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# Model of the innovative ecosystem of advanced lightweight materials in the context of Ukraine's European integration

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**Abstract:** Based on the analysis of the ecosystem approach, the development of theoretical and methodological approaches to innovation ecosystems, the main problems of creating and developing European innovation ecosystems, key ways and approaches to overcoming the challenges of creating and developing European innovation ecosystems. European policy and initiatives on lightweight materials, and key problems in the field of lightweight materials in Ukraine, a model of an innovative ecosystem of advanced lightweight materials in the context of Ukraine's European integration is proposed.

Structurally, the model includes the "Quadruple Helix" environments of the innovative ecosystem of lightweight materials of Ukraine and the "Quadruple Helix" environments of the innovative ecosystem of lightweight materials of Europe. Each environment has spaces of intersection, which creates common environments of interaction, ensuring the European integration of the national innovative ecosystem of lightweight materials of Ukraine into the innovative ecosystem of lightweight materials of Europe. Common environments combine financial, material and intellectual resources of participants and stakeholders for the implementation of technology chains and added value within the framework of joint innovation and investment projects. A feature of the structural arrangement of the proposed model is the allocation of three business environments, one of which had combined with civil society, and the definition of a fourth environment of state institutions combined with scientific institutions/universities.

Within the framework of the proposed model, each environment had aimed at uniting state institutions, business, science and civil society of Europe and Ukraine. The model provides systemic technological, economic, environmental, social and institutional optimization of resources. The activities of the participants of the innovation ecosystem contribute to the development of infrastructure for the creation and implementation of advanced lightweight materials, knowledge transfer and transformation of knowledge into the production of high-tech innovative products of key sectors of the economy of Europe and Ukraine and integration into global chains with high added value. The proposed model provides conceptual flexibility in involving different participants and stakeholders using the results of market research that identifies participants and stakeholders in the light materials sectors of minerals and key domains of light materials in the production of high-tech products in key sectors of the economy. And government agencies and scientific organizations/universities contribute to the transformation of rigid linear chains of technologies and added value into flexible networks of cooperation within the framework of an innovation ecosystem that are more competitive and sustainable in today's dynamic market conditions.

**Keywords:** ecosystem economics, ecosystem approach, innovation ecosystem, theoretical approaches, models, lightweight materials, European policies and initiatives, European integration.

## 1. Introduction

Modern businesses and companies are facing greater uncertainty in the external environment, which determines the need to think outside the box and traditional industries and work in complex, dynamic ecosystems that emphasize collaboration and synergy between various interconnected organizations, companies and stakeholders. [1].

Unlike traditional economics, which focuses on individual organizations, ecosystem economics emphasizes the power of collaboration to create new value. Such a collaborative approach allows for the integration of different products and services into an ecosystem [2].

The ecosystem approach allows for the consolidation of diverse actors, which may be located within or outside traditional industry boundaries. This creates new opportunities for efficiency gains along value chains, while opening up new avenues for value creation for a wide range of ecosystem actors [3].

Innovation ecosystems occupy a special place in the ecosystem economy landscape. Innovation ecosystems act as catalysts for growth, creating environments where ideas can flourish and accelerating innovation, where different ecosystems can support separate stages of the process of creating and implementing innovative scientific and technological developments [4].

The development of theoretical and methodological approaches to innovation ecosystems has gone from the application of "Triple Helix" models, which include as the main stakeholders: state institutions, science, and business [5]. The "Quadruple Helix" models, which additionally include the public or civil society as the fourth helix and have become more popular. This is due, on the one hand, to the expansion of the influence of science in the economic development of civil society, and on the other hand, to the growth of the role of civil society in public policy to address new socio-economic challenges [6].

The European policy on lightweight materials had guided by the general policies and objectives of the European Union (EU), such as the European Green Deal and the Circular Economy, which aim to reduce emissions and promote sustainable development through the application of innovation materials and production [7]. Create a single market for secondary raw materials, increase the supply of recycled materials and stimulate demand for these materials in the EU within the framework of innovation ecosystems. The Action Plan applies life-cycle initiatives, including design, waste prevention, preserving the resources used in the EU economy, and introducing legislative and non-legislative measures targeting areas that bring real added value at EU level [8].

The European Lightweight Materials Cluster Alliance (ELCA) – stimulates the acceleration of the implementation of lightweight materials in strategic industrial sectors [9]. ELCA brings together leading researchers who develop and implement numerous and diverse research projects that respond to the challenges and needs of industry. ELCA aims to improve coordination between users and technology developers and focuses on synergistic collaboration to create new products and technologies [10].

ELCA frequently collaborates with the European Lightweight Materials Association (ELA), a network dedicated to improving the competitiveness and sustainability of European lightweight materials industries, representing over 4,500 companies and 600 research institutions in 12 countries [11]. At the policy level, ELCA will work to harmonize regulations and policies across the EU, facilitating the exchange of best practices and lessons learned between leading and developing countries. ELCA collaborates with the European Lightweight Materials Network (ELN), allowing both structures to collaborate on a common agenda for developing a European innovation strategy for lightweight materials [12].

The Public-Private Partnership Initiative «Innovative Advanced Materials for the EU» (IAM4EU) stimulates the design, development and use of advanced materials [13], contributes to the formation of EU policy on innovative advanced materials and partnerships within the framework of the Horizon Europe program [14]. The European Innovation Council (EIC) programs support

research and technology transfer, start -ups, innovative solutions, including in the development and implementation of advanced and lightweight materials [15].

The EU initiative «Interreg Europe» promotes cooperation between regional political organizations in Europe with the aim of improving regional development policies, exchanging experiences, and improving the implementation of green and digital transition policies [16].

Some EU countries, namely Sweden, Germany, Austria, are developing policies and approaches at the national level to support the development and implementation of new lightweight materials. However, in other EU countries, especially in Eastern Europe, there is a lack of dedicated strategies or coordinated actions. There is a need for coordinated European and national policies in the field of lightweight materials in all EU countries, including the promotion of interregional cooperation, support for research and innovation, and the development of standards for the implementation of lightweight materials. Interregional cooperation within the framework of EU projects of the «Interreg Europe» initiative provides assistance to countries with less developed policies to facilitate the development and implementation of new lightweight materials, contributing to a more unified approach across Europe [17].

The EU initiative «Interreg Europe» should contribute to the EU policy on the promotion of lightweight materials in various industrial sectors, cooperation between public authorities, innovation agencies and research institutes to exchange best practices for a more competitive industry. The projects for the development of international cooperation within the framework of the EU initiative «Interreg Europe» had aimed at supporting the economic recovery of countries thanks to their potential in the field of lightweight materials [18].

## 2. Research of existing solutions of the problem

The creation and development of European innovation ecosystems faces challenges, namely: fragmentation of innovation; weak connections between national, regional and local ecosystems; insufficiently developed cross-border cooperation. Limited access to financing for early-stage startups and scaling up; regulatory and administrative obstacles and unharmonized rules in different countries; weak cooperation between universities, research institutions and industry; talent and skills gap (lack of specialized qualified personnel); geographical differences [19].

The existence of these challenges highlights the need for simpler, innovation-friendly rules, increased funding and better integration of actors to create a more robust European innovation landscape. The challenges of creating and developing the lightweight materials sector are largely similar to those of European innovation ecosystems, including the presence of fierce global competition from Asian countries.

Key challenges for establishing and developing the lightweight materials sector in Europe include the need for better collaboration across the value chain, integration of digital tools and data management (on the life cycle of materials), scaling from laboratory to industrial production. The better regulatory frameworks, ensuring funding for cross-border collaboration, harmonizing national policies, leveraging a strong mature innovation ecosystem and global networks, and strengthening collaboration between European clusters, academia and industry [20].

Key challenges in the development of the lightweight materials sector in Ukraine include the presence of strong research potential and weak implementation of research results, outdated infrastructure, talent drain and weak links between research and business, significant dependence on imported materials, logistical disruptions and resource constraints [21]. The lack of a unified vision of the Ukrainian innovation ecosystem of lightweight materials, regulatory and administrative procedures for its construction and development further complicates the pressing problems.

Overcoming the challenges of creating and developing European innovation ecosystems involves promoting the creation and strengthening of the “Quadruple Helix” environments (academia – scientific organizations/universities, industry/business, government/state institutions, civil society/civil institutions), strengthening cross-border cooperation, ensuring diverse financing

(venture capital, research and development) and using smart territorial mapping to coordinate regional strategies [22].

Key ways and approaches to overcoming the challenges of creating and developing European innovation ecosystems include:

- Improving network integration, including promoting collaboration between start- ups, small and medium-sized enterprises, research organizations and investors, Horizon Europe European Innovation Ecosystems (EIE) programme [23];
- Assistance in developing new technologies and bringing them to market that solve the most pressing societal problems, the new European Innovation Agenda (NEIA) [24];
- Using smart specialization and territorial mapping (STM) tools, which help regions identify their strengths and align their strategies, ensuring that innovations are adapted to the local context and have a European impact [25];
- Support for deep technologies, startups, small and medium-sized enterprises to accelerate the development of breakthrough technologies from research to market, the European Innovation Council (EIC) program [26];
- The developing talent, improving the competences of students, researchers and the workforce to stimulate digital transformation and support entrepreneurship in the EU, European Institute of Innovation and Technology (EIT) [27].

Market research plays a key role in shaping effective innovation ecosystems by identifying key stakeholders, understanding market needs, and facilitating collaboration between different participants. It contributes to a systemic understanding of key participants in innovation ecosystems, mapping and engaging stakeholders, moving from a focus on individual participants to a systemic, networked approach, aligning technological innovations with market demands, using market-oriented strategies, addressing specific business challenges, and overcoming market barriers.

However, the use of marketing research to support the creation and development of innovation ecosystems is only gaining momentum, experience and a limited number of scientific articles on overcoming the problems of creating and developing innovation ecosystems in the field of materials science and lightweight materials are practically absent.

## 3. Research results

The field of materials science is constantly evolving, with researchers and scientists working tirelessly to develop innovative materials that offer unique properties and applications. Lightweight materials have become a particularly important field, with the potential to revolutionize various industries. Lightweight materials are crucial to modern engineering, increasing fuel efficiency, reducing emissions, and improving structural performance in the aerospace, automotive, and construction industries. By reducing density without compromising strength, these materials increase the range of electric vehicles, optimize energy consumption for transportation, and support sustainable, high-performance designs. These materials contribute to the emergence and development of next-generation products, transportation, and infrastructure, combining high performance with reduced environmental impact [28].

Advanced lightweight materials are crucial for weight reduction, circular economy, help decarbonize industrial operations and use resources efficiently. An innovative ecosystem of advanced lightweight materials is a prerequisite for the development of cross- sectorial collaboration in the materials science research network, necessary for more effective using advanced lightweight materials and technologies, contributing to growth and competitiveness [29].

Based on the analysis of the ecosystem approach, the place of innovation ecosystems in the ecosystem economy landscape, the Triple Helix and Quadruple Helix innovation ecosystem models, the main challenges faced by European innovation ecosystems and ways to overcome them, European policy and initiatives on lightweight materials, and key problems in the field of lightweight materials

in Ukraine, a model of an innovation ecosystem of advanced lightweight materials in the context of Ukraine's European integration is proposed, Fig. 1.

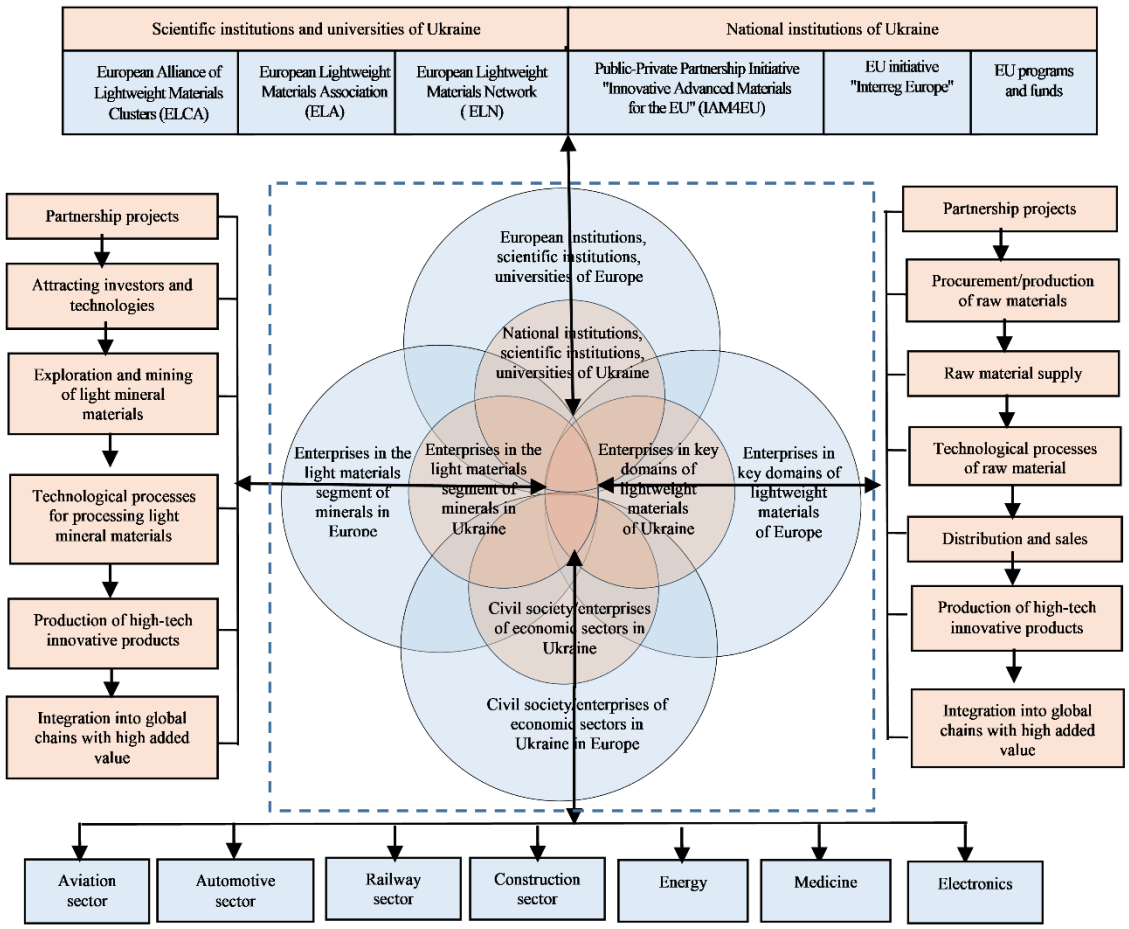


**Fig. 1**. Model of the innovative ecosystem of advanced lightweight materials in the context of Ukraine's European integration.

Structurally, the model includes the “Quadruple Helix” environments of the innovation ecosystem of light materials in Ukraine and the “Quadruple Helix” environments of the innovation ecosystem of light materials in Europe. Each environment has spaces of intersection, which creates common environments of interaction, ensuring the European integration of the national innovation ecosystem of light materials in Ukraine into the innovation ecosystem of light materials in Europe. Common environments combine financial, material and intellectual resources of participants and stakeholders to implement technology chains and added value within the framework of joint innovation and investment projects.

A feature of the structure of the proposed model is the allocation of three business environments, one of which had combined with civil society and the definition of the fourth environment of state institutions combined with scientific institutions/universities.

Within the business environment, regarding light materials of minerals, technology chains and creation of added value had implemented within the framework of partnership projects, attracting investors and technologies, regarding the exploration and extraction of light materials of minerals, and the application of technological processes for the processing of light materials of minerals.

Within the business environment of key domains of lightweight materials, technology chains and added value creation had implemented within the framework of partnership projects, procurement or production of raw materials, supply and processing of raw materials, distribution and sales.

Within the environment of key sectors of the economy, technology chains and added value creation of production of high-tech innovative products and integration into global chains with high added value of advanced lightweight materials had implemented.

Within the environment of civil society and key sectors of the economy of lightweight materials, Ukrainian civil society should join the activities of European civil society and help understand changes in dynamic and changing market trends and consumer demand.

Within the environment of state institutions, national institutions of Ukraine that influence policy in the fields of innovation, industry, ecology, transport and education should join the activities of European institutions and the European public-private partnership initiatives «Innovative Advanced Materials for the EU» (IAM4EU), «Interreg Europe», EU programs and funds, etc. To promote the involvement of Ukrainian enterprises and scientific organizations/universities in participation in European initiatives and activities of European institutions in the field of advanced lightweight materials.

Within the scientific environment, scientific institutions/universities in cooperation with scientific institutions/universities in Europe should join the European Lightweight Cluster Alliance (ELCA) and the European Lightweight Association (ELA), whose activities had aimed at accelerating the implementation of lightweight materials and technologies in strategic industrial sectors and focus on promoting cooperation between industry, research and policy.

Thus, market research provides the analytical data necessary to align the development of advanced lightweight materials with real market needs, identify market gaps, new trends, competitive landscape, which is crucial for building a sustainable and effective innovative ecosystem of lightweight materials, uniting different actors.

Within the framework of the proposed model, various participants from the spheres of state institutions, business, science and civil society of Europe and Ukraine had aimed at ensuring systematic technological, economic, environmental, social and institutional optimization of resources. The activities of participants in the innovation ecosystem, development of infrastructure for the creation and implementation of advanced lightweight materials, knowledge transfer, and transformation of knowledge into the production of high-tech innovative products of key sectors of the economy of Europe and Ukraine and integration into global chains with high added value of advanced lightweight materials.

## 4. Conclusions

The proposed model provides conceptual flexibility in involving various participants and stakeholders using the results of market research that identifies participants and stakeholders in the extraction and processing of light materials of minerals, key domains and the production of high-tech products by key sectors of the economy, government institutions and scientific organizations/universities, which creates flexible sustainable networks of cooperation.

The proposed model of an innovation ecosystem of advanced lightweight materials in the context of Ukraine's European integration helps to understand dynamic and changing market trends, facilitating the transition from the sale of individual light materials and products based on them to the creation of a market-oriented innovation ecosystem of light materials. Such innovation ecosystem of light materials promotes innovation through continuous feedback loops that reflect the ecosystem landscape, including the relationships between buyers, competitors, supply channels, technology chains and the creation of added value, allowing participants in the innovation ecosystem to identify the capabilities of different ecosystem participants and optimize joint growth. This approach transforms rigid, linear chains of technology and added value into flexible networks of collaboration that are more competitive and sustainable within today's dynamic market conditions.

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