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THE STRATEGIC PLANNING OF REGIONAL ECONOMIES IN A MULTIPOLAR WORLD: NEW ENVIRONMENTAL-LEGAL CRITERIA

O PLANEJAMENTO ESTRATÉGICO DAS ECONOMIAS REGIONAIS EM UM MUNDO MULTIPOLAR: NOVOS CRITÉRIOS AMBIENTAIS E JURÍDICOS

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Abstract
In the third decade of the 21st century, the transition to a multipolar world order architecture exposes the systemic insufficiency of monetary strategic planning tools for regional economies. Reliance on GDP and derivative financial aggregates creates an "extrapolation trap"-a methodological distortion where linear financial trends are mechanically projected into the future, ignoring the nonlinear dynamics of natural-scientific systems and biosphere limits. This article substantiates a system of new environmental-legal criteria for strategic planning based on physical invariants: useful power, the coefficient of technological excellence, the structural tension index, and quality of life in energy units. The methodological foundation is a natural-scientific approach to economics within the "Nature–Society–Human" system and the power change analysis model for socio-economic systems. The proposed system of criteria is verified using data from the USA, Scandinavian and Baltic countries, and new industrial economies for the period 1990–2022. The results reveal a

Resumo
Na terceira década do século XXI, a transição para uma arquitetura de ordem mundial multipolar expõe a insuficiência sistêmica das ferramentas de planejamento estratégico monetário para as economias regionais. A dependência do PIB e de agregados financeiros derivados cria uma "armadilha da extrapolação" — uma distorção metodológica em que tendências financeiras lineares são projetadas mecanicamente para o futuro, ignorando a dinâmica não linear dos sistemas científico-naturais e os limites da biosfera. Este artigo fundamenta um sistema de novos critérios ambientais e jurídicos para o planejamento estratégico baseado em invariantes físicas: potência útil, coeficiente de excelência tecnológica, índice de tensão estrutural e qualidade de vida em unidades de energia. A base metodológica é uma abordagem natural-científica da economia dentro do sistema "Natureza–Sociedade–Ser Humano" e do modelo de análise de mudança de potência para sistemas socioeconômicos. O sistema de critérios proposto é verificado utilizando dados dos EUA,

significant discrepancy between traditional economic ratings and ranking by physical invariants. The study justifies a three-level system for the normative consolidation of these criteria, the "Triplex" model as a protocol for the energy expertise of strategic initiatives, and the category of "energy sovereignty" as a constituting principle of regional law in a multipolar world.

Keywords: Multipolar World. Strategic Planning. Energy Invariants. Environmental-Legal Criteria. Sustainable Development. Useful Power. Technological Excellence. Quality of Life. Extrapolation Trap. Energy Sovereignty.

dos países escandinavos e bálticos e das novas economias industrializadas para o período de 1990 a 2022. Os resultados revelam uma discrepância significativa entre as classificações econômicas tradicionais e a classificação por invariantes físicas. O estudo justifica um sistema de três níveis para a consolidação normativa desses critérios, o modelo "Triplex" como protocolo para a avaliação energética de iniciativas estratégicas e a categoria de "soberania energética" como princípio constitutivo do direito regional em um mundo multipolar.

Palavras-chave: *Mundo Multipolar. Planejamento Estratégico. Invariantes Energéticas. Critérios Ambientais e Jurídicos. Desenvolvimento Sustentável. Potência Útil. Excelência Tecnológica. Qualidade de Vida. Armadilha Da Extrapolação. Soberania Energética.*

1 INTRODUCTION

In the third decade of the 21st century, the global economic system is facing a crisis that transcends traditional cyclical fluctuations. This crisis signifies a paradigmatic shift in the global order-a transition from a monocentric model to a multipolar international architecture. This transformation is driven not only by geopolitical rivalry but also by a fundamental migration of economic and technological gravity. Furthermore, the spatial and geopolitical dimensions of the energy transition play a critical role in reshaping these power dynamics, as control over new energy infrastructures directly influences regional hegemony (Palle, 2021). Research by Parag Khanna (2019) confirms that future industrial leadership is increasingly determined by the capacity of Eastern economies to effectively accumulate and transform real-sector resources. This shift occurs amidst unprecedented financial volatility, disrupted supply chains, and intensifying competition for physical assets. Under these conditions, conventional macroeconomic tools-relying on monetary indicators such as GDP, market capitalization, and credit ratings-are losing their predictive power and often distort the actual productive and innovative potential of sovereign territories. Concurrently, the early 21st century has revealed a "data paradox": despite possessing colossal volumes of information and sophisticated processing tools-Big Data, machine learning, and generative AI-the quality of strategic management at the macro level continues to decline. This contradiction is manifested in the deepening global environmental crisis, the fragility of life-support systems, and the rising frequency of socio-economic shocks that traditional econometric models fail to anticipate. The core methodological flaw is the lack of an invariant coordinate system for evaluating socio-economic processes-one independent of market fluctuations and inflationary distortions. Financial metrics, as derivatives of volatile political decisions and speculative expectations, cannot provide a reliable foundation for long-term strategic planning that incorporates environmental constraints. Attempting to measure the sustainability of a physical system (a region or a state) using the "rubber ruler" of floating exchange rates inevitably leads to systemic management errors (Trusina *et al*., 2025). This issue is particularly acute in environmental law and the regulatory framework for sustainable development. While current legal systems formalize ambitious goals-such as the UN 2030 Agenda and the Paris Agreement-the tools for assessing progress remain anchored in monetary indicators devoid of physically verifiable content. Consequently, environmental law operates under a methodological deficit: norms declare objectives but lack the means to measure them in invariant units resistant to political shifts. This vacuum stems from a disregard for the physical constraints of legal matter. As Kulp and Wolf (2021) argue, thermodynamics should be recognized as the systemic foundation of legal regulation; any legal norm that ignores the laws of energy conservation inevitably results in the inefficient distribution of societal resources.

Modern management culture remains captive to the "extrapolation trap": a cognitive and methodological distortion assuming that historical financial growth (GDP, budget revenues) can be mechanically projected into the future, ignoring the nonlinear dynamics of physical systems and the laws of thermodynamics (Abramov *et al*., 2026). In the age of Artificial Intelligence, this trap becomes perilous: neural networks trained on historical financial data, untethered from physical constraints, tend to generate utopian scenarios of infinite growth, creating dangerous illusions for decision-makers. The US economy serves as a poignant illustration. From 1960–2022, the USA GDP (at PPP) showed steady exponential growth with a near-perfect coefficient of determination (R^2=0.99), a curve upon which global investment decisions are modeled (Abramov *et al*., 2026). However, when analyzed through the Sustainable Development Monitoring Model (SDMM) in a power-based coordinate system (Trusina, 2025), a different reality emerges: total consumed power N(t) reached a plateau in 2009 and ceased growing, while virtual value continued to accumulate. This divergence between financial illusion and physical reality is the "extrapolation trap" in its purest form, yet it remains legally invisible within current strategic planning frameworks.

The objective of this study is to substantiate a new system of environmental-legal criteria for regional strategic planning based on a natural-scientific approach within a multipolar context. To achieve this, the following tasks are addressed:

- critical analysis of the limitations of the monetary paradigm and the "extrapolation trap" as systemic threats to sustainable development regulation;
- substantiation of the theoretical basis for power invariants-useful power P(t), the coefficient of technological excellence F(t), the structural tension index STINA, and quality of life in energy units QoLE-as new environmental-legal criteria;
- formalization of a system of measurable indicators for integration into regional management legal mechanisms;
- verification of the proposed system using data from major global regional economies;
- formulation of recommendations for the normative consolidation of these criteria at international, national, and regional levels.

The scientific novelty of this research lies in:

- proposing, for the first time, a system of environmental-legal criteria based on energy invariants (Watts, Joules), adapted for normative integration into state strategic management;
- developing a normative interpretation of the STINA, QoLE, and F indices within the framework of regional sustainable development law in a multipolar world;
- introducing the "Triplex" model as a protocol for mandatory "systems-energy expertise" of strategic initiatives, transitioning from declarative norms to physically verifiable requirements;

The proposed system is verified using data from the USA, Scandinavian countries (Sweden, Finland), the Baltic states (Latvia, Lithuania), and emerging industrial economies (China, India, Brazil) for the period 1990–2022.

2 THEORETICAL FOUNDATIONS: ENERGY LAWS AS THE LANGUAGE OF ENVIRONMENTAL-LEGAL POLICY

The theoretical comprehension of the crisis in modern strategic planning requires, first and foremost, identifying the ontological mismatch between the data used for decision-making and the reality it is intended to reflect. Financial indicators are essentially social conventions, susceptible to inflation, speculation, and political manipulation. In contrast, the laws of nature-specifically the laws of energy transformation and conservation-are invariant. A management culture operating exclusively with financial metrics is comparable to navigating a ship based on the prices in a restaurant menu rather than the gauges in the engine room: "society is forced to make strategic decisions within a coordinate system dependent on political choices based on subjective information" (Trusina & Jermolajeva, 2022). The systematic theoretical justification for this thesis dates back to the early reports of the Club of Rome (Meadows *et al*., 1972), which argued that over-reliance on monetary indicators-particularly GDP-reflects costs rather than welfare and ignores essential benefits existing outside the market. Later, H. Daly (2015) introduced the concept of "uneconomic growth"-a state where the marginal costs of growth exceed the marginal benefits-pointing out that the economy is an open subsystem of a finite ecosphere. This view is further supported by Georgescu-Roegen (1971), who laid the foundations of bioeconomic by demonstrating that the economic process is subject to the second law of thermodynamics, meaning that ignoring physical limits in strategic planning inevitably leads to systemic degradation.

Modern economic growth theory has attempted to overcome the limitations of purely financial metrics. R. Solow (1994) modified the Cobb–Douglas production function by introducing technological development as an independent growth factor. R. Lucas (1988) and P. Romer (1990) developed "endogenous growth theory," asserting that investment in R&D and human capital is the primary driver of long-term development. However, none of these models operationalized "technological development" in physically measurable units, leaving room for financial aggregates to grow without a corresponding increase in the system's physical productivity (Ayres & Warr, 2009). Recent macroeconomic models further reinforce this necessity by integrating thermodynamic potentials to demonstrate that long-term economic dynamics in a finite world are strictly governed by energy constraints and entropy production, rather than purely monetary equilibrium (Herbert *et al*., 2023). This contradiction generates the "extrapolation trap": a cognitive and methodological distortion where historical financial trends are mechanically projected into the future, ignoring the non-linear dynamics of physical systems (Abramov *et al*., 2026). In complex systems, optimizing a single variable often leads to the degradation of the system as a whole-a phenomenon known as Goodhart's Law. In a systems-energy interpretation, it takes the following form: "When a measure becomes a target, it ceases to be a good measure, as the system adapts to simulate the goal at the cost of increasing systemic disorder" (Chrystal & Mizen, 2003). In public administration, this means that orienting strategic planning toward GDP maximization inevitably leads to an accumulation of systemic losses G(t), even amidst formal financial growth. The legal dimension of this problem is that current environmental law and regulatory frameworks for sustainable development reproduce the logic of the monetary paradigm. Goals are formulated in financial or relative indicators (e.g., percentage of renewable energy, volume of "green" investments in dollars), which are just as susceptible to the "extrapolation trap" as GDP itself. A prime example is the implementation of the "Latvia 2030" strategy: indicators move in divergent directions, failing to provide a holistic picture of progress because the strategy is based on political goals unsupported by a calculation of the physical power required for their achievement (Abramov *et al*., 2026). Critical analysis confirms that absolute decoupling of GDP growth from resource use is historically unobserved, rendering strategic plans based on infinite monetary expansion physically unfeasible (Hickel & Kallis, 2020). Overcoming the limitations of neoclassical economics - which treats the economy as a closed system of circular flows-requires a different theoretical ontology. The methodological core of this study is the systems approach, viewing the regional economy as an open subsystem of the global "Nature–Society–Human" triad (Trusina *et al*., 2025). This concept has deep roots, tracing back to V.I. Vernadsky's works on the biosphere and noosphere (Vernadsky, 2006), which substantiated the impossibility of socio-natural systems existing apart from the laws of their conservation and change. S.A. Podolinsky (2004) established that the only true surplus in an economy is accumulated energy, achieved through the effective application of labor and technology. In modern ecological economics, this approach has been advanced by R. Costanza (2004) and F. Capra with O. Jakobsen (2017). According to this framework:

- all socio-economic processes are transformations of energy and material flows;

- the laws of energy conservation and resource dissipation are as imperative for the economy as they are for nature (Trusina *et al*., 2025);
- value is interpreted as a function of the available free energy utilized (Odum, 1996).

The integrated assessment of societal metabolism further demonstrates that socio-economic systems must be analyzed as multi-scale dissipative structures where energy flows define the limits of structural complexity (Giampietro & Mayumi, 2000). The fundamental theoretical basis for the proposed approach is the synthesis of open non-equilibrium systems theory and the physical laws of energy. Any socio-economic system is a "living" open system. According to the principles of theoretical biology formulated by E. Bauer (2002), living systems are characterized by the principle of "sustainable non-equilibrium": they work against equilibrium (stagnation/disorder) by continuously consuming free energy from the environment. Consequently, "sustainable development" is not a static state of resource preservation, but a dynamic process: the system's ability to perform external work to increase useful power and maintain its internal complexity over time (Abramov *et al*., 2026). As shown by P. Kuznetsov and B. Bolshakov: "Development is sustainable if there is a non-decreasing rate of growth in the efficiency of consumed power use, measured by the growth rate of useful power" (Kuznetsov, 2015; Bolshakov *et al*., 2019). An important tool is the synthesis of the Kaldor–Baumol laws (Kaldor, 1967; Baumol, 1967). Kaldor’s laws postulate that manufacturing is the engine of productivity growth, while the Baumol effect ("cost disease") suggests that shifting resources to the service sector leads to a slowdown in aggregate growth. In an energy model, this manifests as a stagnation of useful power P while consumption N continues to rise, leading to a decline in systemic efficiency F (Trusina *et al*., 2025). This synthesis allows us to formulate criteria for the "energetic competitiveness" of regions. A region's ability to act as an independent pole in a multipolar world depends directly on its energy sovereignty and its capacity to generate high net power density, ensuring a high quality of life in its physical-energy equivalent (Trusina *et al*., 2025). In the context of an emerging multipolar world, sovereignty is determined not by money supply, but by the ability to independently generate high-density useful power (Abramov *et al*., 2026). Therefore, transitioning to management based on physically verifiable indicators is a strategic imperative for regions seeking to strengthen their positions in the hierarchy of power centers.

3 METHODOLOGY

The implementation of a natural-scientific approach to the management of regional sustainable development requires a fundamental methodological shift: a transition from stochastic monetary scales to deterministic physical quantities. Unlike monetary units, which are susceptible to inflation, manipulation, and cross-country differences in purchasing power parity, units of energy (joules, kWh) and power (Watts) are invariant in time and space. This allows for precise interregional and international comparisons regardless of currency zones (Trusina *et al*., 2025). The use of energy invariants eliminates the influence of exchange rate fluctuations and inflationary distortions, making data comparable across different macro-regions and over long historical periods.

The methodological basis of this study is a comprehensive approach that combines methods of systemic dynamics, historical comparative analysis, and physical economics. Unlike traditional econometric approaches relying on financial aggregates, this research is based on the socio-economic system power change analysis method (Sustainable Development Management Model, SDMM), which allows for the translation of development indicators into an invariant coordinate system expressed in units of power (Trusina, 2025). This method, detailed in (Trusina & Jermolajeva, 2022), ensures the elimination of inflationary and currency distortions in long-term analysis. An essential component of the methodological framework is the recognition that a successful transition to a scientific management culture requires the creation of a regional digital ecosystem-a comprehensive macro-environment uniting citizens, business, and the state. As shown in recent works (Abramov & Andreev, 2023; 2024), such an ecosystem, based on digital twin technologies and real-time data collection, allows for the optimization of infrastructure operational costs, reduction of emergency consequences, and the creation of new models for territorial development. This is fundamentally necessary for effective monitoring of N(t) and P(t) flows within the proposed system of criteria. At the heart of the methodology lies the principle of a natural-scientific approach to economics, according to which any economic product is the result of the transformation of the available power flow. In this context, power-the rate of performing work-becomes the key parameter of the state of the regional system. The basic equation of the state of a regional system expresses the law of power conservation (Trusina *et al*., 2021):

$$N(t) = P(t) + G(t) \quad (1)$$

where:

N(t) is the total consumed power, representing the aggregate flow of resources (energy, materials, information) entering the region;
P(t) is the useful power, i.e., the portion of the flow converted into useful work: production of goods, provision of services, creation of infrastructure, and reproduction of human capital;
G(t) is the dissipated power (losses), dispersed into the environment and increasing systemic disorder, including both direct losses in energy generation and transmission, and indirect losses from inefficient management, bureaucracy, corruption, and environmental damage mitigation. The dynamics of the system are described by three equations (Trusina *et al*., 2025)

$$N(t+1) = \alpha(t) \cdot N(t) \quad (1)$$

$$P(t+1) = \varepsilon(t) \cdot \varphi(t) \cdot N(t) \quad (2)$$

$$G(t) = N(t-1) - P(t) \quad (4)$$

where:

α(t) is the integral coefficient of power transfer per cycle;
ε(t) is the management and planning coefficient, reflecting the quality of the institutional environment and the effectiveness of state regulation;
φ(t) is the coefficient of technological excellence, characterizing the level of the region's technological development.

These equations have fundamental significance for legal regulation: the coefficient *ε(t)* directly reflects the quality of the institutional environment and legal management, making it a potential object of regulatory impact. Improving the legislative framework, reducing administrative barriers, and anti-corruption measures directly increase *ε(t)*, which, ceteris paribus, leads to the growth of useful power P(t). The principle (criterion) of sustainable development asserts that the development of a socio-economic system is sustainable in the long term if conditions formalized as a system of second-order differential equations for power changes are met (Trusina & Jermolajeva, 2022). Sustainable development in this coordinate system is defined not merely by the growth of consumption N(t), but by the outpacing growth of useful power P(t) while simultaneously reducing or stabilizing losses G(t). Based on these equations, a system of indicators is derived, forming the minimum set for defining and monitoring the sustainable development of the designed object (Trusina, 2025):

1. Key indicator of Technological Excellence (F) or regional system efficiency (Trusina *et al*., 2025):

$$F(t) = \frac{P(t)}{N(t)} \times 100\% \qquad (5)$$

The dynamics of F(t) serve as a more accurate indicator of economic "health" than GDP growth rates. If GDP grows due to service sector inflation or financial speculation, but the physical efficiency of the regional system declines (G(t) increases), the region is on a downward trajectory masked by monetary indicators. For regulatory purposes, a threshold value of F ≥ 38% is proposed, empirically identified as the minimum necessary for the technological viability of a region (Abramov *et al*., 2026). Furthermore, macroeconomic modeling suggests that a society requires a specific net energy surplus to ensure growth, below which the financial system begins to accumulate systemic debt to compensate for the physical deficit (Fizaine & Court, 2016).

2. Specific Useful Power per Capita (U) as a physical measure of the standard of living:

$$U(t) = \frac{P(t)}{M(t)} \qquad (6)$$

where

M(t) is the population. Unlike GDP per capita, this indicator is not subject to inflationary distortions or income redistribution structures, reflecting the actual physical provision of productive capacities to the population (Trusina, 2025).

3. Quality of Life in Energy Units (QoLE). This approach is consistent with empirical evidence showing that a minimum threshold of energy return on investment (EROI) is a prerequisite for maintaining high social indicators, such as the Human Development Index and overall quality of life (Lambert *et al*., 2014). An integral

indicator combining physical provision, environmental quality, and demographics (Trusina *et al.*, 2025):

$$QoLE(t) = U(t) \cdot Q(t) \cdot \frac{TA(t)}{100} \qquad (7)$$

where:

Q(t) = G(t-1) / G(t) is the environmental quality coefficient and TA(t) is life expectancy.

Unlike the Human Development Index (HDI), QoLE considers the real energy accessibility of households and the technological level of infrastructure. Its methodological advantage over HDI is that it is calculated from physically measurable variables and is invariant across currency zones.

4. Structural Tension of Innovation Activity (STINA). A composite index reflecting the imbalance between financial flows and the regional system's energy base (Trusina, 2025):

$$STINA = \frac{100-(Share_{AG}+Share_{IN})}{Share_{AG}+Share_{IN}} \qquad (8)$$

where

$Share_{AG}$ and $Share_{IN}$ are the shares of agriculture and industry in gross value added. This index measures the ratio of the service sector to the real sector. High STINA values, typical of post-industrial economies, are viewed as risk factors indicating a disconnect between the financial superstructure and the production base. A threshold of STINA > 3.5 is suggested as a signal of dangerous deindustrialization.

5. The World Competitiveness Index (WM) characterizes a country's position in the global hierarchy based on its specific useful power:

$$WM_i = \frac{p_i}{m_i} \qquad (9)$$

The Power/GDP Balance Index (WP - World Power/GDP Balance) is one of the most profound analytical tools in the proposed methodology. It conceptualizes the gap between the real economy and the financial superstructure, providing a mathematically rigorous assessment of a state's genuine independence. This serves as an indicator of a country's "energy sovereignty," reflecting the ratio between its share of global useful power and its share of global GDP:

$$WP_i = \frac{p_i}{gdp_i} \qquad (10)$$

where:

p_i is the share of country *i* in the total global useful power P_{world} (expressed as a percentage). This parameter reflects the actual physical contribution of a jurisdiction to performing useful social work on a global scale (production of goods, infrastructure construction, energy generation).
gdp_i is the share of country *i* in the global Gross Domestic Product (expressed as a percentage). This parameter reflects how the global financial system values the country's contribution in monetary terms.

The economic significance of the WP index lies in diagnosing non-equivalent exchange within the global system. It demonstrates the extent to which a jurisdiction's financial valuation (its GDP) corresponds to its actual capacity to generate physical value (useful power). A value of $WP \geq 1.0$ indicates that the country produces more physical value than is reflected in its financial aggregates. Consequently, such a nation possesses the inherent potential to strengthen its position within the emerging multipolar world.

To formalize regional development scenarios, the method of power change analysis is applied. Stability is assessed via time derivatives of the useful power function P(t). The methodology identifies the following states based on the behavior of the first (dP), second (d^2P), and third (d^3P) derivatives (Trusina *et al*., 2021):

– Sustainable Growth: $dP > 0$, $d^2P > 0$ - the system increases useful output with acceleration (technological breakthrough stage).
– Linear Growth: $dP > 0$, $d^2P \approx 0$ - stable development without qualitative leaps.
– Maturity: $dP > 0$, $d^2P < 0$ - growth continues, but the rate slows as the system approaches the limits of the current technological paradigm.

Stagnation and Degradation: $dP \leq 0$ - a decline in useful power signaling a systemic crisis, even if financial indicators show nominal growth.

This classification covers 12 logically possible development scenarios. Legally, "bifurcation points"-transitions between phases like $dP > 0 \rightarrow dP \leq 0$ -can be codified as triggers for mandatory state intervention, enabling a shift from reactive to preventative environmental-legal regulation. The primary target parameters of strategic management, defining the six dimensions of the sustainable development system, are:1.M(t)- the demographic indicator of population change; 2.N(t)- total consumed power; 3.P(t) - useful power; 4.U(t) - specific useful power per capita; 5. Q(t) - the environmental quality coefficient; 6. F(t) - the coefficient of technological excellence (Trusina, 2025). The dynamics of each parameter are decomposed by the algebraic sign of three successive derivatives: the first ($\frac{d}{dt}$), second ($\frac{d^2}{dt^2}$), and third ($\frac{d^3}{dt^3}$). This qualitative sign-based analysis generates a system of power invariants that objectively characterize the technological, economic, environmental, and social capacities and requirements of the regional system.

4 RESULTS

The verification of the proposed methodology was conducted using three primary datasets covering diverse time horizons and geopolitical contexts, ensuring the representativeness of the findings.

The first dataset involves a macro-analysis of long-term trends (USA Case Study), utilizing data from the World Bank and the UN Statistics Division for the period 1960–2022. The selection of the USA is justified by its status as a global leader in technological innovation and digital transformation, allowing the American model to serve as a benchmark for evaluating the modern management paradigm (Abramov *et al*., 2026).

The second dataset focuses on a comparative regional analysis (EU Case Study), using Eurostat data for the Baltic and Scandinavian regions from 1990 to 2022. The sample is divided into two cluster groups: countries with an advanced post-industrial model (Sweden, Finland) and transition economies (Latvia, Lithuania). This enables an assessment of sustainable development strategy effectiveness under varying initial conditions (Trusina, 2025).

The third dataset analyzes the world's largest economies, incorporating World Bank, IEA, and UNDATA records for the USA, China, India, and Brazil (1990–2022).

Including this datas*et al*lows for the verification of the hypothesis regarding the shift in physical competitiveness centers within a multipolar world (Trusina *et al*., 2024).

The analytical procedure consists of three consecutive stages:

Stage 1: Calculation of the total consumed power N(t) as the sum of all incoming energy flows required to maintain the system's functioning.

Stage 2: Calculation of the useful power P(t) and the coefficient of technological excellence F(t), utilizing calibration coefficients that account for the energy balance structure and the loss fraction G(t).

Stage 3: A comparative analysis of the dynamics of physical indicators (N, P, F, QoLE) against financial indicators (GDP). At this stage, bifurcation points and trend divergences are identified and interpreted as indicators of the "extrapolation trap" (Abramov *et al*., 2026).

It should be emphasized that in this study, the Quality of Life (QoLE) is assessed not through subjective surveys, but as a function of useful power per capita, adjusted for life expectancy and environmental quality. This approach aligns with the principles of scientific management culture and ensures the objectification and reproducibility of the results.

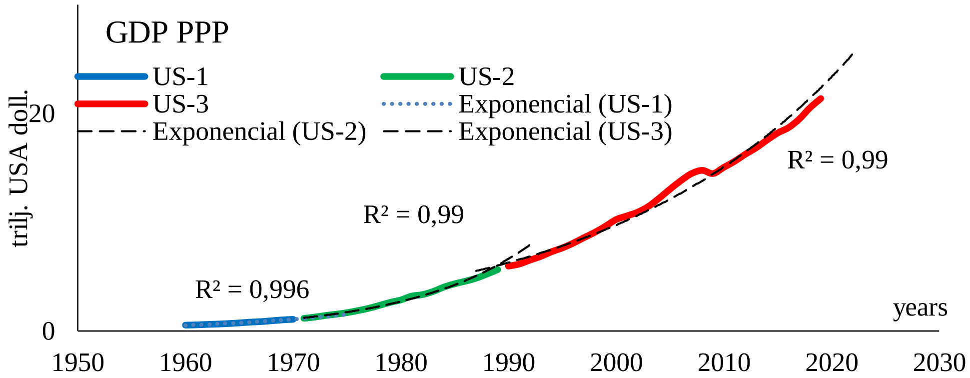
The primary data sources include the World Bank Open Data, the International Energy Agency (IEA), the UN Statistics Division (UNDATA), and the Eurostat database. Calculations were performed using the SDMM and methodology in accordance with the procedures detailed in the doctoral research (Trusina, 2025).

4.1 Verification of the “extrapolation trap”: the USA case

The analysis of the United States (US) economic data allows for the deconstruction of the mechanism behind strategic illusions in modern management and establishes the empirical validity of the "extrapolation trap" phenomenon. The dynamics of the US GDP at purchasing power parity (PPP) for the period 1960–2022 demonstrate steady exponential growth with a coefficient of determination R^2=0.99 (Fig. 1).

Figure 1

The GDP PPP changes of the USA in 1960-2022.



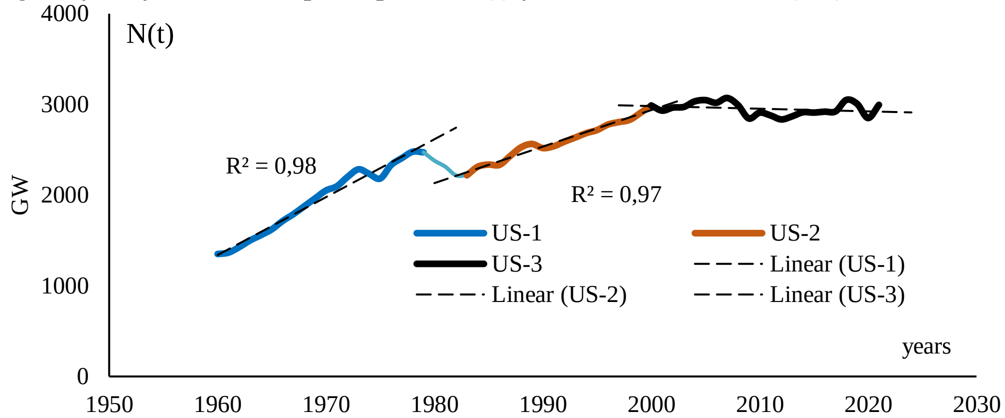
Source: calculated by the author using World Bank Data.

Statistically, this indicator is interpreted as a nearly perfect functional dependency: a manager or an Artificial Intelligence algorithm trained on this dataset would inevitably conclude that the existing model is highly efficient and, by extrapolating the trend, predict continued sustainable growth. However, translating the data into the power coordinate system reveals a fundamentally different picture. The dynamics of the total consumed power N(t) break down into three distinct phases that are indiscernible through GDP analysis (Fig. 2):

- 1960–1973: A period of linear growth in power consumption (R^2=0.98). This was the era of real industrial expansion, where GDP growth was underpinned by the physical growth of energy consumption.
- 1983–2008: A recorded deceleration and transition to a non-linear decline in power growth rates (R^2=0.97). This period marked the active financialization of the economy-GDP continued to rise driven by the service and financial sectors, while the physical base began to lag.
- 2009–20222**:** A stage of stagnation and instability. Total power consumption reached a plateau, effectively ceasing to grow, and the trend turned negative.

Figure 2

The changes of the final consumption power N(t) for the United States (US) in 1960-2022.



Source: Calculated By The Author**.**

The diagnostic significance of the identified divergence between the GDP exponent and the energy consumption plateau is as follows: the USA, demonstrating the highest Structural Tension Index (STINA=4.3) among all studied nations, signals the maximum structural strain among the analyzed economies. Despite formal GDP growth, the physical system is experiencing excessive stress caused by stagnant energy consumption amid sustained high consumer expectations.

Table 1

Minimal Set of Sustainable Development Parameters in Context of SDMM For United States (US), Sweden (SE), Finland (FI) In 2022

country		**dM**	**N**	**P**	**G**	**F**	**U**	**QoLE**	**STINA**	**EIMP**	**WM**	**WP**
		%	GW	GW	GW	%	kW	kW	x	%	x	x
USA	US	32	2150	767	1383	36	2.3	1.9	4.3	7	4.3	0.8

Source: calculated by the author**.**

According to 2022 data, the total consumed power of the USA was N=2150 GW, with a useful power of P=767 GW. This corresponds to a coefficient of technological excellence F=36%-a value below the proposed normative threshold of F ≤38% (Trusina *et al*., 2025). The specific useful power per capita was U=2.3 kW, while the quality of life in energy equivalent was QoLE=1.9 kW.

Legal Conclusion

The legal conclusion drawn from this case study is that current strategic planning systems, oriented toward GDP metrics, legitimize the accumulation of structural tension because they lack the tools for physical diagnostics. A transition to the verification of strategic decisions through F, STINA, and QoLE indicators would allow for the detection of increasing systemic fragility 10–15 years earlier than it manifests in financial data.

4.2 The scandinavian model: high efficiency as a normative benchmark

A comparative analysis of data for Sweden and Finland allows for the identification of a normative benchmark for the target values of environmental-legal sustainable development criteria. Leading Scandinavian countries are characterized by high indicators of technological efficiency F(t) and useful power per capita. In 2022, the coefficient of technological excellence (F) reached 42% in Sweden and 41% in Finland, significantly exceeding the corresponding figure for the USA (36%). This demonstrates a substantially higher capacity to transform consumed resources into useful social work (Table 2).

Table 2

Minimal set of sustainable development parameters in context of SDMM for Sweden (SE), Finland (FI) in 2022

country		dM	N	P	G	F	U	QoLE	STINA	EIMP	WM	WP
		%	GW	GW	GW	%	kW	kW	x	%	x	x
Sweden	SE	+15	47	20	27	42	1.9	1.5	3.3	29	4.1	1.1
Finland	FI	+7	35	14	21	41	2.5	2.0	2.8	44	4.3	1.3

Source: calculated by the author**.**

The Structural Tension Index (STINA) values for Sweden (3.3) and Finland (2.8) indicate the preservation of a balanced production base, where the share of the real sector in Gross Value Added (GVA) remains sufficient to ensure the physical productivity of the system. Of particular note is the fact that among the leading nations, only Sweden and Finland demonstrate positive demographic dynamics: dM = +15% and +7%, respectively, over the study period (Table 2). From the perspective of the physics of open systems, the maintenance and growth of a population is direct evidence of a system's ability to retain and transform energy flows; conversely, depopulation signals that a system is contracting, adapting to a diminished flow of available useful power.

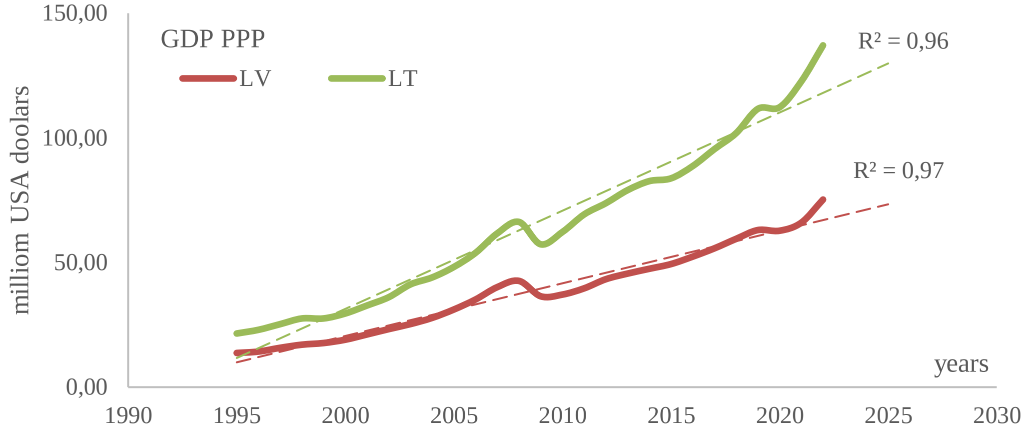
The synthesis of empirical data from the Scandinavian model allows for the formulation of the following normative guidelines for developing regional sustainable development strategies: $F \geq 41\%$, $STINA \leq 3.3$, $QoLE \geq 1.5$ kW, and $dM \geq 0$. It is crucial to emphasize that while maintaining a comparable level of QoLE (Finland - 2.0 kW, USA - 1.9 kW), Finland achieves this result with a significantly lower total consumed power N. This represents a fundamentally different - intensive rather than extensive - path to ensuring the population's quality of life (Table 2). This circumstance carries profound legal significance: it proves that a high QoLE is achievable without increasing the burden on the biosphere, thereby resolving the frequently declared contradiction between the right to development and the right to a favorable environment.

4.3 The baltic model: structural crisis behind the reform facade

The analysis of indicators for Latvia, Lithuania provides the most compelling empirical evidence that monetary-oriented legal regulation can mask the profound structural degradation of regional systems. The GDP (PPP) dynamics of the Baltic countries for the period 1990–2022 demonstrate steady exponential growth with a coefficient of determination $R^2 = 0.96$–0.97, statistically interpreted as a "nearly perfect functional dependency" (Fig. 3). However, translating this data into the power coordinate system reveals a fundamentally different reality.

Figure 3

The GDP PPP changes of Latvia (LV) and Lithuania (LT) in 1990-2022



Source: data compiled by the author from the World Bank

Applying differential analysis to the Latvian economy identifies three distinct phases of post-Soviet development that are not always evident in GDP-based analysis (Trusina *et al.*, 2025):

Phase 1 - Degradation (1990–1995): A sharp decline in gross and net power (dP < 0), driven by deindustrialization and the severance of economic ties. During this period, systemic losses (G) increased while the efficiency coefficient (F) declined.

Phase 2 - Extensive Recovery (1996–2007): Economic growth was primarily fueled by foreign capital inflows and integration into European markets. This growth was sustained by increasing total power consumption N(t) rather than improvements in technological excellence (F).

Phase 3 - Stagnation (2008–2022): Following the 2008 crisis, the economy entered a state of fluctuation near an equilibrium point with low net power growth rates. Despite nominal GDP growth, physical indicators of QoLE and technological excellence remained stagnant (Trusina *et al.*, 2025).

A consolidated analysis of Baltic indicators for 2022 reveals that (Table 3.) the most alarming indicator remains depopulation - Latvia and Lithuania lost approximately 28% of their population during the study period. From the perspective of the physics of open systems, the loss of structural elements (population) is an unambiguous signal of the system's inability to retain and transform energy flows: the system is contracting, adapting to a diminished flow of available useful power.

Table 3

Minimal set of sustainable development parameters in context of SDMM for Latvia (LV) and Lithuania (LT) in 2022

country		**dM**	**N**	**P**	**G**	**F**	**U**	**QoLE**	**STINA**	**EIMP**	**WM**	**WP**
		%	GW	GW	GW	%	kW	kW	x	%	x	x
Latvia	LV	-28	5.5	1.7	3.8	33	0.9	0.7	3.3	40	1.5	1.0
Lithuania	LT	-28	7.1	1.9	5.2	32	0.9	0.7	2.9	76	1.5	0.6

Source: calculated by the author**.**

Data for Latvia (1990–2022) vividly illustrates the monetary paradigm paradox (Trusina *et al*., 2025). While GDP grew from 3.6 to 29.9 billion EUR (an 8.3-fold increase), the useful power (P) in 2022 stood at 1.7 GW-exactly the same as in 2008. The coefficient of technological excellence (F) remained stagnant at 33% for nearly three decades. This configuration represents a "middle-income trap" in physical terms: the system is unable to transition from extensive growth (N) to intensive growth (P) through efficiency gains. An analysis of the "Latvia 2030" strategy confirms that most of its target indicators are unattainable without a paradigm shift, as the strategy is based on aspirational political goals ("reaching EU levels") rather than the physical power calculations required to achieve them (Abramov *et al*., 2026).

4.4 The model of newly industrialized countries: an alternative legal strategy

Applying the developed methodology to the newly industrialized countries (NICs) - China, India, and Brazil - reveals a fundamentally different development trajectory, which is of critical importance for shaping legal strategies in a multipolar world. In contrast to the post-industrial G7 economies characterized by high STINA values, the NICs maintain a balanced structure with a robust manufacturing sector (China: STINA=1.2; India: STINA=1.4) (Table 4). This ensures the steady growth of useful power P(t) and allows them to avoid the efficiency stagnation typical of Western economies (Trusina *et al*., 2024).

Table 4

Minimal set of sustainable development parameters in context of SDMM for China (CN), India (IN) and Brazil (BR) in 2022

Country		dM	N1	P1	G1	F1	U1	QoLE	STINA	EIMP	WM	WP
		%	GW	GW	GW	%	kW	kW	x	%	x	x
China	CN	24	3033	1113	1920	37	1.0	0.6	1.2	15	1.2	1.4
India	IN	59	1035	300	735	36	0.6	0.2	1.4	40	0.3	0.8
Brazil	BR	46	268	110	158	37	0.5	0.4	3.4	13	0.7	0.9

Source: calculated by the author**.**

According to 2022 data, with a total consumed power of N=3033 GW, China provides a useful power of P=1113 GW, resulting in F=37% and STINA=1.2 (Trusina *et al*., 2025). Although its specific useful power per capita (U=1.0 kW) is significantly lower than that of the US, the country demonstrates steady exponential growth in P(t) with a positive second derivative ($\frac{d^2}{dt^2}$ > 0). This indicates a rapid narrowing of the technological gap with global leaders. Conversely, the USA, despite a higher U=2.3 kW, exhibits signs of saturation: the second derivative of its useful power tends toward zero or negative values. Combined with a high index of STINA=4.3 (dominance of the service sector), this signals profound structural vulnerability.

The analysis *of India* is of particular interest. Despite a relatively low absolute useful power per capita (U=0.6 kW), the country demonstrates high efficiency in real-sector investments. A low STINA=1.4 coupled with a high population growth rate (dM=+59%) suggests that the system possesses significant potential for increasing useful power while maintaining a balanced production structure (Trusina *et al*., 2024). Brazil, with STINA=3.4, occupies an intermediate position, exhibiting risks associated with the "resource curse": a high structural tension index paired with relatively low useful power indicates an incomplete industrial transformation.

Comparative analysis confirms the study's core hypothesis: in an invariant coordinate system, it is the ability to transform energy into real assets with minimal losses - rather than the size of the financial superstructure - that determines long-term sustainable development potential. In the context of an emerging multipolar world, leadership is shifting toward those macro-regions that ensure the highest efficiency in converting primary energy into useful work. This finding has direct implications for the formulation of legal strategies for regional development.

4.5 Consolidated system of environmental-legal criteria for strategic planning

Based on the comparative analysis of the four regional models, a system of environmental-legal criteria for strategic planning is established. This framework facilitates the transition from declarative sustainable development norms to physically verifiable regulatory requirements. The proposed system includes seven criteria with threshold values and corresponding legal consequences for non-compliance.

1. Technological Efficiency Criterion (F ≥38%): Diagnoses the minimum required level of a region's technological viability. A decline in F below this threshold indicates that the region consumes more resources than it produces in physical output, necessitating mandatory technological audits and targeted innovation programs (Abramov *et al*., 2026).
2. Structural Balance Criterion (STINA ≤ 3.5): Signals a hazardous level of deindustrialization. Exceeding this threshold serves as the regulatory basis for implementing protective industrial policies, tax incentives for the real sector, and restrictions on the overexpansion of the financial sector (Trusina *et al*., 2025).
3. Energy Quality of Life Criterion (Positive QoLE Dynamics): Reflects the net impact of management decisions on the regional population. Stagnation or a decline in QoLE amid nominal GDP growth is a direct indicator of the "extrapolation trap," requiring an obligatory revision of the development strategy (Abramov *et al*., 2026).
4. Demographic Criterion (dM ≥ 0): Reflects the system's ability to retain human capital as an anti-entropic factor. Sustained depopulation (dM < -5% over a five-year period) constitutes grounds for restructuring regional development programs and introducing population retention and attraction measures (Trusina *et al*., 2025).
5. Energy Sovereignty Criterion (Energy Import Share EIMP ≤ 30% of total consumption): Characterizes the region's vulnerability to external energy shocks and serves as the regulatory foundation for strategic energy security requirements (Trusina *et al*., 2025).
6. Global Competitiveness Criterion (Stabilization or growth of WM): Determines the region's position in the global hierarchy based on specific useful power. A sustained decline in WM despite GDP growth indicates the virtualization of the

economy, requiring a re-evaluation of innovation and industrial policies (Trusina *et al*., 2024).

7. Energy Sovereignty Criterion (WP ≥ 1.0): Characterizes the ratio between the physical and financial value created by the region. A value of WP < 1.0 indicates that the region is financially "overvalued" relative to its physical productivity, creating a risk of systemic fragility during shifts in global market conditions (Trusina *et al*., 2025).

The combination of these criteria forms a physically verifiable, invariant, and legally formalizable coordinate system for strategic planning. This toolkit is capable of transforming declarative sustainable development norms into operational legal requirements with measurable performance parameters, trigger conditions for state intervention, and objective grounds for international legal comparisons.

5 DISCUSSION

5.1 From diagnosis to regulatory prescription: rethinking the role of digital technologies

The presented results reveal a profound discrepancy between prevailing economic metrics and the physical realities of socio-economic systems. The divergence between GDP growth and energy stagnation in the US, alongside the structural degradation of the Baltic states despite declared digital reforms, points to a systemic failure in current management paradigms. This section transitions from diagnostics to proposals for regulatory prescriptions, outlining the legal mechanisms necessary to align strategic planning with the immutable laws of nature. A critical flaw in modern digitalization strategies is the tendency to automate existing processes without fundamental re-engineering based on physical efficiency. This leads to the "digitalization of chaos," where advanced technologies optimize local indicators within energetically inefficient systems (Abramov *et al*., 2026). A prime example is the bureaucratization of public administration: the implementation of e-government document systems, intended to reduce costs, has paradoxically increased reporting volumes and data generation. While transactional costs decreased, systemic entropy (bureaucratic noise) rose, consuming more human attention and energy without a corresponding increase in useful social output

P(t) (Trusina, Jermolajeva, 2021). In energy terms, such digitalization increases the system's total consumption N(t) due to data centers and network infrastructure without improving the technological excellence coefficient F = P/N. The result is a situation metaphorically described as a ship equipped with sophisticated sensors but deteriorating engines: the digital superstructure masks the degradation of the physical base (Abramov *et al*., 2026). Recent studies highlight that digitalization often leads to a net increase in energy demand due to rebound effects, potentially offsetting the efficiency gains intended by technological transitions (Lange *et al*., 2020). To overcome this, we propose a conceptual expansion of the "Digital Twin" beyond its current industrial applications. While modern regional digital twins (e.g., Singapore, New York) successfully handle operational optimization-reducing budgets by at least 20%-most function as "administrative mirrors" rather than predictive power-flow models. In this context, the evolution of digital twins must shift toward simulating the dynamic flows and interactions within urban and regional systems to move beyond static representations (Batty, 2018). Transitioning to a scientific management culture requires transforming digital twins into predictive models of energy flows. A true strategic digital twin must model not just financial flows, but fundamental flows of energy, matter, and entropy, answering the critical question: "If a specific strategic decision is implemented, how will the system's power balance N=P+G change throughout its life cycle?" (Abramov, Andreev, 2024).

5.2 The "triplex" model as a normative framework for verifying strategic initiatives

For the practical operationalization of scientific management principles, the "Triplex" model is proposed-a decision-making protocol designed to verify strategic initiatives across three fundamental dimensions of physical reality (Abramov *et al*., 2026). The introduction of systems-energy expertise for strategic initiatives aligns with modern trends in systemic jurisprudence. Transitioning from formal rule-making to a legal analysis based on principles of entropy and energy return allows for the creation of a resilient legal architecture capable of adequately responding to the physical challenges of the modern era (Kulp & Wolf, 2021). This necessitates a shift toward the "rule of ecological law," where legal norms are fundamentally grounded in the biophysical limits of the Earth's systems (Garver, 2013). Within this model, a strategic decision - whether it is the launch of a new production program, infrastructure construction, or the implementation of a national digitalization program - is deemed justified exclusively when the criteria of three sequential filters are simultaneously met.

The first filter - Energy Return on Investment (EROI) - evaluates the energy viability of an initiative: whether the project generates or saves more useful energy than it consumes throughout its life cycle (Hall *et al*., 2014). Modeling the macro-level risks associated with the energy transition reveals that a declining EROI can significantly impede economic stability, highlighting the critical need to maintain high net energy returns to support societal complexity (Jackson & Jackson, 2021). Many modern financial innovations are energy-parasitic: cryptocurrency mining and high-frequency trading generate significant financial income but have a low or negative social EROI - they consume substantial volumes of high-quality electricity while performing computations that do not create physical goods or services (Abramov *et al*., 2026). Establishing a regulatory requirement for a positive EROI for state-funded projects could filter out systems-energy regressive investments as early as the design stage.

The second filter - Technological Efficiency - assesses whether an innovation improves the P/N ratio. If the implementation of artificial intelligence or blockchain significantly increases total power consumption N(t) - due to data center cooling and intensive computations - but creates value predominantly in the virtual-speculative sector (low P(t)), such an innovation is systems-energy regressive, regardless of potential financial profit (Abramov *et al*., 2026). This filter is operationalized through the requirement for projects to demonstrate a projected increase in F(t) as a condition for receiving state funding or tax incentives.

The third filter - Systemic Resilience - evaluates whether a decision reduces systemic losses G(t) and enhances resilience to external shocks. A high level of G(t) signals systemic fragility; sustainable innovations must purposefully reduce G(t) through intelligent logistics, waste minimization, and circular economy principles (Trusina *et al*., 2025). In the legal dimension, this filter can be operationalized through the requirement for a mandatory Life Cycle Assessment (LCA) of major infrastructure projects, focusing not only on the carbon footprint but also on the project's full power-loss profile.

The institutionalization of the "Triplex" model within the legal system implies the introduction of a mandatory "systems-energy expertise" procedure for major strategic initiatives - analogous to existing state environmental impact assessment (EIA) procedures, but with its scope expanded to the level of physical verification of the power balance. This means that a project receives state approval only with positive values across all three filters, which precludes the legal legitimization of systems-energy regressive investments.

5.3 A three-level system for normative consolidation of physical criteria

Integrating the developed system of environmental-legal criteria into existing legislation requires a three-level normative architecture:

1. International Level: Including QoLE, F, and STINA indicators in the UN Sustainable Development Goals monitoring system. This requires a global standard for the "physical verification of strategic programs," establishing a unified methodology for calculating energy invariants for cross-border comparative analysis (Trusina *et al*., 2025). The World Competitiveness indicator WM can serve as a basis for international legal regulation of resource flows. In a multipolar world, physically verifiable criteria provide the integration of the developed system of environmental-legal criteria into existing legislation involves the formation of a three-tier regulatory architecture, spanning international, national, and regional levels. At the level of international law, it is proposed to include the QoLE, F, and STINA indicators in the UN Sustainable Development Goals (SDGs) monitoring system alongside traditional indicators. This step would require the development of an international standard for the "physical verification of strategic programs" under the auspices of UNEP or UNCTAD, establishing a unified methodology for calculating power invariants for interstate comparative analysis (Trusina *et al*., 2025). The Global Competitiveness Index (WM), reflecting the ratio of a country's share in global useful power to its demographic weight, can serve as a basis for the international legal regulation of transboundary resource flows and the distribution of global burdens on the biosphere. In the context of a developing multipolar world, the presence of physically verifiable, invariant assessment criteria - in contrast to GDP metrics that are easily subject to political manipulation - can create a more equitable legal framework for interstate negotiations on climate and resource use (Trusina *et al*., 2024).
2. At the level of national law, the mandatory inclusion of P(t), F(t), and QoLE in the system of national accounts and state statistical reporting is proposed.

Introducing a requirement for parallel reporting - financial indicators combined with power invariants - forms a dual system of state control in which monetary growth is verified by physical data. The "bifurcation point" principle ($dP \leq 0$ for two consecutive periods) also requires legislative consolidation as a basis for the emergency revision of development strategies (Trusina *et al*., 2025). A specific legal instrument could be the introduction of a provision in budget legislation for a mandatory systems-energy audit of state programs exceeding a set cost threshold - with public reporting on projected changes in F(t) and G(t). Furthermore, digital transformation strategies, an analysis of which in Russian regions revealed a significant gap between planned and actual digital maturity indicators (Abramov & Andreev, 2024), can be supplemented with a "physical verification" requirement - confirming that digital indicators correlate with real growth in P(t) rather than merely imitating it within administrative reporting.

3. At the level of regional law, the development of next-generation sustainable development strategies is proposed, featuring mandatory "systems-energy expertise" and the creation of regional digital ecosystems. Such ecosystems, based on digital twin technologies and real-time data collection, allow for the optimization of operational infrastructure costs, the mitigation of emergency consequences, and the creation of new territorial development models (Abramov & Andreev, 2023). Simultaneously, they provide the necessary information base for monitoring N(t) and P(t) flows within the legal system of strategic planning.

5.4 Energy sovereignty as a new legal category in a multipolar world

In the context of an emerging multipolar world, the theoretical foundations of a scientific management culture acquire critical geopolitical significance. The crisis of the monocentric globalization model is accompanied by financial volatility, making traditional monetary indicators (GDP, credit ratings) ineffective for strategic planning (Trusina *et al*., 2025). The analysis of the potential of newly industrialized economies shows that their physical competitiveness is growing at an accelerated pace compared to the post-industrial West. In a forming multipolar system where Asia and Latin America become key players, energy efficiency and resource autonomy emerge as the primary factors of regional leadership (Khanna, 2019). The transition to renewable energy sources creates a new geopolitical landscape where the capacity to manage energy infrastructures and technology becomes a primary source of strategic influence (Vakulchuk *et al*., 2020). In this new reality, a region's sovereignty is defined not by the volume of its money supply, but by its "energy sovereignty" - the ability to independently generate high-density useful power (Abramov *et al*., 2026). It is proposed to treat "energy sovereignty" as an independent legal category, operationalized through a system of regulatory requirements:

Limitation of energy import share: Setting EIMP ≤ 30% of total energy consumption as a vulnerability threshold. Exceeding this limit triggers a state obligation to form strategic energy reserves and diversify energy supply sources (Trusina *et al*., 2025). Legislative requirements for the minimum level of technological efficiency in the production sector, differentiated by industry. Legal incentives for three classes of innovation: those related to new energy sources (N); those related to increasing the coefficient of technological excellence (F); and those related to improving the quality of planning and management (ε) (Trusina *et al*., 2025). The category of "energy sovereignty" possesses the potential to overcome the long-standing contradiction between the right to development and the right to a favorable environment. The Scandinavian case proves that achieving a high QoLE is possible without extensive increases in N(t) - solely through the growth of F(t). This implies that a legal policy stimulating efficiency growth (F) rather than consumption growth (N) simultaneously ensures both the right to development and ecological responsibility. Consequently, the right to ecological justice can be reformulated in physically invariant units: not as a right to equal monetary income, but as a right to equal specific useful power U(t) while minimizing environmental losses G(t) (Trusina *et al*., 2025). Integrating the principles of energy justice ensures that the transition to a high-efficiency power balance also addresses equitable distribution and social recognition within the regional legal framework (Heffron & McCauley, 2017).

Finally, the systemic nature of the proposed legal transformations must be emphasized. Digital transformation that ignores the energy base risks becoming a tool for accelerating entropy - a mechanism for the efficient processing of data regarding an increasingly inefficient physical reality (Abramov *et al*., 2026). Integrating the proposed environmental-legal criteria into state strategic planning systems allows for the reorientation of artificial intelligence and digital technologies from the generation of virtual value toward the monitoring and optimization of real useful power flows, ensuring a balance between technological progress and the physical sustainability of the biosphere.

6 CONCLUSIONS

The study allows for the formulation of six interconnected conclusions of both a theoretical and applied nature. Together, they substantiate the necessity for a systemic update of environmental-legal criteria in the strategic planning of regional economies within the context of an emerging multipolar world.

Systemic Failure of the Monetary Paradigm: Empirical analysis of data from the USA (1960–2022) and the Baltic states (1990–2022) convincingly demonstrates that GDP-oriented strategic planning generates the "extrapolation trap" phenomenon, where financial growth masks the physical degradation of regional systems. The eightfold growth of Latvia's GDP despite stagnant useful power P from 2000–2022, and the divergence of the US GDP exponent from the energy consumption plateau after 2009, remain undetectable by current regulatory tools and necessitate a fundamental revision of the criteria system.

Theoretical Ontology of New-Generation Criteria: The "Nature–Society–Human" triad and the law of power conservation form the basis for a new generation of environmental-legal criteria. Sustainable development acquires a strict physical definition: a non-decreasing growth rate of useful power P(t) with controlled losses G(t). This allows for the transformation of declarative legal norms into operational requirements with measurable performance parameters.

Verification of Physical Invariants: The indicators F, STINA, QoLE, EROI, WM, and WP constitute a measurable, invariant, and legally formalizable coordinate system for strategic planning. A comparative analysis of six regional economies confirmed their diagnostic power: the Scandinavian model is empirically verified as a normative benchmark, while the Baltic model serves as a systemic warning.

Comparative Advantages of New Industrial Economies: In an invariant coordinate system, the ability to transform energy into real goods with minimal losses-rather than the size of the financial superstructure-determines long-term sustainability potential. The low STINA values of China (1.2) and India (1.4), combined with steady growth, support the hypothesis of a shift in the centers of physical competitiveness within the emerging multipolar world.

Operational Significance of the "Triplex" Model: The introduction of "systems-energy expertise" provides a practical legal tool. Sequential verification of strategic initiatives through three filters-Energy Return on Investment (EROI), Technological Efficiency, and Systemic Resilience -ensures a transition from declarative sustainability goals to physically verifiable regulatory requirements.

Energy Sovereignty as a Constituting Principle: In a world where sovereignty is defined not by money supply but by the ability to independently generate high-density useful power, the category of "energy sovereignty" becomes central. A legal policy stimulating the growth of F(t) while maintaining EIMP ≤ 30% simultaneously ensures the right to development and environmental responsibility, thereby resolving the long-standing contradiction between these two fundamental principles of international environmental law.

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