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INTERNATIONAL EXPERIENCE IN INFRASTRUCTURE TRANSFORMATION BASED ON SUSTAINABLE DEVELOPMENT

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INTRODUCTION

In the contemporary era, we are confronted with a triad of mounting environmental concerns, economic volatilities, and accelerated urban expansion. Conventional infrastructure models, which were deemed adequate two decades prior, are no longer adequate in the present context. These models are characterised by excessive energy consumption, substantial carbon emissions, and vulnerability to climate change and geopolitical crises. In response to these challenges, countries worldwide are formulating green strategies that integrate innovation with environmental responsibility. Consequently, the sustainability and resilience of infrastructure are becoming fundamental principles of long-term development.

The issue of sustainable infrastructure development is becoming increasingly significant. Infrastructure projects that comply with the principles of a "green" economy not only meet the current needs of society, but also create the conditions for long-term economic growth, improved social welfare and minimised negative impact on the environment. In light of these considerations, the majority of the world's leading nations are formulating and implementing national strategies that integrate environmental safety with the innovative development of transport, energy and digital infrastructure.

In the contemporary era, prominent economic powers – such as the European Union, with its Green Deal, and India, with its ambitious National Infrastructure Pipeline and Smart Cities Mission – are illustrating that the implementation of green infrastructure has the potential to catalyse economic growth, generate employment opportunities, and forestall environmental degradation. The scale of these programmes and the funding volumes, which exceed trillions of dollars, demonstrate an understanding that without a transition to renewable energy sources, without the digitalisation of networks and without the widespread implementation of circular economy principles, it will be impossible to achieve ambitious climate goals and ensure resilience to future shocks.

Concurrently, the implementation of green infrastructure necessitates substantial investments and meticulous consideration of regional characteristics, encompassing geography, climate, economic development,

and social expectations of citizens. An increasing number of urban centres are introducing smart solutions in construction and transport, using the Internet of Things and artificial intelligence to monitor air quality, optimise energy consumption and manage urban flows. Consequently, the systematisation and generalisation of practices and tools that have proven their effectiveness based on the use of comparative analysis methods allows for the identification of both common trends – decarbonisation of transport, modernisation of energy networks, development of a circular economy – and regional differences. The primary objective is to formulate pragmatic recommendations for Ukraine, ensuring that the reconstruction and modernisation of our infrastructure systems do not merely represent a "restoration", but rather a significant "leap forward", with due consideration for the most recent environmental and technological trends.

1. Regional models: EU, USA, China, Japan and India

The implementation of projects based on the principles of sustainable development is currently a priority for many countries around the world. The development of strategies is centred on the implementation of innovative infrastructure solutions that not only meet current needs but also have a lasting positive impact on the environment and society. The integration of sustainable development principles into infrastructure projects has been demonstrated to promote a balanced combination of economic growth, environmental safety and social well-being.

An analysis of the practices of five regions of the world in implementing sustainable development strategies has revealed both common features and specific characteristics. Numerous countries are allocating capital towards investments in clean technologies, renewable energy sources, and the modernisation of transport systems. It is evident that there are common elements to such approaches, including the desire to reduce greenhouse gas emissions and combat climate change, support for innovative research, and the involvement of both the private sector and the public in the implementation of initiatives.

The determination of specific priorities is determined by regional characteristics. For instance, island countries are implementing measures to adapt to sea level rise, while countries with arid climates are prioritising effective water resource management (Table 1).

Table 1

Comparison of strategic approaches in key regions of the world

Region	Policy name	Key focus areas	Determining factors
EU	The European Green Deal	Decarbonisation of the economy, energy efficiency, circular economy	Political will, institutional standards, finances
USA	Infrastructure Investment and Jobs Act; Inflation Reduction Act	Development of green transport, renewable energy sources, tax incentives	Political lobby, economic interests, technology
China	Carbon Neutrality for 2060 BRI	Large-scale infrastructure, smart cities, renewable energy	Geopolitical ambitions, government investment, R&D
Japan	Green Growth Strategy for 2050 Carbon Neutrality	Hydrogen economy; resilient buildings; transport electrification	Tax incentives; public-private partnerships; R&D grants
India	National Infrastructure Pipeline; Smart Cities Mission	Energy-efficient networks; ESS; digital city management	PPP; GRIHA; Green Climate Fund

Source: compiled by the authors

A comparison of key regional strategies will be made hereafter. Firstly, it is imperative to direct our attention to the European Green Deal, a comprehensive **EU** strategy aimed at achieving climate neutrality by 2050. The primary objectives of the strategy encompass the reduction of greenhouse gas emissions, the enhancement of energy efficiency, the transition to clean energy sources, and the introduction of innovations across all sectors of the economy, with a particular emphasis on infrastructure[1].

The financial resources allocated to infrastructure projects under the Green Deal are distributed through a number of primary programmes. The Just Transition Fund, which has a budget of €100 billion, has been established to provide support to regions undergoing economic transformation as a result of the phase-out of fossil fuels[2]. The InvestEU programme has been designed to mobilise approximately €1 trillion in private investment for green initiatives, while Horizon Europe is the funding instrument for research and development of environmental technologies. The overarching objective of the Connecting

[1] Інвестиційний план Європейського зеленого курсу. Агенція «Суспільство і довкілля». URL: https://www.rac.org.ua/wp-content/uploads/EGDcards/final_00_06_finances_ua_2021_ua.pdf (дата звернення: 31.05.2025).

[2] Infrastructure Investment and Jobs Act. The White House. URL: https://bidenwhitehouse.archives.gov/briefing-room/statements-releases/2021/08/02/updated-fact-sheet-bipartisan-infrastructure-investment-and-jobs-act (date of access: 09.06.2025).

Europe Facility (CEF) programme is to facilitate the development of transport, energy and digital corridors, in accordance with the principles of sustainable development. For the period 2021–2027, a budget of €108 billion has been allocated to this endeavour[3].

The European Green Deal establishes a strategic framework for the transformation of EU infrastructure, predicated on the principles of sustainability. The initiative's holistic approach is instrumental in ensuring the simultaneous achievement of climate goals, economic growth and improved well-being for citizens[4].

Furthermore, the course places particular emphasis on the modernisation of the transport industry. As a key area, decarbonisation of the transport sector is of particular significance. The development of a network of high-speed charging stations for electric vehicles and hydrogen transport is planned along the main EU corridors. The introduction of clean technologies and novel fuels in aviation and maritime transport, coupled with the modernisation of railway infrastructure to reduce the carbon footprint, is indicative of a broader shift towards sustainable energy sources.

The concept of "smart cities" is of particular interest in this context. Housing and utilities modernisation programmes have been implemented, with the objective of reconstructing buildings using energy-saving materials and technologies. Concurrently, there are plans to increase the share of energy generated by solar panels and wind farms from 7% to 53% in buildings within five years.

The implementation of circular economy principles in the construction sector has been demonstrated to promote the rational use of resources and the recycling of materials, thus reducing waste and lowering the industry's environmental impact.

The United States also has a comprehensive concept of sustainable development enshrined in the Infrastructure Investment and Jobs Act. The act provides for investment in green infrastructure, the development of renewable energy sources, the decarbonisation of transport, and the introduction of innovative technologies[5].

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[3] Europe's moment: Repair and prepare for the next generation. European Commission. URL: https://ec.europa.eu/commission/presscorner/detail/en/ip_20_940 (date of access: 05.06.2025).

[4] European Green Deal Policies and Sustainability. European Commission. URL: https://egd-report-2023.unsdsn.org/european-green-deal-policies-and-sustainability/?gad_source=1&gclid=Cj0KCQjwqv2_BhC0ARIsAFb5Ac9BUVEsGJeWPchwxETUnWWCeiO1ZRVNN0uBtTI9W3LU_7H_55q1CKMaAm_JEALw_wcB (date of access: 05.06.2025).

[5] Infrastructure Investment and Jobs Act. The White House. URL: https://bidenwhitehouse.archives.gov/briefing-room/statements-releases/2021/08/02/updated-fact-sheet-bipartisan-infrastructure-investment-and-jobs-act/ (date of access: 09.06.2025).

A substantial sum, amounting to more than $1.2 trillion, has been earmarked for the modernisation of transport, energy and water infrastructure. A significant proportion of these funds is being directed towards the development of clean transport, with measures including the expansion of the network of charging stations for electric vehicles, the upgrading of railway and the reduction of emissions from motorways[6].

The strategy employed by the US government is predicated on three key pillars: large-scale government investment, the provision of tax incentives for businesses, and the provision of support for technological innovation. By prioritising the modernisation of infrastructure, the deployment of clean energy sources, and the decarbonisation of transport, the United States seeks to achieve two primary objectives. Firstly, it aims to reduce greenhouse gas emissions, and secondly, to generate new economic opportunities that will underpin sustainable growth.

The Biden administration has allocated particular emphasis to the promotion of renewable energy sources and enhancing energy efficiency. The administration has established an objective of achieving carbon neutrality by the year 2050, a commitment that has been formally incorporated into the Infrastructure Investment and Jobs Act. The United States has announced plans to reduce its reliance on fossil fuels and enhance its energy security through a series of measures.

In the United States, transport policy is an area of significant focus for the reduction of fossil fuel consumption. The implementation of extensive tax incentives for manufacturers and consumers of electric vehicles is a key element of this strategy, complemented by substantial investments in a national network of charging stations. By the year 2030, the objective is to have in place more than 500,000 charging points, thereby fostering the development of a comprehensive and accessible charging infrastructure[7]. Concurrently, the modernisation of rail transport is ongoing, with a particular emphasis on the construction of high-speed rail networks aimed at reducing emissions from road and aviation.

However, in **China**, strategies are characterised by differences in scale and state coordination. As one of the world's leading economies, the country is implementing large-scale infrastructure projects based on sustainable development. Government initiatives – the Belt and Road Initiative, the Carbon Neutrality for China 2060 strategy, and a number of regional

[6] Smart Cities Initiative. U.S. Department of Transportation. URL: https://www.transportation.gov/smartcity (date of access: 05.06.2025).

[7] National Electric Vehicle Infrastructure Formula Program. U.S. Department of Transportation. URL: https://www.fhwa.dot.gov/infrastructure-investment-and-jobs-act/nevi_formula_program.cfm (date of access: 04.06.2025).

programmes for the development of smart cities, renewable energy, and clean transport – form a unique model that combines state funding, technological innovation and long-term planning, influencing both the domestic and global infrastructure markets.

In the context of "green" construction in China, there has been an emergence of energy-efficient facilities with minimal carbon footprints. These facilities have been constructed with innovative heat-saving materials and highly efficient heating and air conditioning systems. For instance, zero-emission residential complexes have been constructed in Beijing and Shanghai, powered by solar panels and equipped with autonomous household waste processing facilities[8].

The Belt and Road Initiative, a project of considerable ambition on a global scale, encompasses Asia, Africa and Europe. Despite the fact that it has been the subject of some criticism, the focus has now shifted towards green financing: China is gradually shifting its energy policy towards the promotion of renewable energy sources and away from the construction of coal-fired power plants in foreign countries[9].

China has emerged as a global leader in the transport sector, with an impressive production share of over 60% of electric vehicles and the establishment of the world's largest network of charging stations as of August 2024. A significant number of megacities, including Shenzhen, Guangzhou and Beijing, have transitioned to electric buses, leading to a substantial reduction in pollutant emissions. Concurrently, China is undertaking initiatives to expand its high-speed rail network, which presently encompasses over 42,000 kilometres of track. This endeavour is contributing to a reduction in the country's carbon footprint by decreasing reliance on air travel.

In addition to large-scale infrastructure, attention is also being directed towards digital innovations in urban planning. The concept of "smart cities" is predicated on the utilisation of the Internet of Things, artificial intelligence and big data to optimise urban management and enhance energy efficiency. For instance, intelligent street lighting systems adapt to changing traffic and weather conditions, while air quality monitoring systems facilitate the rapid identification of any exceedances of environmental standards, thereby enabling the adjustment of the city's environmental policy as necessary.

As part of its "Carbon Neutrality by 2060" programme, China is actively increasing its production of renewable energy sources. As of 2023, the country

[8] China's High-speed rail and urban expansion: An empirical study using a time series of nighttime light satellite data in China. *Journal of Transport Geography*. 2018. Vol. 72. P. 106–118. URL: https://doi.org/10.1016/j.jtrangeo.2018.08.011 (date of access: 03.06.2025).

[9] Belt and Road. The State Council of the People's Republic of China. URL: https://english.www.gov.cn/beltAndRoad (date of access: 04.06.2025).

generated more than 30% of the world's solar and wind power. Large-scale projects to create energy storage facilities and large solar farms in the Gobi and Taklamakan deserts have been implemented to compensate for the irregularity of renewable sources and reduce the need for thermal power plants.

Japan also has its own national priorities. The national strategy, entitled "Green Transformation", has been defined in order to set a goal of carbon neutrality by 2050, with an interim reduction of greenhouse gas emissions of 46% by 2030[10].

In October 2020, the Green Growth Strategy Through Achieving Carbon Neutrality in 2050 was approved, identifying 14 priority sectors (energy, hydrogen technology, steel production, chemical industry, etc.) and outlining measures to attract private investment in decarbonisation projects. In February 2021, a roadmap was added to the strategy, which included specific measures and mechanisms to support innovation[11].

The primary financial instrument is the Green Innovation Fund, with a volume of approximately 2 trillion yen (equivalent to around 18 billion US dollars). This fund was established as part of the supplementary budget for the 2020 financial year and is currently under the management of NEDO. The fund allocates capital to research and development initiatives focused on carbon capture and storage (CCUS), green hydrogen, and other technologies exhibiting significant growth potential. In June 2024, the government approved updated climate commitments, including a minimum 60% reduction in emissions by 2035 and 73% by 2040 compared to 2013. These commitments formed the basis of Japan's new Nationally Determined Contributions under the Paris Agreement.

In the context of the construction sector, the CASBEE certification system (administered by IBEC) has been introduced. This system integrates LCA assessment of the carbon footprint throughout the life cycle of buildings and encourages local authorities to require CASBEE reporting when issuing permits.

According to Japan's updated 7th Strategic Energy Plan, the share of renewable energy sources is set to rise to 40–50% and nuclear energy to 20% in the generation mix by 2040, while coal capacity is being progressively reduced and the development of hydrogen and ammonia infrastructure is being expedited.

[10] Green Growth Strategy Through Achieving Carbon Neutrality in 2050. Tokyo, 2020. URL: https://www.meti.go.jp/english/policy/energy_environment/global_warming/ggs2050/index.html (date of access: 02.06.2025).

[11] GRIHA for infrastructure. Green Rating for Integrated Habitat Assesment. URL: https://www.grihaindia.org/griha-cities (date of access: 25.04.2025).

In the context of ongoing developments in the field of transport infrastructure, there has been a notable emphasis on the electrification of various components. This inclination is evidenced by the publication of the Guidelines for Promoting the Development of EV Charging Infrastructure by METI in October 2023. The guidelines stipulate the establishment of at least 300,000 public charging ports by the year 2030, with a range of 90–150 kW designated for utilisation on motorways, and 50 kW allocated for regional roads. Additionally, the guidelines advocate for the consolidation of charging network operators, such as Nippon Charge Service, through the implementation of preferential taxation measures[12].

It is imperative that all new residential and public buildings comply with the Zero Energy Building (ZEB) standard, with full compensation for RES consumption, by 2030. In this regard, the Japanese government revised the Building Energy Conservation Act in October 2021 and initiated a roadmap for demonstration projects, along with guidelines for ZEB design.

India has developed a National Infrastructure Pipeline for 2020–2027, with a total investment of approximately 19.7 trillion rupees (≈ 1.4 trillion US dollars). This ambitious project is set to encompass nearly 7,400 projects in the fields of energy, roads, railways, airports, urban infrastructure and logistics parks. The distribution of funding is as follows: 39% is allocated to state institutions, 40% to states, and 21% to the private sector.

In order to provide support for green initiatives in India, the National Investment and Infrastructure Fund (NIIF) was established with assets amounting to approximately $4.9 billion. This fund invests in the following sectors: energy, transport, digital infrastructure and renewable energy sources. In April 2024, the NIIF allocated $200 million to iBUS Network and Infrastructure for the deployment of broadband access in airports, hospitals and business parks. The energy sector has already exceeded 200 GW of installed renewable energy capacity and is aiming for 500 GW by 2030, but actual investments in 2024 (approximately 13 billion dollars) are significantly behind the required 68 billion dollars due to connection delays, land disputes and regulatory[13].

Transport programmes encompass the construction of over 200,000 km of roads, the modernisation of railways, the establishment of 35 multimodal logistics parks and the development of waterways under the NIP, as well as the implementation of PM Gati Shakti programme (1.2 trillion dollars) to coordinate

[12] Overview of Basic Hydrogen Strategy. Ministry of Economy, Trade and Industry (METI). URL: https://www.meti.go.jp/shingikai/enecho/shoene_shinene/suiso_seisaku/pdf/20230606_4.pdf (date of access: 05.06.2025).

[13] Renewable National Green Hydrogen Mission. Ministry of New Renewable Energy of India. URL: https://mnre.gov.in/en/national-green-hydrogen-mission (date of access: 01.06.2025).

16 ministries through a digital platform. In the field of construction, the GRIHA system, comprising 34 criteria under the MNRE and TERI, has been established for the environmental certification of buildings through the implementation of financial and regulatory incentives. In order to digitise infrastructure, the National Digital Communications Policy 2018 was adopted, with the aim of ensuring a minimum of 50 Mbit/s in all regions, connecting councils to 10 Gbit/s and creating an IoT ecosystem with 5 billion devices by 2026.

Consequently, each region is progressing towards the implementation of sustainable infrastructure projects in a manner that reflects the diversity of approaches, tools and priorities they face in achieving global sustainable development goals.

2. Worldwide trends in the implementation of sustainable infrastructure development models

A summary of the existing approaches of the world's largest economies to the implementation of sustainable infrastructure projects allows us to identify key trends (Figure 1).

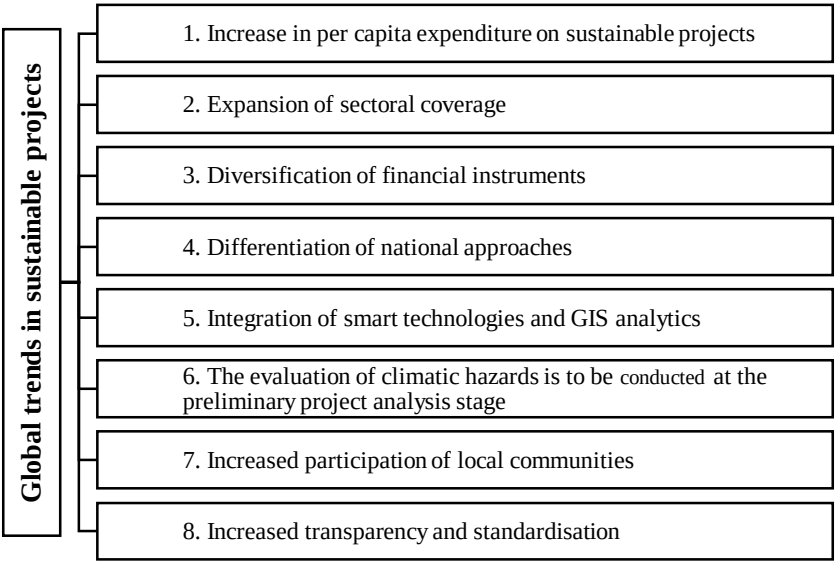

Fig. 1. Major global trends in sustainable projects

Source: compiled by the authors

1. The increase in per capita costs for implementing sustainable projects is attributable not only to the intricacy of technical solutions, but also to the aspiration of ensuring an equitable distribution of resources between regions exhibiting disparate population densities.

2. The expansion of sectoral coverage is evident in the integration of sustainable development principles across various sectors, including energy and transport, digital infrastructure, water supply, healthcare, and waste management systems. These systems are now underpinned by the principles of the circular economy model, emphasising the importance of sustainable resource management. This shift signifies a transition from narrowly focused initiatives to comprehensive solutions that encompass all aspects of social activity.

3. The diversification of financial instruments is a key aspect of financial management that has been demonstrated to be effective in a range of contexts. In addition to conventional budgetary provisions and loans from international financial institutions, there has been an increasing utilisation of green bonds, public-private partnerships (PPPs), and blended finance – a combination of grants, concessional loans, and private investment. This facilitates the attraction of substantial capital under favourable conditions and with minimal risk.

4. A differentiation of national approaches is observable, with developed economies focusing on innovation, strict environmental standards and advanced technologies. In contrast, developing countries primarily engage in the construction of fundamental infrastructure, including roads, bridges, and water supply systems, with the assistance of donor programmes and international agencies. This discrepancy gives rise to a range of models of design, risk management and performance evaluation.

5. The integration of smart technologies, Geographic Information System (GIS) analytics, Internet of Things (IoT) solutions, Digital Twins, and real-time monitoring systems has been demonstrated to improve the accuracy of asset management, allow for infrastructure load forecasting, and enable rapid response to deviations. This has been demonstrated to engender a substantial reduction in operating costs and to extend the service life of facilities.

6. The evaluation of climate risks should be conducted at the stage of pre-project analysis. In consequence of this, technical specifications now include measures to adapt to extreme weather events, to protect against floods and sea level rise, and to calculate the safety margin of structures taking into account future climate scenarios.

7. The success of projects is increasingly contingent on the support of local communities and the transparency of procedures. The introduction of public hearings and consultations has been proposed as a measure to mitigate the risk of social conflict and enhance the legitimacy of decisions.

8. Increased transparency and standardisation through the utilisation of international certification systems (LEED, BREEAM), public disclosure of project implementation data and independent monitoring have been demonstrated to build investor and public confidence, thereby ensuring that all stages comply with sustainable development principles. The regularity with which public hearings and open consultations are conducted at all stages of implementation is conducive to the establishment of trust and the mitigation of the risk of innovations being perceived as a threat to rights or an increase in service prices. Concurrently, the dissemination of interim reports in an accessible format facilitates dialogue with stakeholders and enables timely adjustments to the development strategy[14].

Concurrently, institutional fragmentation engenders substantial impediments, as divergent authorities bear responsibility for financing, permitting procedures, construction, and facility operation. This often results in delays and augmented costs. The enhancement of the legislative framework through the establishment of a clear division of competences, in conjunction with the introduction of a single "project management office" at the local level, has the potential to optimise processes and mitigate corruption risks.

It is imperative to recognise the significance of ensuring the social inclusion of vulnerable groups, including individuals with disabilities, elderly citizens, and internally displaced persons. It is imperative that the needs of these individuals are not only considered during the design stage, but also that they are engaged through advisory councils or focus groups in the formulation of technical tasks and the evaluation of results. This ensures the genuine accessibility of "smart" infrastructure.

The establishment of partnerships with non-governmental organisations (NGOs) and expert centres has been demonstrated to be a fruitful strategy for the acquisition of additional resources and the fostering of community trust. Non-governmental organisations (NGOs) have the capacity to conduct environmental and social audits, to monitor investors" social commitments, and to organise awareness campaigns. The experience of European cities demonstrates the effectiveness of such a model, where NGOs act as independent observers on behalf of citizens.

In order to surmount any inherent resistance to such innovations, it is recommended that initiatives be initiated on a modest scale, for example by installing smart water meters in a single neighbourhood. The demonstration

[14] Sereda V., Nagachevska T., Hryhorova A. Transformation of approaches to shaping and implementing the sustainable development strategy of the eu and ukraine in the context of war and post war reconstruction. *Bulletin of Taras Shevchenko National University of Kyiv. Economics*. 2024. No. 225. P. 69–80. DOI: https://doi.org/10.17721/1728-2667.2024/225-2/7 (date of access: 06.06.2025).

of the efficacy of such cases engenders positive momentum and facilitates the scaling up of initiatives across the city.

Following the implementation of the facilities, it is imperative to initiate feedback mechanisms, such as online surveys, hotlines, and mobile applications for the purpose of documenting any issues. This facilitates the expeditious identification of deficiencies and the refinement of system operations, thereby fostering a sense of collective responsibility among relevant stakeholders, including authorities, investors, and residents. This establishes the foundation for the long-term social sustainability of future infrastructure initiatives.

In general, nations employ disparate mechanisms to achieve sustainable development, taking into account their own economic, political and geographical characteristics. Despite the commonality of their objectives, a discernible distinction exists among their strategic approaches, which are characterised by the presence of shared elements. These distinguishing characteristics serve to differentiate one model from another, thereby shaping the prevailing global order within the domain of green infrastructure (Table 2).

Table 2

Differences in approaches to infrastructure sustainability strategies in regions around the world

Criteria	EU	USA	China	Japan	India
Political and institutional	Supranational directives until 2050.	Federal system, variable IRAs	Centralised single-party rule	Parliamentary democracy with state support	Federation with autonomous states
Economic mechanisms	Green Deal InvestEU + green bonds	Tax breaks and subsidies (IRAs)	Large-scale loans/subsidies from state banks	Mixed financing of state subsidies	State financing + international aid
Technological capacity	R&D in the circular economy and smart cities	Start-up financing, technology parks	Targeted clusters IoT, Digital Twin, rapid pilots	R&D in clean energy and transport	IT develop-ment with regional disparities
Sociocultural priorities	Public participation, strict standards	Balance of freedom and responsibility of NGOs	State priority, quick decisions	Collectivism and inclusion	Focus on population growth
Geopolitical strategies	Coordination of 27 countries, climate diplomacy	Infrastructure for energy dependence	Belt and Road Initiative for exporting the model	Carbon-free diplomacy, technical partnerships	Strategic autonomy, adaptation

Source: compiled based on data from [4; 7; 10; 23]

The United States approach to policy-making is characterised by a multifaceted strategy encompassing public investment, tax incentives, and public-private partnerships (PPPs). A substantial financial investment is being allocated towards the refurbishment of obsolete infrastructure and the advancement of clean technologies. Concurrently, the United States has directed its attention towards financial instruments that incentivise businesses and consumers to adopt energy-efficient solutions and electric vehicles.

The European Union is developing green infrastructure through strict regulation and a number of financial mechanisms: The following three elements must be considered in this context: CBAM (Carbon Border Adjustment Mechanism), ESG criteria and the NextGenerationEU fund. The EU`s position on the matter is that it is in favour of an integrated concept of "smart cities" that combines digitalisation, energy efficiency improvements and carbon footprint reduction.

The People's Republic of China has historically favoured a centralised financial system and direct state planning, disseminating its model through the Belt and Road Initiative. This expansion facilitates the expeditious scaling of large-scale projects, both domestically and internationally, while introducing green standards in construction and transportation.

Japan and **India** have adopted a comprehensive approach, incorporating national strategies, legislative frameworks, special financial instruments and innovative technologies. In both cases, the private sector has been engaged and digital platforms have been created for the purpose of monitoring and managing infrastructure ecosystems.

While all regions support the transition to clean energy, notable differences emerge when considering the specific measures being implemented. The European Union (EU) has been particularly ambitious in its climate goals, aiming to reduce emissions by 55% by 2030 and achieve carbon neutrality by 2050. To this end, the EU is implementing a range of measures, including subsidies for renewable energy sources and carbon regulation. The United States of America places a significant emphasis on market mechanisms and fiscal incentives for companies that invest in green technologies, as well as grants for the modernisation of energy-efficient buildings and transport networks. The People's Republic of China employs state loans and capital investments in solar, wind and nuclear energy, as well as large international Belt and Road Initiative (BRI) projects.

Digital technologies play a key role:

- in China – 5G, AI and big data for optimising the urban environment;
- in the EU – smart city platforms for monitoring emissions and integrating renewable energy sources;

− in the US – solutions for cybersecurity, energy grids and industrial automation.

The primary financial instruments encompass tax reductions, government subsidies, green bonds and loan programmes. The EU employs a comprehensive regulatory framework, supplemented by carbon taxation measures, while the US utilises market incentives and grants. In contrast, China implements centralised budgetary and credit mechanisms.

A comparison of the strategies employed by the EU, the US, China, Japan and India reveals that each region is developing its own unique model for the transition to environmentally friendly technologies. The European Union is distinguished by its stringent regulatory framework, while China is notable for its rapid and extensive project implementation capabilities. The United States, on the other hand, is renowned for its financial incentives and innovative approaches. It is imperative for Ukraine to comprehend these divergent approaches, as it embarks on its reconstruction process. To ensure the formation of a sustainable infrastructure, grounded in sustainable development, it is essential that Ukraine assimilates the most effective global practices. This process must be informed by both Ukraine's inherent characteristics and its potential for EU membership.

CONCLUSIONS

Research into models of infrastructure transformation based on the principles of sustainable development confirms that the key drivers of green strategies are decarbonisation, energy efficiency improvements and support for renewable energy sources. In all regions, from the European Union to India, the focus is on large-scale investments in clean technologies, modernisation of transport and energy networks, development of the circular economy, and certification of construction projects. This approach has been demonstrated to engender a substantial reduction in greenhouse gas emissions, whilst concomitantly establishing the foundations for sustained economic growth and diminished susceptibility to both climate-related and social instabilities.

Concurrently, an analysis of specific programmes and financing mechanisms reveals notable discrepancies: The EU employs a rigid institutional regulatory framework and substantial financial resources, including InvestEU and the Connecting Europe Facility. The US utilises a combination of tax incentives and private investment, while China relies on central planning and large-scale state projects, such as the Belt and Road Initiative. Japan and India, meanwhile, adopt a combination of public-private partnerships. These discrepancies serve to underscore the absence of universally applicable methodologies; rather, each nation adapts the

overarching principles of sustainability to align with its distinct economic, social, and climatic circumstances.

However, all models pay special attention to the digital component. The integration of the Internet of Things, Digital Twin systems and big data analytics into urban management and infrastructure increases transparency, allows real-time monitoring of environmental indicators and optimises resource consumption. Standardisation of processes through international certification (LEED, BREEAM, CASBEE) also reinforces high standards for design and construction, thereby promoting investor and public confidence.

The successful transformation of infrastructure based on sustainability requires the unity of three components: a clear regulatory framework with control and incentive mechanisms, a variety of financial instruments with significant involvement of private capital and international climate funds, and the continuous introduction of technological innovations. The combination of these elements gives rise to a systemic approach that has the potential to achieve ambitious environmental goals, whilst also ensuring economic competitiveness and social sustainability in different regional contexts.

SUMMARY

The article addresses the pressing issue of modernising global infrastructure in the context of mounting environmental threats, climate challenges and urban pressures. The present study employs a comparative analytical approach to examine the green strategies of five leading economies: the EU, the US, China, Japan and India. A number of common trends have been identified, including the decarbonisation of transport, the improvement of energy efficiency, the development of renewable sources and the implementation of circular economy principles. Concurrently, disparities in financial instruments were identified across regions, ranging from stringent regulatory frameworks in the EU to public-private partnerships in China and India. It is important to note that particular attention was paid to the role of digital technologies (IoT, Digital Twin, big data analytics) in increasing the transparency and sustainability of projects. The findings indicated that effective transformation necessitates the incorporation of three components: explicit standards accompanied by incentive mechanisms, a range of financial instruments, and technological innovations. A systematic approach is proposed that can ensure the environmental efficiency, economic competitiveness, and social sustainability of infrastructure solutions.

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