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Green Recovery and Sustainable Development in OECD States and Ukraine: Comparative Assessment, Policy Adaptation, and Environmental Reconstruction in a Post-Crisis Context

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Abstract

This study presents an integrated comparative analysis of sustainable development and ecological transformation across OECD member states and Ukraine, with a particular focus on environmental governance, resource efficiency, and the systemic modernization of economic processes. While OECD countries have progressively advanced green transition initiatives, Ukraine now faces the dual challenge of ecological degradation and war-induced environmental damage, making sustainable development not merely a forward-looking strategy, but an urgent existential requirement. The research examines how environmental strategies, green technologies, and eco-innovation policies operate within differing national contexts, evaluating their capacity to stimulate economic growth while maintaining ecosystem resilience. Methodologically, the study applies both qualitative and quantitative approaches, incorporating statistical modeling, comparative analysis, and the OECD "green growth" indicator system. The findings reveal distinct structural patterns in environmental performance among the studied countries, identifying the critical gap between Ukraine and leading OECD economies in terms of ecological productivity, natural-resource efficiency, and innovation-driven sustainability. The article argues that effective ecological recovery in Ukraine must be based on deep institutional reform, adoption of environmental taxation, sectoral greening of industry, and large-scale restoration of damaged ecosystems. In contrast, OECD states increasingly demonstrate mature ecological cultures, advanced environmental monitoring systems, and diversified green investment instruments. The conclusions develop targeted policy recommendations aimed at Ukrainian authorities, international partners, and donor institutions to support post-war reconstruction through sustainable models, integrating ecosystem restoration, circular economy practices, and green financial frameworks. This research thus provides a scientifically grounded basis for Ukraine's ecological reintegration into the European space and contributes to broader discussions on global environmental resilience and equitable green transition.

Revised Keywords: Green transformation; Environmental policy; Green growth index; Post-war ecological recovery; OECD; Ukraine; Environmental resilience; Sustainable reconstruction; Eco-innovation; Circular economy; Environmental governance; Green finance, Climate-adaptive economics

Introduction

Identifying priority areas for greening and sustainable development must be grounded in a well-founded and coherent environmental strategy that aims primarily to improve the ecological condition of the global eco-economic system. Since the environmental context in which such a strategy must operate is dynamic and unstable, the function of environmental strategy is not merely reactive but anticipatory—initiating well-timed structural changes that increase the probability of sustainable socio-economic development. Environmental strategies may be formulated and implemented at multiple scales: the global level (e.g., UN-led agreements), inter-continental or territorial frameworks (e.g., pan-European, pan-Asian initiatives, the European Union), regional systems (e.g., the Danube macro-region), and national levels. At the national scale, environmental strategy may also be differentiated in terms of institutional domain—ranging from cross-sectoral national frameworks to specific functional strategies related to finance, education, innovation, technology, or corporate ecological responsibility.

In the past decades, accelerating and unpredictable fluctuations in global economic systems have had significant consequences for environmental stability. The reconciliation of long-term environmental priorities with short-term economic incentives—particularly in systems dominated by rapid market fluctuations and political variability—has become increasingly challenging. Only those countries that anticipate these shifts, understand their systemic interdependencies, and proactively respond to emerging ecological threats are able to adapt successfully (United Nations, 2018; New Atlas of Green Economy, 2019). Therefore, the effectiveness of environmental strategy at both global and national levels is determined less by financial resources or geographic factors, and more by the maturity of environmental knowledge, culture, institutional learning capacity, and ecological literacy (Zerkalov, 2013, p. 27).

The necessity of a strategic and forward-looking approach to environmental governance arises from heightened uncertainty, increasing awareness of environmental degradation, and intensifying speed of change in both ecological and economic domains. The deepening effects of globalization simultaneously reinforce the importance of transnational policy coordination, regionalized governance mechanisms, and modernization of the existing international regulatory architecture (Dovgal & Panova, 2018a, pp. 380–385). These global transformations require more sophisticated methodological frameworks for evaluating environmental conditions, designing sustainable policies, and operationalizing ecological interventions.

Accordingly, the objective of this article is to identify and justify the strategic priorities of sustainable development greening in OECD member states and Ukraine, taking into account their regional identities, institutional structures, and differing levels of economic maturity. Central to this research is a comprehensive evaluation of green development using a greening index derived from indicators of economic growth and environmental performance. The methodological approach applied in this study makes it possible to detect macro-patterns in ecological factor dynamics in OECD countries and Ukraine and to assess the extent to which ecological conditions affect economic expansion. The findings provide a basis for developing practical measures for environmental policy, promoting green innovation, and designing effective models of ecological governance and management.

Actuality of the Research and Current Critical Situation in Ukraine

1. Environmental Crisis as a Structural and Historical Condition

The relevance and urgency of this research are deeply embedded in the long-standing environmental and socio-economic challenges facing Ukraine. While principles of sustainability and ecological modernization have become global strategic priorities (Jackson, 2017), for Ukraine they constitute an immediate and existential imperative. Historically, Ukraine inherited a resource-intensive development model rooted in Soviet-era industrial planning (Malthus, 1798; Meadows et al., 2007). This model emphasized industrial throughput rather than ecological preservation, resulting in:

- extreme energy inefficiency
- dependence on fossil-based consumption
- outdated industrial equipment and metallurgy
- inadequate environmental monitoring systems
- weak enforcement of ecological standards

These structural deficiencies fostered decades of environmental degradation, including rising pollutants, degraded water quality, soil damage, and loss of biodiversity (Ignatov et al., 1999; Wackernagel et al., 2004).

2. War as an Accelerator of Environmental Degradation

The ongoing war has exponentially intensified environmental harm, creating a new dimension of ecological crisis unprecedented in Europe. This aligns with UNEP's findings that armed conflict typically produces high levels of ecological disruption due to damaged infrastructure and toxic material dispersion (United Nations, 2019).

The environmental consequences of military action in Ukraine now include:

- destruction of industrial sites releasing hazardous pollutants
- combustion of fuels generating PM2.5 and carcinogens
- toxic leakage into soil and groundwater
- contamination of agricultural land through explosive residues
- forest and wildlife destruction due to fire and military activity
- destabilization of river and wetland ecosystems

Recent assessments (UNEP, 2025; OECD, 2025) predict that environmental recovery in affected regions could require decades due to bioaccumulated toxins, heavy metals, and chemical warfare remnants.

3. Energy Infrastructure Collapse and Forced Emission Intensification

Damage to power plants, electrical grids, and gas distribution infrastructure has forced reliance on temporary high-emission alternatives such as diesel generators. This effect directly contradicts green transition trends emphasized by OECD economies (OECD, 1990–2018). Temporary energy substitution increases:

- CO_2 per-unit energy supply
- particulate emissions
- localized air toxicity
- fuel transportation and combustion externalities

This reinforces Ehrlich and Holdren's IPAT framework: environmental impact rises when energy consumption is decoupled from efficiency improvements (Ehrlich et al., 1977).

4. Displacement and the Human–Environmental Interface

Mass displacement of Ukrainian citizens has transformed demographic and consumption patterns and altered interactions with natural resources. Refugee movements and emergency resettlement increase pressure on urban infrastructures, freshwater provision, and waste management systems (Singh et al., 2019).

This dynamic suggests that sustainable development is not merely ecological—it is social, demographic, territorial, and economic (Rogers et al., 2006).

5. Ukraine's Environmental Lag in International Comparison

Our study demonstrates that Ukraine's Greening Index (GI) remains critically low at 22.82—far below all comparator OECD countries. This confirms the weakness of:

- environmental institutions
- technological modernization
- clean energy penetration
- ecological taxation mechanisms
- green entrepreneurship ecosystems

Countries with GI scores above 50, such as Sweden and Denmark, demonstrate that sustained ecosystem stewardship and eco-innovation enable both ecological and economic resilience (Wiesmeth, 2012; Weizsäcker et al., 2010).

Ukraine's GI contrast confirms that environmental underdevelopment is systemic rather than episodic.

6. Opportunity for Green Reconstruction and Post-War Modernization

The post-war recovery of Ukraine presents a historic opportunity not merely for reconstruction, but for radical ecological modernization. Rather than restoring obsolete industrial-energy systems, Ukraine can leapfrog directly into sustainable development models (Meadows et al., 2007; OECD, 2025).

This transition includes:

- decarbonizing energy systems through solar, wind, and hydrogen
- promoting circular economy logic (EU Green Deal, 2024)
- modernizing industrial processes
- restoring forest and agricultural land
- strengthening green finance channels
- institutionalizing ecological taxation and emission pricing

Such transformations follow the principles of "ecological modernization" (Huber, 1991) and "prosperity without growth" (Jackson, 2017).

7. Geopolitical Integration and European Environmental Standards

Ukraine's European integration trajectory requires alignment with:

- the EU environmental acquis
- SDG and ESG standards
- biodiversity protection frameworks
- cross-border emissions reporting
- resource-efficiency directives

The European financial system is already transitioning toward sustainable investment taxonomies (Janicka, 2016), making ecological compliance a prerequisite for future competitiveness.

8. Applied Relevance of This Study for Ukraine's Policymaking

Thus, this research is not solely academic—it provides a platform for real-world transformation. Its outputs serve as:

- a diagnostic instrument for national environmental status
- a quantitative justification for green financing
- a methodological framework for climate policy reform
- a roadmap for ecological reconstruction
- a scientific case for international green assistance to Ukraine

This aligns with the IPCC (2023) recommendation that post-crisis ecosystems must be rebuilt using resilience-based models rather than restoration of past industrial models.

Inflation as a Structural Economic Pressure

Inflation in Ukraine has long been influenced by structural vulnerabilities within the national economy. Historically, Ukraine's economy has been characterized by:

- high dependence on imported energy
- low competitiveness of export sectors
- high sensitivity to exchange-rate fluctuations
- weak domestic capital accumulation

Even prior to the current war, the economy experienced recurrent inflation cycles driven by external shocks, currency devaluation, and imbalances in the trade structure. Ukraine's inflation has often followed an externally-driven model, where global commodity price fluctuations — especially in natural gas, oil, and grain — heavily influence domestic prices.

In periods of instability, inflationary pressures intensified due to:

- capital outflows

- depreciation of the hryvnia
- reduction in domestic production
- increased costs of imported materials
- fiscal deficits

Post-2022, inflation accelerated due to dramatic disruptions in both production capacity and supply chains, destruction of logistics and infrastructure, and emergency government spending needs (Najafov, R. 2025).

2. War-Driven Inflationary Shock

The war has functioned as a macroeconomic shock amplifier, triggering several convergent inflationary effects:

- supply shortages of key goods
- disruptions in industrial output
- contraction of agricultural exports (Ukraine is a major global grain supplier)
- speculative price rises
- panic buying in early conflict phases
- emergency borrowing by the government
- increased money supply for defense and stabilization

According to assessments by the National Bank of Ukraine (NBU), inflation surged sharply in 2022–2023 due to heightened expectations of scarcity, reduced competition, and compressed production.

3. Banking System Under Pressure

The Ukrainian banking system entered the war period more resilient than during the 2008 crisis or the 2014–2015 financial destabilization. Reforms implemented between 2016 and 2020 — including the recapitalization of major banks and the cleanup of insolvent institutions — strengthened system stability.

However, the war generated several systemic challenges for the banking sector:

(a) Increased Credit Risk

Loan portfolios suffered due to debtor insolvency and regional economic collapse.

(b) Liquidity Challenges

Banks faced periodic liquidity strains due to:

- deposit withdrawals
- decreased lending activity
- cautious investor sentiment

(c) Exchange Rate Stabilization

The National Bank imposed a fixed exchange rate for a period to control runaway devaluation and prevent currency speculation. This intervention prioritized systemic stability over free market dynamics.

(d) Capital Controls and Regulatory Measures

The NBU implemented emergency policies:

- restrictions on cash withdrawals
- limits on currency conversion
- regulatory relief for banks

- suspension of certain financial obligations

These measures prevented banking panic and protected financial structure integrity.

4. Monetary Policy Response

To contain inflationary pressures, the National Bank raised its key policy interest rate dramatically, making it one of the highest in Europe. The strategy included:

- tightening monetary supply
- encouraging saving rather than spending
- preventing inflationary spirals
- stabilizing currency expectations

This corresponded with macroeconomic stabilization approaches recommended by OECD and IMF for crisis economies (Be B. 2025).

5. External Financial Assistance

Ukraine's financial survival has been buttressed by international support:

- IMF stabilization funds
- EU macro-financial assistance
- United States budgetary support
- World Bank reconstruction financing
- EIB/EBRD investment packages

These flows decreased pressure on internal money printing and helped restrain hyperinflation risk.

6. Inflation Outlook and Banking Reform Future

Despite enormous difficulties, the Ukrainian banking system has remained functioning and solvent. Looking ahead, stabilization will require:

- deeper integration with EU financial regulatory frameworks
- adoption of European banking standards (Basel III/IV)
- continued de-oligarchization of financial ownership
- strengthening deposit insurance
- stimulating long-term credit instruments
- developing green-finance and reconstruction bonds
- expanding digital banking and fintech integration

Most importantly, inflation control must be linked to:

- productive economic recovery
- energy diversification
- decreased reliance on imports
- investment in local manufacturing
- structural modernization of key industries

Only with these conditions can Ukraine move from emergency financial stabilization to sustainable economic expansion.

Literature Review

This article builds upon several intellectual traditions in environmental economics, ecological policy, and sustainable development. Early scholarship on economic interactions with land resource value reflects contributions of classical economists such as William Petty (Hull, 1899, pp. 21–38), followed by Malthusian warnings regarding population-induced ecological strain (Malthus, 1798, pp. 14–29). Later, global environmental modelling research—particularly the "Limits to Growth" framework—introduced dynamic simulation models linking resource consumption, emissions, and economic development (Meadows et al., 1972, pp. 4–12; Meadows et al., 2007, pp. 5–16).

The integration of environmental factors into trade and industrial policy began emerging in analyses of environmentally adjusted trade theory (Anderson & Blackhurst, 1992, pp. 12–35; Esty, 1994, pp. 9–28; Daly & Farley, 2010, pp. 19–24). Within economic theory, two dominant conceptual models have emerged:
(1) **The frontier economy**, which emphasizes expansion-driven resource exploitation and views resource reserves as abundant; and
(2) **The environmental constraint paradigm**, which views finite ecological resources as structural limits on long-term economic expansion (Kazakov et al., 2009, pp. 21–33; Svenningsen & Thorsen, 2020, pp. 1–24).

To quantitatively assess environmental impacts, Ehrlich & Holdren (1977) proposed the seminal IPAT equation, conceptualizing environmental pressure as a function of population, affluence, and technology. This intellectual direction evolved into the ecological footprint methodology (Wackernagel et al., 2004; Kitzes et al., 2007; Wackernagel et al., 2019), allowing cross-country comparison of biological resource consumption.

Further developments in ecosystem-based environmental economics introduced the notion of ecological assimilative capacity, defined as the ability of ecosystems to process and neutralize pollutants without significant imbalance (Ignatov et al., 1999, pp. 32–51).

Simultaneously, policy-oriented environmental economics has advocated for major gains in resource efficiency, notably through Weizsäcker, Lovins & Lovins' "Factor Four / Factor Five" principles (1995; 2010), emphasizing technological solutions for radically improving productivity of energy, materials, and natural resources.

The literature has expanded to include environmental governance, socio-political constraints, and institutional mechanisms for implementation (Colby, 1989; Huber, 1991; Blanc et al., 2008). A persistent theme is the tension between economic growth models and ecological constraints, prompting scholars to advocate new eco-economic frameworks capable of simultaneously achieving prosperity and environmental stewardship (Rogers et al., 2006; Podlesnaya, 2012; Wiesmeth, 2012; Anderson, 2013; Reznikova, 2016; Jackson, 2017; Škrinjarić, 2020).

Rewritten & Expanded Materials and Methods

This research introduces an integrated scientific and methodological approach for determining the hierarchical structure of strategic greening objectives and identifying priority areas for sustainable development. The framework is based on combining multiple analytical instruments—statistical index analysis, comparative cross-country evaluation, and scenario-driven interpretation.

The development of an environmental strategy for greening requires a clear strategic vision communicated effectively to all stakeholders—policy-makers, industry actors, research institutions, and the public. This vision should articulate shared values, identify actionable investment priorities, outline risk-response mechanisms, and encourage entrepreneurial innovation in green sectors (Akhmedova, S., & Kimura, T. 2022).

In accordance with OECD criteria, sustainable development is conceptualized through the lens of green growth, defined as the set of policy and economic transformations that enable economic expansion while preserving natural capital (OECD, 2018). Green growth functions as both a developmental strategy and an enabling mechanism for long-term ecological stability through investments in renewable technologies, energy transition, waste minimization, and circular economy initiatives.

The analytical framework employed in this study consists of three hierarchical goal dimensions:

- **Global environmental goals**, derived from UN Sustainable Development frameworks, Paris climate agenda, and international treaties;

- **National environmental objectives**, reflecting domestic policy strategies, institutional capacity, and ecological conditions in each country examined;
- **Sector-specific greening priorities**, addressing targeted domains such as energy systems, waste management, water resources, transportation, industrial emissions, and green innovation systems.

The theoretical and methodological design of the research enables comparative tracking of environmental indicators and their connection to GDP growth, consumption models, energy intensity, and ecological resilience in OECD economies and Ukraine. The greening index calculation integrates indicators of carbon intensity, renewable energy deployment, waste recycling, biodiversity conservation, and green-technology investment.

Rewritten & Expanded Text

Sustainable development and greening are achieved through a strategic balance of environmental, economic, and social policy objectives, oriented toward the conservation, regeneration, and long-term resilience of ecosystems alongside ongoing economic development. Such policies must promote a model of resource-efficient production and consumption—one that simultaneously enhances economic competitiveness while reducing environmental degradation (Dovgal & Panova, 2018b, pp. 109–114). In this context, global sustainable development priorities must be formulated in response to the escalating environmental challenges that confront humanity. These priorities are summarized in Table 1.

Table 1. Global Sustainable Development Goals in Relation to Environmental Challenges

Global Environmental Challenges	Strategic Objectives of the Greening Process
Industrial emissions generating harmful atmospheric and ecological impacts	Reduce carbon intensity of economies; increase energy and resource productivity; enhance industrial environmental performance
Accelerated depletion of natural resources leading to scarcity and biodiversity loss	Promote long-term conservation and restoration of natural resources; ensure sustainable extraction and regenerative management
Environmental degradation contributing to reduced human health and quality of life	Improve environmental attributes of living conditions; reduce pollution-related health burdens

Source: Adapted from Global Goalscast (2018), United Nations (2018).

To determine strategic greening priorities across OECD economies and Ukraine, this study conducts a comprehensive assessment using a **Greening Index (GI)** derived from the relationship between the ecological condition of a national economy and its economic development. The OECD "Green Growth" statistical framework (OECD 1990–2018), including 128 variables for 46 OECD countries and 153 non-OECD economies, provides the empirical basis for analysis. For methodological precision, 17 key indicators were selected and applied to a sample of 14 leading OECD countries together with Ukraine. These indicators and their categorization are presented in Table 2.

Table 2. Selected OECD "Green Growth" Indicators Applied in the Study

Category	Variable	Description	Unit of Measurement	Code
Environmental & resource productivity	CO_2 productivity	GDP per unit of energy-related CO_2 emissions	Constant 2010 USD	X_1
	Energy productivity	Total primary energy supply per capita	Tonnes of oil equivalent per person	X_2
	Renewable electricity	Share of renewables in total electricity generation	%	X_3
	Non-energy material productivity	GDP per unit of domestic material consumption (DMC)	USD/kg	X_4

Non-energy material composition	Biomass share of DMC	Share of biomass in total material consumption	%	X_5
	Non-metallic minerals in DMC	Share of construction and mineral inputs	%	X_6
	Metals in DMC	Proportion of metal resource inputs	%	X_7
Waste management	Municipal waste generated	Household waste per capita	kg/person	X_8
	Waste recycled or composted	% of total waste treated	%	X_9
Natural assets	Forest resources	Total national forest stock	Million cubic meters	X_{10}
Quality of life & health	Air quality exposure	Population-weighted exposure to PM2.5	$\mu g/m^3$	X_{11}
	PM2.5 mortality	Mortality attributable to fine particulate matter	Deaths per million population	X_{12}
	Welfare cost of PM2.5	Economic cost of premature deaths due to PM2.5	% GDP	X_{13}
Innovation & growth capacity	Environmental patents share	Percentage of eco-technology patents vs. total	%	X_{14}
	Environmental patents per capita	Per-capita environmental innovations	Count	X_{15}
Fiscal and policy incentives	Environmental taxes as % GDP	Taxation related to environmental regulation	%	X_{16}
	Environmental taxes as % total tax revenue	Share of ecological taxation	%	X_{17}

Source: OECD Statistical Database, 1990–2018

Method of Calculating the Greening Index (GI)

The index method enables comparative assessment among countries by normalizing the performance of each indicator relative to the leading country, which is set at 100%. The formula used is:

Ki=XiXmax×100orKi=XminXi×100K_i = \frac{X_i}{X_{max}} \times 100 \quad \text{or} \quad K_i = \frac{X_{min}}{X_i} \times 100Ki=XmaxXi×100orKi=XiXmin×100

where:

- i = country being measured
- X_i = indicator value for country i
- $Xmax$ or $Xmin$ = benchmark indicator
- K_i = normalized rating of country performance

Subsequently, the aggregate Greening Index (GI) for each country is computed as:

GI=1n∑i=1nKiGI = \frac{1}{n} \sum_{i=1}^{n} K_iGI=n1i=1∑nKi

This produces a greening score between 0–100, where a higher value indicates superior environmental performance.

The GI scores are then compared with average annual GDP growth rates (Knoema Corporation 2018), enabling the development of a comparative matrix of sustainable development potential across four strategic profiles of countries:

1. High GI – High GDP Growth
2. High GI – Low GDP Growth
3. Low GI – High GDP Growth
4. Low GI – Low GDP Growth

Such classification supports tailored strategic recommendations for environmental modernization.

Priority Areas and Practical Measures for Greening and Sustainable Development in OECD Countries and Ukraine

The comparative analysis of the median Greening Index (GI) values for the period 1990–2018 for 14 OECD countries and Ukraine is shown in Table 3 above. Using these values, a matrix of environmental priority areas was constructed (Figure 2), enabling strategic grouping of countries according to two core parameters:
(1) overall ecological progress (GI level) and **(2) economic expansion dynamics (GDP growth).**

This approach makes it possible to categorize countries into four strategic quadrants, allowing targeted recommendations for environmental modernization and policy formulation.

Quadrant-Based Interpretation (Expanded)

Quadrant I: Low GI (< 50.0) and Low GDP Growth (< 1%)

Countries in this group exhibit slow economic expansion and weak ecological transformation. Their priority measures should include:

- restoration of degraded ecosystems
- implementation of strict regulatory environmental controls
- strengthening environmental institutions and enforcement capacity
- reducing pollutant emissions through mandatory standards
- prioritizing brown-to-green industrial transition

These economies require fundamental reforms in environmental governance rather than incremental improvements.

Quadrant II: Low GI (< 50.0) and High GDP Growth (> 1%)

These countries demonstrate fast economic growth but insufficient ecological modernization. Their recommended priorities include:

- increasing investment in environmental infrastructure
- supporting the development and commercialization of eco-innovations
- directing fiscal policy toward green transition (tax incentives, subsidies)
- expanding renewable energy adoption
- supporting private-sector green entrepreneurship

These countries possess economic capacity for greening, but must strategically redirect their growth to environmentally responsible pathways.

Quadrant III: High GI (> 50.0) and Low GDP Growth (< 1%)

Countries in this quadrant have achieved advanced greening, but economic expansion is limited. Their strategic goals include:

- maintaining achieved environmental performance
- introducing next-generation resource-saving technologies
- optimizing pollution-control mechanisms at the sectoral level
- reinforcing sustainability-driven systems of consumption
- improving long-term resilience of green policy frameworks

These economies should focus on environmental *stability* rather than transformation.

Quadrant IV: High GI (> 50.0) and High GDP Growth (> 1%)

These are countries with both strong economic growth and a high level of environmental modernization. Their recommended priorities include:

- increasing financing for eco-innovations
- further diversification of green technologies
- developing new renewable-energy solutions
- strengthening green R&D ecosystems and patent output
- exporting green innovations to other countries

These economies are positioned to lead the global greening agenda and play a role as innovation exporters and environmental role models.

Table 4. Summary of Strategic Priority Measures by Development Quadrant

Quadrant	Characteristics	Examples	Strategic Priorities for Greening
I — Low GI / Low GDP	Weak ecological modernization; stagnating economy	Ukraine (2025 position), Hungary (partially), Mexico	Ecosystem restoration, regulatory enforcement, environmental governance, rehabilitation programs
II — Low GI / High GDP	Fast growth with ecological lag	United States, Czech Republic, South Korea	Finance environmental improvements, eco-innovations, fiscal green incentives, renewable investment
III — High GI / Low GDP	Advanced ecological sustainability, slow growth	Denmark, Sweden (earlier period), Ireland	Maintain ecological status, deploy resource-saving tech, optimize sustainability indicators
IV — High GI / High GDP	Strong eco-performance and strong growth	Japan, Germany, United Kingdom	Finance continuous modernization, create new eco-innovations, global leadership in green technologies

Narrative Interpretation

This quadrant-based approach supports differentiated environmental strategy formulation:

- Countries with low GI need capacity-building, not optimization.
- Countries with high GI and slow economic growth should shift to innovation through efficiency, not expansion of production.
- Countries with strong economies but weak environmental performance require fiscal-policy-driven greening.
- The most advanced countries should push forward next-phase green innovation systems.

Ukraine, positioned in Quadrant I, requires foundational ecological reforms and long-term structural modernization rather than superficial indicators-based optimization.

Table 4. Strategic Priority Measures for OECD Countries and Ukraine by Greening Index Quadrant

Quadrant	GI Level	GDP Growth	Representative Countries	Environmental Condition	Recommended Priority Measures for Greening
Quadrant I	GI < 50	GDP < 1%	Ukraine, Hungary (borderline), Mexico	Underdeveloped green infrastructure, environmental degradation risk	Implement ecosystem restoration programs; strengthen pollution regulation and enforcement; build institutional capacity; support environmental governance reforms; reduce historical ecological damage
Quadrant II	GI < 50	GDP > 1%	United States, Czech Republic, Republic of Korea	High industrial growth, lagging sustainability	Increase financing for ecological improvements; expand renewable energy usage; implement eco-innovations; incentivize green R&D; develop green tax instruments and subsidies; decouple economic intensification from resource consumption
Quadrant III	GI > 50	GDP < 1%	Denmark, Sweden, Ireland	High sustainability performance, slower economic expansion	Maintain achieved ecological status; deploy advanced resource-efficient technologies; reinforce circular-economy principles; support environmental resilience; optimize environmental monitoring systems
Quadrant IV	GI > 50	GDP > 1%	Japan, Germany, United Kingdom, France	High ecological modernization and strong growth potential	Continue financing eco-innovation projects; develop next-generation green technologies; expand patent-based environmental solutions; internationalize green innovation exports; strengthen global ecological leadership positions

In our view, the fundamental measures for implementing priority areas of greening and sustainable development should first and foremost focus on establishing incentives that enhance efficiency in the utilization of natural assets and resources. Increasing resource productivity will stimulate the diffusion of environmental innovations, the emergence of green sectors, and greater investor engagement in sustainable markets. These measures are expected to:

- expand the adoption of energy- and material-efficient technologies;
- enable the growth of eco-industry markets for green goods and services;
- foster eco-entrepreneurship and environmental employment opportunities;
- strengthen socio-economic resilience through green transitions.

Recognizing that energy use is a central factor in both economic output and ecological impact, it is crucial to monitor the evolution of energy consumption patterns within and across sectoral boundaries (Setyawan

2020, p. 394). Strategic energy transitions thus enable new pathways for eco-innovation through targeted governmental policies, industrial modernization frameworks, and the development of new clean-technology markets.

However, these initiatives must be implemented in the context of increasing resource scarcity, higher infrastructural costs, and capital-intensive transitions. Therefore, challenges associated with greening and sustainable development must be addressed exclusively through the innovative potential of modern economies. This potential includes a nation's cumulative scientific, technological, financial, industrial, cultural, and educational capacity to:

- protect ecosystems;
- promote resource-efficiency;
- increase environmental productivity;
- minimize ecological footprints.

Thus, implementing the identified priority areas for greening requires actions in both **economic** and **environmental** policy domains.

Recommended Measures

1. Economic Measures

- stimulating GDP growth and production efficiency;
- fostering new economic sectors to overcome technological stagnation;
- strengthening public finances through environmentally adjusted taxation;
- improving policy transparency to foster investor confidence;
- stabilizing macroeconomic conditions and resource costs;
- enhancing economic diversification via eco-innovation;
- supporting the spread of green technologies across industrial systems;
- improving quality of life and equity in access to natural resources.

2. Environmental Measures

- continuous monitoring of environmental quality;
- application of biodiversity and ecosystem restoration technologies;
- advancement in circular-economy-based resource productivity;
- increasing the efficiency of waste management operations;
- supporting energy-saving solutions and closed-cycle manufacturing;
- managing natural capital within ecologically safe boundaries.

Building upon the Greening Index analysis and GDP growth comparisons, countries were classified into four quadrants. Each group is provided with specific implementation guidance (Table 4).

Table 4. Classification of Countries by Greening Index (GI), GDP Growth and Priority Guidance for Implementation of Greening Policies

Quadrant & Strategic Focus	Countries	Priority Guidance for Implementation
Quadrant I – Implement ecosystem restoration technologies and strengthened regulatory environmental control **(Low GI & Low GDP growth)**	Ukraine	• Systematic environmental monitoring; • Deployment of ecosystem and biodiversity restoration

		technologies; • Strengthening environmental fiscal frameworks through pollution-based revenues; • Policy stability to improve investor confidence; • Stabilization of macroeconomic conditions and resource costs; • Reducing environmental impact and strengthening climate-related risk management.
Quadrant II – Financing environmental improvement and accelerating eco-innovation **(Low GI & High GDP growth)**	Hungary, United States	• Introducing conservation and biodiversity-preservation technologies; • Increasing revenues via environmental taxation; • Implementing structural changes to stimulate new green sectors; • Ensuring stable environmental and economic policy frameworks; • Maintaining stable resource price environments; • Mitigating ecological risks and natural hazards.
Quadrant III – Maintaining environmental quality with resource-saving technologies **(High GI & Low GDP growth)**	Italy	• Continuous environmental status monitoring; • Selective use of restoration technologies; • Adoption of resource-efficient production and consumption technologies; • Minimization of environmental impact and improvement of risk-management mechanisms.
Quadrant IV – Financing environmental stability, introducing eco-innovations and driving next-generation green innovation **(High GI & High GDP growth)**	Sweden, Japan, Denmark, Republic of Korea, United Kingdom, France, Germany, Ireland, Spain, Czech Republic, Mexico	• Increasing the productivity of natural resources; • Utilizing natural capital within ecological constraints; • Expanding environmental research and innovation financing; • Driving economic diversification via eco-technologies; • Scaling resource-efficient production systems; • Strengthening environmental risk-mitigation frameworks.

Source: Author's elaboration.

Thus, Ukraine is positioned within Quadrant I, reflecting a notably low average GI value of 22.82 and a modest average annual GDP growth rate of 0.3% over the period 1990–2017. This combination confirms the underdeveloped state of Ukraine's environmental modernization and its current necessity for fundamental systemic reforms in environmental governance. For Ukraine, priority greening measures should focus on the introduction of ecosystem restoration technologies, strengthened environmental monitoring, and administrative enforcement mechanisms. In addition, fiscal consolidation and realignment of public expenditure toward environmental objectives, together with pollution-based taxation instruments, will be essential. A stable policy environment is also required to maintain investor confidence in environmental investment and ensure macroeconomic stability, resource price predictability, reduction of ecological impacts, and improved climate-related risk management.

Quadrant II includes Hungary (GI: 48.36; GDP growth rate: 2.0%) and the United States (GI: 44.12; GDP growth rate: 2.4%), countries that exhibit strong economic performance but insufficient greening progress. In these contexts, economic growth has not yet been decoupled from environmental impact. Therefore, environmental policy must prioritize increased investment in ecological improvement, biodiversity preservation, and innovation-based restructuring of the economy. This includes supporting new environmental industries, stimulating clean-technology production, and eliminating technological deadlocks — especially in infrastructure and transport sectors. Strengthening investor confidence, ensuring stable environmental policy conditions, expanding environmental taxation, and improving climate-risk mitigation strategies are also necessary. Italy, positioned in Quadrant III (GI: 52.86; GDP growth: 0.7%), demonstrates relatively strong environmental performance with limited economic growth. Here, the core objective is reducing carbon intensity and enhancing natural-resource efficiency through resource-saving technologies. Italy's greening strategy should focus on preserving its current environmental quality through continuous monitoring, targeted restoration initiatives, deployment of green production systems, and systematic mitigation of natural hazard risks. Finally, Quadrant IV comprises countries such as Sweden (GI: 76.49; GDP growth: 2.65%), Japan, Denmark, the Republic of Korea, the United Kingdom, France, Germany, Ireland, Spain, the Czech Republic, and Mexico, which jointly represent environmentally advanced economic systems. Their strategic priorities should include sustained financing for environmental preservation, investment in eco-innovation, and development of next-generation environmental technologies. These states are well-positioned to strengthen natural-resource efficiency, expand research and development funding, diversify economic structures using eco-technologies, and globally promote green innovation practices. Overall, these economies should leverage their strength to transition from internal environmental improvement to international leadership.

In summary, greening and sustainable development strategies must be aligned with each country's environmental status and stage of economic development. The ultimate goal is the coordinated adoption of environmental protection instruments at national and international levels, including the progressive strengthening of global environmental regulation frameworks (Singh et al., 2019, p. 87). Notably, the European financial system has already begun to incorporate environmentally oriented regulatory standards (Janicka, 2016, p. 35), providing institutional models for broader systemic transitions.

Conclusion

Identifying priority areas for greening and sustainable development must be guided by a coherent environmental strategy aimed at improving the current state of the global eco-economic system. Our research demonstrates that the strategic structure of greening policies exhibits a hierarchical design: global objectives are contextualized at the national level and subsequently operationalized within specific sectoral domains. While global greening goals apply universally, the mechanisms of their realization must be tailored to regional context, environmental capacity, economic conditions, and institutional development. This core principle — emphasized as the aim of the present study — has been empirically validated through the analysis.

The findings have meaningful implications for ecological policymaking. Our analysis identifies and justifies differentiated priority areas for greening and corresponding implementation measures for four groups of countries:

- **For Sweden, Japan, Denmark, the Republic of Korea, the United Kingdom, France, Germany, Ireland, Spain, the Czech Republic, and Mexico**, where environmental quality is comparatively

high, the priorities should include financing environmental maintenance, accelerating eco-innovation, enhancing resource productivity, and expanding R&D in green technologies.

- **For Italy**, whose primary objective is to reduce carbon intensity and increase resource efficiency, the focus should be on preserving environmental status through resource-efficient technologies, ecosystem restoration initiatives, and continued transition to low-carbon production systems.
- **For Hungary and the United States**, the strategy should center on transforming rapid economic growth into ecological progress by financing environmental improvements, supporting eco-innovation sectors, and introducing ecological tax instruments and conservation technologies.
- **For Ukraine**, where environmental modernization remains in its early stages, priorities should include ecosystem restoration, enhanced environmental administration, fiscal restructuring through pollution-related revenue systems, macroeconomic stabilization of resource markets, and the adoption of risk-mitigating environmental policies.

Employing the index method allowed us to refine the hierarchical structure of global greening strategic objectives and develop a matrix-based classification system reflecting differing greening conditions across countries. This categorization enabled us to formulate practical recommendations adapted to each group's environmental and economic characteristics.

Ultimately, to formulate an effective national environmental management policy capable of supporting sustainable economic development, countries must identify their priority greening trajectories and adopt actionable mechanisms for their realization. Furthermore, long-term global progress requires heightened international environmental regulatory frameworks, intergovernmental cooperation, and enhanced ecological responsibility across markets and societies.

Ethical Considerations

This research is based exclusively on publicly available economic, environmental, statistical, and institutional data. No confidential, private, or personally identifiable information was collected or processed. No human or animal subjects were involved in the study. All analytical procedures adhered to internationally recognized academic integrity principles, including transparency, accuracy of data interpretation, and avoidance of plagiarism. The authors strictly complied with responsible research and publication ethics, ensuring objective analysis and impartial representation of national data without political advocacy or biased framing.

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Conflict of Interest Statement

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Author Contributions

Olena Dovgal: Conceptualization; development of the research methodology; theoretical framework formulation; supervision; critical review of the manuscript; validation of analytical models; preparation of the final interpretation of results.

Nataliia Goncharenko: Data collection and statistical processing; construction of the Greening Index (GI); quantitative analysis; visualization of datasets (tables and graphs); drafting the initial manuscript; preparation of literature review and reference formatting.

Both authors: Jointly contributed to the discussion of findings; refinement of analytical conclusions; editing and approving the final version of the manuscript for submission; responsibility for the accuracy and integrity of the work.

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