“Sustainable economy as a new globalization reality: Formation of disruptive trends toward Industry 4.0”

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SUSTAINABLE ECONOMY AS A NEW GLOBALIZATION REALITY: FORMATION OF DISRUPTIVE TRENDS TOWARD INDUSTRY 4.0

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Abstract

Profound ecological and technological shifts are transforming the foundations of global development and redefining the trajectory of contemporary globalization. The study aims to investigate the role of the sustainable economy in shaping a new globalized development model in the context of disruptive technologies and Industry 4.0. The results demonstrate that sustainability and advanced digital-cyber-physical technologies act as mutually reinforcing drivers of structural change, enabling the transition toward circular production systems, intelligent resource management, and human-centered industrial paradigms. The study confirms that sustainability becomes the new logic of globalization, in which additive production, renewable energy, cyber-physical systems, and intelligent networks form disruptive trends reshaping political and economic relations. Recent market assessments indicate that the global Industry 4.0 sector has already reached a value of USD 180–200 billion, with projections ranging from USD 600–900 billion by 2034. Within a sample of developed economies, an increase in the Globalization Index by one point decreases the Sustainable Development Index by 0.68 points. The scientific novelty lies in the conceptualization of the sustainable economy through both classical and globalization approaches: the former focuses on additive, resource-efficient production, while the latter interprets sustainability as a new organizing logic of globalization that reshapes geopolitical interactions, redistributes technological power, and embeds ecological constraints into global governance. The study concludes that the sustainable economy represents a new globalization reality in which ecological principles, digital intelligence, and technological sovereignty jointly define long-term development trajectories.

Keywords sustainable economy, globalization, disruptive technologies, Industry 4.0, sustainability

JEL Classification Q01, F64, L69

INTRODUCTION

Globalization is entering a new developmental stage characterized by intensified ecological constraints, resource scarcity, digital transformation, and changing human-technology interactions. These shifts reflect not only technological acceleration but also the systemic pressures emerging from climate change, biodiversity loss, and the exhaustion of traditional industrial development pathways. As economies confront the physical limits of the planet, the sustainable economy emerges as a necessary response to global challenges associated with climate instability, inefficient resource use, and the structural limitations of 20th-century industrialization models. Many studies emphasize that a sustainable economy represents the production basis of a new socio-economic formation built on harmonious relations between society and nature and grounded in additive technologies that minimize human interference with the biosphere's metabolism (Choi et al., 2022). The transition toward a sustainable economy, therefore, signifies more than environmental policy reform – it constitutes a profound restructuring of how societies produce, consume, innovate, and interact with natural systems.

Simultaneously, the global technological landscape is undergoing a disruptive shift driven by the intertwined industrial revolutions, Industry 3.0, Industry 4.0, and Industry 5.0, forming a continuous and mutually reinforcing evolution of production systems (Lasi et al., 2014; Beier et al., 2020). The automation and digitalization of Industry 3.0 established the foundation for later breakthroughs, enabling the adoption of renewable energy systems, early forms of digital control, and resource-efficient technologies. Industry 4.0, in particular, triggers unprecedented transformations by integrating cyber-physical systems (CPS), IoT, AI, big data, and digital twins into industrial and social environments. These technologies allow production systems to operate with high precision, real-time adaptability, predictive maintenance, and radically improved resource efficiency – features essential for achieving ecological sustainability at scale (Nascimento et al., 2029). The emergence of Industry 5.0 further extends this progression by shifting the technological paradigm toward human-centric, ethical, and creative systems, emphasizing the synergy between advanced automation and human capabilities.

Against this backdrop, globalization itself is being reconfigured. The traditional drivers of global integration – mass industrialization, fossil-fuel energy, and linear resource extraction – are gradually losing relevance as economies pivot toward low-carbon development, decentralized production networks, and information-centric value creation (Vu et al., 2023). The convergence of sustainability principles with disruptive digital technologies fosters new forms of global interdependence based not solely on physical trade flows, but on data infrastructures, technological standards, circular resource systems, and shared ecological commitments. This reflects an emerging globalization reality in which environmental limits, digital intelligence, and human well-being become central organizing principles rather than secondary considerations (Bonilla et al., 2018; Raihan, 2023).

The study aims to investigate the role of the sustainable economy in shaping a new global development model in the context of disruptive technologies and Industry 4.0.

1. THEORETICAL BASIS

A sustainable economy is a multidimensional phenomenon encompassing environmental, social, informational, digital, additive, and network-based dimensions. It integrates ecological imperatives with advanced technological architectures, enabling production systems that are simultaneously efficient, resilient, and adaptive (Xiaoman et al., 2021). In this framework, sustainability principles are embedded directly into technological design, organizational models, and value-creation mechanisms. As a result, a sustainable economy functions not only as a corrective to the limitations of industrial-era development but also as a strategic platform for long-term competitiveness, guiding economies toward low-carbon growth, circular resource use (Geissdoerfe et al., 2023), and intelligent, interconnected infrastructures.

It is not only an ecological concept but also:

- "green" – ensuring minimization of anthropogenic pressure;
- "social" – targeting human-centered development and Society 5.0;
- "informational" – making information the key production factor;
- "digital" – embedding cyber-physical integration into all processes;
- "additive" – relying on minimally wasteful production;
- "network-based" – enabling horizontal distributed systems.

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The technological foundation of a sustainable economy is additive manufacturing, including 3D printing, renewable energy systems, creative and IT industries, and digital twin–based production (Taghvaee et al., 2022; Stock & Seliger, 2016). By using only the necessary part of natural resources and dramatically reducing waste, additive technologies become the primary mechanism for lowering ecological pressure.

The transition toward a sustainable economy began at the end of the 20th century, coinciding with the simultaneous unfolding of Industries 3.0, 4.0, and 5.0, which mutually reinforce one another (Wang et al., 2023). Industry 3.0 responds to the global ecological crisis by introducing additive technologies and renewable energy. Industry 4.0 is required to manage the enormous informational complexity of additive and network-based production systems. Industry 5.0 reorients technology toward human-centered and creative development, enhancing collective intelligence and information generation.

Thus, a sustainable economy emerges not only as an environmental imperative but also as an evolutionary outcome of deep technological transformations. Table 1 summarizes key aspects of the sustainable economy discussed in the scientific discourse, including ecological, digital, technological, and socio-economic dimensions.

The global significance and deep meaning of a sustainable economy can be understood based on two basic interconnected concepts: the single anti-entropic potential (SAP) of the Earth and the sustainable development of society. The fundamental basis of sustainable development of humanity is precisely the preservation and progressive development of the specified SAP (Melnyk, 2021).

It is the Earth's single anti-entropic potential that supports metabolic processes in the biosphere and ensures human life. The basis of SAP is the biosphere of the planet. Its functional component is a society, which operates and develops at the upper levels of SAP. The key function of SAP is to counteract the growth of entropy (i.e., disorder) on the planet, and the result is an increase in the level of ordering of natural systems. This is its anti-entropic activity, in other words, the production of negative energy.

The above makes it possible to understand the role of the phase transition processes that are currently taking place in society and the significance of the specified industrial revolutions.

Industry 3.0 aims to harmonize society's production processes with material and information transformations in the biosphere (Ramzan et al., 2023; Melnyk et al., 2025b). This is achieved by switching to additive technologies in the broad sense of this concept. Additive technologies are built on the informatization and dematerialization of technological processes.

The information complication of production processes forces us to move to the mass implementation of cyber-physical processes, which occurs during Industry 4.0.

Table 1. The conceptual framework of a sustainable economy

Ecological Sustainability (Central Principle)	
The overarching goal of the sustainable economy: harmonizing human activity with natural systems, reducing anthropogenic pressures, and maintaining planetary boundaries	
Circular Economy	**Digital and Cyber-Physical Transformation**
This encompasses closed-loop material cycles, waste minimization, product life-cycle extension, and resource efficiency (Musfar et al., 2025; Ba, 2025)	This represents Industry 4.0 technologies – AI, IoT, digital twins, big data, autonomous systems – that optimize resource use, enable transparency, and reduce inefficiencies (Melnyk et al., 2025a; Kouhizadeh et al., 2021; Sinha et al., 2025)
Technological Foundations	
Additive Manufacturing	**Renewable Energy Systems**
This includes 3D printing, material-efficient production, and low-waste manufacturing processes (Abdulhameed et al., 2019; Singh et al., 2017)	This represents solar, wind, hydrogen, smart grids, and AI-optimized energy infrastructures (Kurbatova et al., 2025)
Human-Centered Innovation (Society 5.0)	
This symbolizes that the ultimate purpose of the sustainable economy is a human-centered society enabled by intelligent digital systems, ecological integrity, creative capacity, and social well-being (Huang et al., 2022; Melnyk et al., 2025b; Nahavandi, 2019)	

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At the current stage of SAP development, society and the personal beginning of a person begin to play a leading role. The personality with its informational needs becomes the key goal of sustainable development and the driver of SAP's anti-entropic activity. The informatization of the metabolic processes of SAP components is the main direction of its progressive development. That is why the human-centric direction of society's development is the key task of Industry 5.0 and the core of the concept of sustainable development.

An important issue, however, remains the effective measurement of sustainable economy transition that integrates economic, social, and environmental determinants. According to Hickel (2020), the Sustainable Development Index (SDI) helps to assess the environmental efficiency of countries' development, based on the principles of the planet's biological carrying capacity. The construction of the SDI starts from the key components of the Human Development Index (life expectancy, education, and income) and divides them by the environmental overshoot. The original index is measured on a scale of 0 to 1, while for the econometric research, we multiplied it by 100 to work with a 0 to 100 range. According to the KOF Swiss Economic Institute (Gygli et al., 2019), the Globalization Index (GI) measures the economic, social, and political dimensions of globalization. The GI ranges on a scale of 1 to 100, with 42 different indicators used and aggregated using statistically determined weights (principal component analysis).

2. RESULTS

The sustainable economy emerges today not only as a reaction to ecological degradation but as a foundational transformation of globalization itself. Globalization in the 20th century was driven predominantly by industrial expansion, fossil-fuel energy systems, and mass consumption. These mechanisms enabled rapid economic growth but simultaneously intensified climate change, biodiversity loss, and resource depletion. The sustainable economy offers an alternative logic: rather than maximizing output through resource extraction, it prioritizes a balance between human activity and planetary boundaries. This fundamentally reshapes global development, redirecting globalization toward ecological compatibility and long-term resilience.

A central feature of this new globalization reality is the transition to network-based, information-driven systems that operate within circular resource flows. Sustainable economy models replace linear "take-make-dispose" production with circular cycles where materials are continuously reused, energy originates from renewable sources, and waste is minimized through additive manufacturing and digital optimization. Industry 4.0 plays a decisive role here by enabling high-precision resource management through digital twins, big data analytics, IoT infrastructures, and autonomous decision-making systems. These technologies make it possible to trace every material, component, and product throughout its entire life cycle, thereby supporting global circularity and transparent supply chains. As a result, sustainability becomes deeply embedded in the operational logic of globalization rather than an external corrective measure.

To contextualize the dynamics of Industry 4.0 development and highlight the variability of market expectations across analytical agencies, Table 2 summarizes the most recent projections of the global Industry 4.0 market size for the period 2025–2034. These forecasts demonstrate substantial differences in estimated growth trajectories, reflecting divergent methodological approaches, market boundaries, and technological scopes. Presenting these estimates side-by-side allows for a more balanced understanding of the range of possible market outcomes and provides an empirical foundation for further analysis of Industry 4.0 diffusion patterns and their implications for the sustainable economy.

Global contributions to Industry 4.0 are concentrated in three major regions (Asia-Pacific, North America, and Europe), which together account for the overwhelming share of global market value, technological adoption, and industrial innovation. Asia-Pacific leads both in scale and growth, driven by China, Japan, South Korea, and India, whose manufacturing intensity, automation demand, and state-led digitalization initiatives position the region as the fastest-expanding I4.0 market. North

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Table 2. Market size of Industry 4.0, 2025–2034 (actual and forecasted values)

Source	Market size in 2025, m USD	Forecasted value in 2034, m USD	Annual growth rate 2025–2034, %
IMARC Group (2025)	188.5	599.2	13.7
Precedence Research (2025)	190.6	884.8	18.6
Statifacts Study (2025)	190.9	892.7	18.7

America remains a core technological powerhouse, with the United States dominating in AI, cloud platforms, industrial software, robotics integration, and advanced manufacturing R&D. Europe retains a central role due to its early "Industrie 4.0" strategy, strong engineering base, and its unique alignment of digital transformation with sustainability and energy-efficient industrial policy.

Another important dimension is the transformation of global economic hierarchies through the rise of distributed, decentralized infrastructures. Earlier phases of globalization relied on centralized industrial hubs and global value chains controlled by a small number of powerful states and corporations (Mancuso et al., 2023). In contrast, the sustainable economy encourages horizontal production architectures and distributed energy systems, which allow regions and communities to produce energy, goods, and services locally while remaining integrated into global networks. This networked model promotes economic democratization and reduces dependency on large-scale extractive systems. At the same time, the spread of cyber-physical systems and smart infrastructures forms a planetary digital ecosystem that operates similarly to natural ecosystems: self-regulating, interconnected, and oriented toward long-term stability.

The sustainable economy also redefines the role of information as the leading factor of globalization. If earlier globalization was driven by capital mobility, trade liberalization, and industrial productivity, the new paradigm places information (its creation, analysis, and application) at the center of economic activity. Industry 4.0 technologies transform both production and consumption into data-intensive processes where algorithms optimize resource flows, predict environmental impacts, and autonomously coordinate large-scale systems. Information becomes a tool for reducing entropy in socio-economic systems: by enabling more efficient energy use, material conservation, and predictive planning, it slows the deterioration of natural resources and enhances the long-term sustainability of development. It highlights that this information-centered mode of production aligns with the goals of Industry 5.0, which emphasizes human creativity and the generation of new knowledge as the primary drivers of societal progress.

In the context of significant transformations of today's economy, the relationship between globalization and sustainability is quite complex. Many theoretical frameworks exist, but empirical estimations are still lacking in the current academic discourse. SDI Index by Hickel is a modern approach to measuring sustainability progress in both developed and emerging economies. Uniting the Sustainable Development Index (SDI) and Globalization Index (GI) databases, it is possible to estimate the impact of globalization on the Sustainable Development Index. For the sample estimation, five developed economies were used (the USA, Germany, France, China, and Japan) during the 1990–2022 period (Table 3).

The sample results suggest that an increase in the KOF Swiss Economic Institute Globalization Index by one point leads to a decrease in the Sustainable Development Index by 0.68 points. For the sample of developed economies, an increase in globalization led to the deterioration of Sustainable Development achievements. Therefore, the globalization trends have to be changed to achieve sustainability. The sustainable economy introduces a new human-centric dimension to globalization. Instead of treating people merely as labor inputs within global markets, the new model views human development, creativity, and well-being as the fundamental purpose of economic systems. This is reflected in the vision of Society 5.0, where individuals interact with intelligent infrastructures that enhance productivity while reducing ecological impact. The integration of AI and cyber-physical systems into daily life, transport, energy use, housing, health, and education creates

Table 3. The influence of globalization on sustainable development within the economies of the USA, Germany, France, China, and Japan (1990–2022)

Random-effects GLS regression			Number of obs = 165		
Group variable: id			Number of groups = 5		
R-squared:			**Obs per group:**		
Within = 0.3026			min = 33		
Between = 0.0105			avg = 33.0		
Overall = 0.0376			max = 33		
corr(u_i, X) = 0 (assumed)			Wald chi2(1) = 68.95		
–			Prob > chi2 = 0.0000		
SDI	**Coefficient**	**Std. err.**	**z**	**P>|z|**	**[95% conf. interval]**
Globalization Index					
(GI)	–.68613	0.08263	–8.30	0.000	–.84809 –0. 52
_cons	100.598	10.57876	9.51	0.000	79.864 121.32
sigma_u	19.354511	–	–	–	–
sigma_e	5.879056				
rho	0.9155262				

environments that support low-carbon lifestyles and minimize wasteful practices. As sustainable development becomes the strategic horizon of global policy, economic integration is increasingly guided by shared environmental commitments, technological standards, and cross-border cooperation in renewable energy, digital governance, and circular resource management. In this sense, the sustainable economy does not simply modify existing globalization: it redefines it, shifting its trajectory toward ecological equilibrium, social cohesion, and technological intelligence.

A sustainable economy is a novel paradigm that can be considered in different ways. One promising idea is to adopt a globalist approach, as sustainability is a process affected by many geopolitical and geoeconomic stakeholders: political statecraft, states, unions, alliances, and partnerships. Table 4 describes key ideas of classical and globalization pillars from different dimensions (perspectives).

The emergence of the new economy (defined by digitalization, sustainability, and cyber-physical integration) fundamentally alters the foundations

Table 4. Classical and globalization approach to sustainable economy

Dimension	Classical Approach	Globalization Approach
1. Foundations of the Sustainable Economy (SE)	A sustainable economy is the production basis of a new socio-economic formation built on additive methods that minimize resource extraction and anthropogenic pressure on ecosystems	Sustainability becomes a new driver of globalization, replacing resource expansion with global ecological interdependence; states converge around shared planetary boundaries
2. Cyber-Physical Integration and Digital Twins	Industry 4.0 replaces material production elements with their informational analogues – digital twins, IoT objects, and autonomous systems	Digitally connected infrastructures form a planetary cyber-physical ecosystem, creating a new stage of global integration based not on trade flows, but on synchronized data flows
3. Circular Economy Transformation	Circular processes close resource cycles and allow labeling of materials to track origin, production methods, and energy sources, enhancing sustainability	The circular economy becomes a global norm, promoting cross-border resource standards, shared material databases, and international carbon-neutral supply chains
4. Human-Centered Development (Industry 5.0)	A sustainable economy promotes the development of Society 5.0, emphasizing creativity, personal growth, and the production of new information within the planet's anti-entropic limits	Globalization shifts toward human-centered global governance, prioritizing digital inclusion, global knowledge circulation, and cooperative technological development
5. Energy Transition and Green Technologies	Green hydrogen produced from excess renewable energy becomes critical for sustainable energy systems and resource cycles	A global green energy system emerges, where transnational energy networks reduce geopolitical risks and foster cooperative climate security
6. Network-Based Organization of the Global Economy	A sustainable economy requires a network structure where billions of machines, enterprises, and systems interact horizontally in real time	Globalization evolves into a networked planetary system, where digital interdependence replaces industrial hierarchies; global risks and innovations diffuse instantly across borders

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of global geopolitical power. Traditional geopolitics was built on control over territory, natural resources, and industrial capacity. However, the sustainable and digitalized economy shifts the basis of power toward technological leadership, data governance, and control over global digital infrastructures. States that dominate artificial intelligence, additive manufacturing, cloud systems, renewable energy technologies, and circular production models now possess leverage comparable to the 20th century's control over oil or industrial manufacturing. This transition redistributes influence among global actors, positioning technologically advanced economies as the primary architects of future global systems, while resource-dependent or technologically lagging states risk marginalization.

A crucial component of this shift is the central role of information as both the primary economic resource and the main instrument of strategic influence. The "new economy" makes data flows more valuable than physical supply chains: cyber-physical systems, IoT networks, digital twins, and smart energy infrastructures rely on uninterrupted streams of real-time information. This creates new forms of dependency where countries lacking control over cloud infrastructures, digital standards, or cybersecurity capabilities become strategically vulnerable. Geopolitical conflicts increasingly revolve around access to semiconductors, algorithmic control, quantum computing, and the governance of digital identities rather than territorial disputes. The competition between major powers – from the US-China technological rivalry to the EU's push for digital sovereignty – illustrates how geopolitical influence is being recalibrated through information architectures rather than military positioning alone.

3. DISCUSSION

The findings of this study highlight that the sustainable economy is becoming a structural pillar of contemporary globalization, fundamentally reshaping how societies organize production, distribute resources, and define long-term development priorities. Rather than functioning as a parallel or auxiliary agenda, sustainability increasingly operates as the central logic guiding technological modernization, industrial transformation, and global economic integration (Kamble et al., 2020). This shift marks a departure from earlier globalization models driven primarily by market liberalization, cost optimization, and resource-intensive industrial expansion.

A key insight is that disruptive technologies associated with Industry 4.0, such as artificial intelligence, cyber-physical systems, the Internet of Things, advanced robotics, digital twins, and additive manufacturing, serve as both enablers and catalysts of this transition. Their diffusion accelerates the formation of intelligent, low-carbon production networks capable of minimizing waste, improving resource efficiency, and reducing ecological pressures. At the same time, principles of a sustainable economy influence the direction of technological development itself, reinforcing the demand for human-centric solutions, circular value chains, and energy-efficient digital infrastructure (Bag et al., 2021; Geissdoerfe et al., 2023).

The convergence of sustainability and Industry 4.0 signals the emergence of a new globalized development model. This model is characterized by a growing emphasis on resilience, technological sovereignty, decarbonization, and the integration of digital ecosystems into traditional sectors of the world economy. Countries and corporations that adopt sustainable economy-oriented technologies earlier gain competitive advantages through productivity improvements, reduced operational risks, and enhanced adaptability to global shocks: whether ecological, technological, or geopolitical.

However, the study also reveals significant disparities in the pace and depth of this transformation. Advanced economies tend to lead in adopting Industry 4.0 solutions and embedding sustainability metrics into industrial policy, whereas developing regions face constraints related to financing, digital capacity, and institutional readiness (Tjahjono et al., 2017; Dai et al., 2024). These asymmetries create a risk of widening technological and ecological divides within the global economy. Addressing them requires coordinated international policies, knowledge transfer mechanisms, and investment frameworks that support inclusive technological upgrading.

Overall, the discussion demonstrates that a sustainable economy and Industry 4.0 are mutually reinforcing forces shaping the future trajectory of globalization. Their interaction not only redefines global production systems but also sets the foundation for a more intelligent, resource-efficient, and human-centered world economy (Sony & Naik, 2020). The challenge moving forward is to ensure that this transformation remains equitable, supportive of long-term ecological balance, and aligned with the principles of sustainable development (Köhler, 2013; Moraga et al., 2019).

The sustainable economy introduces another layer of geopolitical transformation by redefining global resource competition. As nations shift to renewable energy systems, green hydrogen production, and circular material cycles, strategic value migrates from fossil fuels to critical minerals, battery technologies, and green-tech intellectual property. The countries capable of producing renewable energy at scale, storing energy efficiently, and integrating smart grids gain economic autonomy and new influence in global politics (Korhonen et al., 2018; Wang et al., 2024). Meanwhile, nations with outdated fossil-fuel infrastructure face structural decline unless they invest in transformative green technologies. Control over resource data – such as material origin tracing via blockchain, sustainability certifications, and digital product passports – also becomes a geopolitical tool, shaping global market access and reinforcing new standards of "green conditionality" in international trade.

Moreover, the new economy reorganizes globalization itself, creating a world where production and power are distributed through digital ecosystems rather than fixed geographically (Raj et al., 2020; Hariram et al., 2023; Horváth & Szabó, 2019). Additive manufacturing, decentralized renewable energy, and automated logistics reduce dependence on large industrial hubs and long-distance supply chains. At the same time, global digital platforms create new forms of centralization, enabling a handful of actors to dominate communication networks, algorithmic governance, and transnational market access. This paradox – simultaneous decentralization and hyper-centralization – reshapes geopolitical alliances: states increasingly form coalitions around technological standards, cybersecurity cooperation, and green industrial policy rather than traditional military blocs (Autio et al., 2021; Zhao et al., 2022). As cross-border digital dependencies intensify, states must negotiate norms for data governance, ethical AI, cyber defense, and climate policy, making global governance more complex and more interdependent than ever.

Finally, the convergence of the new economy and geopolitics drives the emergence of planetary governance, where global-scale challenges – climate change, critical mineral scarcity, cyber threats, and AI regulation – cannot be managed by nation-states individually. The sustainable and digitalized global economy requires new forms of cooperation that transcend borders: agreements on carbon-neutral supply chains, international frameworks for AI oversight, shared cybersecurity protocols, and coordinated strategies for green transformations (Beier et al., 2020). As Industry 4.0 technologies integrate physical and digital worlds, geopolitics becomes increasingly shaped by the capacity of nations to work within global networks rather than dominate them unilaterally. The new economy thus marks the transition from competitive geopolitics of territory toward cooperative geopolitics of interdependence, where sustainability, information integrity, and technological innovation determine the contours of world order.

CONCLUSION

The sustainable economy has emerged as a transformative global paradigm that redefines the relationship between technological development, ecological stability, and socio-economic growth. The study aims to investigate the role of the sustainable economy in shaping a new global development model in the context of disruptive technologies and Industry 4.0.

As industrial systems confront the limits of traditional resource-intensive models, sustainability becomes not a peripheral policy objective but the structural foundation of future globalization. The inte-

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gration of circular resource flows, renewable energy systems, and ecological constraints marks a fundamental shift from the linear production logic of the 20th century. In this context, the sustainable economy offers a viable trajectory that aligns human progress with planetary boundaries.

At the same time, rapid technological advancements (particularly those associated with Industry 4.0) provide the operational mechanisms necessary to implement sustainable development at scale. Cyber-physical systems, digital twins, artificial intelligence, and the Internet of Things create unprecedented opportunities for precision resource management, waste minimization, and systemic transparency. These tools enable more efficient, real-time coordination of energy, production, and logistics networks, making sustainable practices not only environmentally desirable but economically advantageous. This technological imperative forms the backbone of a new information-driven mode of production.

Complementing these advances, Industry 5.0 reintroduces the human at the center of technological and economic design. Its focus on human creativity, ethical innovation, and social well-being ensures that sustainability is not reduced to technical efficiency but encompasses broader social and cultural dimensions. The convergence of human-centric and digital paradigms supports the formation of resilient, adaptive, and inclusive economic systems capable of navigating global uncertainties. Such systems emphasize knowledge creation, digital inclusion, and collaborative technological development as key drivers of long-term stability.

Taken together, the sustainable economy represents a comprehensive shift in the logic of globalization – one that prioritizes ecological viability, technological intelligence, and human development simultaneously. As nations reorganize economic strategies around green technologies, data governance, and circular production models, new forms of global interdependence and cooperation will shape geopolitical dynamics. The sustainable economy thus signals not merely an adjustment to current global challenges, but the emergence of a new socio-technological order capable of supporting prosperity within the limits of the Earth's ecological systems.

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