

Belarus in the Context of Global Nanotechnology Market

Demidova M.A.

Educational Establishment "Vitebsk State Technological University"

Nanotechnology is an influential tool for solving global problems and a key component of sustainable development strategies for countries. Scientists consider nanotechnology to be the technology of the future, noting its limitless possibilities and the uniqueness of the created nanocoatings, materials and structures. Nanotechnology is widely represented in all industries, including biotechnology, drug delivery, wound healing, tissue engineering, microelectronics, environmental protection, energy harvesting and storage and others.

Currently, the development of the nanoindustry is recognized as a key factor in increasing the country's competitiveness in the international arena. In this regard, it is relevant to analyze the global nanotechnology market, areas of their commercialization, as well as to determine the place and role of the Republic of Belarus in the nanoindustry.

The purpose of the study is to analyze and evaluate the development of the nanotechnology sphere in the Republic of Belarus, identify its main problems and features, development trends, and create recommendations for its improvement.

Material and methods. *For the article a comprehensive strategy of searching for statistical data and literature on the research topic was used through various online resources including Google Scholar, Web of Science, Springer, websites of foreign and national nanotechnology organizations. The author used general scientific and special methods: comparison, analysis and synthesis and graphical models.*

Findings and their discussion. *The study showed that global investments in nanotechnology market in 2020 was \$1.76 billion and is projected to reach \$33.63 billion by 2030, registering a compound annual growth rate of 36.4% from 2021 to 2030. It's expected that The Europe Nanotechnology Market would grow for 32.0% CAGR from 2023 to 2030.*

An analysis of the largest players in the global nanotechnology market showed that on average, investment in developments ranges from \$250,000 to \$30 billion, depending on the size of the company and the number of developments. The largest number of nanosector companies are concentrated in the United States, United Kingdom, France, Japan and India, with the main areas of investment in nanotechnology being the production of carbon and graphene nanotubes.

The Belarusian nanotechnology market is currently at the initial stage of its development and has a number of problems. It is characterized by a small number of nanotechnology developments, the prevalence of technologies, product ideas and prototypes over ready-made versions of serial production, predominantly state financing, closed information on the size, directions and participants in the financing of nanoprojects, underdeveloped communication between the main agents of commercialization of nanotechnology.

Conclusion. *Based on the conducted research, the main problems and features of the development of the nanotechnology sphere in the Republic of Belarus were identified. A number of recommendations were proposed to strengthen the ties between the main agents of the nanotechnology market, as well as to create a favorable information, investment and production climate for the further development of nanotechnology in the country.*

Key words: *nanoindustry, nanotechnology, nanoproducts, nanosector, nanotechnology market, commercialization of nanotechnology.*

Беларусь в контексте глобального рынка нанотехнологий

Демидова М.А.

Учреждение образования «Витебский государственный технологический университет»

Нанотехнологии являются влиятельным инструментом решения глобальных проблем и ключевым компонентом стратегий устойчивого развития стран. Ученые считают нанотехнологии технологией будущего, отмечая ее безграничные возможности и уникальность создаваемых нанопокровов, материалов и структур. Нанотехнологии широко представлены во всех отраслях промышленности, включая биотехнологии, доставку лекарств, лечения ран, тканевую инженерию, микроэлектронику, защиту окружающей среды, сбор и хранение энергии и другие.

В настоящее время развитие сферы наноиндустрии признано ключевым фактором повышения конкурентоспособности страны на международной арене, в связи с чем актуальным является анализ глобального рынка нанотехнологий, направлений их коммерциализации, а также определение места и роли Республики Беларусь на мировой арене в контексте индустриализации нанотехнологий.

Цель исследования – анализ и оценка развития сферы нанотехнологий в Республике Беларусь, выявление ее основных проблем и особенностей, тенденций развития, разработка рекомендаций по ее улучшению.

Материал и методы. *При написании статьи использовалась комплексная стратегия поиска статистических данных и литературы по вопросам исследования через различные онлайн-источники, включая Google Scholar, Web of Science, Springer, сайты зарубежных и национальных нанотехнологических организаций. Автором применялись общенаучные и специальные методы: сравнение, анализ и синтез, статистический и графический.*

Результаты и их обсуждение. *Исследование показало, что мировые инвестиции в рынок нанотехнологий в 2020 году составили 1,76 млрд долларов США и, по прогнозам, достигнут 33,63 млрд долларов США к 2030 году, что соответствует*

совокупному годовому темпу роста в 36,4% в период с 2021 по 2030 год. Ожидается, что европейский рынок нанотехнологий будет расти на 32,0% в год в период с 2023 по 2030 год.

Проведенный анализ наиболее крупных игроков на глобальном рынке нанотехнологий показал, что в среднем размеры инвестиций в разработки варьируются от 250 тыс. долл. до 30 билл. долл. в зависимости от размера компании и числа направлений разработок. Наибольшее число компаний наносектора сосредоточено в США, Великобритании, Франции, Японии и Индии, при этом основными сферами инвестирования в нанотехнологии являются производство углеродных и графеновых нановолокон, производство водных и воздушных фильтров и сепараторов, нанополупроводников, создание фармацевтических наноматериалов и нанолекарств, производство медицинских и биомедицинских наноматериалов, нановолокон и нанопокровов, создание энергоэффективных наноматериалов. Установлено, что белорусский рынок нанотехнологий в настоящий момент находится на начальном этапе своего развития и имеет ряд особенностей и проблем. Для него характерно небольшое количество нанотехнологических разработок, превалирование технологий, идей продукта и опытных образцов над готовыми вариантами серийного производства, преимущественно государственное финансирование, закрытость информации о размерах, направлениях и участниках финансирования нанопроектов, малоразвитость связи между основными агентами коммерциализации нанотехнологий.

Заключение. На основании проведенного исследования выявлены основные проблемы и особенности развития сферы нанотехнологий в Республике Беларусь, предложен ряд рекомендаций для укрепления связей между основными агентами рынка нанотехнологий, а также создания благоприятного информационного, инвестиционного и производственного климата для дальнейшего развития нанотехнологий в стране.

Ключевые слова: наноиндустрия, нанотехнологии, нанопродукты, наносектор, рынок нанотехнологий, коммерциализация нанотехнологий.

A high level of economic development is possible with sustainable scientific and technological progress, which is related to such industries as agriculture, healthcare, food production, energy, etc. Differences in technological capabilities underlie differences in economic development across regions and countries. Governments around the world spend vast sums to support research and development to create technological competitiveness. The conventional view of technological change is of long-term technological cycles, each arising from a revolutionary new scientific advance. Nanotechnology has now become an influential tool for solving global problems and a component of sustainable development strategies for countries.

By creating nanoscale objects, materials and structures, scientists have made it possible to find new opportunities for the development of various industries and fields of knowledge [1]. The nanoindustry is one of the priority areas of economic development in countries, which proves the relevance of research on this topic. Nowadays, scientists consider nanotechnology to be the technology of the future, noting its limitless possibilities and the uniqueness of the created nanocoatings, materials and structures [2; 3].

A new scientific field of science in the form of nanotechnology was created because it was observed that materials, products, and devices developed from nanoscale particles almost always exhibit properties different from those of large-scale bulk materials [2; 4; 5]. Nanofibrous materials are known to be of great significance for a variety of applications including biotechnology, drug

delivery, wound healing, tissue engineering, microelectronics, environmental protection, energy harvesting and storage and other applications [6].

An important aspect of the development of nanotechnology and its industrialization is the need for commercialization of technologies [7; 8]. The nanoindustry offers a wide range of advantages of the proposed products and technologies for improving various spheres of life of the population – economic, social, environmental, etc., but only if these developments are commercialized and deployed at a large scale, taking into consideration the intellectual property protection, finding target markets and financial resources.

The purpose of the article is to analyze and evaluate the development of the nanotechnology sphere in the Republic of Belarus, identify its main problems and features, development trends and develop recommendations for its improvement.

Material and methods. For the article a comprehensive strategy of searching for statistical data and literature on the research topic was used through various online resources including Google Scholar, Web of Science, Springer, websites of foreign and national nanotechnology organizations. The author used general scientific and special methods: comparison, analysis and synthesis and graphical models.

Findings and their discussion. The analysis of the Global Nanotechnology Market size [9] states that global investments in nanotechnology market in 2020 was \$1.76 billion and is projected to reach \$33.63 billion by 2030, registering a compound annual growth

rate (CAGR) of 36.4% from 2021 to 2030. It's expected that The Europe Nanotechnology Market would grow for 32.0% CAGR from 2023 to 2030 (figure 1).

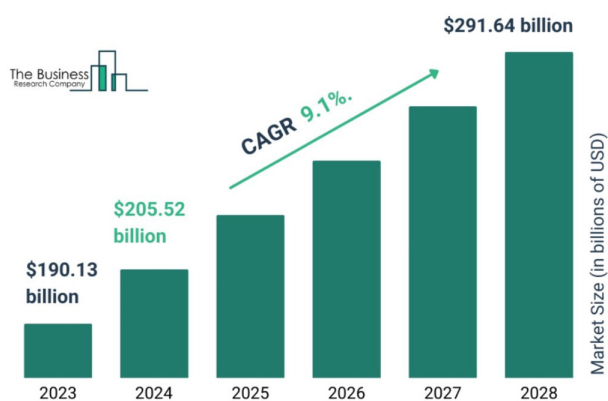


Figure 1 – Nanotechnology services global market report 2024

Footnote. [9].

Statistical data, collected by [9] shows the increasement of spendings on nanotechnology market, especially in the segment of healthcare. In the United Kingdom total current healthcare expenditures in the in 2020 amounted to £257.6 billion, or £3,840 per person. The increased

investment in healthcare has created opportunities to develop innovative nanotechnology-based solutions to improve patient care, diagnostics, and treatment. The Germany market dominated the Europe Nanotechnology Market, By Country in 2022, and would continue to be a dominant market till 2030; thereby, achieving a market value of \$2,014.4 million by 2030. The UK market is experiencing a CAGR of 30.9% from 2023 to 2030. The France market would exhibit a CAGR of 33% from 2023 to 2030 [9].

Developing countries are still lagging behind because they are unable to match the industrial progress of the previous decade, primarily due to the lack of accumulated financial, industrial and scientific-methodological assets. However, experts from the scientific communities of both developed and developing countries recognize the fact that nanotechnology will become the next step in the technological generation [10].

The Europe Nanotechnology Market Size, Share & Industry Trends Analysis Report 2023–2030 [9] presents the list of the main commercial global organizations involved in the development and commercialization of nanotechnology. We have collected information on the types of nanotechnology projects and innovations they invest, as well as the size of these investments (table 1).

Table 1 – Commercialized nanotechnology innovations by global companies, 2024

№	Company	Nanotechnology innovations	Money spent, 2024
1.	AdvanceTEC LLC (USA)	Carbon nanotube and graphene production. Smart glass with liquid nanocrystals. Innovative batteries with carbon nanotubes and graphene. Glass nanofibers (Kevlar) and carbon nanofibers. Unbreakable glass with graphene. Solar cell panels with carbon nanotubes and graphene. Bulletproof glass without lamination. Self-healing glass. Batteries that don't require recharging for five years	\$70 millions
2.	Abbie Gregg Inc. (USA)	Nanosemiconductor production. Nano- and microelectronics production. Airflow nanofilters	\$30 billions
3.	BREC Solutions Limited (UK, France, Poland)	Nano advisory sensors. Nanomaterials and supplier selection. Hydrogen Storage materials. Thermal analysis nanodevices. Green chemistry nanotechnologies. Natural nanomaterials for pharma and cosmetics. Nanobubbles	No open information
4.	Cambridge Innovation Consulting Limited (UK, USA)	Nanomaterials for seed treatments. Nano-cellulose-based synthetic leather	\$250 million

5.	Ike Scientific Corporation (USA)	Nanoherbicides and nanofertilizers. Temperature-responsive and enzyme-degradable nanoparticles for localization of diseased tissues. Hernia nanomeshes. Lensless imaging nanodevices	No open information
6.	Innovationsgesellschaft mbH (Switzerland)	Piezoelectric nanoparticles for polyfluorinated alkyl breakage. Nanostructures for bendable screen production. Cinnamon-based nanokiller antimicrobial technology	No open information
7.	Intelligent Enclosures Inc. (USA)	Micro- and nanoelectronic devices. Airflow nanofilters. Nanosemiconductors	\$250 thousands
8.	Kilopico LLC (Iran)	Energy saving nanodevices	\$8 million
9.	NanotechPlus LLC (USA)	Nanopharmaceuticals. Nanomaterials for energy storage. Nanomaterials for transportation. Nanomaterials for construction. Marine nanomaterials. Aerospace nanomaterials. Nanocoating. Nanosensors. Nanooptics	No open information
10.	Porter Wright Morris & Arthur LLP (USA)	Production of nanoscale materials: quantum dots, nanoscale silver, silver ions, nanoscale gold, carbon nanotubes, fullerenes, nanofibers, graphene, nanocomposites, nanoalloys, nanoscale titanium, nanoscale zinc, nanoscale aluminum, cerium oxide, iron oxide. Nanoscale electronic devices. Nanoemulsions for medicine. Nanodrugs. Medical devices with nanoscale features	No open information
11.	Research Facilities Design Inc. (USA)	Nanobiomedecine. Cleanroom nanoequipment. Nanotechnologies in agriculture	\$210 millions
12.	Yole Developpement SA (France)	Nanosemiconductors	\$25 millions
13.	Nanonics Imaging Ltd. (Israel)	Lensed and tapered nanofibers. Nanolithography. Carbon nanotubes. Graphene. Photonics. Nanosemiconductors	No open information
14.	DuPont de Nemours Inc. (USA, Australia, China, Hong Kong, India, Indonesia, Japan, South Korea, Malaysia, Phillipines, Taiwan, Thailand, Vietnam, Belgium, Czech Republic, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Pakistan, Poland, Saudi Arabia, Spain, Switzerland, Turkey, UK, Egypt, Kenya, Morocco, South Africa, Brazil, Costa rica)	Nanofilters. Nanosepatators. Nanotechnologies for advanced construction. Nanotechnologies for energy efficiency. Nano-multi-materials. Nanobiopharmaceuticals	\$12.1 billions

15.	Arkema S.A. (France, Algeria, Spain, Brazil, Mumbai, Saudi Arabia, Malaysia, South Korea, United Arab Emirates, India, Teheran, Turkey, Thailand, Greece, Bangalore, Jakarta, Egypt, Singapore, Indonesia)	Carbon nanotubes. Thermoplastic nanocomposites. Technical fluids. Specialty nanoscale polyamides. Specialty nanoscale acrylates & crosslinkers. Specialty nanoscale oleochemicals. Nanoscale thiochemicals. Nanoscale organic peroxides. Nanoscale electroactive polymers	12 billion euro
16.	Hummingbird Scientific Pvt Ltd., (USA, Japan, India)	Triangular indium nanoplates. Hydroxide-derived Cu nanoelectrocatalysts. Nano-manipulators. Metal-insulator-metal nanocapacitors. Nanocatalysts. Nanomotors. Nanoparticle films. Nanocrystals. Nanostructured matrixes. Nanorods	\$8.1 millions
17.	Actnano Inc. (USA, China, Germany, India, Japan, Mexico, Singapore, South Korea, Taiwan, Vietnam)	Waterproof nanocoatings. Nanomedical devices. Nanoinverters & Solar. Integrated Battery & Solar Charging Systems. Advanced nanocoating technologies. Advanced nanohydrophobic coatings. Anti-fog technology	\$40 millions

Footnote. Created by author.

According to the Europe Nanotechnology Market Size, Share & Industry Trends Analysis Report 2023 – 2030 [9], companies such as EMC Service Inc. (USA), Foley & Lardner LLP (USA, Mexico, Belgium, China, Japan), HDR Inc. (USA, Germany, Australia), M+W Group GmbH (Germany), Malsch TechnoValuation GmbH (Netherlands), NanoTEN LLC (USA), The Microscopy & Imaging Place Inc. (USA), DUST Identity Inc. (USA), Voyant Photonics Inc. (USA), It's Nanoed Inc. (USA), LakeHawk Technologies Inc. (USA), eLux Medical Inc. (USA), 4wave Inc. (USA) are also engaged in the commercialization of innovations in the field of nanotechnology. However, they do not publish open information about research areas or funding volumes, and therefore were excluded from the analysis of the commercialized nanotechnology market.

The size of investments in nanosector developments varies from \$250,000 to \$30 billion, depending on the size of the company and the number of development areas. The largest number of nanosector companies are concentrated in the USA (23), United Kingdom (4), France (4), Japan (4), and India (4).

The main areas of investment in nanotechnology are production of:

1. carbon nanotubes and nanofibers
2. graphene
3. water and air nanofilters and nanoseparators
4. nanosemiconductors
5. nanomaterials for pharma (nanodrugs, nanopharmaceuticals)
6. medical and biomedical nanomaterials
7. energy efficiency nanomaterials.

In the Republic of Belarus, the development of the nanotechnology sphere is one of the priority areas of the country's development. Developments are focused mainly in the public sector, in educational programs from leading universities and technology parks, as well as the Republican Association of Nanoindustry. The nanotechnology sphere is described in the Comprehensive Forecast of Scientific and Technological Development of the Republic of Belarus, the Strategy for Sustainable Socioeconomic Development and other state strategies and documents. There is no global analysis of the nanotechnology sphere and the number of commercialized projects in this area in the Republic of Belarus.

According to the results of the comprehensive forecast of scientific and technological progress (CFSP) of the Republic of Belarus for 2021–

Table 2 – Nanotechnology in the Republic of Belarus

№	Industry	Global total market capacity, trillion US dollars	Number of nanotechnology projects
1.	Organic agricultural and food products based on domestic raw materials	10,98	Total number: 1, where: – prototype – 1.
2.	Autonomous electric transport	48,38	Total number: 1, where: – prototype – 1.
3.	High-tech medical equipment	9,33	Total number: 3, where: – idea, concept – 1; – prototype – 1; – technology – 1.
4.	Industrial collaborative robots	10,43	Total number: 5, where: – idea, concept – 2; – technology – 1; – ready for serial production – 2.
5.	Innovative structural materials with specified properties	32,53	Total number: 5, where: – idea, concept – 2; – prototype – 4; – technology – 4; – ready for serial production – 4.

Footnote. Created by the author based on [11].

2025 and for the period up to 2040, a list of promising technologies, goods and services related to the nanoindustry was identified. Each technology, product and service was given a rating, determined by the degree of readiness for production in the Republic of Belarus and serving as a guideline for determining the priority of organizing their production or development.

Table 2 provides information on the areas of industry with nanotechnology projects and solutions in the Republic of Belarus.

The Belarusian nanotechnology market is at the stage of its development, its main trends are a small number of nanotechnology projects, the prevalence of promising technologies, product ideas and prototypes over ready-made versions of serial production, the share of which in the total volume of projects is 23% (figure 2).

The analysis showed that the investment areas of the Belarusian nanotechnology market correspond to the trends of the global market. However, unlike the global world nanotechnology market, collecting information on the nature and size of investments in the nanosector in the Republic of Belarus is difficult. The main reasons for these difficulties, in addition to the

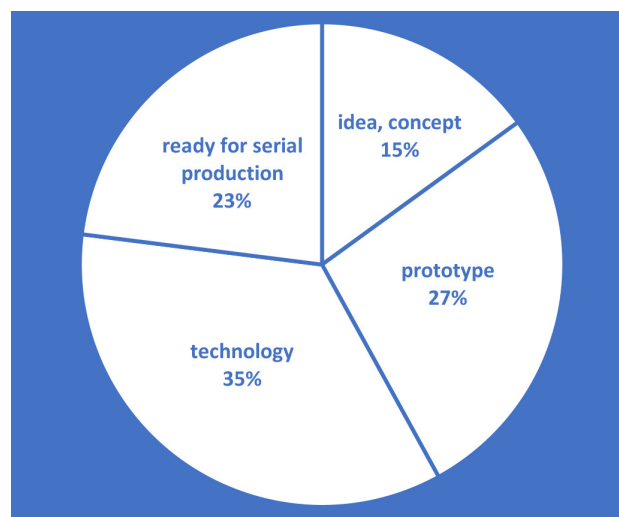


Figure 2 – Structure of nanotechnological developments in the Republic of Belarus

underdevelopment of the nanotechnology sector, are:

- most of the projects under state funding within the framework of state scientific research programs are at the stage of scientific development and are not commercialized;

– a number of completed projects are currently looking for investors and have not been commercialized;

– individual developments and nanotechnological innovations have been commercialized by private companies that do not publish open information on the size and areas of investment (JSC Integral, OJSC Optoelectronic Systems, RUP Belmikronaliz, LLC Essentoptiks and others).

The Belarusian nanotechnology market is currently facing typical problems of nanoindustry sector development, the most significant of which are:

- lack of material and technical base of enterprises;
- lack of opportunities or desire of enterprises to invest in risky or little-known technologies that have not yet established themselves in the market;
- lack of qualified personnel capable of mastering technologies and equipment;
- lack of effective developments in the field of activity of enterprises interested in innovations;
- lack of information among enterprises about innovative developments;
- lack of access to resources and technologies required for the production of innovative products, or difficult access to them.

All the above-described problems are insoluble without the creation of a comprehensive approach to recommendations for the development of the nanotechnology sector in the country and their successful commercialization.

The Belarusian nanotechnology market is at the initial stage of its development. It is characterized by a relatively small number of nanotechnology developments, prevalence of technologies, product ideas and prototypes over ready-made versions of serial production, and is also mainly financed by the state. Its distinctive features are the closed information on the size, directions and participants of nanoproject financing, underdeveloped communication between research centers and universities for conducting joint research, underdeveloped communication between the main agents of commercialization of nanotechnology (suppliers and consumers of nanotechnology). All these problems significantly hinder the development of the nanotechnology sector in the country, since they lead to the dispersion of scientific research and improper spending of state funding, low presence of private investment in innovative nanoprojects, and a decrease in the commercialization potential of the resulting developments. All this negatively affects the country's development potential, since nanotechnology is one of its key vectors, and slows down the formation of strong competitive advantages in the international arena.

In this regard, a list of recommendations was proposed to improve the development of the nanosector in the Republic of Belarus:

- expansion of the material, technical and scientific base of universities, laboratories and enterprises;
 - the formation of knowledge-intensive clusters “university-laboratory”, “laboratory-production”, which in the long term will be able to influence the acceleration of the introduction of theoretical and scientifically proven innovations into production;
 - creation of a system of information exchange and feedback “developer-manufacturer”, “manufacturer-consumer”;
 - targeted financing of the most relevant areas for the development of the country's economy, organization of joint developments and projects for research centers and universities to level out the dispersion of efforts and create a synergistic effect;
 - organization of nano-exhibitions to strengthen the connection between suppliers of nanotechnology (universities and research centers) and their consumers (enterprises of the country and the general public);
 - organization of centralized assistance in the creation and distribution of advertising documentation on developments carried out in universities and research centers;
 - creation of a common database of universities and research centers with the described areas of nanodevelopment they are conducting, a database of enterprises in the country interested in investment projects in the nanosector, as well as private investors;
 - strengthening the training of personnel for the nanosector – scientists, technologists and specialists in the production of specific nanomaterials and structures capable of mastering technologically complex equipment;
 - conducting active coverage of scientific developments and achievements in the media in order to inform the public about the features of nanoproducts and technologies and to form a favorable image of them.
- Also no less important is the factor of interaction with government agencies. It can become a key factor in the development of the nanoindustry by working in the following areas:
- simplification of the patenting procedure for innovative technologies, goods and services; acceleration of the procedure for reviewing applications for patenting nanotechnological products and technologies, reduction of patent fees;
 - creation of a preferential tax system for nanotechnological and innovative production;

– state support for scientific research in the field of nanotechnology by providing monetary funding through a system of grants and state programs for scientific research, holding competitions for scientific projects, creating a common database of science-intensive start-ups, etc.

The proposed set of measures will be able to significantly influence the development of the nanoindustry in the Republic of Belarus, strengthen its position in the international arena and ensure long-term competitive advantages.

Conclusion. There are more than 38 large commercial organizations on the global nanotechnology market, with investment in nanosector developments ranging from \$250,000 to \$30 billion depending on the size of the company and the number of nanoprojects. The largest number of nanotechnology companies are located in the United States, United Kingdom, France, Japan, and India. The main areas of investment in nanotechnology are the production of carbon nanotubes and nanofibers.

The Belarusian nanotechnology market is at the initial stage of its development. Its main features are a relatively small number of developments, prevalence of technologies, product ideas and prototypes over ready-made versions of serial production, mainly state financing. The main areas of financing correspond to global trends. Access to information on the size, directions and participants in the financing of nanoprojects in the country is practically closed. The connections between the main agents of the nanotechnology market – research centers, universities, enterprises and consumers of nanoproducts – are poorly developed. A list of recommendations has been developed based on the described problems. The proposed recommendations are focused on strengthening the connections between the main agents of the nanotechnology market, while the key role is played

by the creation of a favorable information, investment and production climate for the further development of nanotechnology in the country. In the future, this will improve not only the state of the nanotechnology sphere in the country, but will also contribute to strengthening its position in the international arena.

References

1. Elzein, B. Nano Revolution: “Tiny tech, big impact: How nanotechnology is driving SDGs progress” / B. Elzein // *Heliyon*. – 2024. – Vol. 10. – Art. e31393.
2. Malik, S. Emerging Applications of Nanotechnology in Healthcare and Medicine / S. Malik, K. Muhammad, Y. Waheed // *Molecules*. – 2023. – Vol. 28. – Art. 6624.
3. Trivedi, D. Advantages of using nanobiotechnology in enhancing the economic status of the country / D. Trivedi [et al.] // *Nanobiotechnology for the Livestock Industry Animal Health and Nutrition*. – 2023. – Pp. 369–392.
4. Hulla, J.E. Nanotechnology: History and Future / J.E. Hulla, S.C. Sahu, A.W. Hayes // *Hum. Exp. Toxicol.* – 2015. – Vol. 34. – Pp. 1318–1321.
5. Wong, I.Y. Nanotechnology: Emerging Tools for Biology and Medicine / I.Y. Wong, S.N. Bhatia, M. Toner // *Genes. Dev.* – 2015. – Vol. 27. – Pp. 2397–2408.
6. Wang, H.S. Functional polymeric nanofibers from electrospinning / H.S. Wang, G.D. Fu, X.S. Li // *Recent Patents on Nanotechnology*. – 2009. – Vol. 3. – Pp. 21–31.
7. Jeffcoat, P. (Re)imagining purpose: A framework for sustainable nanotechnology innovation / P. Jeffcoat [et. al.] // *NanoImpact*. – 2024. – Vol. 35. – Art. 100511.
8. Nanotechnology commercialization: manufacturing processes and products // *Focus Catalogue*. – 2017. – Vol. 7.
9. Tewari, D. Europe Nanotechnology Market Size, Share & Industry Trends Analysis Report By Type (Nanodevice, and Nanosensor), By Application, By Country and Growth Forecast, 2023–2030 / D. Tewari, S. Mutreja // *Emerging and next generation technologies*. – 2021. – 248 p.
10. Salamanca-Buentello, F. Nanotechnology and the developing world / F. Salamanca-Buentello [et. al.] // *PLoS Medicine*. – 2005. – Vol. 2. – Art. 97.
11. Results of a comprehensive forecast of scientific and technological progress of the Republic of Belarus for 2021–2025 and for the period up to 2040 / ed. A.G. Shumilina. – Minsk: State Institution “BelISA”, 2020. – 92 p.

Поступила в редакцию 23.04.2025