025). This evidence rule is applied throughout the revised analysis.

4.8. Evidence strength and the limits of effectiveness estimates

A central result of the review is methodological: the available evidence supports directional and context-specific conclusions more strongly than universal percentage estimates. The same nominal intervention can generate different outcomes depending on vehicle duty cycle, electricity mix, facility baseline, network structure, financing, and enforcement. The appropriate question is therefore not „What percentage does this instrument always save?" but „Under what conditions, and with what evidence, can this instrument change performance?"

Table 3. Evidence hierarchy for claims about greening effectiveness

Evidence type	What it can support	What it should not be used to claim
Binding law / official regulation	Verified policy targets, scope, dates, regulated actors	Actual company-level emissions reductions
Peer-reviewed empirical study	Context-specific measured or modelled effects within stated boundaries	Universal percentages transferable to all modes and countries
Systematic or structured review	Patterns across a documented literature corpus	A pooled effect unless methods and comparable effect sizes justify meta-analysis
Corporate sustainability disclosure	Illustrative implementation, targets, and company-reported performance	Independent sector-wide evidence or country--specific performance without disaggregation
Conceptual / governance analysis	Instrument roles, causal mechanisms, sequencing, policy design	Causal impact estimates without empirical identification

This hierarchy changes the interpretation of synergy. The literature gives strong reasons to expect complementarity: vehicle electrification works better with charging infrastructure; carbon pricing works better when low-emission substitutes are available; reporting is more useful when targets and responsibilities are defined; and route optimisation has greater value when dispatch decisions can act on the data. However, the reviewed sources do not justify a universal statement that combining all five categories produces a specific 35-45% reduction. The revised framework therefore treats synergy as a governance proposition to be tested in specific implementations, not as a pooled numerical result.

The same correction applies to payback-period claims. Route optimisation or energy-efficiency projects may have short paybacks in some firms, but fleet electrification, warehouse retrofit, and infrastructure investment can require much longer horizons. Decision makers should use project-level total-cost-of-ownership analysis and scenario testing rather than generic payback numbers.

4.9. Structural barriers and a governance sequence for Ukraine

The Ukrainian context requires a sequencing framework that links environmental ambition to implementation capacity. The principal barriers identified in the literature and policy context are financial constraints, damaged and insufficient infrastructure, regulatory and administrative capacity, weak data and reporting capability, and wartime security risk. These barriers should not be assigned arbitrary criticality scores unless a documented stakeholder or multi-criteria assessment has been conducted.

Table 4. Structural barriers and governance responses for Ukraine

Barrier	Why it matters	Governance response
Finance and investment risk	High capital costs, war-risk premiums, and short planning horizons can delay fleet and infrastructure investment	Blend public guarantees, concessional finance, private capital, and transparent green eligibility criteria
Charging, grid, and terminal infrastructure	Vehicle transition is constrained if charging power, grid connections, and logistics nodes are unavailable or unreliable	Coordinate transport, energy, reconstruction, and local infrastructure planning; prioritise interoperable corridors
Regulatory and administrative capacity	EU-aligned standards require inspection, data, enforcement, procurement capability, and inter-agency coordination	Link legal approximation to implementation plans, staff capacity, digital registries, and enforcement resources
Data and competence gaps	Firms, especially SMEs, may lack emissions baselines, TCO capability, or ESG reporting expertise	Provide standard methods, training, shared tools, and technical assistance before imposing complex reporting obligations
Wartime and security risk	Assets and energy systems face disruption; firms prioritise continuity and survival	Design resilient and modular investments; integrate environmental criteria into recovery finance without undermining essential logistics

On the basis of these barriers, a six-step governance sequence is proposed. Step 1 is measurement: establish reliable activity, energy, and emissions baselines. Step 2 is regulatory alignment: identify which EU-derived standards and reporting requirements apply now and which require phased preparation. Step 3 is infrastructure coordination: align fleet policy with charging, grid, terminal, and corridor investment. Step 4 is finance: connect requirements with grants, guarantees, concessional lending, procurement, and carbon-price signals. Step 5 is implementation: deploy technical and organisational measures according to operational suitability. Step 6 is verification and learning: monitor performance, disclose results, audit material claims, and revise the instrument mix.

This sequence is deliberately iterative. Measurement can reveal that a presumed priority is not the dominant emissions source; infrastructure constraints can change technology choice; financing conditions can alter deployment speed; and monitoring can show that a measure does not perform as expected. Sustainable governance therefore requires feedback rather than a fixed one-time plan.

5. Conclusions

This study develops a five-category classification of greening tools in transport and logistics operations: legal and regulatory, technical and technological, economic, organisational-managerial, and informational-analytical. The main contribution is not a new list of technologies, but a governance interpretation of how the categories interact. Regulation defines obligations, technology provides physical alternatives, economic instruments shape investment incentives, organisational tools improve the use of assets and networks, and information systems make performance measurable and accountable.

The review also identifies an important methodological limitation in effectiveness assessment. The evidence base is too heterogeneous to justify universal percentage ranges for entire instrument categories or a single pooled reduction figure for an integrated portfolio. Effect estimates depend on system boundaries, baseline conditions, functional units, technologies, and national contexts. The revised framework therefore replaces false precision with an evidence hierarchy and requires quantitative claims to remain tied to their original scope.

For Ukraine, the policy implication is that greening transport and logistics should be treated as part of accession and reconstruction governance. EU alignment is moving beyond general Association Agreement commitments toward detailed acquis implementation. At the same time, war damage creates exceptional infrastructure and financing constraints. The appropriate strategy is therefore to integrate environmental standards into reconstruction planning, coordinate transport and energy infrastructure, develop administrative capacity, and use financing instruments that make compliance feasible for firms.

The proposed six-step governance sequence - measurement, regulatory alignment, infrastructure coordination, finance, implementation, and verification - offers a practical way to translate the five-category classification into policy and corporate action. It also makes clear that no single instrument can deliver the transition independently. Standards without infrastructure may be infeasible; subsidies without measurement may be poorly targeted; technology without organisational change may underperform; and reporting without accountability may become symbolic.

Future research should test the framework empirically using comparable company or corridor-level data. Priority designs include longitudinal studies of freight fleets, matched comparisons of logistics operators adopting different instrument mixes, total-cost-of-ownership analysis under Ukrainian energy and financing conditions, and evaluation of reconstruction projects that incorporate low-carbon transport requirements from the outset. Such work could eventually support quantitative estimates of interaction effects, but those estimates should be produced from documented data rather than assumed in advance.

Funding

This research received no external funding.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability

No new dataset was generated for this conceptual and regulatory analysis. The study relies on the cited academic literature, public legal acts, and publicly available policy documents.

Ethics Statement

The study did not involve human participants, personal data collection or experimental procedures; therefore, research ethics approval was not required.

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