UKRAINIAN SCIENCE AND TECHNOLOGY FORESIGHT

Strategic Priority Directions and Prospects for the Development of Science and Technology

KYIV 2024

REVIEWERS:
Viktor Terekhov, Professor, Doctor of Economic Sciences/Doctor of Economics
Iryna Yashchyshyna, Doctor of Economic Sciences/Doctor of Economics

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Using the Delphi method survey, expert assessments and proposals from over 500 leading scientists were collected to evaluate shifts in research priorities over the past three years. These shifts respond to the challenges of full-scale war and global science and technology development trends."

The scientific community's evaluations of Ukraine's current science and technology policy have been consolidated, leading to proposals for improvement. This includes identifying priority research directions across nine research clusters that cover the main fields and vectors of Ukrainian science development.

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CONTACT FOR COLLABORATION AND ADDITIONAL INFORMATION

Dobrov Institute for Scientific and Technological Potential and Science History Studies of the NAS of Ukraine

01032, Kyiv, Taras Shevchenko Blvd, 60
phone: +38 (044) 486 95 94
email: steps@nas.gov.ua,
steps_2004@ukr.net
www.stepscenter.org.ua

«Foresight. Institute for Political Economy»

phone: +38 (050) 380 10 35,
+1 (504) 312 85 67
email: info@foresight-institute.org,
press@foresight-institute.org
www.foresight.in.ua

This project was carried out by the Dobrov Institute for Scientific and Technological Potential and Science History Studies in collaboration with the public organization «Foresight. Institute for Political Economy», with support from the Friedrich-Ebert-Stiftung Representative Office in Ukraine.

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INTRODUCTION

In leading countries around the world, particularly after 2020, there has been a significant increase in government support for scientific research and development, alongside a substantial rise in the subsidization of innovative projects in advanced technology sectors.

In response to the full-scale Russian invasion that began in 2022, Ukrainian government has declared the urgent need for a radical enhancement of support for research, development, and the implementation of new technologies, especially in the defense sector. Notably, a large-scale initiative known as "Army of Drones" has been launched to support the development and production of drones, among other projects.

As of September 2024, however, Ukraine's defense industrial complex is operating at only one-third of its capacity. Our research indicates that the utilization rate of scientific and technological potential ranges from 25% to 50%. Moreover, most scientists surveyed believe that the state has yet to establish an adequate science and technology policy that reflects the current situation.

1 *The war is going badly. Ukraine and its allies must change course // The Economist. – 2024, September 26. https://www.economist.com/leaders/2024/09/26/the-war-is-going-badly-ukraine-and-its-allies-must-change-course*

Defining research priorities, concentrating resources, and formulating an effective state policy for the implementation of innovations and the scaling of production are critically important for Ukraine's survival. Despite the ongoing war, the country retains significant scientific and technological potential, especially when compared to nations with similar GDP per capita. The relatively high standards of scientific and engineering culture have contributed to the unexpectedly high effectiveness of the Armed Forces of Ukraine in countering the Russian invasion, as noted by many foreign analysts.

Ukraine's capacity to develop and implement new technologies is a crucial resource that can ensure victory and enable successful post-war recovery. However, without urgent measures to restore scientific and technological potential in key areas of fundamental and applied research, the country risks losing the ability not only to innovate but also to effectively utilize modern Western technologies in the near future. This would undermine our defense capabilities and pose a significant threat to statehood.

Despite some successful government programs, such as "Army of Drones," broader declarations about technological breakthroughs have not yet translated into systemic changes in science and technology policy or industrial policy. The findings of this survey provide an opportunity to assess the current potential in Ukraine in key areas of science and technology development, as well as to understand the evaluation offered by scientists regarding the effectiveness of the state's efforts to mobilize this potential.

In comparison to a previous survey conducted by the National Academy of Sciences of Ukraine in 2021, at the initiative of the National Council of Ukraine for Science and Technology Development, the relevance of certain research areas has significantly increased, while others have lost relevance. For several areas, there has been a decline in the potential for their development.

The aim of this study, carried out in accordance with the resolution of the Presidium of the National Academy of Sciences of Ukraine and supported by the Friedrich Ebert Foundation in Ukraine, is not only to clarify the list of promising research areas but also to explore and evaluate new ideas for implementing the state's science, technology policy and innovation policy, particularly in terms of new approaches to developing the country's innovation system.

The report comprises nine research clusters, each evaluated by experts concerning the relevance and availability of potential and resources necessary for continuing research (approximately ten areas identified in 2021 for each cluster), as well as for new areas proposed during this year's survey. It is important to emphasize that low evaluations of potential (including talent, equipment, and contributions) in highly relevant research areas may signal not a lack of prospects, but rather the urgent need to concentrate resources on their restoration.

In addition to sections corresponding to the research clusters, the report includes a dedicated section assessing the overall science and technology policy, including recommendations for improving the organizational model of such policy and restoring talent pool.

The survey, conducted from July to December 2024 in three rounds using the Delphi method, involved a total of 543 experts.

METHODOLOGY

The survey was conducted in three rounds using the Delphi method, in accordance with the latest methodological recommendations from the RAND Corporation, and informed by the experiences of previous forecasting and analytical studies conducted by the National Academy of Sciences of

2 Methodological Guidance for Conducting and Critically Appraising Delphi Panels. – RAND Corporation. – 2023. https://www.rand.org/pubs/tools/TLA3082-1.htm

Ukraine, particularly in 2004-2006 and 2021. The starting point for evaluating the relevance of research areas and their corresponding potential was the results of a study conducted in 2021.

The Delphi method allows each expert to review anonymized responses from other survey participants, refine their evaluations, suggestions, and arguments. The overall scheme of the survey is as follows:

DELPHI METHOD

FIRST ROUND:

→ Preliminary Assessment of the Relevance of Pre-war Research Areas

→ New Ideas Regarding Priorities and Policies

SECOND ROUND:

→ Clarification of Pre-War Research Directions Assessments

→ Preliminary Assessment of New Ideas

THIRD ROUND:

→ Final Assessment of New Ideas Regarding Research Directions, Priorities, and Policies

The complete text of the working methodology, approved by the Director of Dobrov Institute for Scientific and Technological Potential and Science History Studies of National Academy of Sciences of Ukraine (STEPS Center of NAS of Ukraine), is available for public access on the website of the NGO "Foresight," which is a co-executor of this study.

A score assessment of relevance, talent, available equipment, contributions, and international cooperation is conducted using the following scales:

TABLE 0.1.

"RELEVANCE" SCORING SCALE

Score	Description
5	Very relevant; deserves priority support
4	Relevant in the global science context, but currently lacks development opportunities in Ukraine
3	Relevant, but not a priority
2	Hard to say
1	Not relevant

TABLE 0.2.

"TALENT" SCORING SCALE

Score	Description
5	Qualified personnel and some scientific contributions are available
4	There are qualified specialists available, but the equipment is significantly outdated
3	Development possible only through participation in foreign centers
2	Hard to say
1	Original ideas exist, but there is no potential for development

3 *Working Methodology of Foresight Delphi Survey on Ukrainian Scientific and Technological Priorities. – Foresight NGO. – 2024. https://foresight.in.ua/methodology_EN.pdf*

TABLE 0.3.

"CONTRIBUTIONS" SCORING SCALE

Score	Description
5	Active research is underway, yielding significant results
4	Original ideas are present, but research is just beginning
3	Experience in related work at foreign scientific centers
2	Hard to say
1	No own achievements available

TABLE 0.4.

"EQUIPMENT" SCORING SCALE

Score	Description
5	Fully sufficient for conducting research at a modern level
4	Sufficient for at least the initial stage of work
3	Somewhat outdated but functional, requiring more time than the latest equipment
2	Partially available but needs supplementation
1	Absent

TABLE 0.5.

"INTERNATIONAL COOPERATION" SCORING SCALE

Score	Description
5	Active collaboration with leading scientific centers worldwide; participation in joint projects and programs
4	Established regular communication and information exchange with foreign colleagues
3	Organized internships for domestic researchers at foreign scientific centers
2	Communication occurs only during international conferences
1	Practically no cooperation

In the tables of average scores (Tables 1.1-9.2), we use the standard method of averaging the scores provided by experts, based on those who responded. The "TOP RELEVANCE" indicator is calculated as the percentage of the highest scores from the total responses received. Since some experts refrained from evaluating certain research directions, the histograms of score distributions (Figures 1.1-1.6, 2.1-2.4, 3.1-3.4, 4.1-4.5, 5.1-5.7, 6.1-6.5, 7.1-7.5, 8.1-8.5, 9.1-9.2) display the percentage of these scores relative to the total number of experts participating in the survey for each research cluster.

Fundamental Mathematics and Natural Sciences

The study on the research cluster *"Fundamental Research in Emerging Areas of Mathematics and Natural Sciences"* involved 73 experts, including 5 Academicians[4], 16 Corresponding Members[5] of the NASU, 42 Doctors of Sciences[6], and 9 Candidates of Sciences[7].

This cluster covers a broad spectrum of scientific specialties and fields. In the most developed countries, its advancement is primarily supported by state budgets.

In the first half of the 20th century, Ukraine was a leading global center for fundamental science, particularly in theoretical physics, chemistry, and mathematics. Notably, Nobel laureate Lev Landau conducted pioneering work in quantum theory at the Ukrainian Institute of Physics and Technology in Kharkiv.

Since independence, fundamental sciences have been less affected by funding cuts, as certain theoretical research topics do not always require expensive experimental equipment. Fundamental theoretical research in physics and mathematics continues in Ukraine at a high international level. This is evidenced by Maryna Viazovska receiving the Fields Medal in 2022, the highest honor in mathematics. The election of Anatolii Zagorodnii, an esteemed director of the Bogolyubov Institute for Theoretical Physics, as President of NASU in 2020 also underscores the recognition of high-level research in theoretical physics.

“Table 1.1” presents new assessment results of relevance and potential for research directions identified in a foresight study conducted in 2021[8].

4 Academician (академік): The highest rank, awarded to distinguished scientists with groundbreaking contributions. Academicians are full members of NASU, similar to a "Fellow" in Western societies, with significant national recognition and responsibilities.

5 Corresponding Member (член-кореспондент): A rank below Academician, granted to scientists with significant achievements. They are part of NASU with a more limited decision-making role, comparable to an "Associate Fellow" in some Western organizations.

6 Doctor of Sciences (доктор наук): A higher degree for significant contributions to a field, requiring extensive research beyond the Candidate of Sciences level. It is comparable to a Habilitation in some European countries.

7 Candidate of Sciences (кандидат наук): Similar to a Ph.D., this degree is awarded after completing postgraduate studies, conducting original research, and defending a dissertation.

8 Popovych, O. S. "Pro zavershennia ta osnovni pidsumky kompleksnoho prohnozno-analitychnoho doslidzhennia z metoiu vyiavlennia naibilsh aktualnykh napriamiv naukovoho poshuku" [On the Completion and Main Results of a Comprehensive Forecast and Analytical Study to Identify the Most Relevant Areas of Scientific Research]. Nauka ta naukoznavstvo [Science and Science Studies], 2022, no. 3 (117), pp. 68–60.

TABLE 1.1.

RESEARCH DIRECTIONS WITHIN THE CLUSTER: **"FUNDAMENTAL RESEARCH IN EMERGING AREAS OF MATHEMATICS AND NATURAL SCIENCES"** ACCORDING TO THE 2021 LIST, AND THE CURRENT ASSESSMENT OF THEIR RELEVANCE AND POTENTIAL.

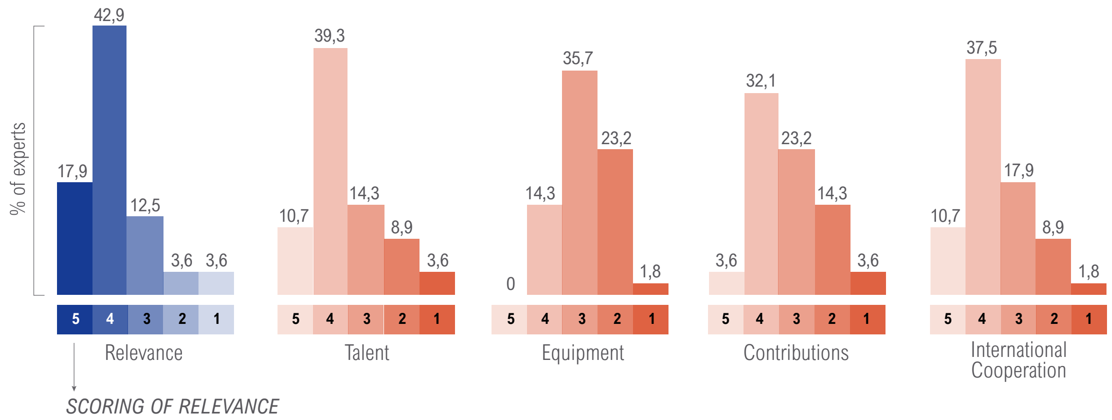
TOP RELEVANCE (percentage of experts who gave the highest relevance score)	*AVERAGE SCORE*					*RESEARCH DIRECTIONS IDENTIFIED IN 2021*
	Relevance	Talent	Equipment	Contributions	International Cooperation	
80%	4,53	3,72	3,18	3,40	3,85	1. Energy saving, renewable energy sources. Safety in the operation of Ukrainian nuclear power plants. Prospective research in thermonuclear energy
67%	4,33	3,72	3,02	3,58	3,88	2. Study of the effects of dimensional reduction on material properties: nanophysics, nanochemistry, nanobiology, nanomaterials, nanotechnology
76%	4,50	3,63	3,15	3,34	3,62	3. Advanced information technologies: hardware, software, methods, and technologies for information processing; high-performance computing systems and networks; robotics. Artificial intelligence. Prospective developments in quantum computing
65%	4,33	3,68	3,18	3,61	3,92	4. Physical-chemical biology: bioorganic chemistry and biochemistry, molecular biology and genetic engineering, genetics, biophysics. Neurophysiology. Genomics and plant biotechnology
80%	4,59	3,72	3,18	3,46	3,40	5. Innovations in micro- and nanoelectronics, materials for communications systems, microwave electronics, computer technology, and interdisciplinary applications in medicine and engineering
75%	4,55	3,47	2,97	3,39	3,43	6. Micro- and macromechanics of materials. Mechanics of rocket-space and aviation systems
22%	3,83	3,62	2,84	3,23	3,62	7. Nuclear physics and elementary particle physics. Physics of the universe
28%	3,95	3,37	3,08	3,34	3,32	8. Catalysis and catalytic processes. Physics, chemistry, and biology of water
51%	4,19	4,00	3,32	3,71	3,90	9. Mathematics: fundamental and applied, mathematical problems of natural and social sciences, computational mathematics. Statistics
54%	4,20	3,28	2,87	3,21	3,33	10. Earth physics. Climate change issues. Recent research ensuring efficient mineral exploration, sustainable exploitation of deposits, and environmental protection

As shown in Table 1.1, the most challenging directions within this cluster are *"Nuclear Physics and Elementary Particle Physics. Physics of the Universe"* and *"Catalysis and Catalytic Processes. Physics, Chemistry, and Biology of Water."*

From the distribution of scores in Figures 1.1 and 1.2, it is evident that most experts regard these research directions relevant in the context of global science. However, **there are currently no real opportunities for their development in Ukraine** (rated "4" on the "Relevance" scale). There are specialists in these topics, but the equipment is very outdated, and development is possible only through participation in foreign centers (rated "3" and "4" on the "Personnel" scale). Therefore, revitalizing research to achieve significant results will require substantial efforts.

FIGURE 1.1.

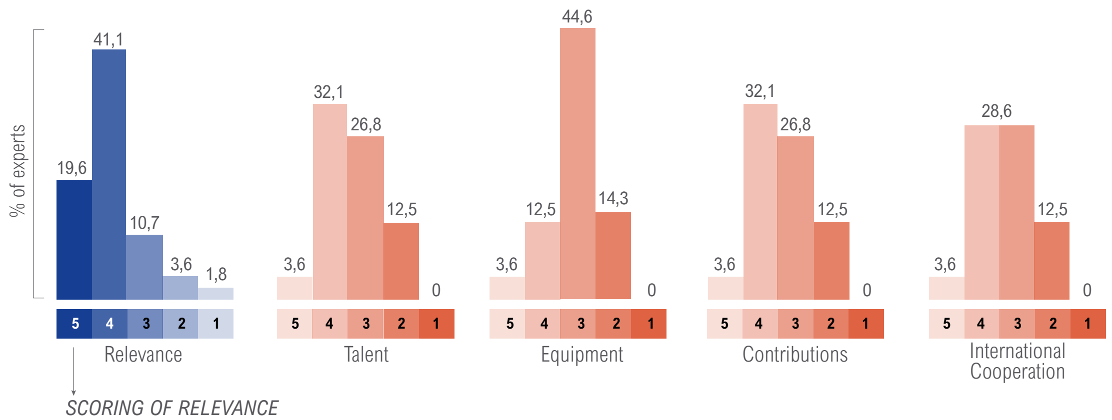
DISTRIBUTION OF SCORES FOR THE RESEARCH DIRECTION:
"NUCLEAR PHYSICS AND ELEMENTARY PARTICLE PHYSICS. PHYSICS OF THE UNIVERSE"



Survey results reveal that while Ukraine possesses a rich history of fundamental research in mathematics and natural sciences, supported by esteemed institutions, the state's inadequate funding for this sector hinders its potential to drive national innovation.

FIGURE 1.2.

DISTRIBUTION OF SCORES FOR THE RESEARCH DIRECTION:
“CATALYSIS AND CATALYTIC PROCESSES. PHYSICS, CHEMISTRY, AND BIOLOGY OF WATER”



It is worth noting that in discussions about developing nuclear weapons, the critical state of research in nuclear physics could significantly complicate the realization of such a project.

The highest “Relevance” scores were given to *“Energy Saving, Renewable Energy Sources. Safety in the Operation of Ukrainian Nuclear Power Plants. Prospective Research in Thermonuclear Energy”* and *“Innovations in Micro- and Nanoelectronics, Materials for Communications Systems, Microwave Electronics, Computer Technology, and Interdisciplinary Applications in Medicine and Engineering.”*

As seen in Figures 1.3 and 1.4, despite 80% of experts rating these areas as high-priority (rated “5” on the “Relevance” scale), the assessments of talent potential, equipment, and overall development are strikingly low.

FIGURE 1.3.

DISTRIBUTION OF SCORES FOR THE RESEARCH DIRECTION:
“ENERGY SAVING, RENEWABLE ENERGY SOURCES. SAFETY IN THE OPERATION OF UKRAINIAN NUCLEAR POWER PLANTS. PROSPECTIVE RESEARCH IN THERMONUCLEAR ENERGY”

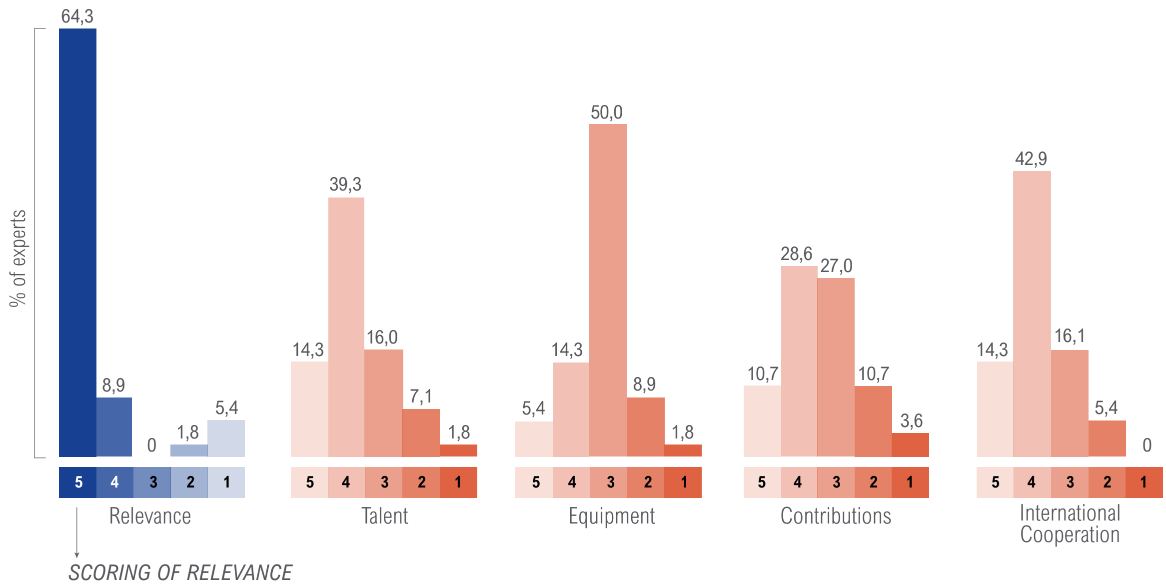
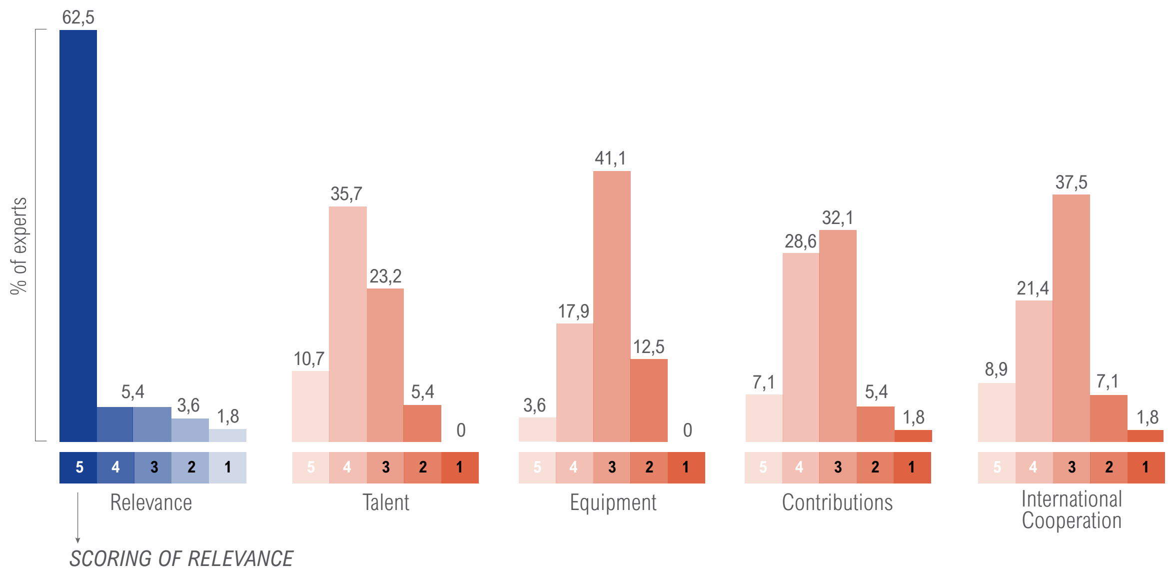


FIGURE 1.4.

DISTRIBUTION OF SCORES FOR THE RESEARCH DIRECTION:
“INNOVATIONS IN MICRO- AND NANOELECTRONICS, MATERIALS FOR COMMUNICATIONS SYSTEMS, MICROWAVE ELECTRONICS, COMPUTER TECHNOLOGY, AND INTERDISCIPLINARY APPLICATIONS IN MEDICINE AND ENGINEERING”



This mirrors the challenges found in the most problematic research topics where “the equipment is very outdated, and development is possible only through participation in foreign centers”. Less than 20% of experts believe that these research directions have sufficient talent (rated “5” on the “Talent” scale).

International cooperation is particularly lacking in *“Innovations in Micro- and Nanoelectronics, Materials for Communications Systems, Microwave Electronics, Computer Technology, and Interdisciplinary Applications in Medicine and Engineering.”* Over half of the experts rated it “3” or lower (cooperation is limited to internships for domestic researchers at foreign scientific centers and participation in international conferences).

In addition to assessing the most promising research directions that were identified in 2021, prior to the full-scale invasion of Russian troops into Ukraine, experts also proposed and evaluated new ideas for prospective research.

“Table 1.2” presents a summarized assessment of the most supported new ideas for augmenting the list of promising research directions within this cluster.

TABLE 1.2.

NEW IDEAS FOR RESEARCH DIRECTIONS WITHIN THE CLUSTER: **"FUNDAMENTAL RESEARCH IN EMERGING AREAS OF MATHEMATICS AND NATURAL SCIENCES"** AND EVALUATION OF THEIR RELEVANCE AND POTENTIAL

TOP RELEVANCE (percentage of experts who gave the highest relevance score)	*AVERAGE SCORE* Relevance	Talent	Equipment	Contributions	International Cooperation	*RESEARCH DIRECTION*
73%	*4,5*	*3,5*	*3,1*	*3,4*	*3,5*	1. Detection and neutralization of mines and chemical contaminants
63%	*4,2*	*3,3*	*3,0*	*3,1*	*3,2*	2. Artificial intelligence, machine learning, large language models, computer vision, and data science
53%	*4,2*	*3,4*	*3,0*	*3,3*	*3,3*	3. Biomechanics and regenerative medicine
45%	*3,9*	*3,2*	*2,7*	*2,9*	*3,0*	4. Quantum computing and programming, quantum engineering, and technologies
45%	*4,0*	*3,2*	*3,1*	*3,3*	*3,2*	5. Socio-behavioral research, psychological support, and recovery
45%	*4,2*	*3,5*	*3,2*	*3,3*	*3,3*	6. "Green" chemistry and environmentally friendly technologies
42%	*4,1*	*3,4*	*2,9*	*3,2*	*3,4*	7. Laser physics and directed energy technologies
40%	*4,0*	*3,1*	*2,8*	*3,0*	*3,2*	8. Metamaterials, topological materials, quantum metamaterials
26%	*3,7*	*3,1*	*2,8*	*3,1*	*3,3*	9. Nanomagnetism, spintronics, magnonics

"Nanomagnetism, spintronics, magnonics" received the lowest rating in terms of relevance.

While most experts consider the research directions outlined in Figures 1.5 and 1.6 to be highly relevant and deserving of support (rated "5" on the "Relevance" scale), assessments of existing talent, equipment, and contributions paint a less optimistic picture.

A recurring theme across these research areas is the presence of outdated equipment, hindering progress and demanding significant upgrades.

More concerning are the low ratings for research contributions and international collaboration. Many experts struggle to assess the value of work produced by Ukrainian scientists. In the direction of *«Detection and Neutralization of Mines and Chemical Contaminants,"* this difficulty may stem from the fact that active research is only just starting. However, in historically strong fields like AI, this could be a sign of a potential decline.

FIGURE 1.5.

DISTRIBUTION OF SCORES FOR THE RESEARCH DIRECTION:
"ARTIFICIAL INTELLIGENCE, MACHINE LEARNING, LARGE LANGUAGE MODELS, COMPUTER VISION, AND DATA SCIENCE"

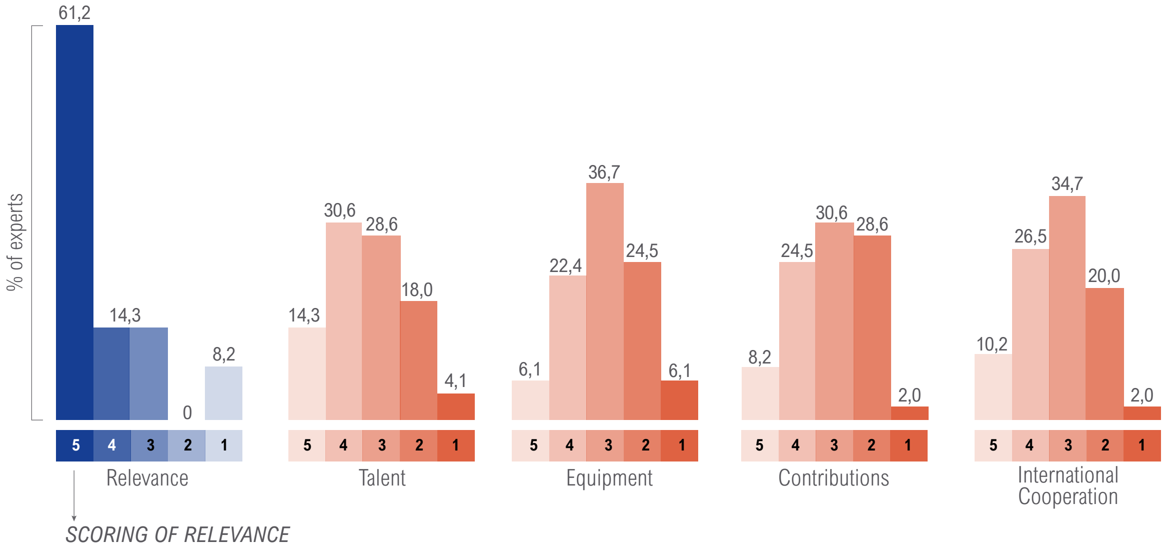
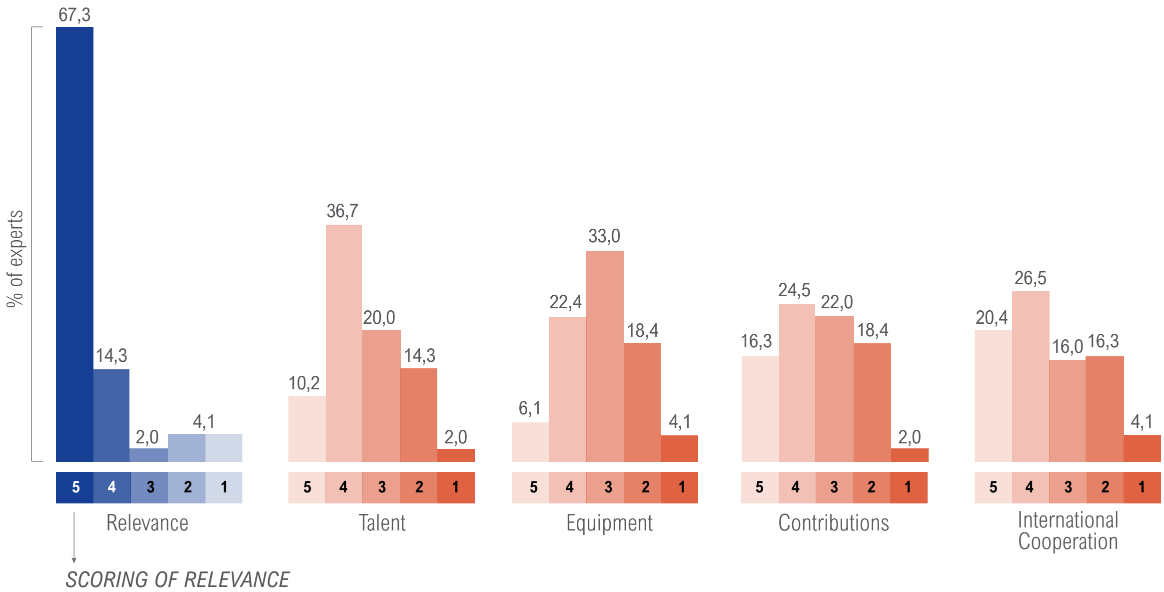


FIGURE 1.6.

DISTRIBUTION OF SCORES FOR THE RESEARCH DIRECTION:
"DETECTION AND NEUTRALIZATION OF MINES AND CHEMICAL CONTAMINANTS"



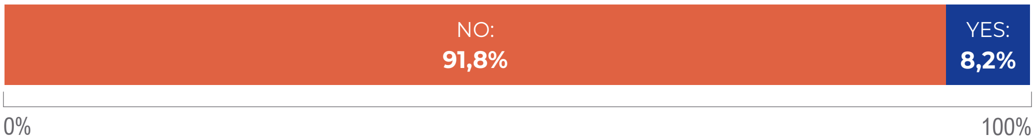
Only a small number of experts report active collaboration with leading scientific centers around the world, with the situation in AI being particularly concerning. Most experts feel that international collaboration is limited to communication, information sharing, and organizing internships (rated "3" and "4"). Only 10% of experts report involvement in joint projects or programs with leading global scientific centers (rated "5").

Additionally, experts were asked to evaluate **the state`s science and technology policy.** Over 90% of those in this cluster believe that the government has yet to establish an adequate science and technology policy that addresses the current situation (see Figure 1.7).

FIGURE. 1.7.

PRESENCE OF GOVERNMENT POLICY

(responses to the question "Do you agree that the state has established a science and technology policy that is suitable for the present circumstances?")

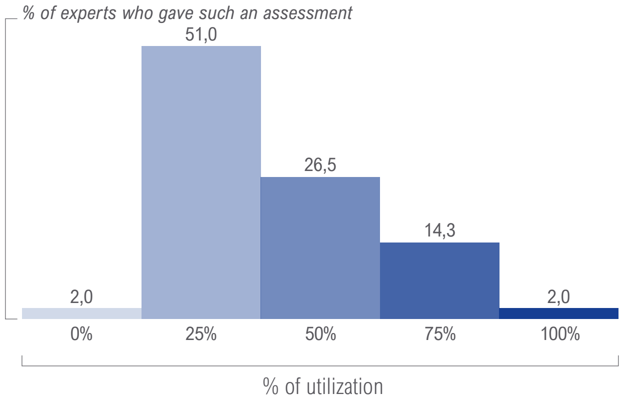


Experts have also assessed the utilization of Ukraine's scientific and technological potential in *"Fundamental Research in Emerging Areas of Mathematics and Natural Sciences"* as extremely low. The most frequent rating for the level of utilization is only 25% (see Figure 1.8).

FIGURE 1.8.

UTILIZATION OF SCIENTIFIC AND TECHNOLOGICAL POTENTIAL BY THEMATIC AREA

(responses to the question "Approximately, to what percentage do you estimate the scientific and technological potential of the country is currently being utilized?")



National Security and Defense

In the intersectoral cluster *"Research and Development for National Security and Defense, Dual-Use Technologies"* 64 experts were involved, including 6 Academicians, 12 Corresponding Members of the National Academy of Sciences of Ukraine, 32 Doctors of Sciences, and 14 Candidates of Sciences. Additionally, experts from all thematic blocks of the project contributed ideas for new defense-oriented research.

By the end of 1991, a significant portion of scientific research conducted by the National Academy of Sciences of Ukraine and higher educational institutions was focused on the needs of the Soviet military-industrial complex. In fact, Ukrainian scientists played a role in the development of nearly all advanced weaponry.

After Ukraine gained independence, research in this area was drastically reduced, leading to a considerable loss of scientific potential. Interest in defense-related research was only revitalized after 2014, driven by the need to restore the Armed Forces in response to Russian aggression. However, even up until the full-scale invasion of Russian troops in 2022, there had not been a significant increase in research volume dedicated to national security and defense needs.

A survey conducted in 2021 identified several priority research directions. Some of the promising technologies highlighted at that time have now become crucial for enhancing the Defense Forces' capabilities in countering the aggressor. Unfortunately, substantial government support for these areas began only after the onset of the full-scale war, largely influenced by the realities of combat operations rather than recommendations from the scientific community.

“Table 2.1” presents the average scores for 11 research directions identified in the previous survey.

TABLE 2.1.

RESEARCH DIRECTIONS WITHIN THE CLUSTER: **"RESEARCH AND DEVELOPMENT FOR NATIONAL SECURITY AND DEFENSE, DUAL-USE TECHNOLOGIES"** ACCORDING TO THE 2021 LIST, AND THE CURRENT ASSESSMENT OF THEIR RELEVANCE AND POTENTIAL.

TOP RELEVANCE (Percentage of experts who gave the highest Relevance score – 5 points, %)	*AVERAGE SCORE*					*RESEARCH DIRECTION*
	Relevance	Talent	Equipment	Contributions	International Cooperation	
77%	4,57	3,80	3,27	3,30	3,05	1. Development of comprehensive intelligence systems for national security, including novel approaches to aggregating diverse data from various sources
37%	3,72	3,26	3,07	3,21	2,84	2. Creation of knowledge bases and automated conclusions (assessments, forecasts) within a unified information space
77%	4,49	3,72	3,44	3,28	3,05	3. Application of modern information and communication technologies to create a defense resource management system
72%	4,49	3,37	3,14	3,37	3,02	4. Establishment of a robust defense resource management system
60%	4,35	3,42	3,28	3,09	2,93	5. Use of artificial intelligence to support decision-making and optimize defense strategie
63%	4,42	3,53	3,37	3,38	3,07	6. Development of a scientific base and algorithms for coordinated management of intelligent robotic complexes
79%	4,67	3,43	3,41	3,24	2,83	7. Development and application of swarm intelligence in planning operations using groups (swarms) of mobile robotic systems acting as a team
56%	4,21	3,47	3,09	3,05	2,88	8. Creation of national-level situational centers for assessing and forecasting critical areas, supporting decision-making, and strategic planning using mathematical modeling and expert systems
44%	4,05	3,19	3,02	3,05	2,79	9. Development of technology for producing aviation biofuels from plant materials to aid decarbonization and enhance Ukraine's energy independence
79%	4,56	3,49	3,28	3,19	3,02	10. Development of over-the-horizon radar systems for territorial water protection and enhancing high-resolution satellite remote sensing technologies
88%	4,77	3,98	3,63	3,60	3,21	11. Research aimed at ensuring data protection in information and communication systems

Six directions were rated highest for relevance (the highest relevance scores given by over two-thirds of the experts). Among these, two highly promising research directions—over-the-horizon radar development (see Fig. 2.1) and swarm intelligence—specifically, the application of groups (swarms) of mobile robotic systems (see Fig. 2.2)—suffer the most from inadequate equipment and talent.

FIGURE 2.1.

DISTRIBUTION OF SCORES FOR THE DIRECTION:
"DEVELOPMENT OF OVER-THE-HORIZON RADAR SYSTEMS FOR TERRITORIAL WATER PROTECTION AND ENHANCING HIGH-RESOLUTION SATELLITE REMOTE SENSING TECHNOLOGIES"

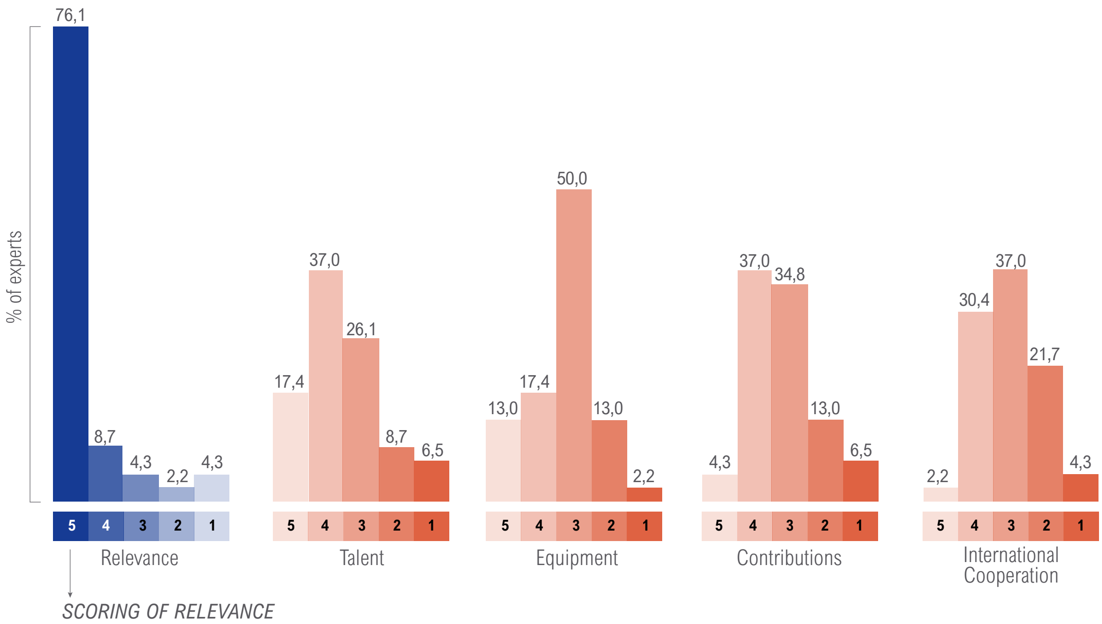
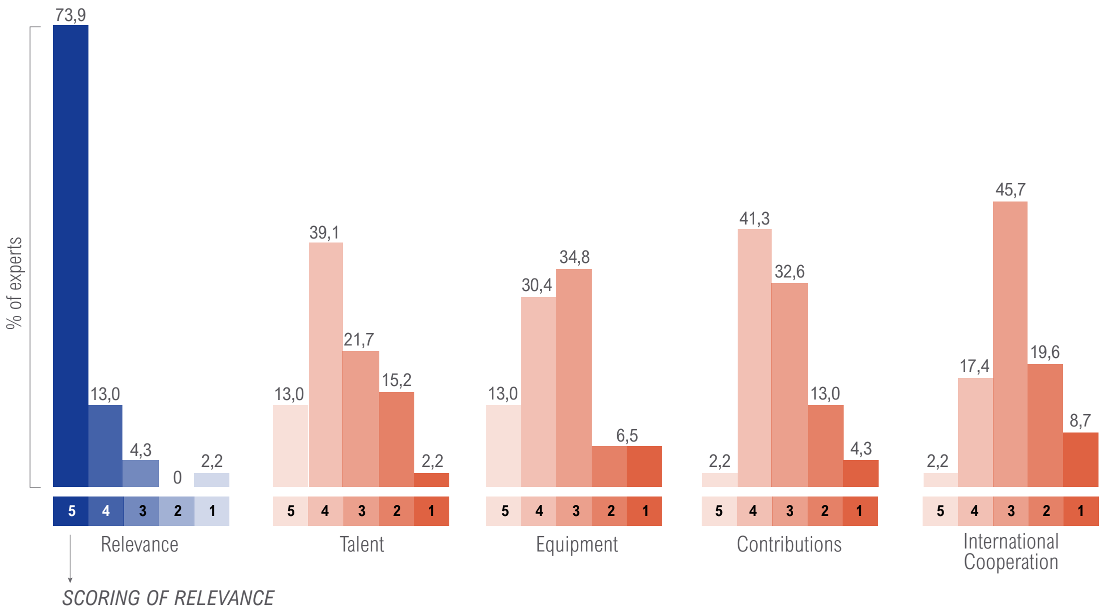


FIGURE 2.2.

DISTRIBUTION OF SCORES FOR THE DIRECTION:
"DEVELOPMENT AND APPLICATION OF SWARM INTELLIGENCE IN PLANNING OPERATIONS USING GROUPS (SWARMS) OF MOBILE ROBOTIC SYSTEMS ACTING AS A TEAM"



It is noteworthy that the swarm intelligence research direction was a leader in relevance as of the 2021 study, prior to the full-scale Russian invasion. Its importance has since grown and is widely discussed in the media. Unfortunately, the survey results indicate that state and industry support for this area remains insufficient.

According to experts, the research directions of *"Creating Knowledge Bases and Automated Conclusion Generation (Assessments, Forecasts) within a Unified Information Space"* and *"Developing Technology for Producing Liquid Biofuels for Aviation from Plant Materials to Promote Decarbonization and Enhance Ukraine's Energy Independence"* have largely lost their relevance.

“Table 2.2” provides a summary evaluation of the most expert-supported new ideas for expanding the list of promising directions in this cluster.

TABLE 2.2.

NEW IDEAS FOR RESEARCH DIRECTIONS WITHIN THE CLUSTER: **"RESEARCH AND DEVELOPMENT FOR NATIONAL SECURITY AND DEFENSE, DUAL-USE TECHNOLOGIES"** AND EVALUATION OF THEIR RELEVANCE AND POTENTIAL

TOP RELEVANCE (Percentage of experts who gave the highest Relevance score – 5 points, %)	*AVERAGE SCORE*					
	Relevance	Talent	Equipment	Contributions	International Cooperation	*RESEARCH DIRECTION*
94%	4.81	3.83	3.63	3.60	3.15	1. Development of modern systems to counter UAVs, guided missiles
88%	4.73	4.04	3.62	3.58	3.13	2. Development of hardware-software complexes for reconnaissance-fire loops, including UAVs and highly organized robotic systems
88%	4.75	4.08	3.72	3.77	3.35	3. Missile and anti-missile technologies: improving missile systems and air and missile defense systems capable of effectively responding to various threats
83%	4.71	3.91	3.68	3.68	3.40	4.Cyber protection of large information exchange systems from espionage and cyberterrorism
83%	4.65	3.94	3.60	3.58	3.29	5. Development of remote explosive detection systems
81%	4.69	3.92	3.54	3.50	3.23	6. Development of systems to protect against enemy electronic warfare
79%	4.63	3.96	3.49	3.63	3.10	7. Creation of interference-resistant secure telecommunication systems for the frontline
79%	4.60	3.96	3.65	3.75	3.15	8. Drone control systems, active-passive reconnaissance systems using acoustic and electromagnetic fields

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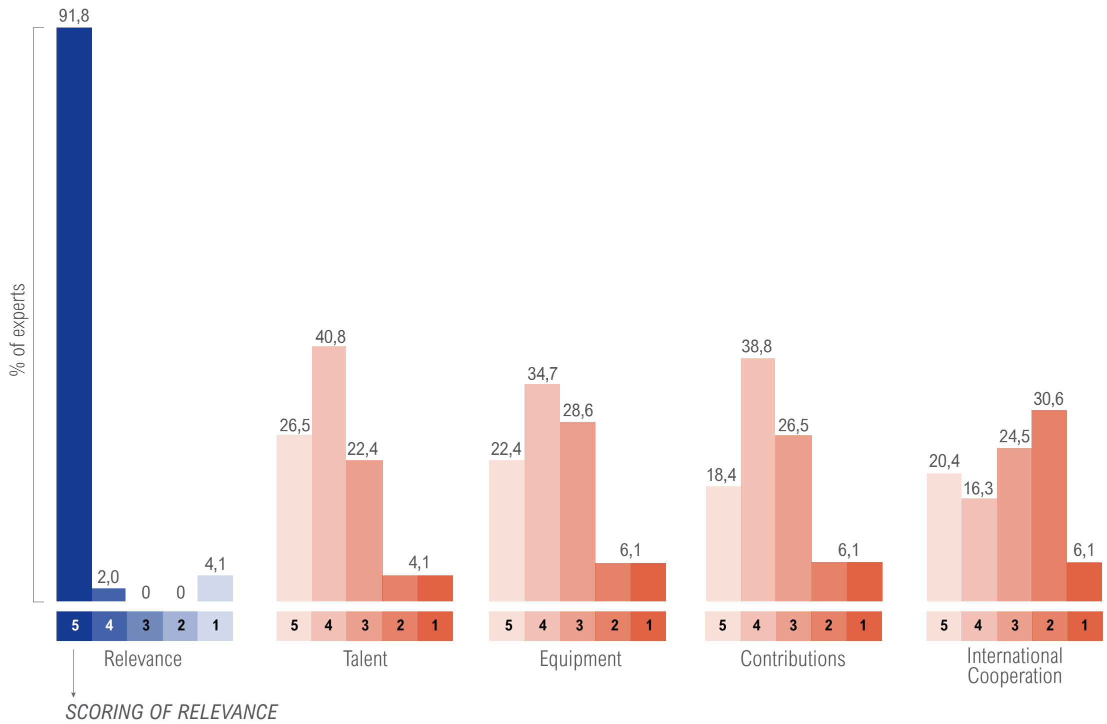
TOP RELEVANCE (Percentage of experts who gave the highest Relevance score – 5 points, %)	AVERAGE SCORE: Relevance	Talent	Equipment	Contributions	International Cooperation	RESEARCH DIRECTION
79%	4.60	3.74	3.45	3.43	3.21	9. Development of early warning systems for air defense
75%	4.50	3.81	3.48	3.60	3.15	10. Development of methods and materials to enhance the effectiveness of munitions
74%	4.57	3.66	3.43	3.53	3.33	11. Demining technologies: detection and neutralization of mines and chemical contaminants, including unmanned solution
74%	4.51	3.79	3.55	3.64	3.38	12. Development of affordable and effective hemostatic and disinfectant preparations and modern methods for treating combat trauma and its consequences
73%	4.50	3.77	3.50	3.42	3.13	13. Development of systems for decrypting communication channels of Russian force
73%	4.56	3.81	3.46	3.40	3.17	14. Development of robotic platforms for engineering support of military operations, communication systems operable under active electronic warfare
70%	4.45	3.79	3.38	3.51	3.02	15. Improvement of explosive manufacturing technologies. Development of explosives for artillery needs, mine production, etc.
66%	4.43	4.15	3.64	3.70	3.45	16. Creation of advanced materials for vehicle and personal armor, ultra-strong materials for offensive and defensive means, including special ceramics for body armor
65%	4.35	3.79	3.63	3.58	3.23	17. Development of automated troop management systems for tactical levels
62%	4.30	3.81	3.32	3.30	3.13	18. Stealth materials and technologies: new composite materials for aviation and missile technology, materials for camouflage (radio-absorbing, heat-absorbing for concealing people and equipment)
56%	4.15	3.48	3.11	3.19	2.87	19. Creation of ultra-high-power laser systems
53%	4.21	3.66	3.38	3.30	3.23	20. Development and implementation in therapeutic practice of methods and tools for overcoming post-traumatic (PTSD) and combat stress disorders
52%	4.31	3.81	3.63	3.58	3.27	21. Improvement of pattern recognition systems
50%	4.19	3.60	3.10	3.31	3.29	22. Research aimed at the development of space technologies and earth surface sensing tools

The clear leader in relevance among the proposed new directions is *"Development of Modern Systems to Counter UAVs, Guided Missiles"* (see Fig. 2.3). However, even in this area, there is a shortage of talent and equipment.

FIGURE 2.3.

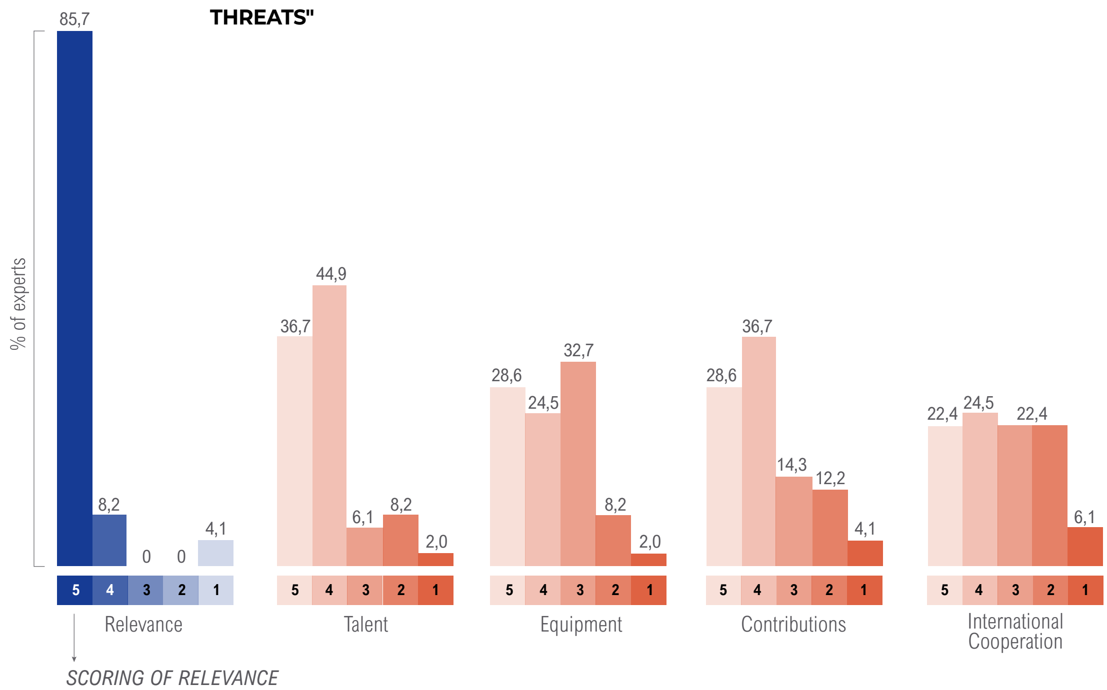
DISTRIBUTION OF SCORES FOR THE DIRECTION:
"DEVELOPMENT OF MODERN SYSTEMS TO COUNTER UAVS, GUIDED MISSILES"



A comparable situation arises in the area of "*Missile and anti-missile technologies: improving missile systems and air and missile defense systems capable of effectively responding to various threats."* This research direction is rated higher than others across all potential indicators. However, a major challenge remains: outdated equipment, which is a significant barrier to progress.

FIGURE 2.4.

DISTRIBUTION OF SCORES FOR THE DIRECTION:
"MISSILE AND ANTI-MISSILE TECHNOLOGIES: IMPROVING MISSILE SYSTEMS AND AIR AND MISSILE DEFENSE SYSTEMS CAPABLE OF EFFECTIVELY RESPONDING TO VARIOUS THREATS"

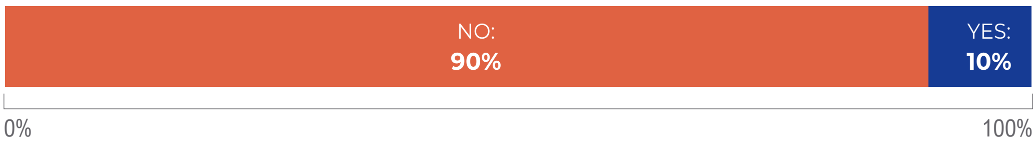


Experts were additionally asked to assess **the state of the country's science and technology policy.** 89.6% of experts in this cluster of studies believe that the government has not yet developed a science and technology policy adequate to the current situation (see Fig. 2.5).

FIGURE 2.5.

PRESENCE OF STATE POLICY

(responses to the question "Do you agree that the state has established a science and technology policy that is suitable for the present circumstances?")

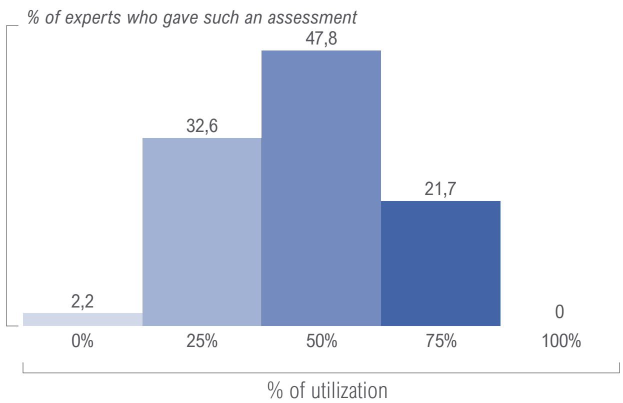


Experts assess the utilization of Ukraine's science and technology potential as very low. In the cluster *"Research and Development for National Security and Defense, Dual-Use Technologies"* the most common rating of potential utilization is 50% (see Fig. 2.6).

FIGURE 2.6.

UTILIZATION OF SCIENTIFIC AND TECHNOLOGICAL POTENTIAL BY THEMATIC DIRECTION

(responses to the question "Approximately, to what percentage do you estimate the scientific and technological potential of the country is currently being utilized?")



The extreme conditions of war have made Ukraine's need for scientific and technological advancements in national security and defense more critical than ever. This urgent need should motivate the creation of a robust and effective national innovation policy, drawing upon historical examples where Ukraine has successfully leveraged similar situations to drive innovation.

Digital Technologies, Artificial Intelligence, and Cybersecurity

The survey on the research cluster *"Information and Communication Technologies, Digital Technologies, Artificial Intelligence, Robotics, Cybersecurity"* included 37 experts, among them four Academicians and Corresponding Members of the National Academy of Sciences of Ukraine (NASU), 23 Doctors of Sciences, and 10 Candidates of Sciences. Proposals directly related to this field were also made by experts from other clusters.

Ukraine boasts a rich history and strong traditions in these disciplines. A landmark achievement was the creation of MESM in 1950, the first electronic computer in continental Europe, built in Kyiv at the Institute of Electrical Engineering of the Ukrainian SSR Academy of Sciences under the guidance of Academician Sergey Lebedev.

This legacy continued with the establishment of the Institute of Cybernetics at NASU in 1962 by renowned computer scientist Academician Viktor Glushkov. Robust scientific schools also emerged in Lviv, Kharkiv, Odesa, and other cities. This strong foundation in research and development paved the way for the rise of a powerful IT sector in independent Ukraine, with ongoing pioneering research in various fields.

A testament to this continued excellence is Ukrainian scientist Illia Polosukhin, co-author of foundational work on large language models, which underpin modern technologies like ChatGPT.

“Table 3.1” presents the average scores for 10 research directions identified in the previous survey conducted in 2021.

TABLE 3.1.

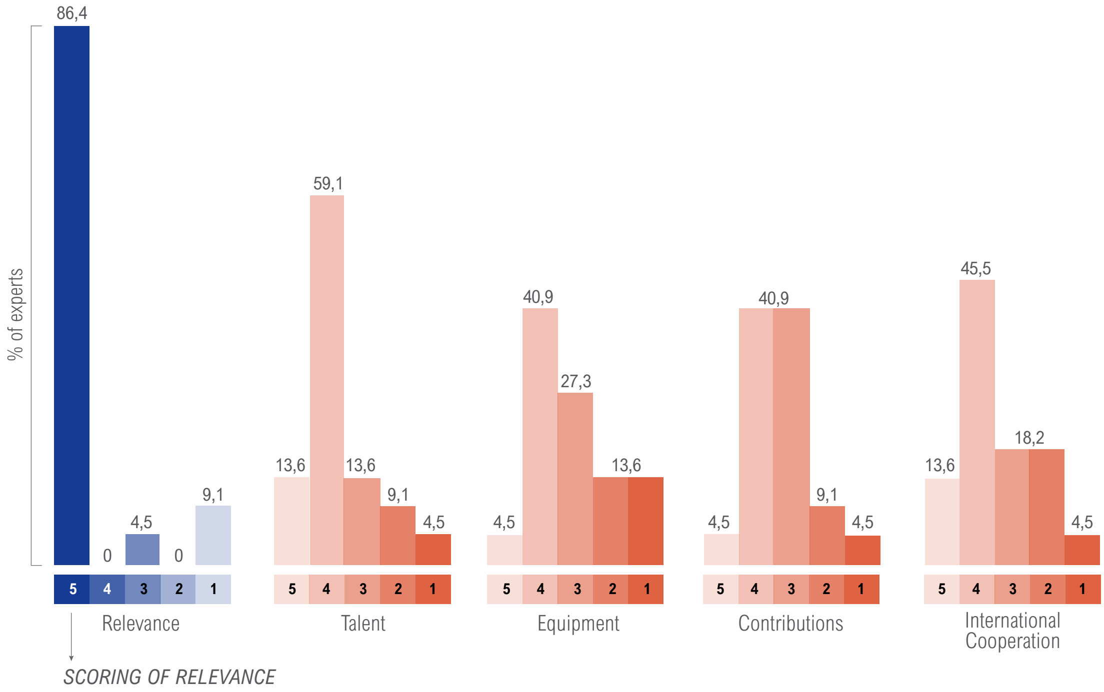
RESEARCH DIRECTIONS WITHIN THE RESEARCH CLUSTER: **"INFORMATION AND COMMUNICATION TECHNOLOGIES, DIGITAL TECHNOLOGIES, ARTIFICIAL INTELLIGENCE, ROBOTICS, CYBERSECURITY"** ACCORDING TO THE 2021 LIST, AND THE CURRENT ASSESSMENT OF THEIR RELEVANCE AND POTENTIAL

TOP RELEVANCE (Percentage of experts who gave the highest Relevance score – 5 points, %)	*AVERAGE SCORE*					*RESEARCH DIRECTION*
	Relevance	Talent	Equipment	Contributions	International Cooperation	
83%	*4,44*	*3,50*	*2,83*	*3,22*	*3,33*	1. Ensuring cybersecurity of state critical infrastructure
50%	*4,00*	*3,53*	*2,75*	*3,47*	*3,59*	2. Cloud and Grid technologies
59%	*4,35*	*3,33*	*2,82*	*3,00*	*2,94*	3. Development of quantum information protection technologies, including quantum cryptography
71%	*4,53*	*3,56*	*3,06*	*3,41*	*3,12*	4. Cybersecurity of automated control systems for technological processes
50%	*4,06*	*2,72*	*2,61*	*2,59*	*2,76*	5. Psychological security of individuals and communities in cyberspace
82%	*4,59*	*3,11*	*2,83*	*3,00*	*3,11*	6. Rapid conversion of scientific research into breakthrough applied developments through broad cooperation
39%	*3,94*	*3,33*	*2,83*	*2,94*	*2,78*	7. Theoretical and practical foundations of digital transformation of scientific and educational processes
50%	*4,11*	*3,50*	*3,00*	*3,35*	*3,11*	8. Risk management research to identify industrial cyber risks affecting the environment
50%	*4,06*	*3,11*	*3,00*	*2,59*	*2,94*	9. Legal support of information security for individuals, society, and the state
75%	*4,38*	*3,69*	*2,94*	*3,60*	*2,94*	10. Application of information technologies in medicine

The research direction *"**Ensuring Cybersecurity of State Critical Infrastructure**"* was identified as highly important, with over 80% of experts affirming its relevance (see Fig. 3.1). However, most experts noted that while there are qualified specialists, the equipment is significantly outdated, and they were skeptical about the actual scientific contributions.

FIGURE 3.1.

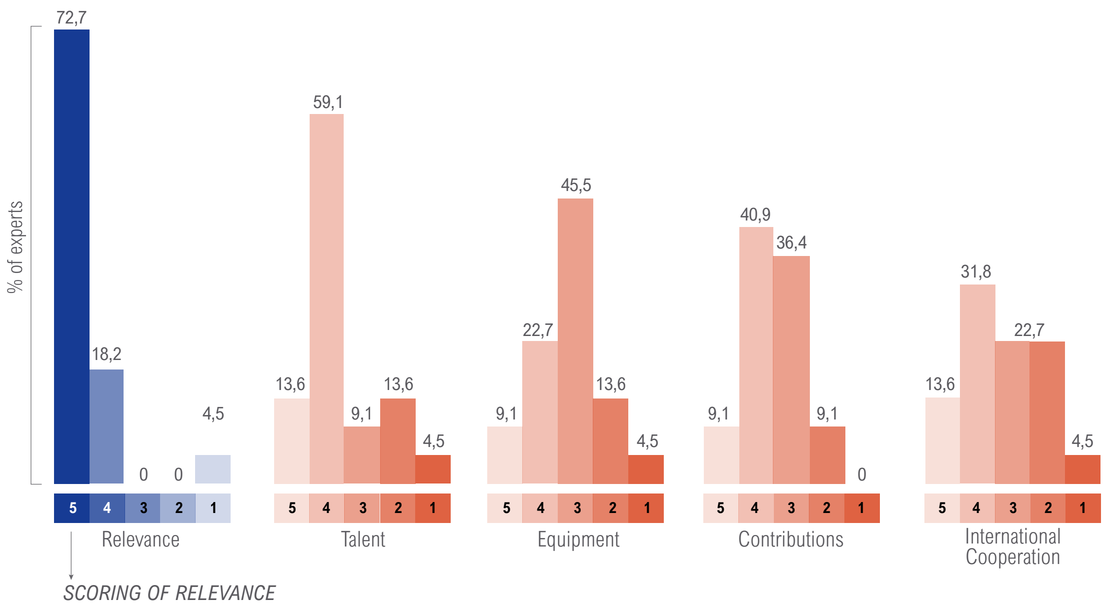
DISTRIBUTION OF SCORES FOR THE RESEARCH DIRECTION:
"ENSURING CYBERSECURITY OF STATE CRITICAL INFRASTRUCTURE"



The research direction *"Application of Information Technologies in Medicine"* received almost unanimous support (Fig. 3.2), with 75% of experts confirming its relevance, the presence of specialists, and contributions. IT specialists support the digitalization of medicine. Importantly, medical experts in the research cluster 6 *"Healthcare, New Medical Tools and Technologies,"* also supported it. However, traditional for Ukrainian science problems with equipment and international cooperation are noted.

FIGURE 3.2.

DISTRIBUTION OF SCORES FOR THE RESEARCH DIRECTION:
"APPLICATION OF INFORMATION TECHNOLOGIES IN MEDICINE"



Direction *"Rapid conversion of scientific research into breakthrough applied developments through broad cooperation"* also received high relevance ratings. However, such a formulation is unlikely to be classified as a research direction, although solving this issue is undoubtedly a crucial task for Ukraine. Nevertheless, we believe it should be emphasized in recommendations for improving science policy and removed from the research priorities of this cluster.

The research topic *"Theoretical and Practical Foundations of Digital Transformation of Scientific and Educational Processes"* appears to be problematic. Fewer than 40% of experts regard it as relevant and there is skepticism about the feasibility of prioritizing its development at this time.

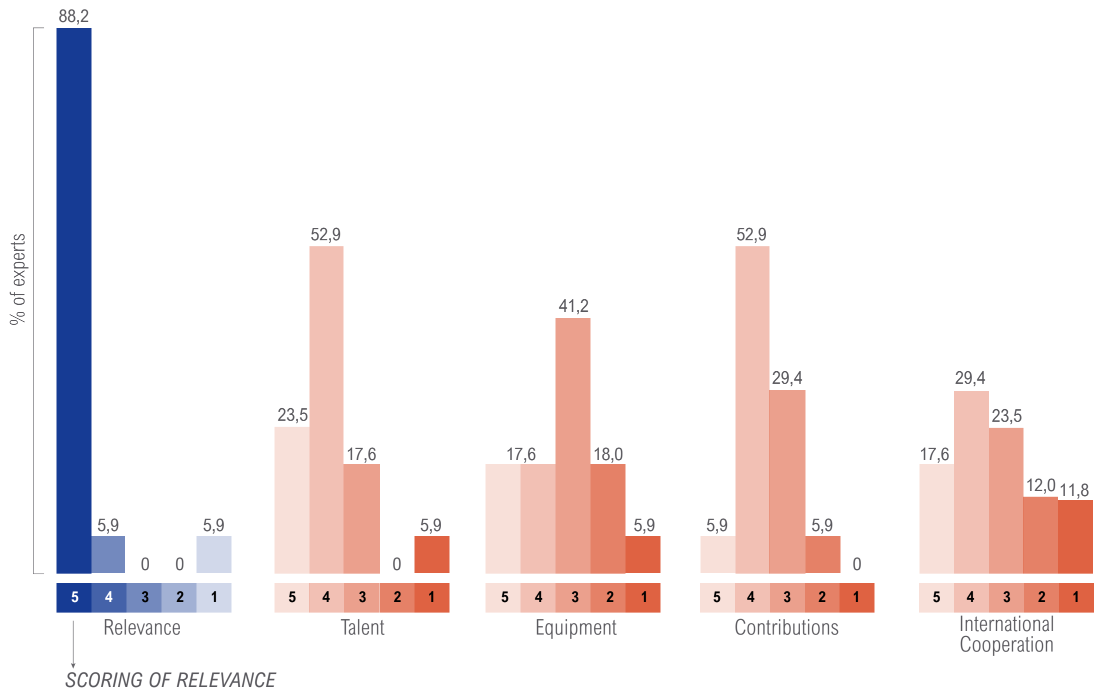
Only half of the experts affirm the relevance of the research topic *"Risk Management Research to Identify Industrial Cyber Risks Affecting the Environment."* However, over 60% believe that Ukraine has talent capable of advancing this research, despite challenges related to equipment and limited contributions.

Similarly, 50% of experts recognize the relevance of the research topic *"Legal Support of Information Security for Individuals, Society, and the State."* About 30% of experts, while not dismissing its importance, express doubts about whether it is worthwhile to focus on this critical issue in the context of the ongoing Russian invasion.

"Table 3.2" presents a summarized assessment of the most supported new ideas for supplementing the list of promising research directions within this research cluster.

FIGURE 3.3.

DISTRIBUTION OF SCORES FOR THE RESEARCH DIRECTION:
"DEVELOPMENT OF ADAPTIVE CYBERSECURITY SYSTEMS."



It should be noted that the relevance of this research direction is rapidly increasing with digitalization.

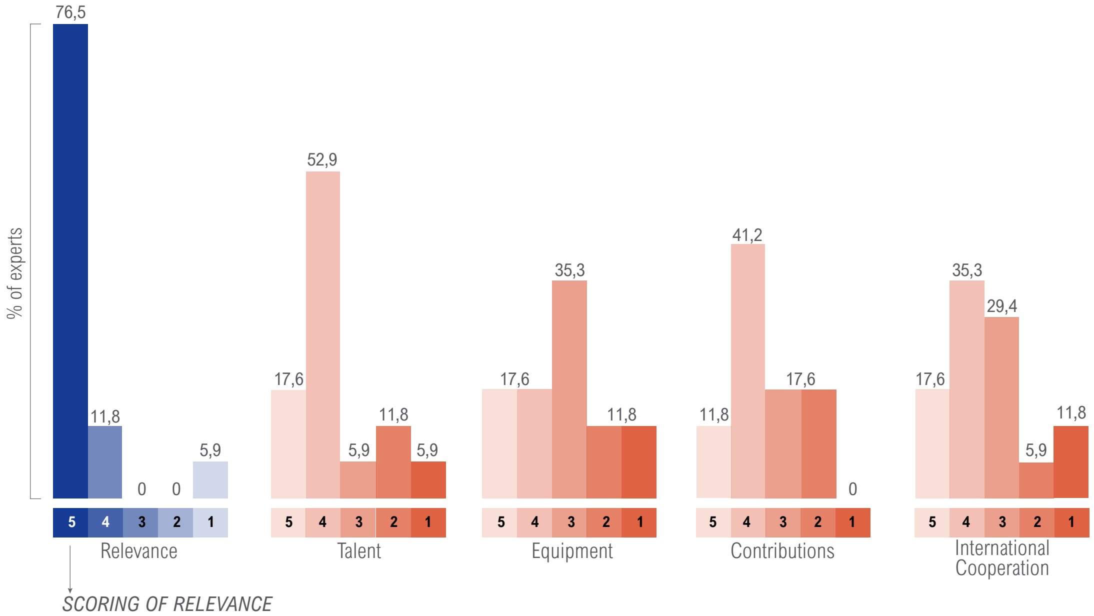
TABLE 3.2

NEW IDEAS FOR RESEARCH DIRECTIONS WITHIN THE CLUSTER: **"INFORMATION AND COMMUNICATION TECHNOLOGIES, ARTIFICIAL INTELLIGENCE, ROBOTICS, CYBERSECURITY"** AND EVALUATION OF THEIR RELEVANCE AND POTENTIAL

TOP RELEVANCE (Percentage of experts who gave the highest Relevance score – 5 points, %)	Relevance	Talent	Equipment	Contributions	International Cooperation	*RESEARCH DIRECTION*
	AVERAGE SCORE					
88%	4,71	3,88	3,24	3,63	3,31	1. Development of adaptive cybersecurity systems
81%	4,63	3,69	3,19	3,53	3,41	2. Development and management of autonomous AI systems; research on swarm intelligence of autonomous entities
76%	4,59	3,71	3,31	3,24	3,29	3. Cybersecurity and functional safety of unmanned/mobile systems and robotic complexes
65%	4,41	3,65	3,18	3,29	3,29	4. Ensuring cybersecurity of robotic process management systems
53%	4,00	3,35	3,06	3,13	3,12	5. Autonomous systems based on "strong AI"
47%	4,00	3,12	2,88	3,00	3,12	6. Development of AI technology in the public safety sector
35%	3,82	3,18	3,06	3,00	3,24	7. Development of ethical and transparent AI algorithms
35%	4,06	3,12	2,71	2,76	2,94	8. Quantum computing and quantum information technologies
35%	3,94	2,94	3,18	2,53	3,18	9. Legal regulation of AI technology usage
24%	3,65	3,00	2,76	2,94	2,88	10. Cognitive technologies
24%	3,76	3,35	3,13	3,24	3,18	11. Reconfigurable computing
24%	3,59	3,06	2,82	2,88	2,82	12. Enhancing the reliability of information transmitted at speeds close to the channel's bandwidth capacity
24%	3,82	3,41	3,12	3,00	3,18	13. Internet of Things; digital transformation of the household-service sector
12%	3,35	2,82	2,76	2,59	2,76	14. Social informatics

FIGURE 3.4.

DISTRIBUTION OF SCORES FOR THE DIRECTION:
"DEVELOPMENT AND MANAGEMENT OF AUTONOMOUS AI SYSTEMS; RESEARCH ON SWARM INTELLIGENCE OF AUTONOMOUS ENTITIES"

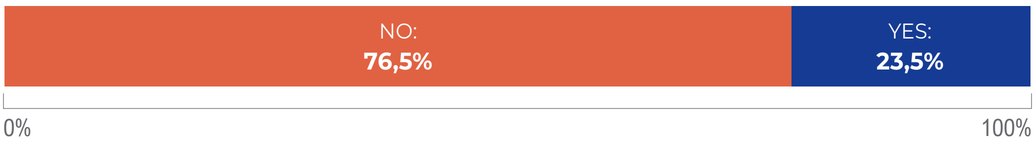


As noted, this research direction receives strong support from IT specialists and has been prominently featured in Cluster 2, *"Research and Development for National Security and Defense, Dual-Use Technologies"* (Figure 2.2). Despite its significant relevance, there are ongoing concerns regarding the level of capabilities available to effectively pursue this area of study.

FIGURE 3.5.

PRESENCE OF STATE POLICY

(responses to the question "Do you agree that the state has established a science and technology policy that is suitable for the present circumstances?")

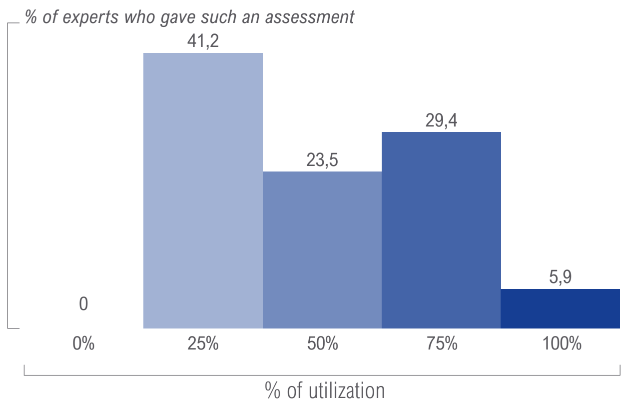


Only 23.5% of experts believe that the state has established a clear science and technology policy. However, this figure is notably higher than the percentages reported by experts in other research clusters, with the exception of the energy sector. Therefore, it can be concluded that the government's efforts to stimulate advancements in this area are beginning to yield results, although these outcomes have not yet reached an acceptable level.

FIGURE 3.6.

UTILIZATION OF SCIENTIFIC AND TECHNOLOGICAL POTENTIAL BY RESEARCH DIRECTION

(responses to the question "Approximately, to what percentage do you estimate the scientific and technological potential of the country is currently being utilized?")



The low level of utilization of the existing scientific and technological potential indicates that researchers may not be sufficiently involved in implementing state programs for the deployment of digital technologies and artificial intelligence, such as the "Drone Army," "Robot Army," and others.

New Substances and Nanotechnologies

In the research cluster *"New Substances and Materials, Nanotechnologies, and Additive Technologies"* 64 experts were engaged, including 5 Academicians, 15 Corresponding Members of the National Academy of Sciences of Ukraine (NASU), 32 Doctors of Sciences, and 12 Candidates of Sciences.

Materials science research within the National Academy of Sciences of Ukraine (NASU) boasts a strong legacy, driven largely by the demands of the Soviet military-industrial complex before Ukraine's independence. Prime examples of this collaboration include developing new materials for ballistic missiles and pioneering welding technologies, where Ukraine held a global lead for decades. This central role of materials science was further cemented by the long tenure of Academician Borys Paton, Director of the E. Paton Electric Welding Institute of NASU, who presided over the Academy from 1962 to 2020.

During this period, materials science institutes spearheaded the renowned "Paton Maneuver," a strategic approach to scientific development that even catalyzed the emergence of new industrial sectors. However, economic hardships have since significantly diminished the demand for materials science research and development, impacting both the research itself and its potential applications.

“Table 4.1” provides the current average scores for 10 research directions identified in the previous survey conducted in 2021.

TABLE 4.1.

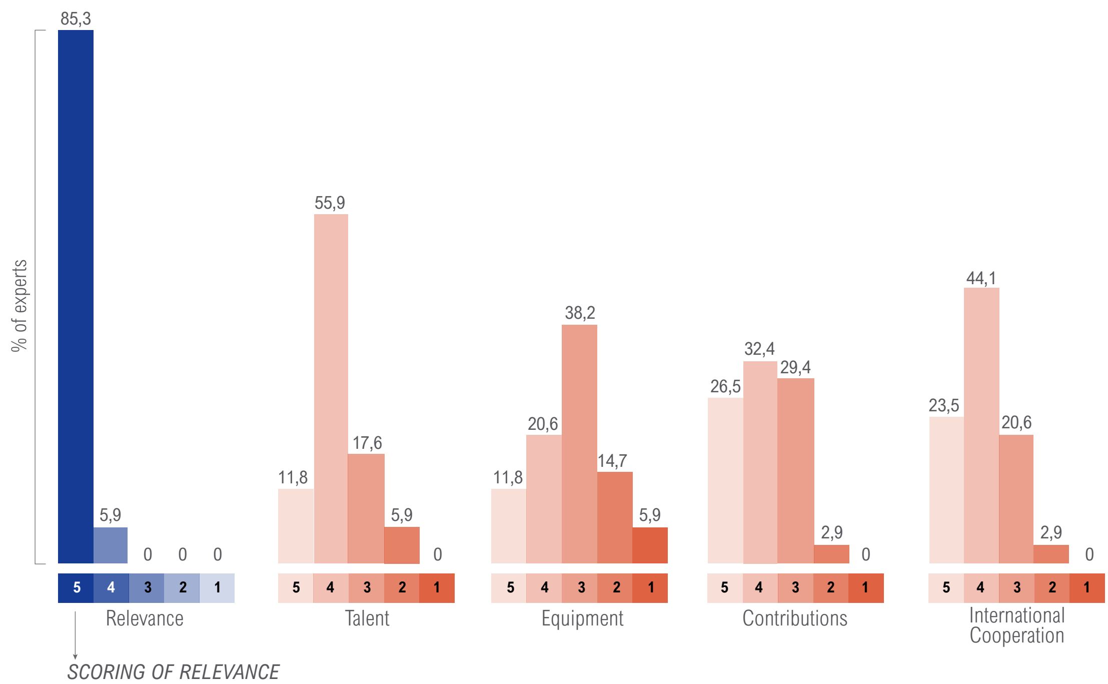
RESEARCH DIRECTIONS WITHIN THE RESEARCH CLUSTER **"NEW SUBSTANCES AND MATERIALS, NANOTECHNOLOGIES, AND ADDITIVE TECHNOLOGIES"** ACCORDING TO THE 2021 LIST, AND THE CURRENT ASSESSMENT OF THEIR RELEVANCE AND POTENTIAL

TOP RELEVANCE (Percentage of experts who gave the highest Relevance score – 5 points, %)	*AVERAGE SCORE*					*RESEARCH DIRECTION*
	Relevance	Talent	Equipment	Contributions	International Cooperation	
94%	4,94	3,81	3,19	3,90	3,97	1. Physicochemical aspects of obtaining new materials, including the development of scientific foundations and methodologies for producing nanomaterials for various industries, notably medicine and environmental protection
28%	3,88	3,33	2,88	2,96	2,71	2. Developments and research aimed at decarbonizing metallurgical production
60%	4,32	3,60	3,00	3,24	3,40	3. Membrane materials and technologies, substance separation
74%	4,63	3,74	3,26	3,30	3,37	4. Creation, research, and implementation of polymer composites, including their manufacturing and joining technologies
81%	4,63	3,65	3,38	3,70	3,54	5. Fluorine-containing compounds for treating cancer, viral, and cardiovascular diseases, alongside high-strength materials like titanium and aluminum
40%	4,20	3,64	3,32	3,36	3,27	6. New substances for agrochemistry (fine organic synthesis products for plant protection and agricultural production)
93%	4,93	3,86	3,34	3,66	3,76	7. New substances and materials for renewable energy, focusing on developing compact, efficient devices for energy generation and storage, including new materials for ion batteries and supercapacitors
35%	3,81	3,08	2,80	2,96	3,08	8. Functional materials capable of actively responding to changes in independent thermodynamic parameters
37%	3,93	3,31	3,15	3,23	3,08	9. Development of physicochemical foundations for inorganic material formation technologies
81%	4,67	3,81	3,41	3,74	3,44	10. Development of theoretical foundations and technological processes for obtaining high-wear-resistant nanostructured surfaces on products, multilayer cast reinforced structures, and composite materials ensuring reliable operation under increased wear, variable loads, and aggressive environments

The leading research directions in terms of relevance are *"Physicochemical Aspects of Obtaining New Materials, including for the Development of Scientific Foundations and Methodologies for Producing Nanomaterials for Various Sectors, Particularly Medicine and Environmental Protection"* (Fig. 4.1) and *"New Substances and Materials for Renewable Energy, Focusing on Developing Compact, Efficient Devices for Energy Generation and Storage, Including New Materials for Ion Batteries and Supercapacitors"* (Fig. 4.2). Ukrainian scientists have significant achievements and talent in these areas. International cooperation is also most developed in these directions, often involving close collaboration with foreign colleagues. For example, the synthesis of new materials may occur in Ukraine, while the resulting samples are studied in the EU and the USA

FIGURE 4.1.

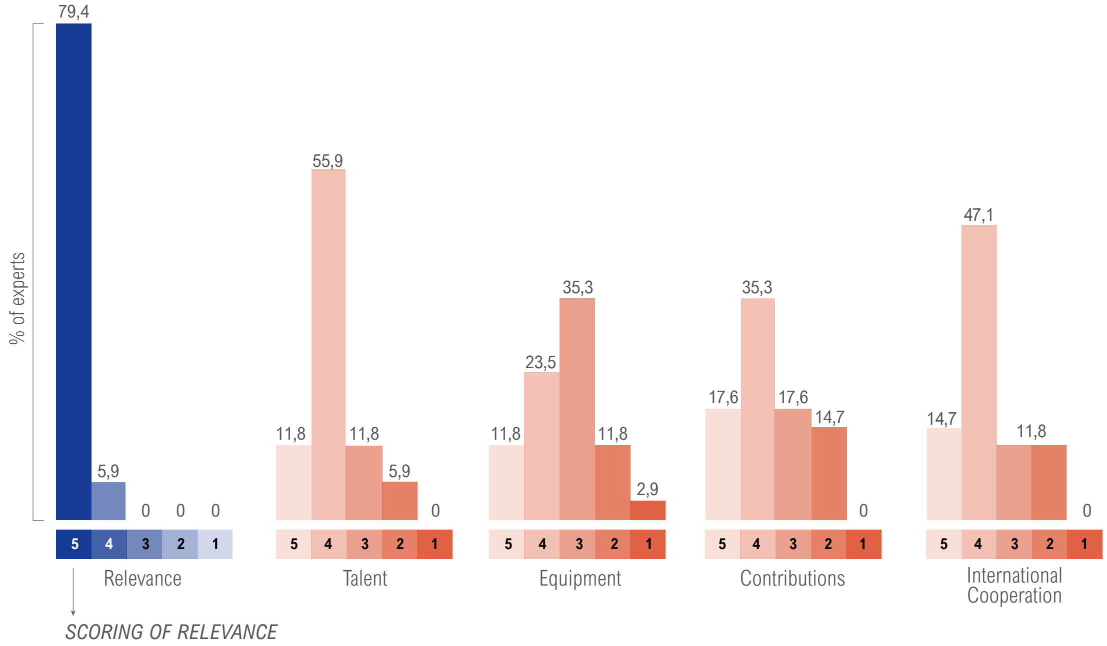
DISTRIBUTION OF SCORES FOR THE DIRECTION:
"PHYSICOCHEMICAL ASPECTS OF OBTAINING NEW MATERIALS, INCLUDING FOR THE DEVELOPMENT OF SCIENTIFIC FOUNDATIONS AND METHODOLOGIES FOR PRODUCING NANOMATERIALS FOR VARIOUS SECTORS, PARTICULARLY MEDICINE AND ENVIRONMENTAL PROTECTION"



Fundamental research in this area is especially crucial due to the increasing use of nanomaterials with unique properties. While these materials offer significant potential, their impact on ecosystems, wildlife, and their overall environmental stability remain poorly understood, highlighting the need for further investigation.

FIGURE 4.2.

DISTRIBUTION OF SCORES FOR THE DIRECTION:
"NEW SUBSTANCES AND MATERIALS FOR RENEWABLE ENERGY, FOCUSING ON DEVELOPING COMPACT, EFFICIENT DEVICES FOR ENERGY GENERATION AND STORAGE, INCLUDING NEW MATERIALS FOR ION BATTERIES AND SUPERCAPACITORS"



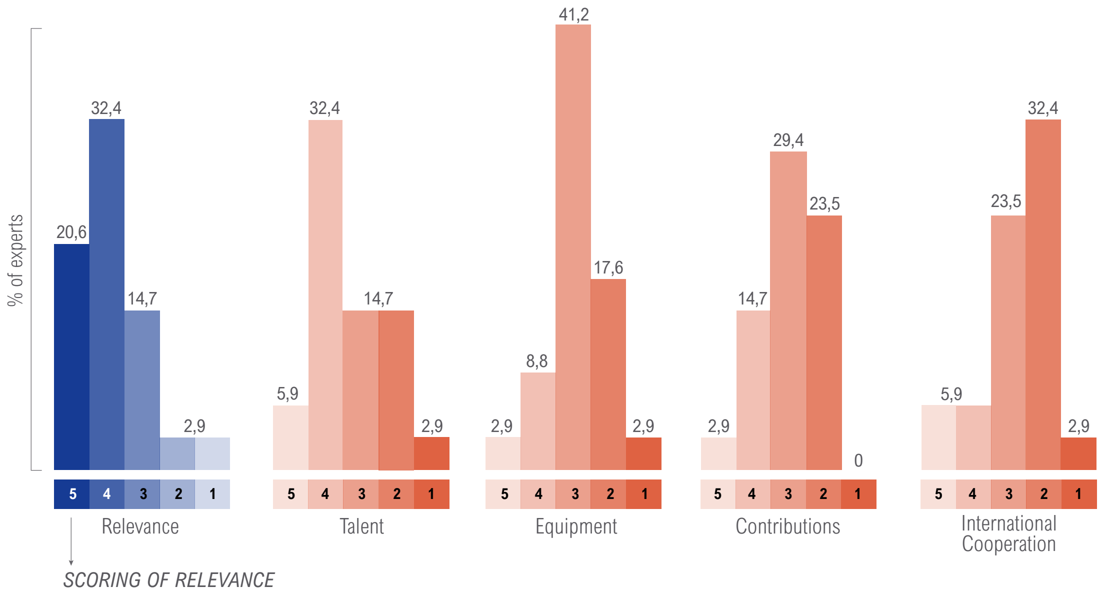
It is possible that the creation of new materials will define the main directions for the development of renewable and distributed energy.

Significantly less relevant are the directions:

- Developments and research aimed at decarbonizing metallurgical production (Fig. 4.3).
- Functional materials capable of actively responding to changes in independent thermodynamic parameters (Fig. 4.4).
- Development of physicochemical foundations for inorganic material formation technologies.

FIGURE 4.3.

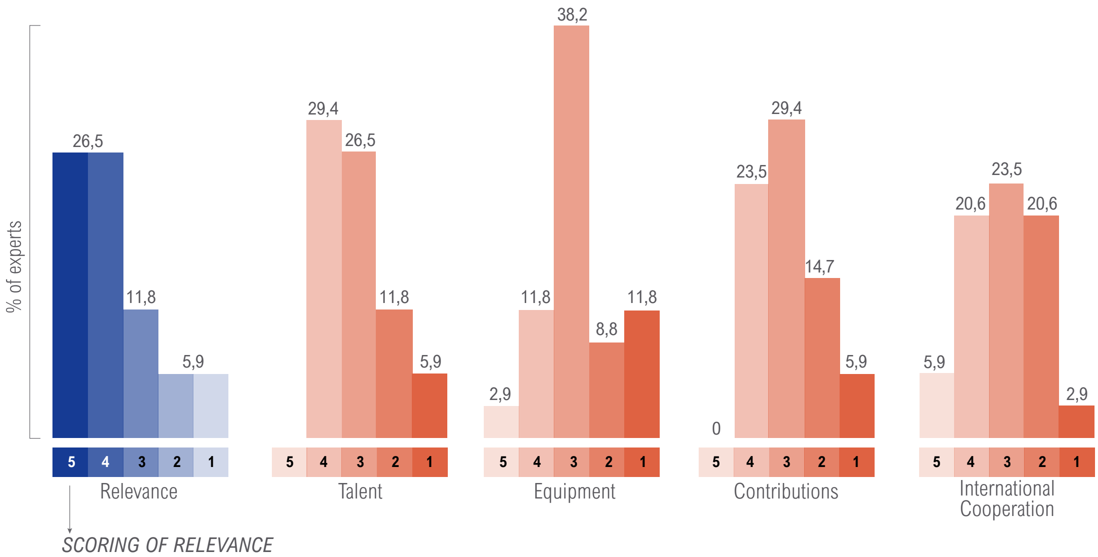
DISTRIBUTION OF SCORES FOR THE DIRECTION:
"DEVELOPMENTS AND RESEARCH AIMED AT DECARBONIZING METALLURGICAL PRODUCTION"



It is difficult to argue that in the context of intense war and post-war recovery, the decarbonization of metallurgy is not timely.

FIGURE 4.4.

DISTRIBUTION OF SCORES FOR THE DIRECTION:
“FUNCTIONAL MATERIALS CAPABLE OF ACTIVELY RESPONDING TO CHANGES IN INDEPENDENT THERMODYNAMIC PARAMETERS”



Research in this area may yield interesting results, but most experts do not consider it worthy of priority support.

“Table 4.2.” summarizes the expert-supported new ideas for enhancing the list of promising research directions within this research cluster.

The most supported new research directions are:

- Development of alternative and autonomous energy sources and materials for their support.
- Development of fundamental and technological foundations for high-strength, wear-resistant alloys with enhanced performance in aggressive environments for aviation and military needs.
- Restoration of the production cycle of gunpowder and explosives (beginning with nitric acid production).

Despite the lack of international cooperation and challenging equipment conditions, experts consider the restoration of the full production cycle of explosives to be an extremely relevant and feasible task, given sufficient state interest (see Figure 4.5).

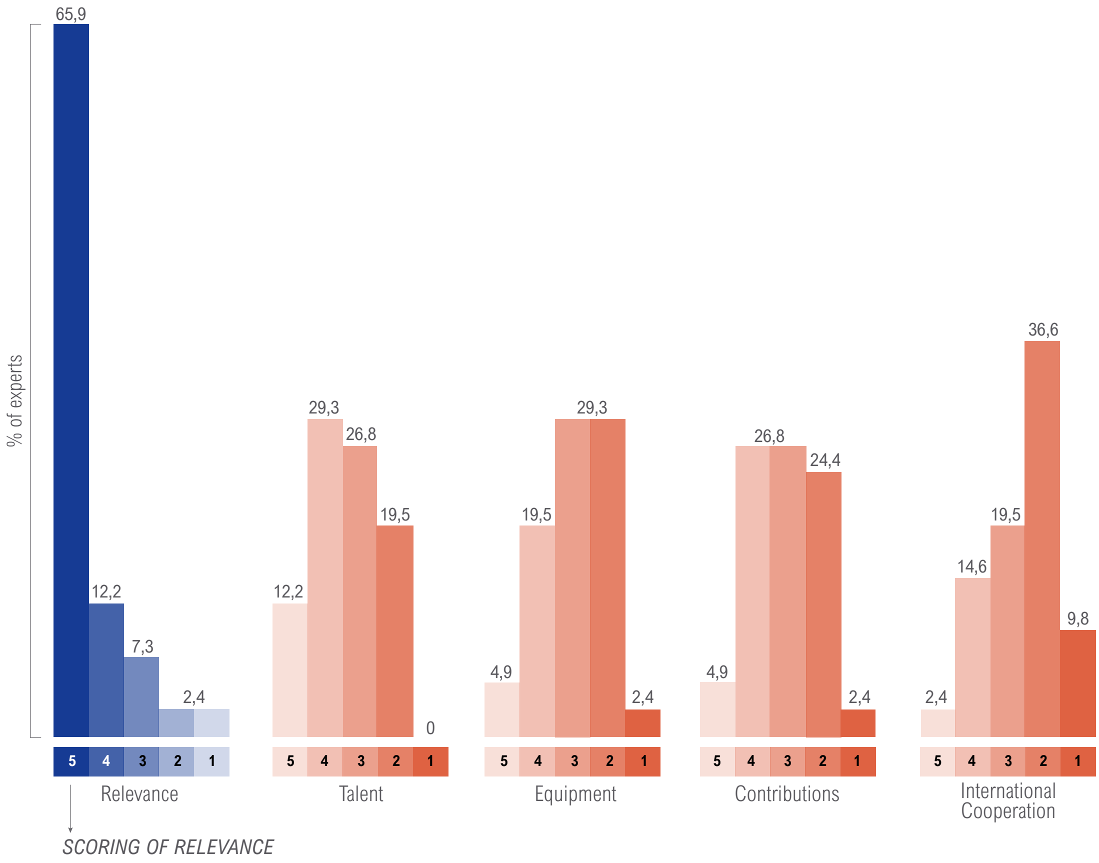
TABLE 4.2.

NEW IDEAS FOR RESEARCH DIRECTIONS WITHIN THE CLUSTER: **"NEW SUBSTANCES AND MATERIALS, NANOTECHNOLOGIES, AND ADDITIVE TECHNOLOGIES"**: EVALUATION OF THEIR RELEVANCE AND POTENTIAL

TOP RELEVANCE (Percentage of experts who gave the highest Relevance score – 5 points, %)	Relevance	Talent	Equipment	Contributions	International Cooperation	*RESEARCH DIRECTION*
			AVERAGE SCORE			
73%	4,51	3,39	2,94	3,09	2,56	1. Restoration of the production cycle of gunpowder and explosives (beginning with nitric acid production)
72%	4,54	3,47	2,97	3,03	3,24	2. Development of alternative and autonomous energy sources and materials for their support
71%	4,45	3,92	3,34	3,83	3,31	3. Development of fundamental and technological foundations for high-strength, wear-resistant alloys with enhanced performance in aggressive environments for aviation and military needs
66%	4,39	3,73	3,28	3,67	3,35	4. Biocompatible materials for implantation, prosthetics, and rehabilitation
63%	4,40	3,46	3,00	3,32	3,26	5. 3D printing technologies and additive manufacturing for metal, ceramic, and composite materials
59%	4,31	3,55	3,09	3,31	3,09	6. Creation of ultralight materials for aviation technology
54%	4,27	3,75	3,29	3,66	3,49	7. Nanomaterials for biomedical and pharmaceutical applications
49%	4,18	3,50	3,08	3,31	3,19	8. Functional materials for hydrogen generation, storage, and utilization for alternative energy
47%	4,00	3,50	3,11	3,29	3,20	9. Materials for solar cells
46%	4,00	3,21	2,89	3,22	3,16	10. Smart materials

FIGURE 4.5.

DISTRIBUTION OF SCORES FOR THE DIRECTION:
"RESTORATION OF THE PRODUCTION CYCLE OF GUNPOWDER AND EXPLOSIVES (BEGINNING WITH NITRIC ACID PRODUCTION)"



This is primarily a direction for the development of the defense industry, but undoubtedly requires scientific support.

FIGURE 4.6.

PRESENCE OF STATE POLICY

(responses to the question "Do you agree that the state has established a science and technology policy that is suitable for the present circumstances?")

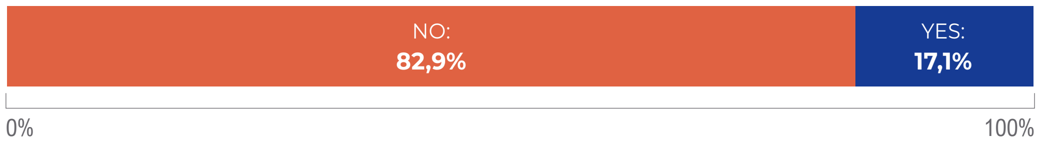
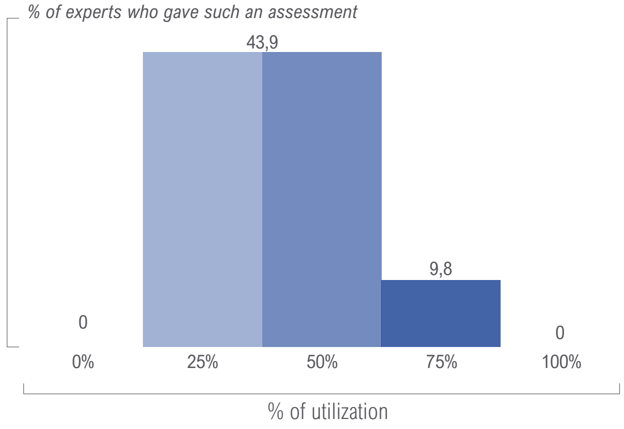


FIGURE 4.7.

UTILIZATION OF SCIENTIFIC AND TECHNOLOGICAL POTENTIAL BY RESEARCH DIRECTION

(responses to the question "Approximately, to what percentage do you estimate the scientific and technological potential of the country is currently being utilized?")



There's a clear consensus among materials science experts that their field's potential in Ukraine is significantly underutilized, though they differ on the degree. While half believe they are operating at only 50% of their potential, the other half estimate a stark 25% utilization.

Despite these challenges, Ukrainian materials science holds substantial untapped potential. By leveraging its existing expertise and resources, this sector can play a critical role in bolstering national defense and driving innovation-led economic recovery in the post-war period.

SECTION V

Efficiency, Reliability, and Safety of Energy

In the research cluster *"Efficiency, Reliability, and Safety of Energy"* 56 experts were involved, including 3 Academicians, 6 Corresponding Members of the National Academy of Sciences of Ukraine (NASU), 31 Doctors of Sciences, and 16 Candidates of Sciences.

In the latter half of the 20th century, a network of institutes in Ukraine addressed energy issues, actively supporting the rapid expansion of the country's energy system by tackling mainly applied problems. During periods when the USSR attempted to centralize applied science within industry ministries, Borys Paton made significant efforts to retain energy institutes within the NASU structure, thereby preserving the theoretical foundation for applied developments in this sector.

Over the past decade, attention to alternative energy sources has significantly increased. The introduction of "green tariffs," the widespread construction of solar power plants, and the search for energy independence have been prominent.

This research cluster gained particular relevance due to Russia's full-scale war against Ukraine in 2022. NASU institutions and scientists involved in developing strategies to enhance the resilience of the energy system and find optimal recovery methods after Russian attacks feel more valued by the state compared to researchers in other scientific fields.

"Table 5.1" provides the average scores for 15 research directions identified in the previous survey conducted in 2021.

TABLE 5.1.

RESEARCH DIRECTIONS WITHIN THE RESEARCH CLUSTER **"EFFICIENCY, RELIABILITY, AND SAFETY OF ENERGY"** ACCORDING TO THE 2021 LIST, AND THE CURRENT ASSESSMENT OF THEIR RELEVANCE AND POTENTIAL

TOP RELEVANCE (Percentage of experts who gave the highest Relevance score – 5 points, %)	AVERAGE SCORE: Relevance	Talent	Equipment	Contributions	International Cooperation	RESEARCH DIRECTION
82%	4,68	3,73	3,28	3,77	3,39	1. Development of new and improvement of existing technologies for energy resource conservation and increasing the share of renewable energy sources and alternative fuels in Ukraine's energy balance
48%	4,14	3,21	2,71	3,14	3,07	2. Development of new technologies for high-pressure hydrogen production and its use in the energy sector
75%	4,64	3,73	3,34	3,73	3,20	3. Development of technologies and systems to extend the lifespan of complex energy infrastructures and traditional and renewable electricity systems
63%	4,45	3,58	3,03	3,24	2,79	4. Enhancing the energy efficiency, reliability, and safety of power transmission systems in industrial regions and megacities of Ukraine, particularly using modern power cables with solid nanostructured insulation
67%	4,54	3,69	3,21	3,38	2,87	5. Improvement of electrical and semiconductor converters to enhance energy quality in networks of traditional, renewable, and autonomous energy sources and for implementing advanced industrial electrotechnologies
59%	4,41	3,43	2,98	3,12	2,85	6. Development of new technologies and electrical equipment implementing artificial intelligence in Ukraine's energy sector to improve safety, reliability, and energy resource efficiency
76%	4,59	3,90	3,29	3,59	3,38	7. Development of modern technologies for manufacturing reactor, turbine, thermahydraulic, and electrical equipment for domestic nuclear power plants
54%	4,31	3,72	3,21	3,39	3,00	8. Enhancement of monitoring systems for energy quality and diagnostics of reliability and environmental safety of traditional, renewable, and nuclear power plant facilities
37%	4,05	3,66	3,34	3,50	3,00	9. Development of modern methods for computational analysis of energy quality in power supply systems, as well as the reliability, environmental friendliness, and residual resource of their equipment (including nuclear power plants)
59%	4,41	3,71	3,15	3,54	2,98	10. Increasing the energy and environmental efficiency of technologies using carbon-containing raw materials (coal, ash, mine methane), hydrogen, and industrial waste
66%	4,50	3,58	3,03	3,29	2,97	11. Creation of technologies and equipment for producing materials resistant to extreme thermal and mechanical impacts in energy systems
78%	4,58	3,69	3,15	3,36	3,21	12. Development of alternative environmentally friendly technologies, equipment, and materials for creating modern autonomous power sources
22%	3,75	3,19	2,92	2,89	2,78	13. Creation of hybrid catalytic materials for electrodes of energy-conversion devices
50%	4,10	3,70	3,23	3,35	2,83	14. Scientific support for the development and moderniza-tion of turbines, compressors, and turbodetanders. Improvement of thermal schemes of power units
42%	4,11	3,55	3,26	3,47	2,92	15. Forecasting the reliability, dynamic strength, and resource of machine-building structures, elements of power plants, and other technical objects

The leading areas in terms of relevance, identified in 2021, include:

→ Development of new and improvement of existing technologies for energy resource conservation and increasing the share of renewable energy sources and alternative fuels in Ukraine's energy balance.

→ Development of alternative environmentally friendly technologies, equipment, and materials for modern autonomous power sources.

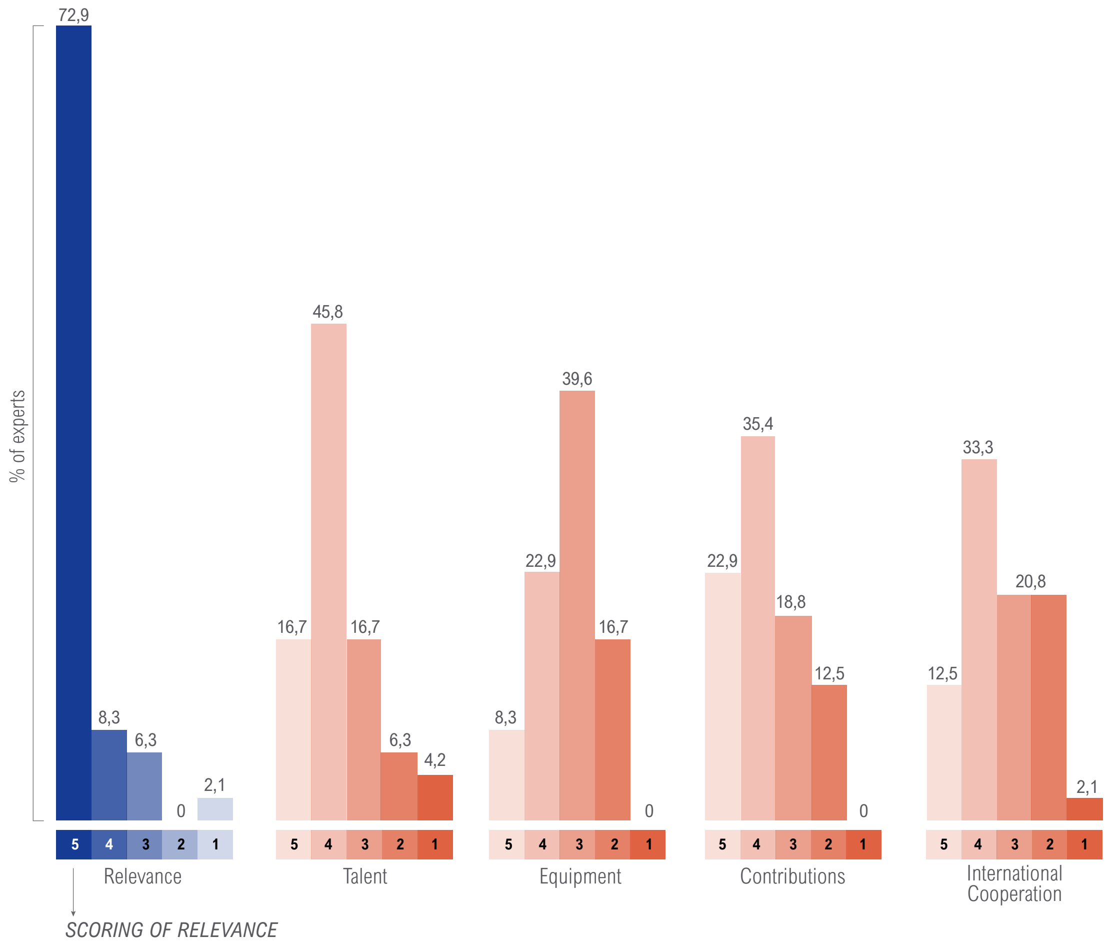
→ Development of modern technologies for manufacturing reactor, turbine, thermahydraulic, and electrical equipment for domestic nuclear power plants.

→ Development of technologies and systems to extend the lifespan of complex energy infrastructures and traditional and renewable electricity systems.

Beyond doubt, these must be retained in the updated list.

FIGURE 5.1.

DISTRIBUTION OF SCORES FOR THE DIRECTION
"DEVELOPMENT OF NEW AND IMPROVEMENT OF EXISTING TECHNOLOGIES FOR ENERGY RESOURCE CONSERVATION AND INCREASING THE SHARE OF RENEWABLE ENERGY AND ALTERNATIVE FUELS IN UKRAINE'S ENERGY BALANCE"



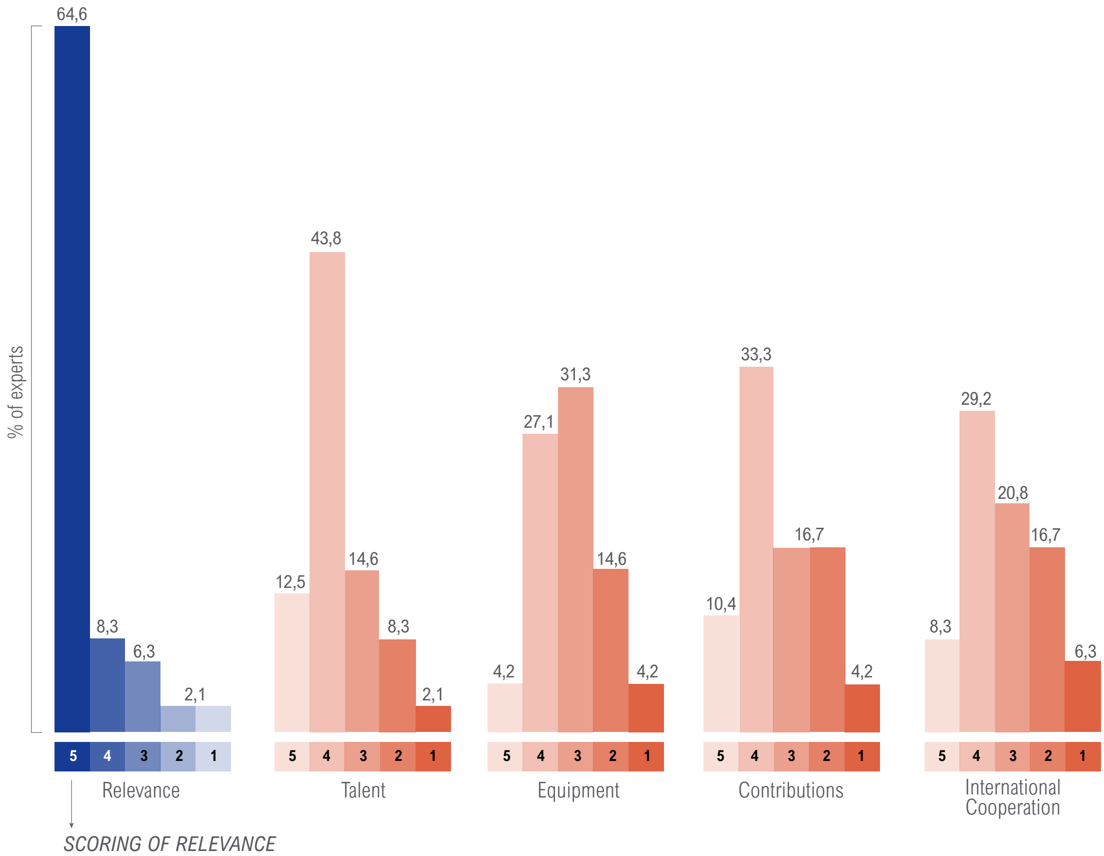
Scores for energy-saving technologies, renewable energy, and alternative fuels (Figure 5.1) reflect the current situation in Ukraine. Experts understand the importance and necessity of addressing these issues but confirm that research and development in this area have long been undervalued. The existing equipment is outdated, leading to unproductive time expenditures by researchers (dominant score of "3" on the "Equipment" scale).

A similar situation is noted for the creation of modern autonomous power sources (Figure 5.2): despite high relevance, experts report difficulties with equipment.

In both areas mentioned above, only 12.5% and 8% of experts, respectively, report participation in joint research with foreign scientists.

FIGURE 5.2.

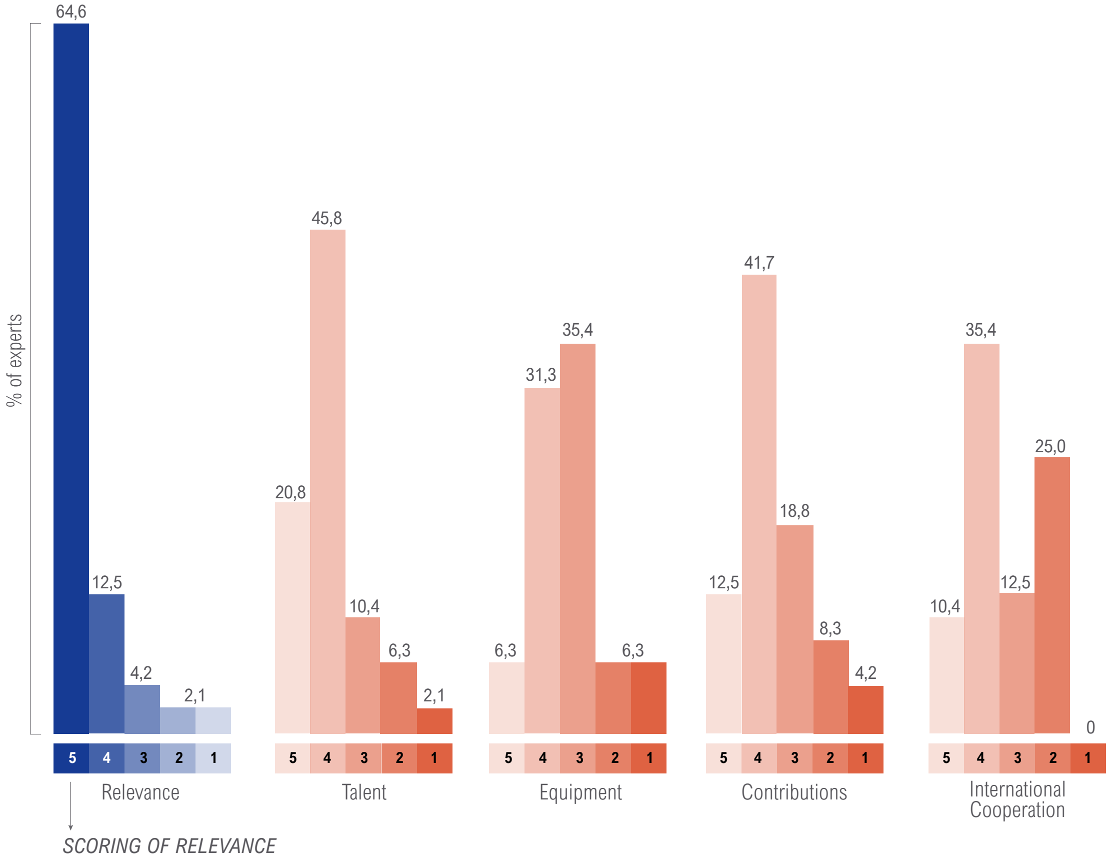
DISTRIBUTION OF SCORES FOR THE DIRECTION
"DEVELOPMENT OF ALTERNATIVE ENVIRONMENTALLY FRIENDLY TECHNOLOGIES, EQUIPMENT, AND MATERIALS FOR MODERN AUTONOMOUS POWER SOURCES”



The notably positive assessment of the originality of ideas within the research cluster focused on reactor, turbine, thermohydraulic, and electrical equipment for nuclear power plants (Figure 5.3) is significant. This indicates the potential for substantial advancements, given adequate support. Prioritizing this research direction could pave the way for the country’s energy independence.

FIGURE 5.3.

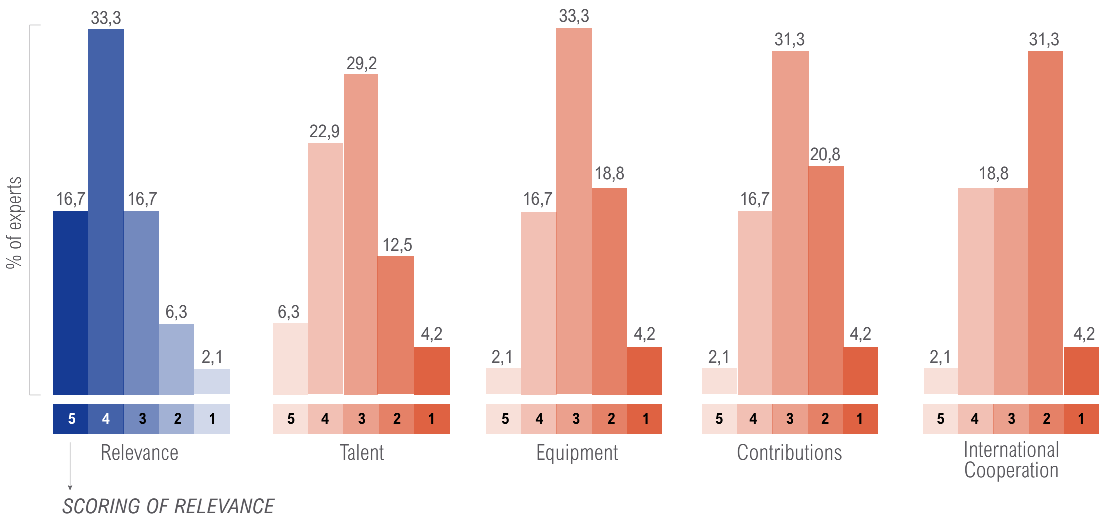
DISTRIBUTION OF SCORES FOR THE DIRECTION:
"DEVELOPMENT OF MODERN TECHNOLOGIES FOR MANUFACTURING REACTOR, TURBINE, THERMOHYDRAULIC, AND ELECTRICAL EQUIPMENT FOR NUCLEAR POWER PLANTS"



The most challenging area, according to experts, is the research direction of *"Creation of Hybrid Catalytic Materials for Electrodes in Energy-Conversion Devices"* (Figure 5.4). Only 22% of experts assesed it as highly relevant. Despite its potential being rated optimistically compared to some other directions, there is a lack of confidence in its significant relevance within the Ukrainian context. The prevailing opinion is that, despite its global scientific importance, Ukraine lacks the capacity to develop this area.

FIGURE 5.4.

DISTRIBUTION OF SCORES FOR THE DIRECTION
"CREATION OF HYBRID CATALYTIC MATERIALS FOR ELECTRODES IN ENERGY-CONVERSION DEVICES"



The worst situation regarding equipment availability is found in the research direction *"Development of New Technologies for High-Pressure Hydrogen Production and its Use in the Energy Sector"* (Figure 5.5). A quarter of experts note that only part of the necessary equipment for research is available.

FIGURE 5.5.

DISTRIBUTION OF SCORES FOR
"DEVELOPMENT OF NEW TECHNOLOGIES FOR HIGH-PRESSURE HYDROGEN PRODUCTION AND ITS USE IN THE ENERGY SECTOR"

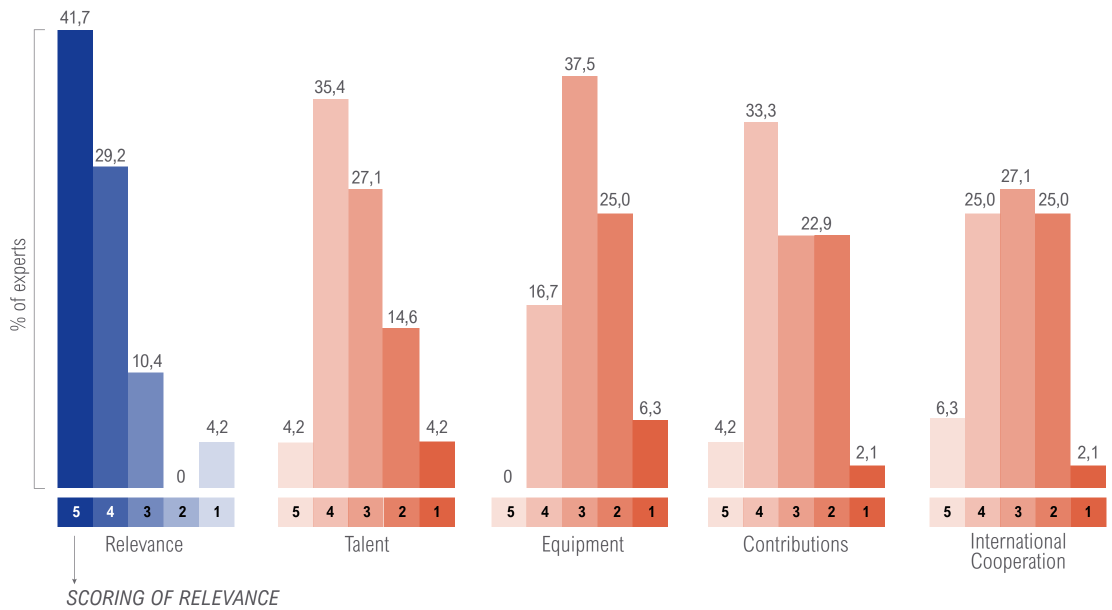


TABLE 5.2.

NEW IDEAS FOR RESEARCH DIRECTIONS WITHIN THE CLUSTER
"EFFICIENCY, RELIABILITY, AND SAFETY OF ENERGY" AND EVALUATION OF THEIR RELEVANCE AND POTENTIAL

TOP RELEVANCE (Percentage of experts who gave the highest Relevance score – 5 points, %)	Relevance	Talent	Equipment	Contributions	International Cooperation	RESEARCH DIRECTION
	AVERAGE SCORE					
83%	4,57	3,60	3,11	3,28	3,15	1. Security, resilience, and robustness of the country's energy system, installations, and systems against terrorist acts and military actions
76%	4,47	3,69	3,23	3,27	3,18	2. Development of means to ensure the safety of nuclear power plants
68%	4,45	3,66	3,18	3,27	3,11	3. Cybersecurity of large information exchange systems in the energy sector against cyber-espionage and cyber-terrorism
65%	4,41	3,61	3,15	3,39	3,07	4. Energy storage: development of technologies, equipment, and materials for creating modern energy storage systems with a wide range of capacities and power to support critical infrastructure and regulate consumption in energy systems

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TOP RELEVANCE
(Percentage of experts who gave the highest Relevance score – 5 points, %)

AVERAGE SCORE

Top relevance	Relevance	Talent	Equipment	Contributions	International Cooperation	*RESEARCH DIRECTION*
63%	*4,30*	*3,69*	*3,18*	*3,36*	*2,96*	5. Energy recovery, conservation of energy resources
62%	*4,38*	*3,72*	*3,45*	*3,45*	*3,28*	6. Scientific support for the creation of a distributed generation system: design, implementation, and operation
60%	*4,30*	*3,70*	*3,35*	*3,49*	*3,19*	7. Increasing energy efficiency of buildings: development of technologies, equipment, materials, and solutions for existing and new buildings
59%	*4,36*	*3,74*	*3,28*	*3,47*	*3,09*	8. Smart grids: research on development prospects and implementation of smart technologies to increase the reliability and efficiency of Ukraine's power systems
51%	*4,06*	*3,68*	*3,20*	*3,57*	*3,04*	9. Restoration of thermal power plants: improving the reliability and efficiency of equipment, load regulation range
50%	*4,18*	*3,53*	*3,17*	*3,26*	*2,91*	10. Development of concepts, creation of energy clusters, smart communities, and smart cities to maximize autonomy in energy supply and incorporate all available local energy sources into the energy balance
46%	*4,02*	*3,29*	*2,73*	*3,13*	*3,13*	11. Creation of technology for the production, transportation, and efficient use of new fuels, including green hydrogen and synthetic renewable methane, derived from the conversion of energy from renewable and alternative sources
43%	*4,20*	*3,59*	*3,07*	*3,35*	*3,02*	12. Energy use of biomass, peat, solid municipal waste, RDF: reconstruction of existing and creation of new thermal energy equipment
34%	*3,83*	*3,43*	*3,27*	*3,33*	*3,09*	13. Forecasting economic-energy development
33%	*3,71*	*3,09*	*2,66*	*2,64*	*2,80*	14. Research on the possibility and methods of replacing destroyed coal power plants with small modular reactors (SMRs)
32%	*3,84*	*3,28*	*3,02*	*3,07*	*2,83*	15. Development of technologies for integrating energy and transport technologies
26%	*3,67*	*3,49*	*3,19*	*3,14*	*2,93*	16. Creation of energy-efficient and reliable electric drives for pump and compressor equipment using renewable energy systems

“Table 5.2” provides a summary evaluation of the new ideas most supported by experts regarding the addition of promising research directions within this research cluster.

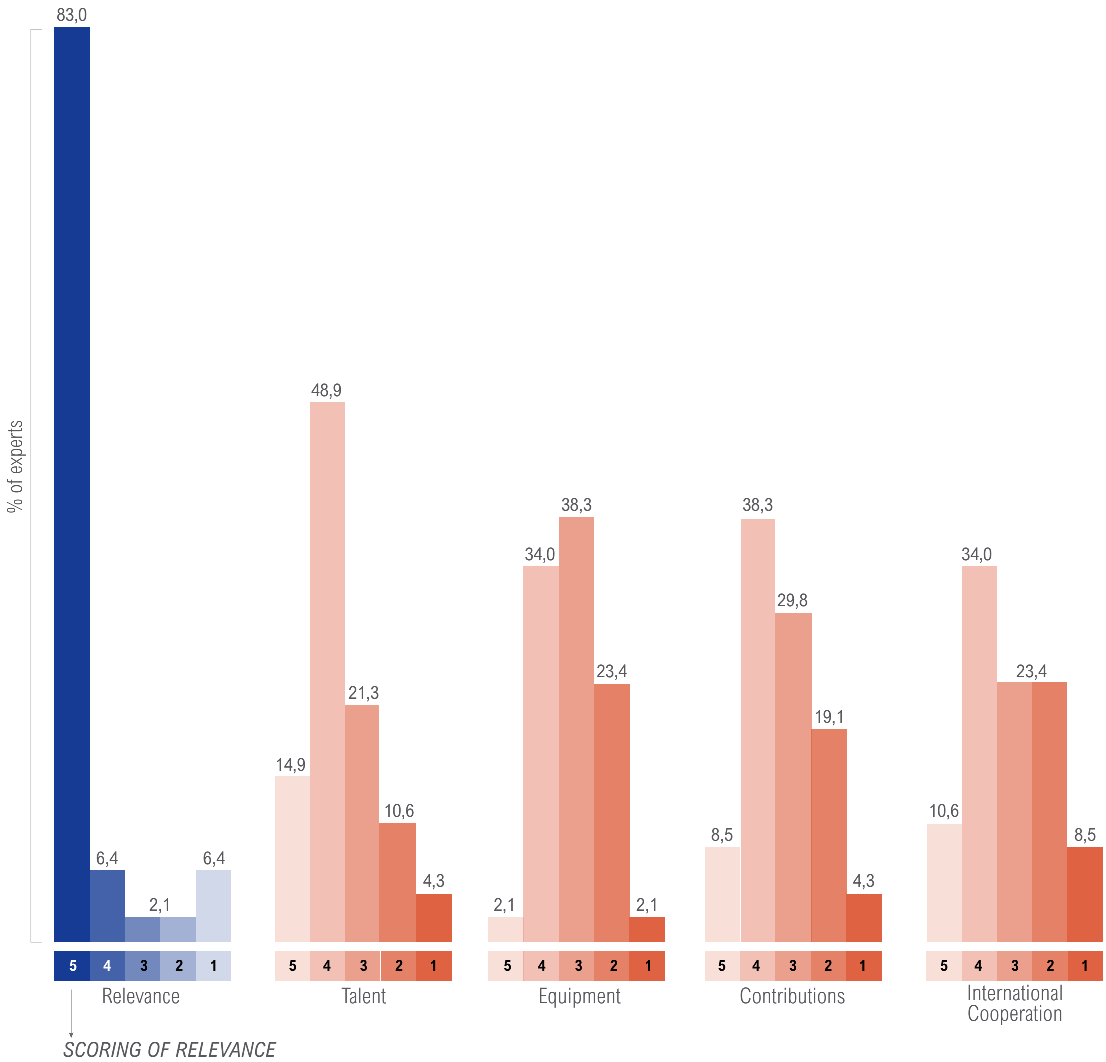
Notably, over 50% of experts supported research directions aimed at solving problems caused by war. The top priorities among them are:

→ Security, resilience, and robustness of the country’s energy system, installations, and systems against terrorist acts and military actions.

→ Development of means to ensure the safety of nuclear power plants.

FIGURE 5.6.

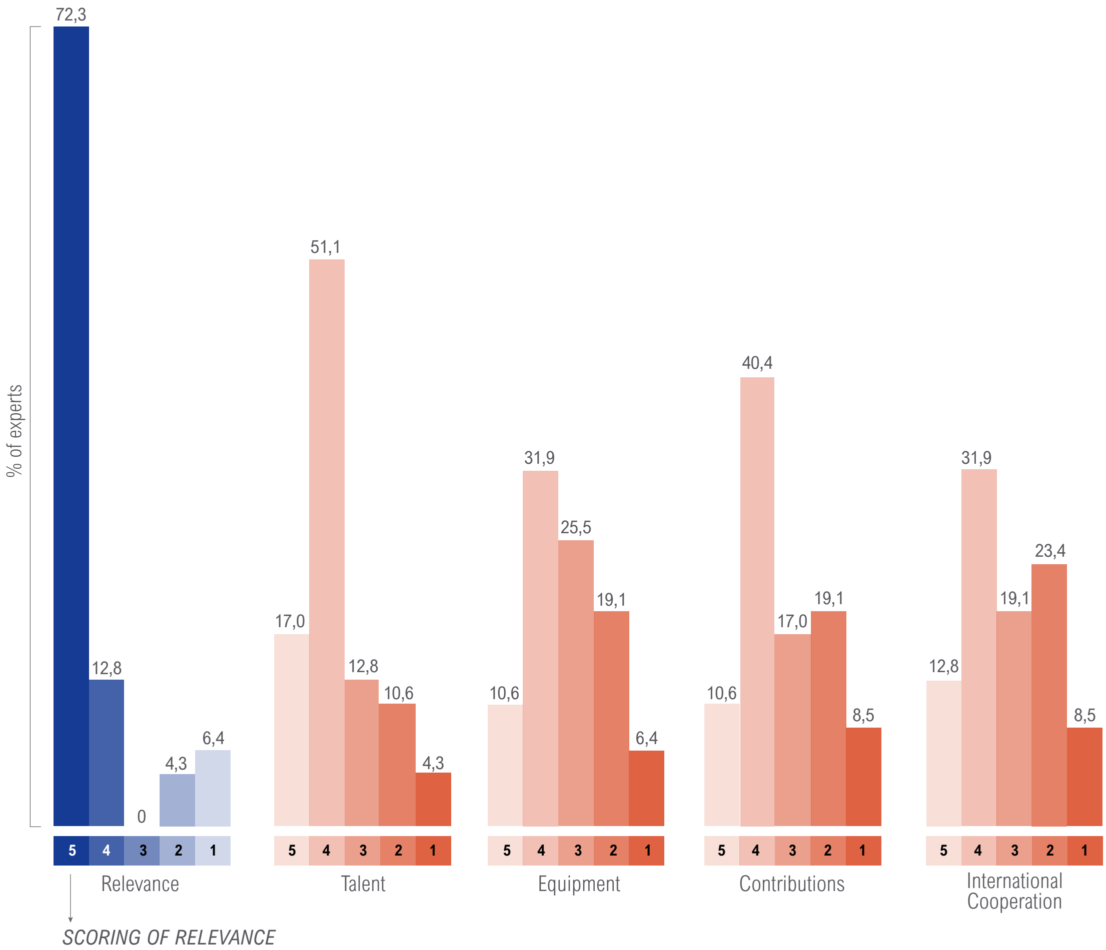
DISTRIBUTION OF SCORES FOR THE DIRECTION:
"SECURITY, RESILIENCE, AND ROBUSTNESS OF THE COUNTRY’S ENERGY SYSTEM, INSTALLATIONS, AND SYSTEMS AGAINST TERRORIST ACTS AND MILITARY ACTIONS"



The diagrams in Figure 5.6 indicate that despite a nearly unanimous assessment of the relevance of developing new protection technologies for energy installations, experts lack confidence in the capabilities. Thus, substantial state support is urgently needed here.

FIGURE 5.7.

DISTRIBUTION OF SCORES FOR THE DIRECTION:
"DEVELOPMENT OF MEANS TO ENSURE THE SAFETY OF NUCLEAR POWER PLANTS"

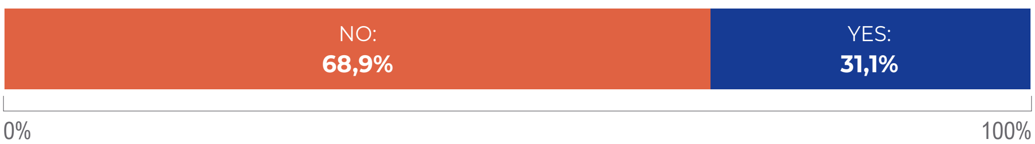


The direction *"Development of Means to Ensure the Safety of Nuclear Power Plants"* is also recognized as extremely relevant (Figure 5.7). However, it is evident that research development opportunities are insufficient and urgently require priority support from the state.

FIGURE 5.8.

PRESENCE OF STATE POLICY

(responses to the question "Do you agree that the state has established a science and technology policy that is suitable for the present circumstances?")

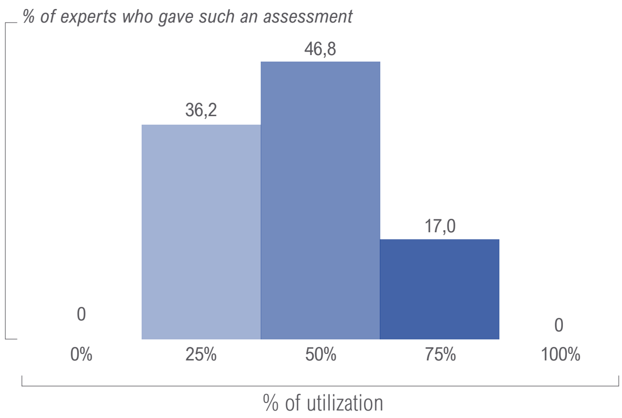


The energy research sector stands out with the highest level of recognition in state policy compared to other research clusters (Fig 5.8). This signifies a positive shift in government focus towards energy. However, the impact of this increased attention is yet to be felt on the ground, with nearly 70% of experts reporting no tangible change.

FIGURE 5.9.

UTILIZATION OF SCIENTIFIC AND TECHNOLOGICAL POTENTIAL BY RESEARCH DIRECTION

(responses to the question "Approximately, to what percentage do you estimate the scientific and technological potential of the country is currently being utilized?")



The ongoing war has made research in this area not just relevant, but critical for Ukraine's survival. It's now among the most urgent national priorities, directly impacting the country's future. However, despite this urgency, the potential of scientific research in this area remains tragically underutilized (Fig 5.9). It is imperative that we mobilize all available resources and opportunities to fully support and accelerate research in this vital field.

Healthcare and Medical Technologies

Within the research cluster *"Healthcare, New Medical Means, and Technologies"* 50 experts were engaged, including two Academicians, three Corresponding Members of the National Academy of Sciences of Ukraine, two Academicians of the National Academy of Medical Sciences of Ukraine, 30 Doctors of Sciences, and 14 Candidates of Sciences.

Ukraine has a rich tradition in research development in this field, with significant contributions from renowned figures such as Mykhailo Pyrohov, Nobel laureate Illya Mechnikov, and academician Oleksandr Bohomolets, along with generations of distinguished medical scientists.

This strong scientific foundation has greatly advanced the pharmacological industry in Soviet Ukraine and continues to thrive in the years of independence. The global recognition of Ukrainian medical schools is reflected in the popularity of medical specialties among international students. Tens of thousands of students from various countries are pursuing higher medical education in Ukraine, even following the onset of the full-scale war in 2022.

The research direction within this cluster has consistently garnered public interest, which has intensified due to recent significant events, including the coronavirus pandemic and the ongoing war. A notable aspect of this research cluster is the increasing application of scientific findings from disciplines that may seem unrelated to medicine and biology, such as informatics, materials science, chemistry, and even social sciences like social psychology.

"Table 6.1" provided the average scores for 10 research directions identified in a prior survey conducted in 2021.

TABLE 6.1.

RESEARCH DIRECTIONS WITHIN THE RESEARCH CLUSTER **"HEALTHCARE, NEW MEDICAL MEANS, AND TECHNOLOGIES"** ACCORDING TO THE 2021 LIST, AND THE CURRENT ASSESSMENT OF THEIR RELEVANCE AND POTENTIAL

TOP RELEVANCE (Percentage of experts who gave the highest Relevance score – 5 points, %)	Relevance	Talent	Equipment	Contributions	International Cooperation	*RESEARCH DIRECTION*
	AVERAGE SCORE					
72%	4,42	3,44	2,89	3,28	3,19	1. Study and systematization of molecular-genetic and epigenetic disorders in the development of common and hereditary diseases for improved diagnosis and design
66%	4,46	3,69	3,03	3,29	3,31	2. Development of technologies for the isolation, cultivation, identification, standardization, and storage of stem cells for regenerative and personalized medicine
69%	4,44	3,64	3,14	3,17	3,17	3. Creation of biobanks, human tissue, organ cells, and hybridomas for regenerative medicine and the advancement of domestic biotechnologies
68%	4,43	3,22	3,19	2,95	2,73	4. Establishment of information-analytical bases of molecular-genetic, cytomorphological results, and laboratory studies to develop AI algorithms for optimizing the diagnosis and treatment of common diseases
89%	4,81	3,86	3,08	3,65	3,11	5. Development of pharmacological and biotechnological agents for prolonged action and targeted delivery of antiviral and antitumor drugs
81%	4,65	3,92	3,22	3,59	3,14	6. Study of antiviral and antitumor effects of natural biologically active compounds and synthetic substances
81%	4,64	3,78	3,14	3,50	2,78	7. Creation of a medical biotechnology cluster for the production of vaccines, serums, and other preparations for preventing infectious and oncological diseases
50%	4,22	3,56	3,06	2,86	2,86	8. Creation of a database of harmful and especially dangerous environmental factors and development and standardization of molecular-genetic methods for identifying health risks caused by them
76%	4,62	3,54	3,00	3,51	2,70	9. Development and standardization of medical devices and biocompatible materials
49%	4,03	3,24	2,97	2,89	2,54	10. Development of advanced software-hardware diagnostic systems for screening common diseases

Among the research directions identified in 2021, experts recognized the following as most relevant:

→Development of pharmacological and biotechnological agents for prolonged action and targeted delivery of antiviral and antitumor drugs.

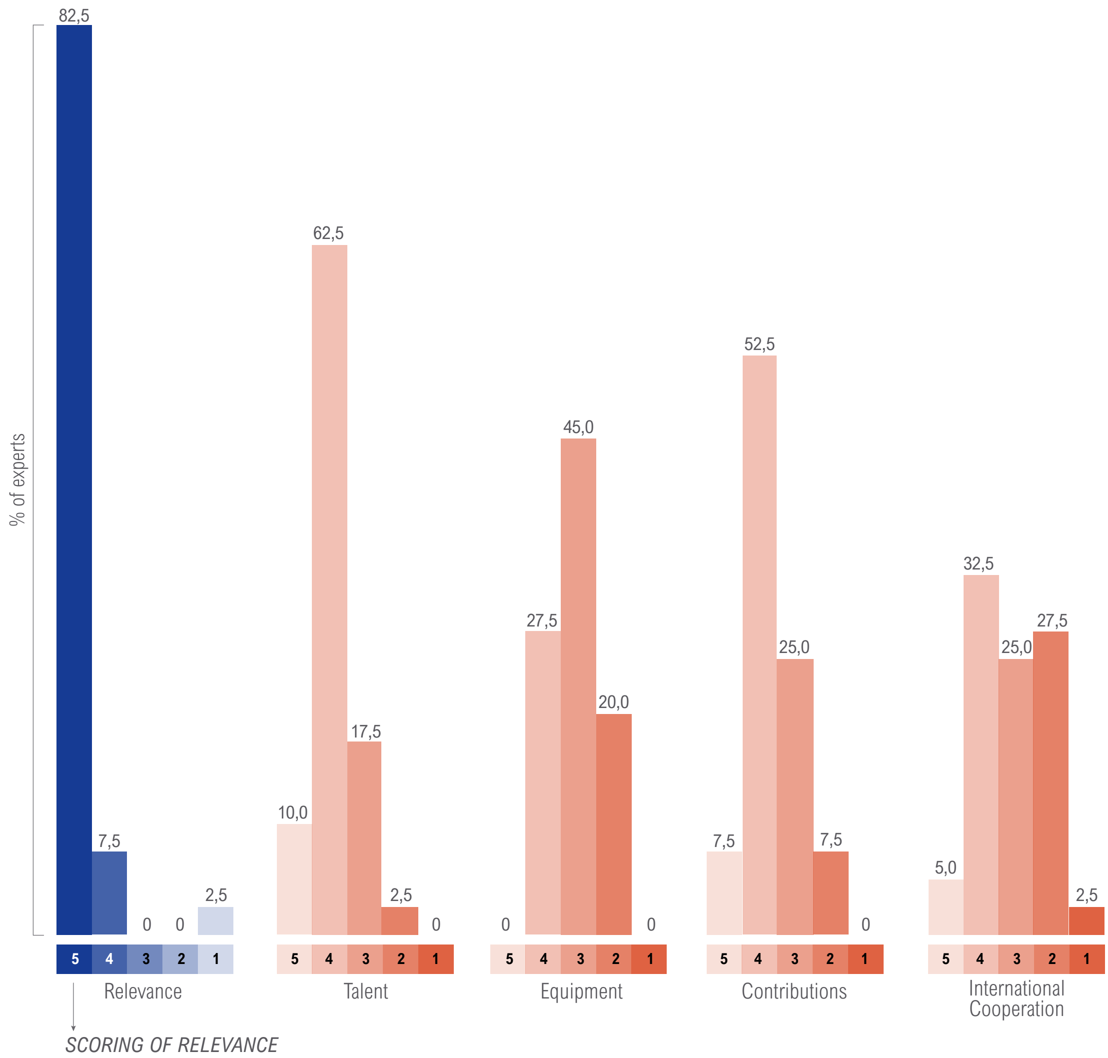
→Study of antiviral and antitumor effects of natural biologically active compounds and synthetic substances.

→Creation of a medical biotechnology cluster for the production of vaccines, serums, and other preparations for preventing infectious and oncological diseases.

The third direction is not only a scientific task but fundamentally a governmental one. However, it cannot be accomplished without scientific participation.

FIGURE 6.1.

DISTRIBUTION OF SCORES FOR THE DIRECTION
"DEVELOPMENT OF PHARMACOLOGICAL AND BIOTECHNOLOGICAL AGENTS FOR PROLONGED ACTION AND TARGETED DELIVERY OF ANTIVIRAL AND ANTITUMOR DRUGS"

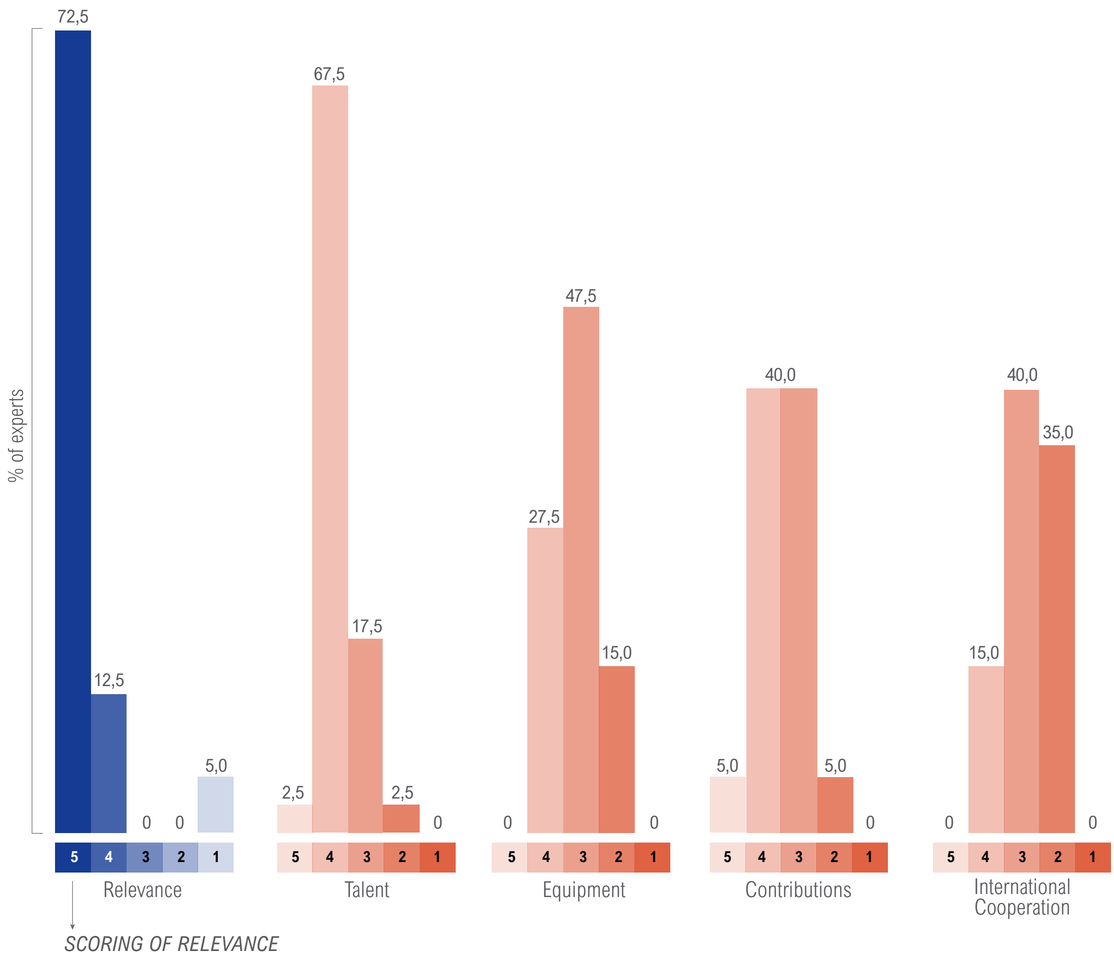


The high relevance of the direction *"Development of Pharmacological and Biotechnological Agents for Prolonged Action and Targeted Delivery of Drugs"* (Figure 6.1) highlights a certain dissonance between relevance and capabilities. Only 27.5% of experts believe there is sufficient equipment to start work; 45% emphasize its obsolescence; only 5% report ongoing research with significant results. Unfortunately, such dissonance exists in many research directions.

The assessments for the direction *"Creation of a Medical Biotechnology Cluster"* (Figure 6.2) can be interpreted as cautious optimism. Despite equipment issues and minimal groundwork, there are original ideas and specialists capable of implementing them.

FIGURE 6.2.

DISTRIBUTION OF SCORES FOR THE DIRECTION
"CREATION OF A MEDICAL BIOTECHNOLOGY CLUSTER FOR THE PRODUCTION OF VACCINES, SERUMS, AND OTHER PREPARATIONS FOR PREVENTING INFECTIOUS AND ONCOLOGICAL DISEASES"



"Table 6.2" presents a summary evaluation of the new ideas most supported by experts for supplementing the list of promising research directions within the health care and medical technologies research cluster.

TABLE 6.2.

NEW IDEAS FOR RESEARCH DIRECTIONS IN THE CLUSTER **"HEALTH CARE, NEW MEDICAL MEANS AND TECHNOLOGIES"** EVALUATION OF THEIR RELEVANCE AND POTENTIAL

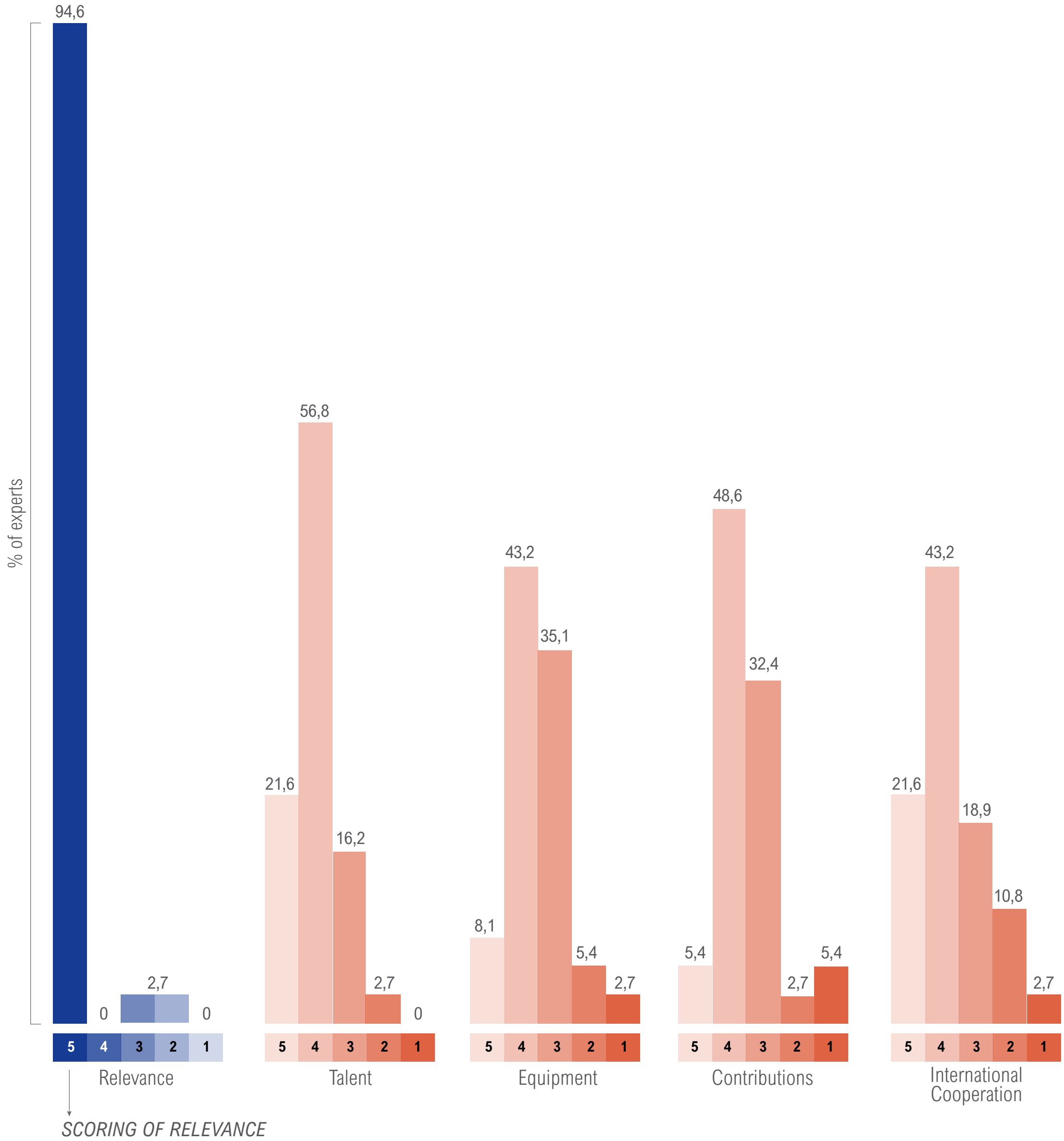
TOP RELEVANCE (Percentage of experts who gave the highest Relevance score – 5 points, %)	Relevance (*AVERAGE SCORE*)	Talent (*AVERAGE SCORE*)	Equipment (*AVERAGE SCORE*)	Contributions (*AVERAGE SCORE*)	International Cooperation (*AVERAGE SCORE*)	*RESEARCH DIRECTION*
97%	4,90	4,07	3,52	3,36	3,61	1. Development and expansion of production for musculoskeletal prosthetics, endoprosthetics of upper and lower limbs, improvement of existing bionic prosthetics for fingers, hands, and legs for adults and children, and neuroprosthetics
93%	4,93	4,21	3,61	3,86	3,39	2. Development, certification, and production implementation of highly effective hemostatic and wound-healing agents
90%	4,90	3,93	3,39	3,32	3,18	3. Development and implementation of a national program for the creation of domestic vaccines and restoration of state production of strategic medicines
86%	4,75	4,00	3,33	3,59	3,15	4. Development of anti-infective therapy agents considering microbial antibiotic resistance, especially hospital infection pathogens (phage therapy, combined use of anti-infective chemotherapy/phage therapy with immunomodulators)
83%	4,76	4,04	3,64	3,61	3,46	5. Development and integration of therapeutic methods and means to address PTSD, and physical and psychological rehabilitation for veterans
72%	4,66	3,50	2,89	2,86	3,14	6. Development of neuroimplants for transmitting audio signals in case of hearing loss, and neuroimplants for transmitting visual signals in case of vision loss to the brain cortex
69%	4,62	3,43	3,11	3,11	3,14	7. Development of tissue regeneration strategies for the human body, primarily myocardium and nerve cells, and diagnostic systems for monitoring traumatic brain injury, post-traumatic stress disorder (PTSD), anxiety disorders, etc.
69%	4,38	3,50	3,00	2,82	2,89	8. Creation of a database of harmful and particularly dangerous factors of military environmental pollution and development and standardization of molecular-genetic methods for assessing the health risks they pose
68%	4,61	3,70	3,27	3,22	2,96	9. Development of effective anti-tuberculosis drugs due to the increase in tuberculosis in Ukraine related to the war
62%	4,55	3,50	2,93	2,79	2,96	10. Nanobiomaterials, genetic engineering. Development of synthetic analogs of human tissues. New methods of molecular gene cloning. Gene therapy, bionic prosthetics, medical robotics. Pharmacogenetics
57%	4,21	3,48	2,93	2,85	2,81	11. Development of innovative genetically-based methods for the prevention and treatment of cardiometabolic and neurological diseases
55%	4,21	3,39	3,14	2,75	2,89	12. Development of advanced software and hardware information-diagnostic systems for screening the most common diseases
55%	4,28	3,54	3,25	2,75	3,07	13. Development of AI-based programs for diagnosing human diseases using imaging methods (CT, MRI, ultrasound). Priority should be given to CT, which has clear standardized densitometry data
55%	4,28	3,71	3,11	2,86	2,89	14. Study of the impact of military actions on the country's ecology and public health
43%	4,21	3,85	3,41	3,48	3,15	15. Development and standardization of microbial biotechnologies for the production of therapeutic, diagnostic, and preventive products, including functional food products for human health
43%	4,14	3,23	2,89	2,81	3,00	16. Creation of miniature sensor monitoring systems and corresponding IT technologies for controlling human life parameters; assessment of stress levels and physical reserve of personnel
36%	4,00	3,59	2,89	3,15	2,96	17. Creation of a biobank of microorganisms and viruses to form an information-analytical base for implementation in the international system
31%	3,83	3,29	2,81	2,89	2,82	18. Development of telemedicine technologies and digitalization of healthcare

As we see, nearly all proposals for supplementing priorities focus on addressing problems caused by the war: creation of effective hemostatic agents, treatment and rehabilitation of the wounded, diagnosis of traumatic brain injuries, prosthetics (including bionic), etc.

The highest relevance score was given to the **prosthetics** direction (see Fig. 6.3). It also received the highest score for international cooperation, with over 20% of experts reporting joint projects with foreign colleagues. The war has increased the demand for prosthetics, but the capabilities remain insufficient. Immediate support is needed, especially through increased private investment.

FIGURE 6.3.

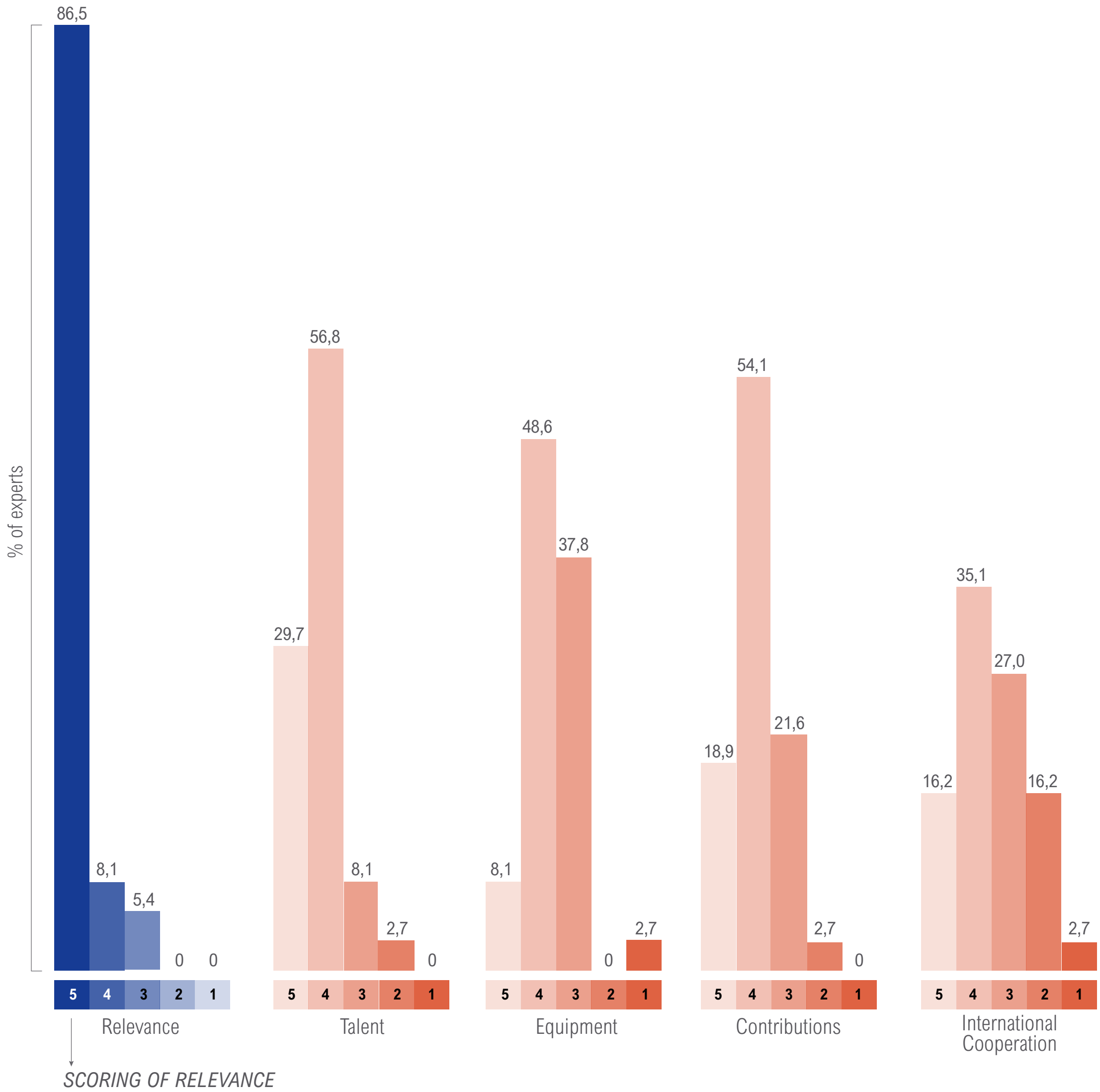
DISTRIBUTION OF SCORES FOR THE DIRECTION
"DEVELOPMENT AND EXPANSION OF PRODUCTION FOR MUSCULOSKELETAL PROSTHETICS, ENDOPROSTHETICS OF UPPER AND LOWER LIMBS, IMPROVEMENT OF EXISTING BIONIC PROSTHETICS FOR FINGERS, HANDS, AND LEGS FOR ADULTS AND CHILDREN, NEUROPROSTHETICS"



For the direction of developing **hemostatic and wound-healing agents** (Fig. 6.4), the evaluations indicate a general understanding of relevance, availability of specialists, and some progress. However, scientists complain about the difficulty in organizing production: management structures that could facilitate this are not established.

FIGURE 6.4.

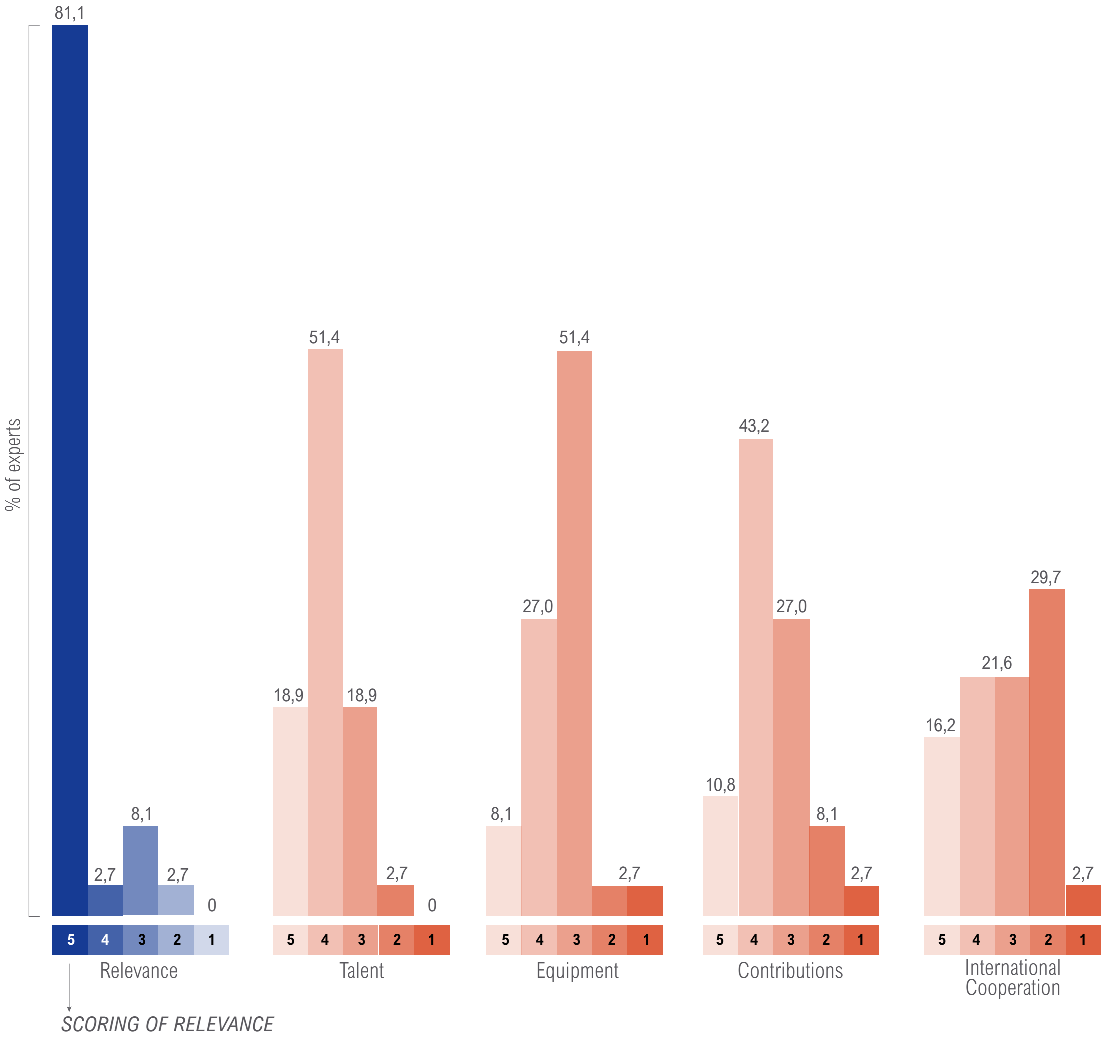
DISTRIBUTION OF SCORES FOR THE DIRECTION
"DEVELOPMENT, CERTIFICATION, AND PRODUCTION IMPLEMENTATION OF HIGHLY EFFECTIVE HEMOSTATIC AND WOUND-HEALING AGENTS"



The war has significantly exacerbated the problem of **antibiotic resistance.** Over 80% of experts (Fig. 6.5) confirm its critical relevance. Talent exists, but solutions are not yet developed.

FIGURE 6.5.

DISTRIBUTION OF SCORES FOR THE DIRECTION
"DEVELOPMENT OF ANTI-INFECTIVE THERAPY AGENTS CONSIDERING ANTIBIOTIC RESISTANCE OF MICROORGANISMS, ESPECIALLY HOSPITAL INFECTION PATHOGENS (PHAGE THERAPY, COMBINED USE OF ANTI-INFECTIVE CHEMOTHERAPY/PHAGE THERAPY WITH IMMUNOMODULATORS)"

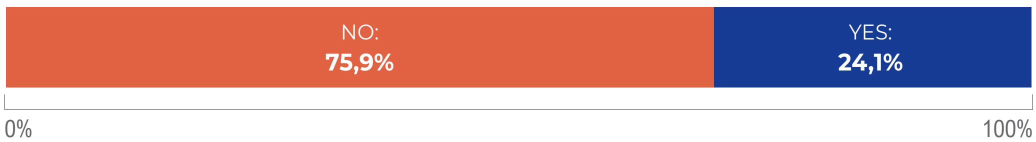


The cluster of medical studies has a relatively high level of recognition in state policy compared to other research clusters (see Figure 6.6). This indicates their high demand during wartime. However, more than 75% of experts still believe that the state has not formulated an adequate science and technology policy in the field of healthcare and medical technologies suitable for the current situation.

FIGURE 6.6.

PRESENCE OF STATE POLICY

(responses to the question "Do you agree that the state has established a science and technology policy that is suitable for the present circumstances?")

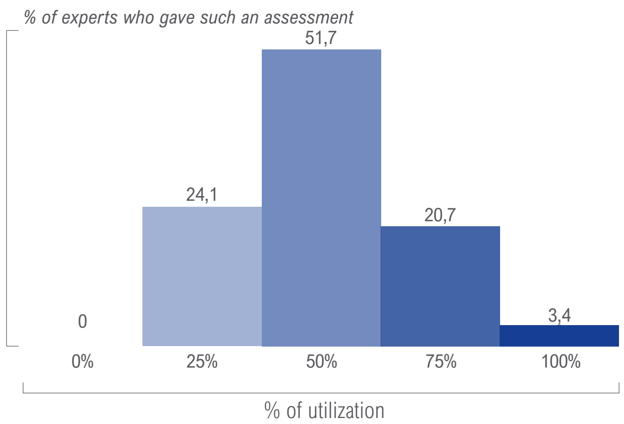


The utilization of the scientific and technological potential in this sector also remains low (see Figure 6.7), with a dominant assessment of only 25% of potential capabilities being utilized.

FIGURE 6.7.

UTILIZATION OF SCIENTIFIC AND TECHNOLOGICAL POTENTIAL BY RESEARCH DIRECTION

(responses to the question "Approximately, to what percentage do you estimate the scientific and technological potential of the country is currently being utilized?")



Overall, the analysis of this research cluster's questionnaires allows us to conclude that medical science is actively engaging in solving problems caused by the war. However, adequate support from the state, particularly from the Ministry of Defense of Ukraine, remains insufficient.

Adaptation to Climate Change

Within the research cluster *"Preservation and Rational Use of Natural Resources under Global Climate Change Conditions"* 71 experts were involved, including 3 Academicians, 12 Corresponding Members, 33 Doctors of Sciences, and 23 Candidates of Sciences.

The issue of adapting to climate change is a global challenge that humanity has recognized only relatively recently. Ukraine possesses significant potential and a rich tradition of meteorological and climate research dating back to the late 19th and early 20th centuries. Ukrainian scientists participate not only in climate change modeling but also in monitoring the state of the planet's atmosphere and the world's oceans, with research conducted at the "Akademik Vernadsky" station in Antarctica.

At the same time, the focus is shifting from monitoring and forecasting climate changes to developing adaptation strategies, particularly new technologies for natural resource management. Although public and scientific attention is currently concentrated on national defense, the issue of climate change remains pertinent. After the war, this challenge will resurface with renewed intensity, as the need for adaptation and environmental restoration will become a key aspect of the country's sustainable development.

Given the unique breadth of this research field, experts included ecologists, as well as researchers from biology, geology, chemistry, agriculture, law, economics, materials science, and information and communication technologies.

"Table 7.1" presents the average scores for ten research directions identified in a previous survey conducted in 2021.

TABLE 7.1.

RESEARCH DIRECTIONS WITHIN THE RESEARCH CLUSTER **"PRESERVATION AND RATIONAL USE OF NATURAL RESOURCES UNDER GLOBAL CLIMATE CHANGE CONDITIONS"** ACCORDING TO THE 2021 LIST, AND THE CURRENT ASSESSMENT OF THEIR RELEVANCE AND POTENTIAL

TOP RELEVANCE (Percentage of experts who gave the highest Relevance score – 5 points, %)	*AVERAGE SCORE*					*RESEARCH DIRECTION*
	Relevance	Talent	Equipment	Contributions	International Cooperation	
65%	4,16	3,86	3,07	3,58	3,43	1. Biodiversity studies, development of conservation measures, biocontamination control, creation of seed banks as a basis for selection, breeding, and reproduction
62%	4,02	3,64	3,00	3,24	3,24	2. Research on the organization, structure, functioning, development, and productivity of ecosystems (including forests) through monitoring, mapping, remote sensing, bioidentification, and evaluation of ecosystem services for management, development of management plans, and conservation of energy reserves and resources
71%	4,44	3,66	3,15	3,29	3,23	3. Improvement of agricultural systems to protect and maintain soil fertility, counteract depletion, erosion, degradation, desertification, salinization, and other negative processes
73%	4,46	3,55	3,17	3,51	3,50	4. Scientific foundations for assessing the conservation state, effective use of water resources, improvement of water quality, combating eutrophication, predicting changes, and preventing negative consequences
68%	4,39	3,15	2,95	2,90	2,77	5. Comprehensive processing (recycling and utilization) of accumulated organic and solid waste, reclamation of disturbed ecosystems
51%	4,23	3,56	3,15	3,33	2,92	6. Assessment and monitoring of the geological environment, optimization of mineral resource use, rehabilitation (post-mining) of mining regions, development of new and improvement of existing extraction and processing technologies to minimize environmental disruption
66%	4,56	3,70	3,30	3,30	3,15	7. Development of biotechnologies (including nanotechnologies in agriculture, biomedicine, biopharmaceuticals, industrial and food biotechnology), "green energy," selection, acclimatization, and introduction
44%	4,07	3,17	2,88	2,80	2,78	8. Protection of the atmosphere by reducing greenhouse gas emissions, implementing fire prevention, and other measures to decrease CO2 emissions and other substances affecting temperature increase
34%	3,78	3,43	2,80	3,21	3,33	9. Assessment of the state and evaluation of research methods for marine resources, their conservation, sustainable use, and reproduction
63%	4,29	3,56	3,39	3,15	3,08	10. Optimization of land management, assessment of land use types, creation of a comprehensive cadastre, expansion, and improvement of the nature reserve system according to EU criteria

Most experts did not support all the directions deemed relevant in 2021. Only 34% believe that there are possibilities and feasibility to continue **marine resource research and conservation** in Ukraine (Direction 9 in "Table 7.1").

The priority of greenhouse gas emission research is also in question. Only 44% of experts support the high relevance of the direction "Protection of the Atmosphere by Reducing Greenhouse Gas Emissions, Implementing Fire Prevention, and Other Measures to Decrease CO2 Emissions and Other Substances Affecting Temperature Increase."

The most relevant research directions remain:

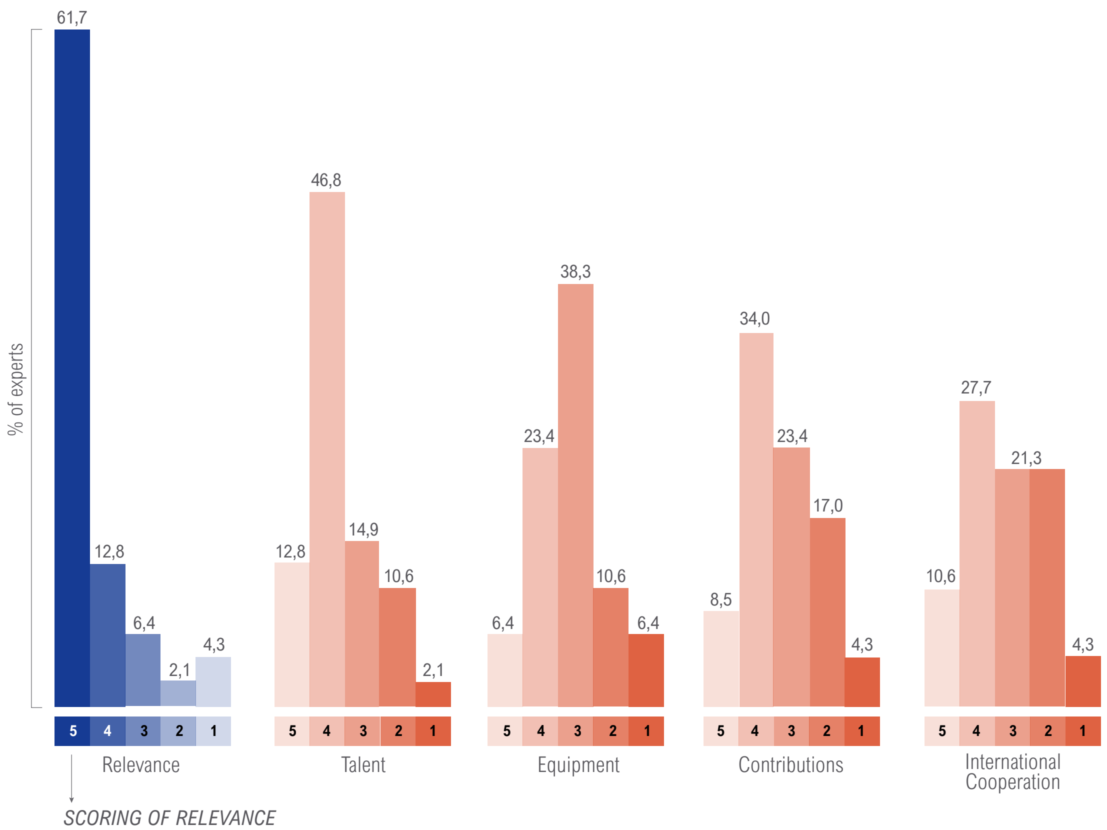
→ Improvement of agricultural systems to protect and maintain soil fertility, counteract depletion, erosion, degradation, desertification, salinization, and other negative processes.

→ Scientific foundations for assessing the conservation state, effective use of water resources, improving water quality, combating eutrophication, predicting changes, and preventing negative consequences.

Expert assessments (Figure 7.1) confirm the high relevance and urgent need to enhance support for research aimed at preserving soil fertility. However, a lack of new equipment is evident across many directions, with about 40% of experts noting that outdated equipment leads to inefficient use of researchers' time.

FIGURE 7.1.

DISTRIBUTION OF SCORES FOR THE DIRECTION
"IMPROVEMENT OF AGRICULTURAL SYSTEMS TO PROTECT AND MAINTAIN SOIL FERTILITY, COUNTERACT DEPLETION, EROSION, DEGRADATION, DESERTIFICATION, SALINIZATION, AND OTHER NEGATIVE PROCESSES"



The leading direction in this cluster is water resource utilization (Figure 7.2). However, despite high relevance scores, the main contributions are mainly original ideas.

From the scores presented in Figure 7.3, it can be concluded that, under the conditions of a full-scale war, civilian research in this direction has become virtually impossible and has largely lost relevance for Ukraine, at least until the end of hostilities.

FIGURE 7.2.

DISTRIBUTION OF SCORES FOR THE DIRECTION:
"SCIENTIFIC FOUNDATIONS FOR ASSESSING THE STATE OF CONSERVATION, EFFECTIVE USE OF WATER RESOURCES, IMPROVEMENT OF WATER QUALITY, COMBATING EUTROPHICATION, PREDICTING CHANGES, AND PREVENTING NEGATIVE CONSEQUENCES"

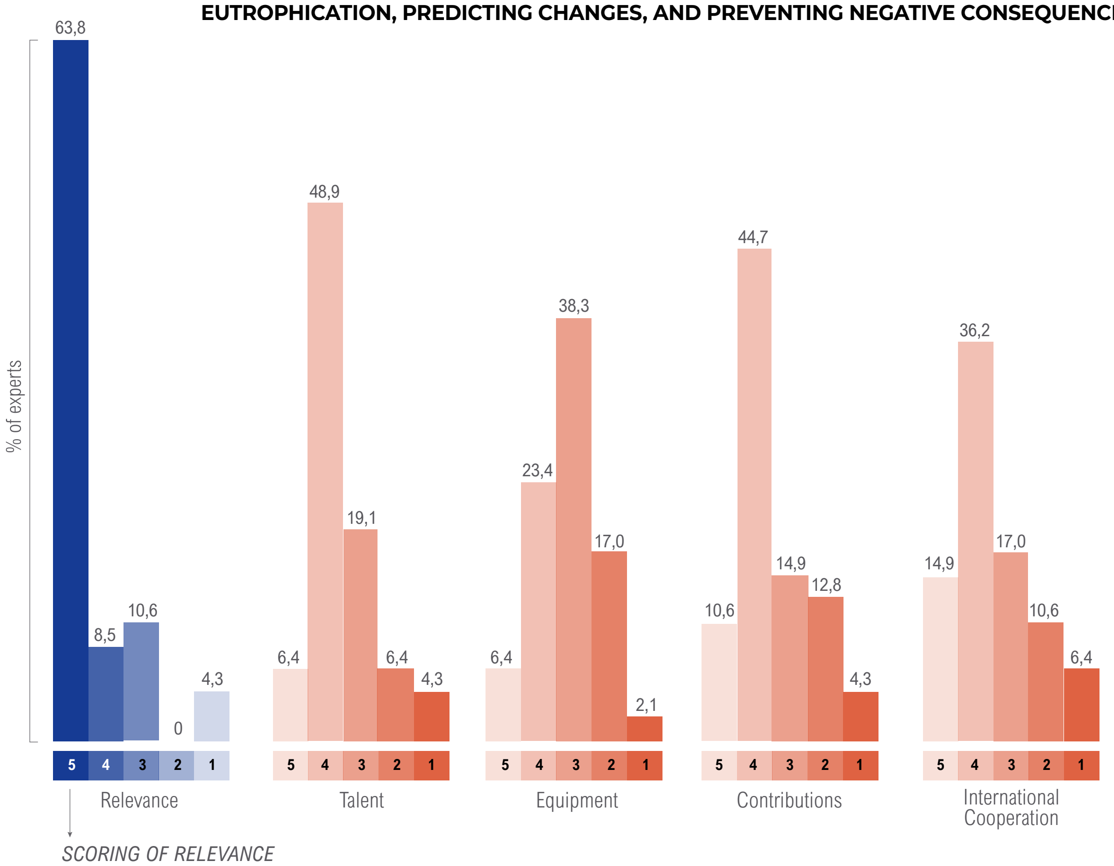
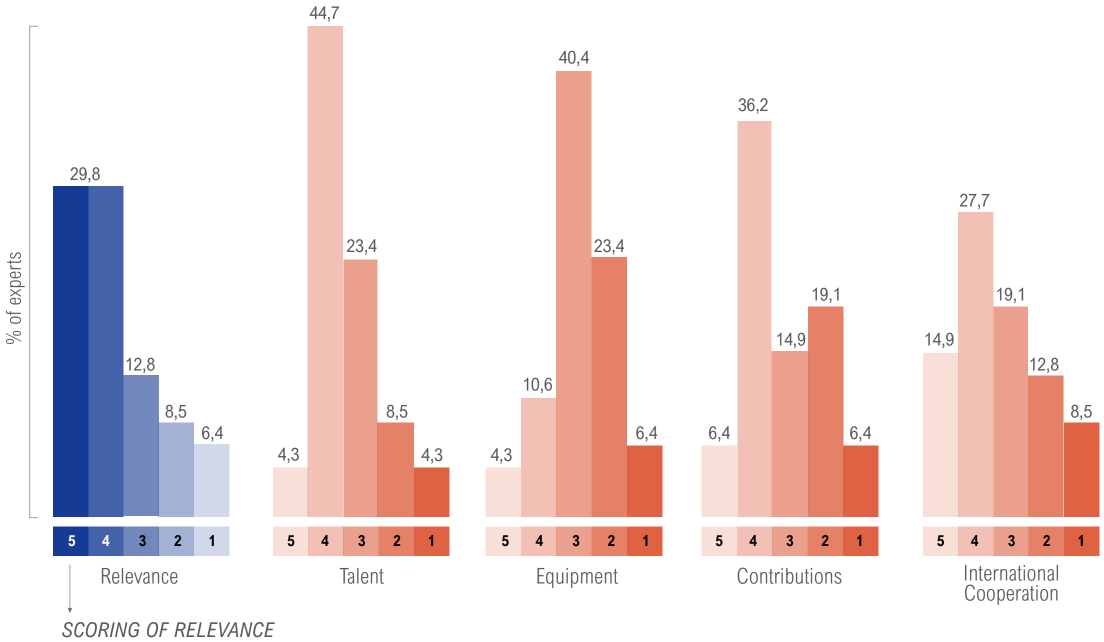


FIGURE 7.3.

DISTRIBUTION OF SCORES FOR THE DIRECTION:
"ASSESSMENT OF THE STATE AND EVALUATION OF RESEARCH METHODS FOR MARINE RESOURCE, THEIR CONSERVATION, SUSTAINABLE USE, AND REPRODUCTION"



"Table 7.2." provides a summary evaluation of the new ideas most supported by experts regarding the addition of promising research directions within the research cluster related to climate change.

TABLE 7.2.

NEW IDEAS ON RESEARCH DIRECTIONS WITHIN THE RESEARCH CLUSTER: **"CONSERVATION AND RATIONAL USE OF NATURAL RESOURCES UNDER GLOBAL CLIMATE CHANGE CONDITIONS"** EVALUATION OF THEIR RELEVANCE AND POTENTIAL.

TOP RELEVANCE (Percentage of experts who gave the highest Relevance score – 5 points, %)

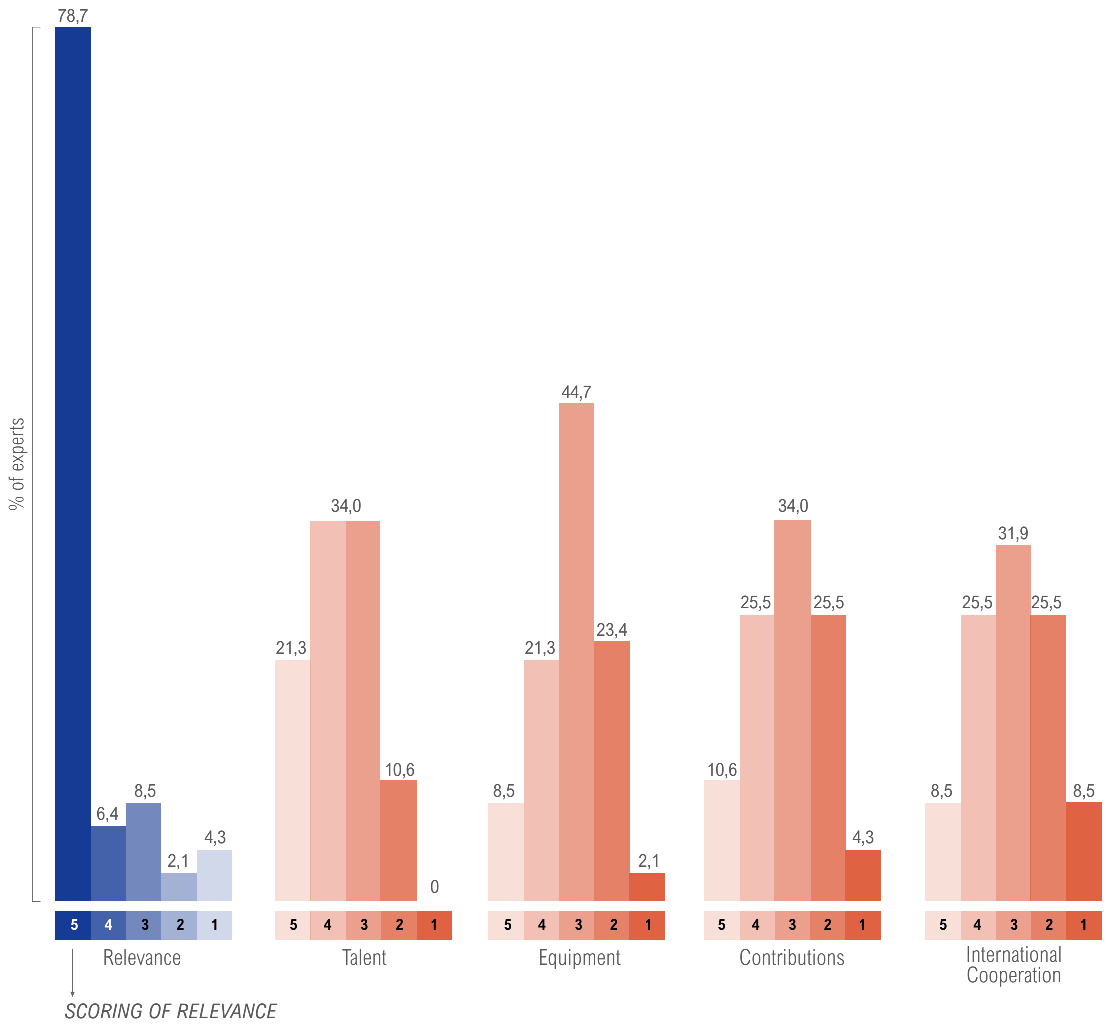
AVERAGE SCORE

TOP RELEVANCE	Relevance	Talent	Equipment	Contributions	International Cooperation	*RESEARCH DIRECTION*
79%	4,53	3,66	3,11	3,13	3,00	1. Military degradation and pollution of soils, water bodies, monitoring, remediation, rehabilitation of areas contaminated by hostilities
70%	4,49	3,83	3,26	3,38	3,15	2. Post-war environmental water resource stabilization of the Dnipro basin, security issues of main hydrotechnical structures and city water intakes
64%	4,28	3,91	3,26	3,49	3,20	3. Impact of military actions on biodiversity conservation, monitoring, ecological management, and ecosystem restoration. Issues of protected areas, creation of flora and fauna cadastres
59%	4,22	3,41	3,16	3,04	3,13	4. Strategic planning of environmental policy for post-war recovery considering Ukraine's euro-integration prospect
40%	3,98	3,43	3,11	3,21	3,07	5. Threat of bioterrorism. Monitoring of animal and plant disease
37%	3,91	3,18	2,93	2,77	2,91	6. Scientific justification of permissible levels of anthropogenic changes in essential natural resources
37%	3,83	3,33	2,91	2,85	2,71	7. Operational geo-monitoring of areas whose geo-ecological state changed due to hostilities
34%	3,86	3,68	3,30	3,57	3,35	8. Study of biological invasions in ecosystems
33%	3,69	3,27	2,98	2,93	2,52	9. Post-mining of developed ("old") mining areas in Donbas, Kryvbas, the Carpathian region, Prydniprovia uranium ore region, etc. Recycling of metallurgical industry waste
30%	3,61	3,11	2,80	3,00	2,80	10. Current issues in the conservation of Ukraine's palace and park heritage, restoration problems, conservation, prospects for adapting and using historical estates and manors
24%	3,62	2,84	2,77	2,73	2,86	11. Development of carbon farming and low-carbon cultivation technologies in the context of minimizing the harmful impact of military-origin factors and climate change
24%	3,49	3,19	2,84	2,82	2,88	12. Prevention of resistance to pesticides in weeds, pests, and pathogens of agricultural crops
20%	3,33	3,00	2,82	2,86	2,88	13. Evolution, morphology, bionics, and biomimetics, analysis of digital images of living organisms and ecosystem elements
15%	3,32	3,22	2,76	2,85	3,03	14. Environmental and organismal omics considering OneHealth principles: eDNA, transcriptomics, microbiomics, proteomics, metabolomics

The score distribution diagrams for **military degradation and pollution** in Figure 7.4 show a pronounced dissonance between the highest relevance score in this research cluster and the real possibilities for research development. It is clear that significant resources will need to be directed by the state and business to address this issue. We hope that science will help utilize these resources most efficiently.

FIGURE 7.4.

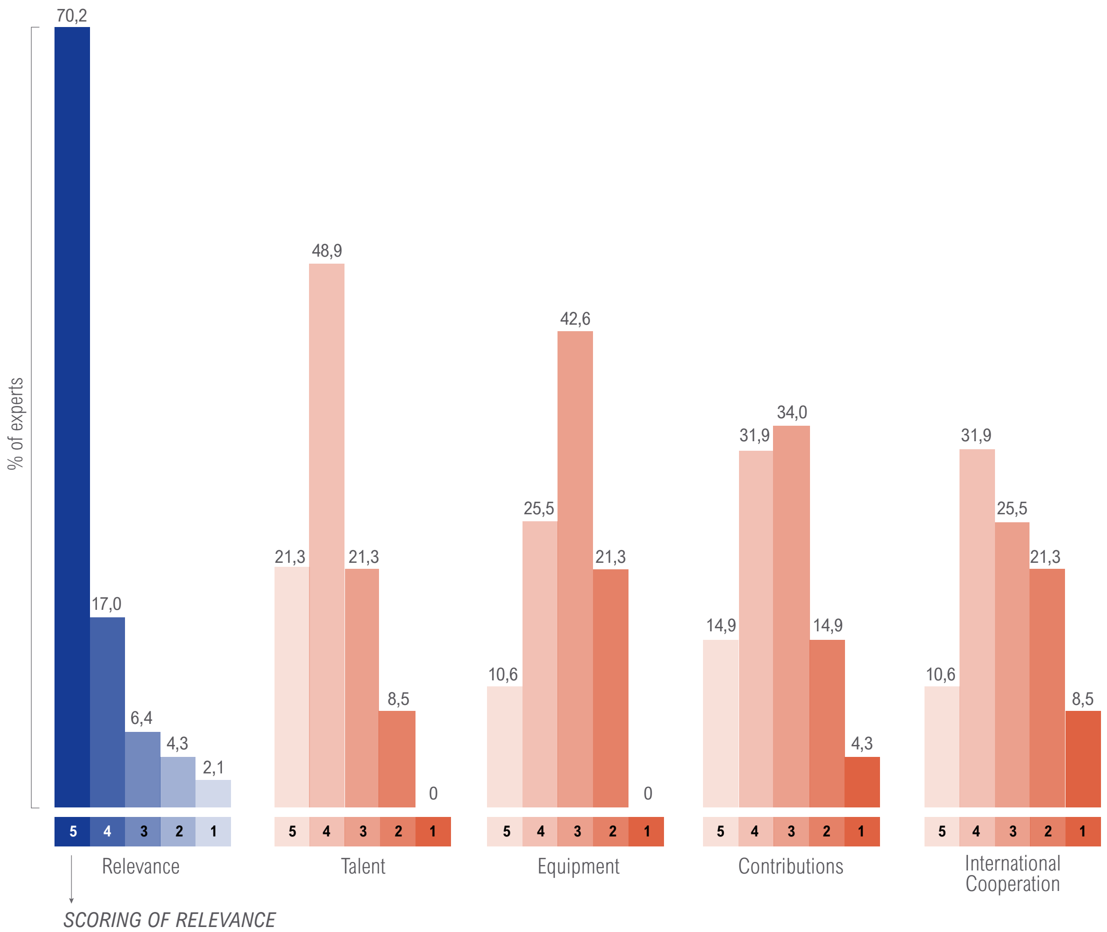
DISTRIBUTION OF SCORES FOR THE DIRECTION:
"MILITARY DEGRADATION AND POLLUTION OF SOILS, WATER BODIES, MONITORING, REMEDIATION, REHABILITATION OF AREAS CONTAMINATED BY HOSTILITIES"



The diagrams presented in Figure 7.5 also provide undeniable confirmation of the relevance of research in the direction of *"Post-War Environmental Water Resource Stabilization of the Dnipro Basin, Security Issues of Main Hydrotechnical Structures and City Water Intakes."* However, the potential scores in this direction indicate ineffective, outdated equipment and generally insufficient capabilities that need to be expanded.

FIGURE 7.5.

DISTRIBUTION OF SCORES FOR THE DIRECTION:
"POST-WAR ENVIRONMENTAL WATER RESOURCE STABILIZATION OF THE DNIPRO BASIN, SECURITY ISSUES OF MAIN HYDROTECHNICAL STRUCTURES AND CITY WATER INTAKES"

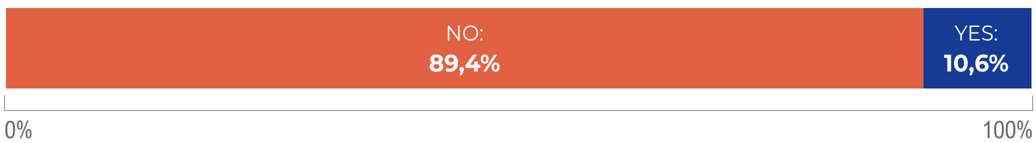


Overall, the expert assessment of nearly all directions within this research cluster clearly illustrates the significant damage caused to the environment by the aggressive war against Ukraine. It highlights how this conflict has intensified challenges related to climate and natural resource conservation, as well as the substantial funding and effort needed for recovery.

FIGURE 7.6.

PRESENCE OF STATE POLICY

(responses to the question "Do you agree that the state has established a science and technology policy that is suitable for the present circumstances?")

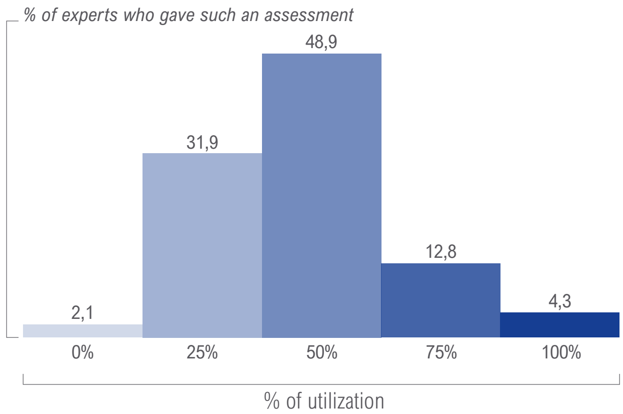


The climate research cluster has a low level of recognition for the effectiveness of state policy in this area (Figure 7.6). Only slightly more than 10% believe that the state has primarilty formulated an adequate science and technology policy.

FIGURE 7.7.

UTILIZATION OF SCIENTIFIC AND TECHNOLOGICAL POTENTIAL BY RESEARCH DIRECTION

(responses to the question "Approximately, to what percentage do you estimate the scientific and technological potential of the country is currently being utilized?")



In the assessment of the utilization of scientific and technological potential, almost half of the experts chose 50%, and about a third chose 25% or less. Therefore, there is significant untapped potential that the state can and should rely on (Figure 7.7).

Food Security and Bioeconomy

Within the research cluster *"Food Security, Sustainable Agricultural Development and Related Technologies, Bioeconomy"* 56 experts were involved, including three Academicians and five Corresponding Members of the National Academy of Sciences of Ukraine (NASU), one Academician and four Corresponding Members of the National Academy of Agrarian Sciences of Ukraine (NAASU), 31 Doctors of Sciences, and 9 Candidates of Sciences (mainly agronomists, as well as economists, legal scholars, etc.).

Ukraine has long played a key role in global grain production (particularly rye and wheat) and is historically one of the first regions in Europe where agriculture originated. Throughout the 19th and 20th centuries, Ukraine consistently acted as one of the leading food exporters to global markets. Even in the context of full-scale war, our agricultural exports remain significant for ensuring global food security.

The first agricultural research institutions in Ukraine appeared in the 19th century—in Odesa, Uman, and later in Kharkiv. In the 20th century, Ukrainian scientists made significant contributions to the development of agricultural science. Notably, the scientific foundations for breeding new varieties of grain crops were established, methods for enhancing soil fertility were developed, and advanced agrotechnical practices were implemented. After Ukraine gained independence in 1991, agricultural science underwent transformations aimed at integrating into the global scientific community, developing the bioeconomy, and implementing sustainable technologies in agriculture.

These efforts contributed to increased food security and the stable development of the country's agricultural sector. The strong scientific and technological potential of the sector has become an important factor in the formation of modern Ukrainian agricultural holdings, which play a leading role in the state's economy.

In recent decades, despite the previously proclaimed concept of building Ukraine as a "food superpower," the degradation of the scientific and technological potential of agricultural science has occurred at roughly the same pace as in other sectors. Therefore, it is not surprising that scientists rate the adequacy of the state's science and technology policy extremely low.

"Table 8.1." provides the average scores for 10 research directions identified in the previous survey conducted in 2021.

TABLE 8.1.

RESEARCH DIRECTIONS WITHIN THE RESEARCH CLUSTER:
"FOOD SECURITY, SUSTAINABLE AGRICULTURAL DEVELOPMENT AND RELATED TECHNOLOGIES, BIOECONOMY" ACCORDING TO THE 2021 LIST, AND THE CURRENT ASSESSMENT OF THEIR RELEVANCE AND POTENTIAL

TOP RELEVANCE (Percentage of experts who gave the highest Relevance score – 5 points, %)	Relevance	Talent	Equipment	Contributions	International Cooperation	*RESEARCH DIRECTION*
			AVERAGE SCORE			
46%	3,94	3,83	3,40	3,57	3,66	1. Building a qualitatively new paradigm of eco-socio-economic growth based on inclusivity
64%	4,28	3,79	3,28	3,49	3,28	2. Genetic foundations for increasing the productivity of cereal grains with enhanced adaptive potential to adverse environmental factors
82%	4,55	3,62	3,16	3,30	3,43	3. Nanotechnology, biotechnology for efficient processing of agricultural raw materials into food and technical products, "green" energy
66%	4,37	3,63	3,43	3,26	3,54	4. Institutional support for national security and sustainable development through comprehensive national economic, defense, and welfare programs
37%	3,77	3,32	2,82	2,94	3,09	5. Genomic selection in animal husbandry
68%	4,32	3,70	3,22	3,24	3,30	6. Energy- and resource-saving technologies and technical means of agro-industrial production
57%	4,14	3,59	3,19	3,27	3,43	7. Information-resource screening of soil conditions in Ukraine for their natural and artificial restoration
39%	3,81	3,39	3,08	3,08	3,11	8. Formation of a valuable genotypic base of new high-protein crops as an alternative source of animal-origin products for sustainable food security
59%	4,11	3,39	2,97	3,17	3,28	9. Development of methods for targeted manipulation of plant heredity. Genetic improvement of plants using molecular genetics and marker-assisted selection with enhanced adaptive potential to adverse environmental conditions
53%	4,08	3,42	3,06	3,28	3,08	10. Biofortification of grains (increasing the content of essential phytonutrients in grains)

The undisputed leader in relevance and prospects is the synthetic direction of *"Nanotechnology, Biotechnology for Efficient Processing of Agricultural Raw Materials into Food and Technical Products, 'Green' Energy"* (Figure 8.1). However, experts note outdated and inefficient equipment, leading to unproductive time expenditure for researchers.

Next in relevance within the agricultural cluster is the direction of r**esource-saving technologies** (Figure 8.2). However, the evaluation of contributions in this direction is significantly lower. Great hopes are placed on the development of international cooperation: over 30% of experts report organizing internships for domestic researchers in foreign scientific centers.

FIGURE 8.1.

DISTRIBUTION OF SCORES FOR THE RESEARCH DIRECTION:
"NANOTECHNOLOGY, BIOTECHNOLOGY FOR EFFICIENT PROCESSING OF AGRICULTURAL RAW MATERIALS INTO FOOD AND TECHNICAL PRODUCTS, 'GREEN' ENERGY"

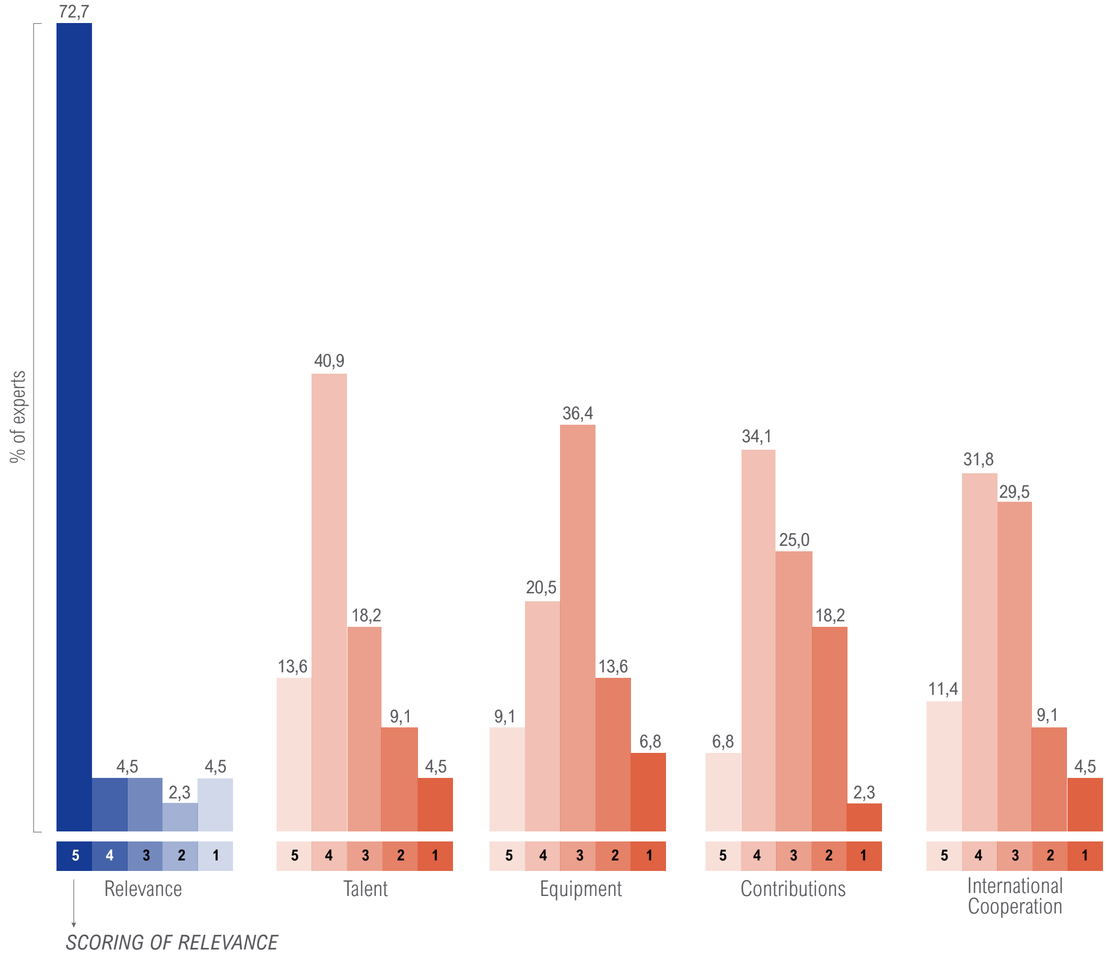
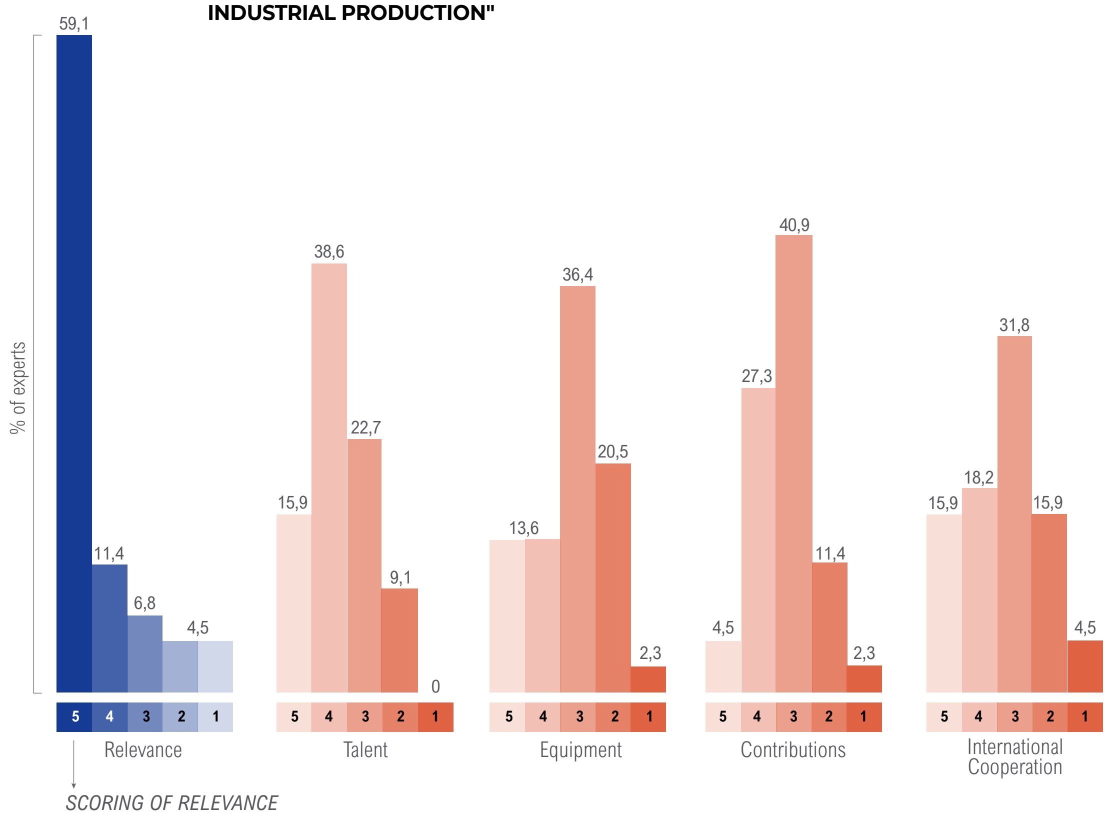


FIGURE 8.2.

DISTRIBUTION OF SCORES FOR THE DIRECTION:
"ENERGY- AND RESOURCE-SAVING TECHNOLOGIES AND TECHNICAL MEANS OF AGRO-INDUSTRIAL PRODUCTION"

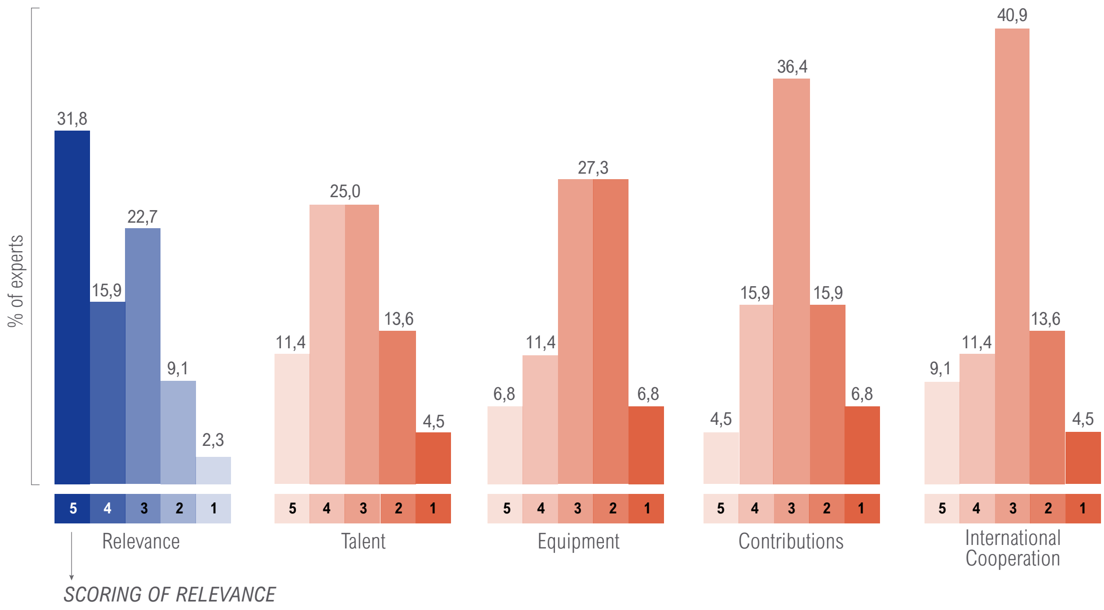


Some directions related to selection, namely *"Genomic Selection in Animal Husbandry"* and *"Formation of a Valuable Genotypic Base of New High-Protein Crops as an Alternative Source of Animal-Origin Products for Sustainable Food Security"* have largely lost their relevance (see "Table 8.1").

The worst situation in all indicators is for the direction *"Genomic Selection in Animal Husbandry"* (Figure 8.3). Most experts do not consider it deserving of priority support. Nearly a third note that current equipment is insufficient for conducting research, or it is simply absent. Another third considers the current equipment outdated and ineffective. Only 6.8% believe the equipment is sufficient. Evaluations of talent potential, contributions, and international cooperation indicate that the development of this direction is possible only through participation in the work of foreign scientific centers.

FIGURE 8.3.

DISTRIBUTION OF SCORES FOR THE DIRECTION:
"GENOMIC SELECTION IN ANIMAL HUSBANDRY"



"Table 8.2." provides a summary evaluation of the new ideas most supported by experts regarding the addition of promising research directions within the research cluster related to food security and bioeconomy.

The highest rating among new proposals was given to the direction *"Development of Post-War Restoration Methods for Agro-Ecosystems, Including Agricultural Lands, Cleaning of Soils and Water Resources Contaminated as a Result of the Large-Scale Invasion of the Russian Federation into the Territory of Ukraine"* (Figure 8.4). However, like in many other directions, there is a noted equipment shortage here. Moderate evaluations of contributions and ambiguity in international cooperation assessments were also received: 22% note active collaboration and participation in joint research projects. However, even more consider cooperation with foreign scientific centers very limited.

Thus, the survey results highlight the urgent need for immediate efforts in scientific support for the restoration of disrupted agro-ecosystems and the remediation of war-related damage. There are available specialists, ideas, and some groundwork for this. However, resources remain the primary challenge.

TABLE 8.2.

NEW IDEAS FOR RESEARCH DIRECTIONS WITHIN THE RESEARCH CLUSTER: **"FOOD SECURITY, SUSTAINABLE AGRICULTURAL DEVELOPMENT AND RELATED TECHNOLOGIES, BIOECONOMY"** EVALUATION OF THEIR RELEVANCE AND POTENTIAL

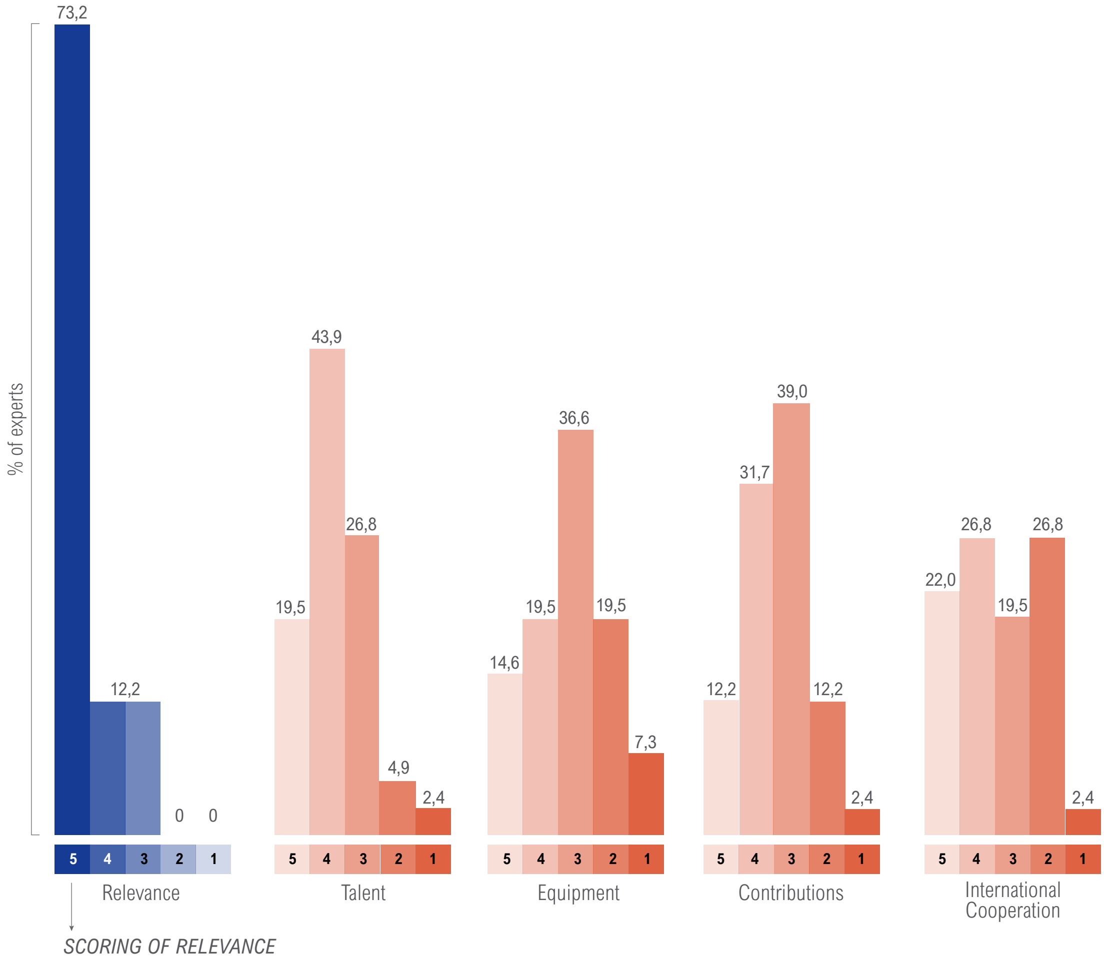
TOP RELEVANCE (Percentage of experts who gave the highest Relevance score – 5 points, %)

AVERAGE SCORE

TOP RELEVANCE	Relevance	Talent	Equipment	Contributions	International Cooperation	*RESEARCH DIRECTION*
74%	4,62	3,72	3,10	3,36	3,36	1. Development of post-war restoration methods for agrophytocenoses, including agricultural lands, cleaning of soils and water resources contaminated as a result of the large-scale invasion of the Russian Federation into the territory of Ukraine
65%	4,40	3,73	3,23	3,55	3,15	2. Enhancing drought resistance of agricultural crops. Searching for new approaches to increase crop yields
63%	4,35	3,93	3,30	3,83	3,20	3. Development of national breeding, national seed production, intellectual property in seed production. Creation and implementation of high-quality grain crops as the basis for food and economic security of the state
55%	4,28	3,55	3,20	3,40	3,18	4. Creation and transfer of the first grain crop varieties in Ukraine with unique grain characteristics intended for the production of healthy food products
51%	4,22	3,38	3,03	3,05	3,22	5. Development of technologies and technical means for ensuring sustainable agricultural production and food security of the country. Circular economy
51%	4,31	3,51	3,10	3,34	3,08	6. Environmental protection, restoration of the country's ecological security. Integration of fundamental agroecology principles into agricultural development. Sustainable natural resource management
49%	4,08	3,61	3,39	3,44	3,33	7. Development of technologies for producing ethanol biodiesel fuel based on renewable raw materials
44%	4,11	3,42	3,03	3,14	3,08	8. Biotechnologies for accelerated reproduction of agricultural animals, ensuring veterinary and sanitary well-being. Development of serums and vaccines for agricultural animals
44%	3,97	3,26	2,92	3,00	3,05	9. Genetic engineering of plants and animals; transgenic organisms. Research on the impact of genetically modified products on the human body
43%	4,14	3,35	3,19	3,14	2,95	10. Development of unmanned (remote) monitoring systems for agricultural lands based on artificial intelligence
39%	4,11	3,32	2,97	3,29	3,13	11. Phytosanitary condition of agrocenoses. Formation of a genetic bank of domestic varieties of fruit and ornamental crops. Development of plant protection systems and tools based on NBIC technologies
26%	3,42	3,19	2,79	2,87	2,76	12. Development of new environmentally safe plant growth regulators based on azagheterocycle derivatives to increase productivity and stress resistance of agricultural crops
24%	3,73	3,38	3,14	3,11	3,05	13. Creation and implementation of systems for efficient resource use (nitrogen/nutrients, crop protection agents, etc.) to reduce greenhouse gas emissions and increase the profitability of crop production

FIGURE 8.4.

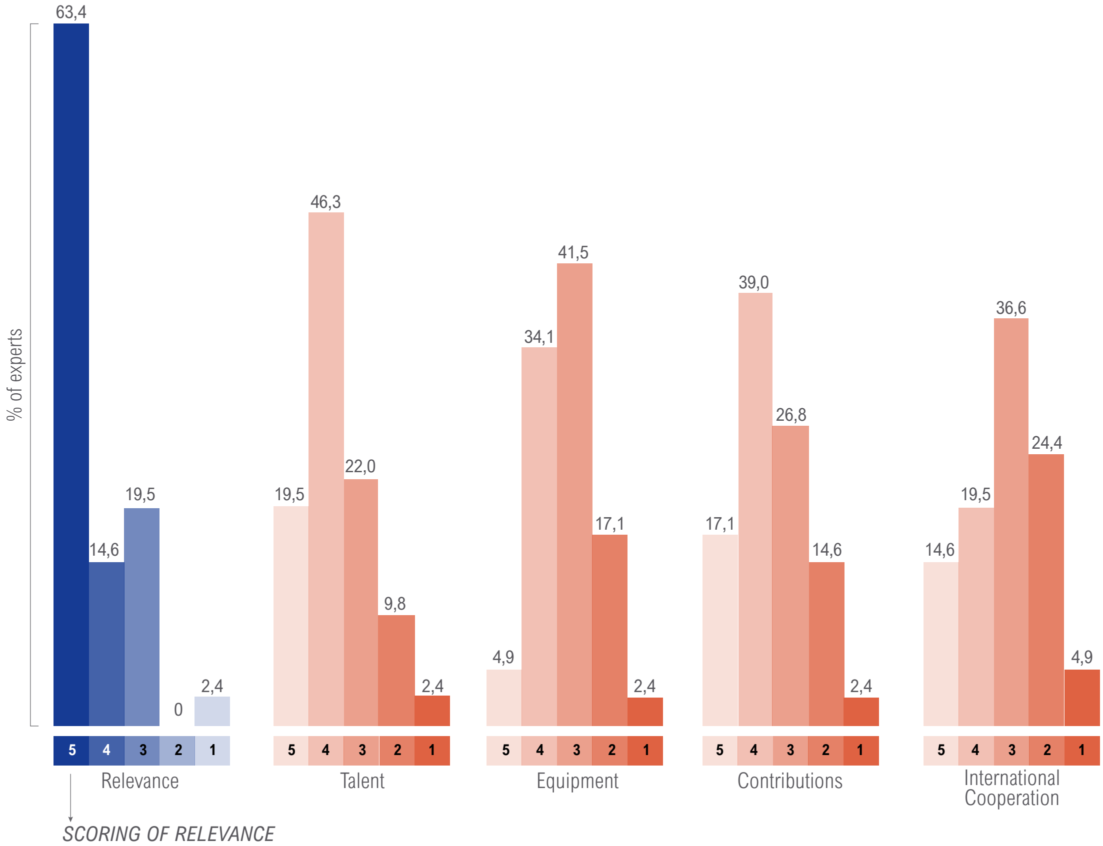
DISTRIBUTION OF SCORES FOR THE DIRECTION:
"DEVELOPMENT OF POST-WAR RESTORATION METHODS FOR AGRO-ECOSYSTEMS, INCLUDING AGRICULTURAL LANDS, CLEANING OF SOILS AND WATER RESOURCES CONTAMINATED AS A RESULT OF THE LARGE-SCALE INVASION OF THE RUSSIAN FEDERATION INTO UKRAINE"



Climate change trends indicate the relevance of enhancing drought resistance. Most experts agree with this assessment and based on the score distribution (Figure 8.5) they view the prospects of solving this problem with cautious optimism.

FIGURE 8.5.

DISTRIBUTION OF SCORES FOR THE DIRECTION:
"ENHANCING DROUGHT RESISTANCE OF AGRICULTURAL CROPS. SEARCHING FOR NEW APPROACHES TO INCREASE CROP YIELDS"

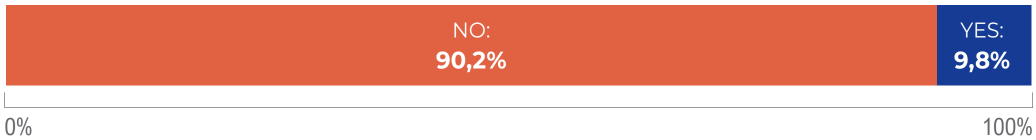


The food security and bioeconomy cluster predominantly assess the presence of state policy negatively (Figure 8.6). Less than 10% of experts believe that the state has largely formulated an adequate science and technology policy.

FIGURE 8.6.

PRESENCE OF STATE POLICY

(responses to the question "Do you agree that the state has established a science and technology policy that is suitable for the present circumstances?")

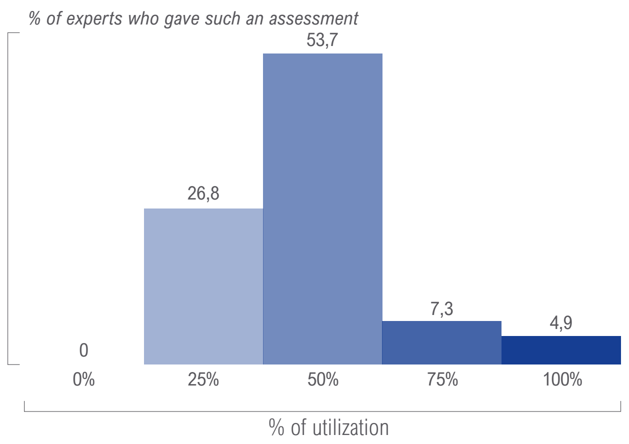


In the assessment of scientific and technological potential utilization within this research cluster, more than half of the experts chose 50%. Therefore, there is significant untapped potential that needs to be relied upon (Figure 8.7).

FIGURE 8.7.

UTILIZATION OF SCIENTIFIC AND TECHNOLOGICAL POTENTIAL BY RESEARCH DIRECTION

(responses to the question "Approximately, to what percentage do you estimate the scientific and technological potential of the country is currently being utilized?")



Overall, the analysis of expert assessments regarding the research cluster on **food security and bioeconomy** reveals that, despite official statements emphasizing the importance and priority of the agricultural sector, experts rate the condition of research and government policy in this area lower than in many other scientific fields.

Support for the agro-industrial complex has not resulted in significant improvements in agricultural science, which continues to encounter similar challenges and issues as most other research sectors.

Social Sciences and Humanities

In the research cluster *"Human Development, Socio-Humanitarian, Economic and Social Transformations, Modern Social Relations and Their Legal Support"* 72 experts were involved, including eight Academicians and Corresponding Members, 45 Doctors of Sciences, and 18 Candidates of Sciences.

This research cluster is distinct in its focus on understanding issues of individual and societal existence, addressing concerns that impact both individuals and society. The complexity of analysis arises from the need for experts to juxtapose questions related to values, ideals, and future visions, while being deeply rooted in historical contexts, influenced by the present, and oriented towards the future.

Theoretical and practical aspects of the development of humanitarian, social, economic, political, and legal spheres are analyzed. These issues have always been complex and contentious, as there is no single path for civilizational development. However, they become particularly acute during pandemics, social upheavals, and wars.

During the current Russia-Ukraine war, the challenges of socio-humanitarian and economic development have taken on a threatening existential character. Ukrainian scholars must seek ways to overcome humanitarian and societal challenges, recommend strategic goals for state development, defend Ukraine's agency in the geopolitical arena, develop strategies and goals for post-war reconstruction, enhance national consciousness and citizen solidarity, advance technologies to counter manipulative enemy propaganda in the information war, and develop psychological protection tools and provide psychological support to military personnel, victims, and temporarily displaced citizens, contributing to the preservation and development of human potential, and more.

The development of the socio-humanitarian field is directly linked to ensuring national security, which should be a primary priority in the country's post-war reconstruction. Another important task is the demographic revival of Ukraine, which is impossible without achieving a high standard of living and ensuring citizens' rights and freedoms.

“Table 9.1” presents the average scores for the ten research directions identified in the previous survey.

TABLE 9.1.

RESEARCH DIRECTIONS WITHIN THE RESEARCH CLUSTER
"HUMAN DEVELOPMENT, SOCIO-HUMANITARIAN, ECONOMIC AND SOCIAL TRANSFORMATIONS, MODERN SOCIAL RELATIONS AND THEIR LEGAL SUPPORT"
ACCORDING TO THE 2021 LIST AND CURRENT ASSESSMENT OF THEIR RELEVANCE AND POTENTIAL

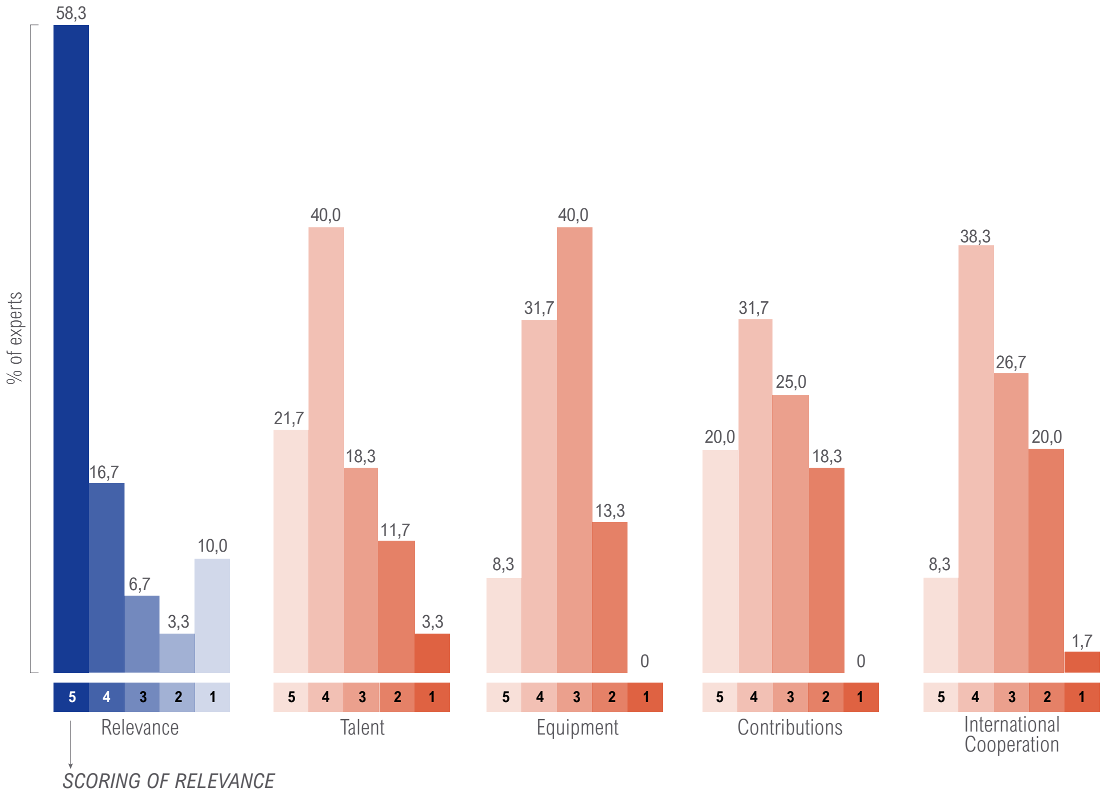
TOP RELEVANCE (Percentage of experts who gave the highest Relevance score – 5 points, %)	*AVERAGE SCORE* Relevance	Talent	Equipment	Contributions	International Cooperation	*RESEARCH DIRECTION*
45%	4,00	3,66	3,29	3,66	3,46	1. Humans in the context of technological civilization
34%	3,61	3,45	3,20	3,31	3,25	2. Sociocultural transformations in the 21st century: synchrony of visual, ethical, anthropological, and linguistic turns
55%	4,13	3,61	3,36	3,58	3,45	3. Development of social capital and population well-being
63%	4,16	3,70	3,40	3,57	3,34	4. Study of the sociocultural environment and identities of Ukrainian citizens
57%	4,05	3,63	3,25	3,56	3,20	5. Development of the cultural ecosystem and creative economy, unifying values, preservation of language, national memory, and cultural heritage, socio-psychological and legal support for managing innovation processes in the socio-humanitarian domain
50%	4,00	3,50	3,14	3,29	3,11	6. Professional training of modern teachers in the context of globalization processes
59%	4,00	3,43	3,25	3,54	3,23	7. State-building challenges

A notable feature of this research direction is the lack of unanimity in assessments. The percentage of experts who rated the relevance at the highest level ranges from 34% to 63%, which is significantly lower compared to other research clusters. No direction received the highest relevance score from more than two-thirds of the experts.

The direction *"Study of the Sociocultural Environment and Identities of Ukrainian Citizens"* received the most top relevance scores, yet the assessments of contributions in this direction are also low (see Figure 9.1).

FIGURE 9.1.

DISTRIBUTION OF SCORES FOR THE DIRECTION **"STUDY OF THE SOCIOCULTURAL ENVIRONMENT AND IDENTITIES OF UKRAINIAN CITIZENS"**



The charts in Figure 9.1 show that 63% of experts confirmed this direction is highly relevant and deserves priority support. However, based on other responses, it has not received sufficient attention to date.

"Table 9.2" presents a summarized evaluation of the most popular ideas for supplementing the list of promising research directions within this cluster.

TABLE 9.2.

NEW IDEAS FOR RESEARCH DIRECTIONS WITHIN THE CLUSTER:
"HUMAN DEVELOPMENT, SOCIO-HUMANITARIAN, ECONOMIC AND SOCIAL TRANSFORMATIONS, MODERN SOCIAL RELATIONS AND THEIR LEGAL SUPPORT" AND EVALUATION OF THEIR RELEVANCE AND POTENTIAL

TOP RELEVANCE (Percentage of experts who gave the highest Relevance score – 5 points, %)

AVERAGE SCORE

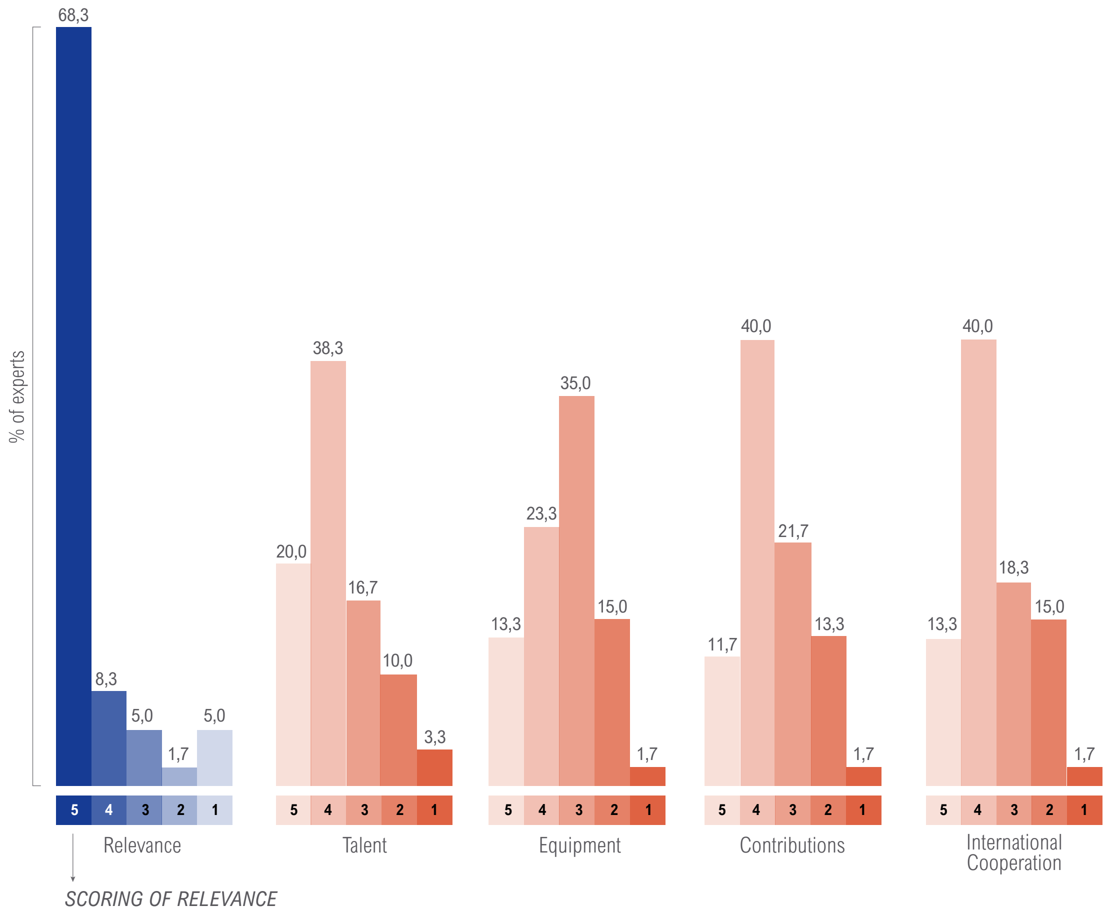
TOP RELEVANCE	Relevance	Talent	Equipment	Contributions	International Cooperation	*RESEARCH DIRECTION*
77%	4,5	3,7	3,4	3,5	3,5	1. Mobilization of the economy for defense needs (optimization of legislation, state planning and administration, resource mobilization, public-private partnerships, etc.)
75%	4,5	3,6	3,4	3,6	3,5	2. Migration policy and human capital restoration. Mechanisms for preserving the country's human potential
72%	4,5	3,7	3,5	3,5	3,6	3. Post-war recovery (legal and economic aspects). New models of state economic development, economic transformations crucial for solving social issues and ensuring military strength
70%	4,4	3,9	3,4	3,6	3,4	4. Demographic security. Forecasting demographic development in Ukraine and labor force movement
64%	4,4	3,7	3,5	3,6	3,5	5. Problems of solidarity and desolidarization during war. Policies for the reintegration of veterans, internally displaced persons, residents of de-occupied territories, and other victims of the Russian invasion. Issues of social psychology and social trauma. Mental health, human development, and human capital in extreme conditions (war and post-war recovery)
62%	4,3	3,5	3,3	3,4	3,2	6. Monitoring the destruction of cultural heritage objects in the context of the Russo-Ukrainian war (compiling a list of museum items taken by Russian invaders; development and implementation of methodologies for preserving museum buildings)
58%	4,2	3,6	3,4	3,5	3,3	7. Research in the field of information space protection, freedom of speech, and countering disinformation
53%	4,2	3,4	3,3	3,3	3,4	8. Issues of democratic participation, transparency, and anti-corruption
52%	4,1	3,5	3,3	3,4	3,2	9. Formation of a new civic (national/supranational/multi-cultural) identity of the Ukrainian people
42%	4,0	3,5	3,3	3,2	3,1	10. Issues of social justice and social dialogue, labor law, and trade unions in times of war and post-war recovery
42%	3,8	3,5	3,3	3,3	3,2	11. War and wartime in the light of conceptual proposals in intellectual and cultural history. Representation of socio-cultural catastrophes and modernizations in Ukrainian society of the 20th century: concepts, strategies, models
38%	3,7	3,4	3,2	3,2	3,1	12. Decolonial studies (imperialism, russification, identity, minority rights, anti-colonial solidarity, memory politics)
36%	3,9	3,3	3,2	3,2	3,3	13. Ethical and security issues of modern information technologies

It is noteworthy that support for new directions is significantly more unanimous than for those identified in 2021. Over 70% of experts recognized the most highly rated directions as very relevant, whereas no such consensus exists for the older topics. Additionally, there is a marked shift towards specific issues directly related to the war.

Among the new proposals, the undisputed leader is the direction *"Mobilization of the Economy for Defense Needs (optimization of legislation, state planning and administration, resource mobilization, public-private partnerships, etc.)"* (Figure 9.2).

FIGURE 9.2.

DISTRIBUTION OF SCORES FOR THE DIRECTION
"MOBILIZATION OF THE ECONOMY FOR DEFENSE NEEDS"



The distribution of expert assessments shown in Figure 9.2 allows us to conclude that state measures for economic mobilization for defense needs have scarcely affected science, thus not considering its potential.

As seen in Figure 9.3, among social scientists and humanitarians, the smallest proportion of researchers perceive the existence of a science and technology policy that is adequate to current challenges. Such a low evaluation is unique to this cluster. The assessments of potential utilization are also exceedingly low (Figure 9.4).

FIGURE 9.3.

PRESENCE OF STATE POLICY

(responses to the question "Do you agree that the state has established a science and technology policy that is suitable for the present circumstances?")

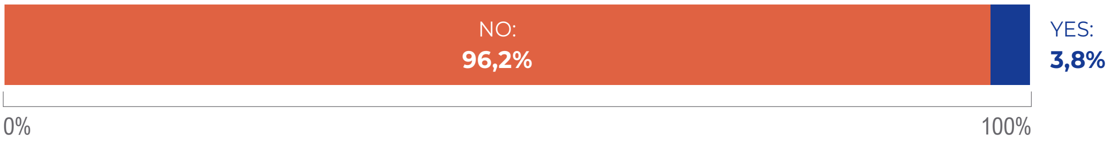
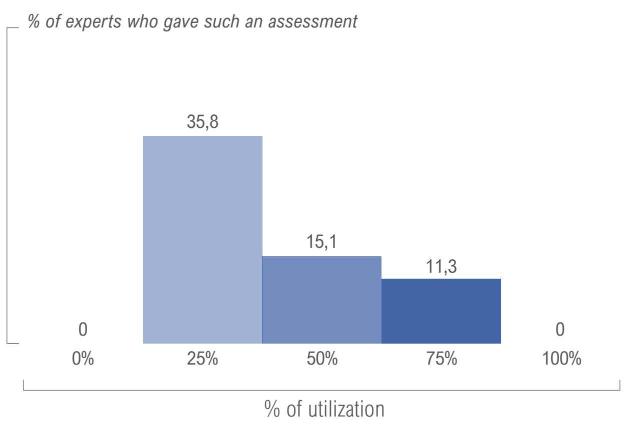


FIGURE 9.4.

UTILIZATION OF SCIENTIFIC AND TECHNOLOGICAL POTENTIAL BY RESEARCH DIRECTION

(responses to the question "Approximately, to what percentage do you estimate the scientific and technological potential of the country is currently being utilized?")



As previously emphasized, the development of the socio-humanitarian sector is an extremely important condition for ensuring national security that should be one of the main priorities in the country's post-war reconstruction.

The dynamics of expert evaluations demonstrated in this study indicate a desire and readiness among social scientists and humanitarians to more actively engage in the formation and implementation of Ukraine's policy in this area.

Science and Technology Policy in Ukraine

Global experience demonstrates that the influence of science on a country's innovative development is significantly determined by the effectiveness of its science and technology policy. In independent Ukraine, discussions regarding the specifics of this policy remain contentious, particularly concerning the management mechanisms required for its formulation and implementation, as well as the government bodies responsible for its execution.

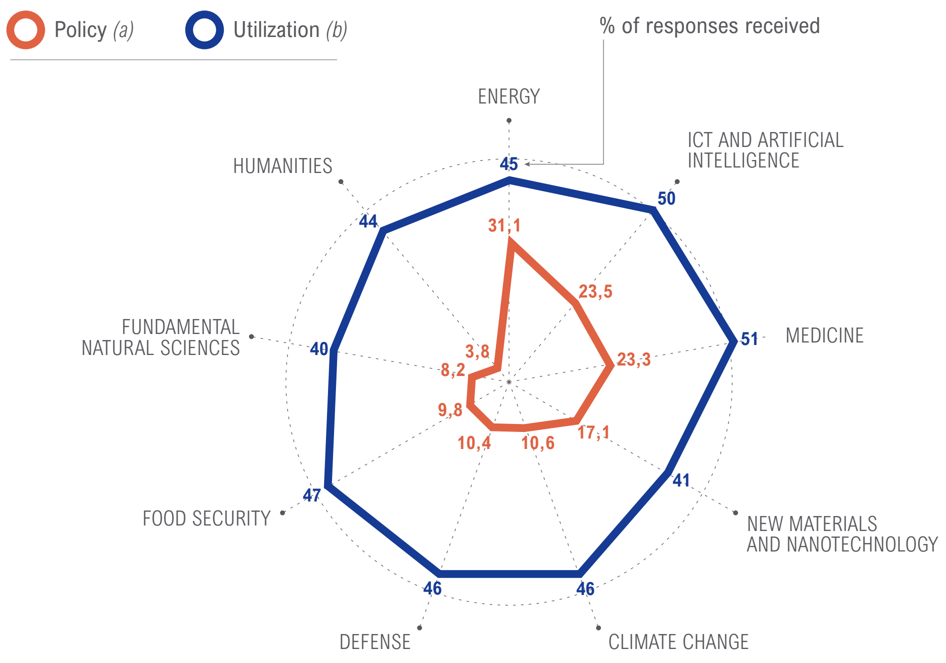
In light of this, alongside the project's primary objective of assessing the priority and feasibility of implementing urgent research directions, we have included questions in the questionnaires to gauge experts' perspectives on these matters. These questions were uniformly presented to all experts within each research cluster.

We will begin our analysis with a review of the aggregated responses.

Figure 10.1 illustrates the evaluations concerning the formation of state policy and the utilization of scientific and technical potential, highlighting the state's impact on research development and the effectiveness of capability utilization within each research cluster.

FIGURE 10.1.

COMPARISON OF ASSESSMENTS OF THE PRESENCE OF ADEQUATE STATE POLICY AND UTILIZATION OF SCIENTIFIC AND TECHNICAL POTENTIAL BY RESEARCH CLUSTER



As depicted in Figure 10.1(a), experts generally assign a very low rating to the adequacy of the state's science and technology policy across all nine research clusters surveyed.

A minority of experts in each cluster responded positively to the question, **"Do you agree that the state has established a science and technology policy suitable for the present circumstances?"** The lowest ratings—less than 10% positive responses—were recorded in the fields of "Social Sciences and Humanities" (Cluster 9) and "Fundamental Mathematics and Natural Sciences" (Cluster 1). In contrast, the most favorable assessments were noted in energy, digital technologies, artificial intelligence, and medicine. This indicates that targeted state efforts to mobilize potential in these directions are recognized by the scientific community but are still considered insufficient.

The attempts by Russian invaders to undermine domestic energy infrastructure have notably prompted the state to take action, which has been felt by energy researchers. Similarly, the COVID-19 pandemic has led to an increased focus on the field of medicine. Materials science ranks third in terms of responsiveness.

A comparison of utilization levels (i.e., the application of scientific and technical potential in the respective directions) reveals significant untapped resources in nearly all areas of domestic science that can and should be fully leveraged. Additionally, this comparative analysis, illustrated in diagram form (see Figure 10.1), highlights state policy activity in these directions. It is evident that state engagement is most pronounced in energy, followed by medicine (in response to COVID-19), while activity in other areas remains exceedingly low.

The most surprising finding was the low assessment of science and technology policy in defense developments, with only one in ten experts deeming it appropriate for the current circumstances. Experts expressed concerns that the state has yet to address strategic defense issues or identify effective methods to mobilize domestic research and development potential. Furthermore, there are significant delays in the implementation of even those developments that have been successfully completed in accordance with state orders.

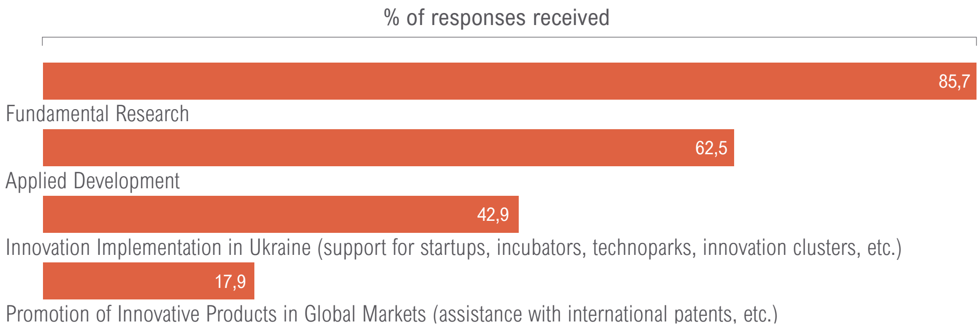
As illustrated in Figure 10.1(b), the evaluations of state policy and the utilization of potential in the respective fields of science generally exhibit a correlation. Specifically, for the research clusters of digital technologies and artificial intelligence (Cluster 3) and medicine (Cluster 6), scientists assess potential utilization as above average. In contrast, the utilization of potential in defense research areas remains low. Overall, experts estimate the average level of utilization for scientific and technical potential to be below 50%.

The inadequate level of utilization of scientific and technological potential may be attributed to the challenges associated with the implementation of new technologies and innovations, often referred to as the "valley of death" between fundamental research and large-scale market deployment of innovation. For example, experts in the second research cluster, "Research and Development for National Security and Defense, Dual-Use Technologies," identify the stages of applied development (86.9%) and implementation (61.4%) as the most problematic in the innovation process (see Figure 10.2).

Thus, state efforts to support startups in the defense sector appear to be insufficient. Additionally, these startups tend to prioritize the rapid deployment of fully developed solutions, often neglecting new developments. Therefore, it can be concluded that to enhance defense capabilities, the state must place significantly greater emphasis on supporting both fundamental and applied research. Without this focus, all initiatives aimed at supporting startups will likely be far less effective.

FIGURE 10.2.

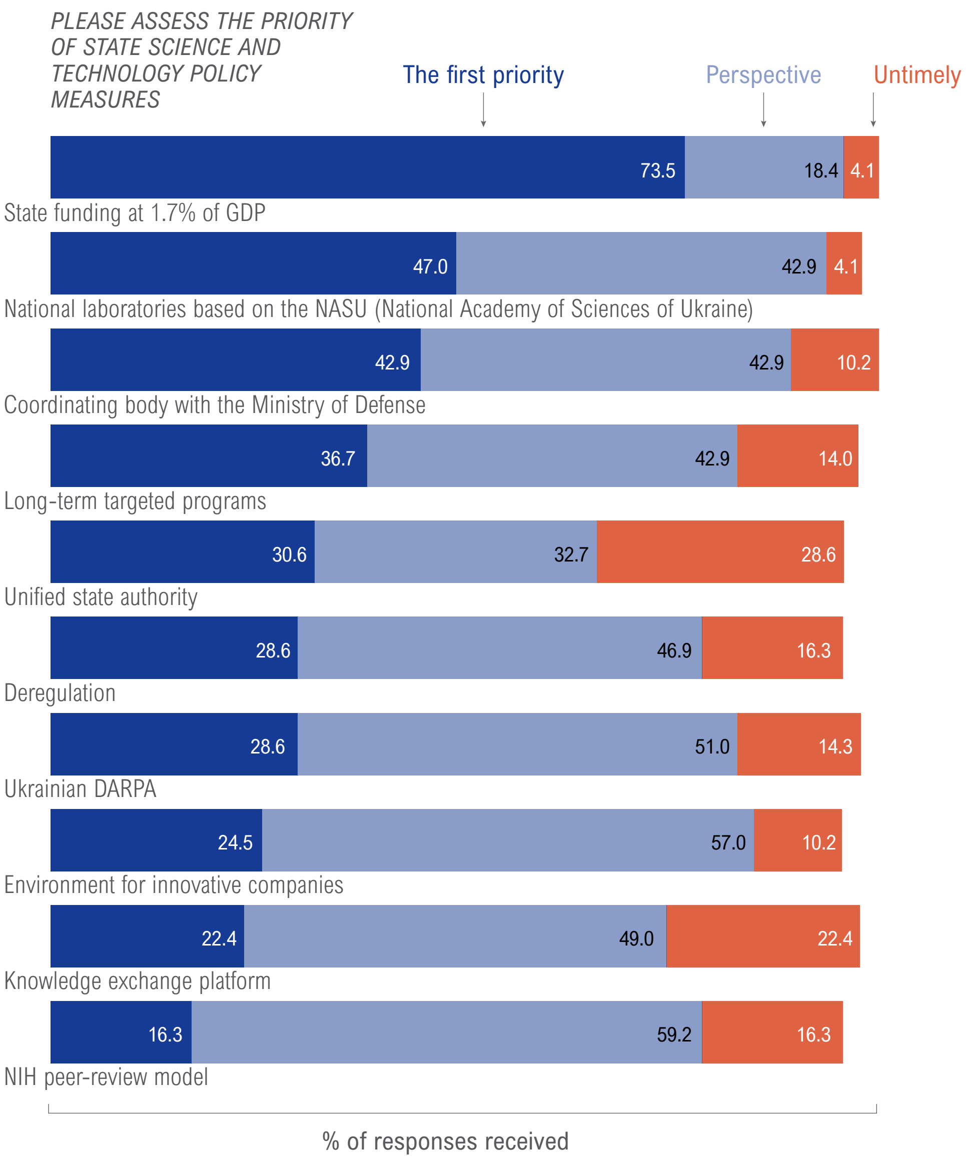
ASSESSMENT OF THE MOST PROBLEMATIC STAGES OF INNOVATION IMPLEMENTATION BY EXPERTS IN THE RESEARCH CLUSTER **"RESEARCH AND DEVELOPMENT FOR NATIONAL SECURITY AND DEFENSE, DUAL-USE TECHNOLOGIES"**



Experts have identified and evaluated proposals to address the inadequacies and disorganization in the state's science and technology policy. In the area of defense developments and technologies (see Figure 10.3), they have highlighted several urgent priorities: ensuring adequate funding in accordance with legal standards, establishing national laboratories based on the institutes of the National Academy of Sciences of Ukraine (NASU) following the American model, and creating a coordinating body involving the Ministry of Defense to unify the efforts of scientific organizations.

FIGURE 10.3.

ASSESSMENT OF PRIORITY MEASURES FOR OPTIMIZING SCIENCE AND TECHNOLOGY POLICY IN **"RESEARCH AND DEVELOPMENT FOR NATIONAL SECURITY AND DEFENSE, DUAL-USE TECHNOLOGIES"** (overall for all directions)



Unfortunately, in Ukraine, the legal requirement to allocate 1.7% of GDP to science has been perceived by officials more as a burdensome social obligation than as an essential investment in the future. With new technologies proving vital on the battlefield, restoring the scientific capacity lost over previous decades has become a matter of national survival, particularly regarding current and strategic defense capabilities.

Currently, the state allocates significant funds to defense, which includes financing the creation of new weapons and related research and development. However, the existing procedure focuses on contracting for the purchase of finished products, which forces contractors to seek their own funding for necessary research and development activities.

This creates a detrimental cycle that stifles innovation: funding is required for development and prototyping, yet obtaining state support before testing is nearly impossible. As a result, private startups can only afford to create basic prototypes based on established civil sector technologies, as seen with FPV drones and small-scale electronic warfare. Opportunities to develop more advanced technologies remain virtually nonexistent.

It is important to note that funding for defense research in countries such as the United States employs an integrated approach, where the government finances all stages of the innovation cycle for new weaponry—from fundamental and applied research to prototype testing and production scaling. Special emphasis is placed on intermediate stages: development, prototyping, demonstrations, and testing.

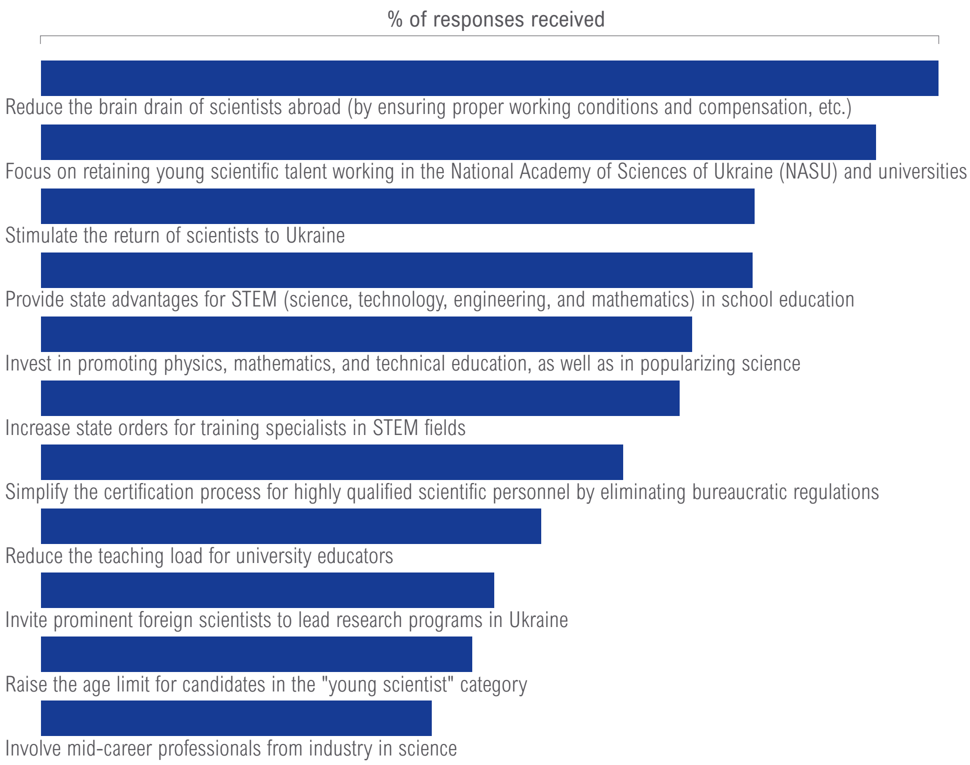
In Ukraine, a coherent system of targeted state programs for the development of new weapons is just beginning to emerge. It is hoped that this process will draw on both advanced international practices and insights from scientists who possess an in-depth understanding of these processes.

In addition to challenges related to the focus of science and technology policy and outdated equipment, a significant issue facing Ukrainian science is the **scarcity of skilled personnel** and the overall decline of talent pool within the scientific and technological and innovation sector.

Experts were consulted on potential strategies to revitalize this talent pool. In response to open-ended questions, many ideas were expressed regarding ways to **restore the talent pool of Ukrainian science.** Many of them highlighted the necessity to enhance the prestige of scientific careers and their attractiveness to younger generations. In the third round of evaluations, experts assessed these proposals, as depicted in the diagram below.

FIGURE 10.4.

EVALUATION OF PROPOSALS FOR RESTORING THE TALENT POOL (overall for all directions)



The findings indicate that the highest priority (83%) is to mitigate the brain drain of scientists leaving for opportunities abroad by ensuring adequate working conditions and compensation. The second priority (74%) focuses on retaining young scientific talent within the National Academy of Sciences of Ukraine (NASU) and universities. Some experts suggested that national sectoral academies also warrant consideration. The third most supported measure (59%) involves encouraging scientists to return to Ukraine. Additionally, 58% of experts endorsed the idea of providing state advantages for STEM (science, technology, engineering, and mathematics) education at the school level.

Somewhat unexpectedly for the Ministry of Education and Science of Ukraine and the National Agency for Higher Education Quality Assurance, a significant portion of experts (41%) ranked the simplification of the certification process for highly qualified scientific talent—by reducing bureaucratic regulations—as the fourth priority. This suggests that the increasing bureaucratic oversight of dissertation defenses in Ukraine has become a notable barrier to youth entering the scientific field, further obstructing efforts to restore the domestic talent pool.

The current state of the Ukrainian scientific talent pool is critical; without significant measures for its revitalization, the rate of decline may accelerate sharply. A considerable influx of new talent is essential to offset these losses. Without this, Ukraine risks losing not only its ability to conduct world-class research within a decade but also its capacity to implement advanced foreign technologies due to a shortage of qualified personnel.

CONCLUSIONS

The "Ukrainian Science and Technology Foresight" project facilitated an expert evaluation of the relevance of research directions identified in 2021 and formulated proposals for integrating new, pressing issues. Additionally, expert opinions on the state's science and technology policy were analyzed both generally and within specific research clusters and fields.

Based on these studies, the State Institution "Dobrov Institute for Scientific and Technological Potential and Science History Studies of the NAS of Ukraine" has formulated proposals to update the list of priority research directions, which are available on the institution's website[9]. Directions confirmed as relevant by over 50% (in some cases, over 40%) of experts have been included. **We believe this list can be submitted for consideration by the Presidium of NAS of Ukraine.**

This method of selecting priority directions should not be viewed as the only approach. In certain instances, it may be necessary to concentrate efforts on the most critical areas—those that are underfunded yet essential. Ultimately, the determination of state priorities must result from **political decisions made by state authorities,** informed by foresight research of this nature.

Feedback from the questionnaires and interactions with experts during the project suggest that, despite significant losses in scientific capacity, Ukraine has managed to retain some researchers who continue to work productively and stay informed about global scientific advancements.

However, it is crucial to recognize that **among the research directions and developments evaluated by experts, there is virtually none for which the majority claims that development is adequately supported by talent and equipment.** This underscores the unprecedented losses experienced by domestic science over the past decades, further exacerbated by the Russian invasion. Consequently, restoring this sector will require substantial and extraordinary efforts.

The research affirms that the Ukrainian state possesses the capability to support the development of science and technology. Scientists perceive positive potential in certain measures being implemented in areas such as energy, medicine, and information technology, though perceptions are less favorable in the defense sector. Nonetheless, the overall science and technology policy of the state remains inadequate and disorganized. Ukrainian scientists increasingly feel that the majority of initiatives and proposals put forth by the Ministry of Education and Science of Ukraine to enhance science management fail to address current challenges and may even hinder recovery efforts.

Despite facing significant financial challenges, Ukraine must substantially enhance its investment in research and development (R&D). Relying exclusively on the acquisition of ready-made solutions or hoping for the market to spontaneously cultivate Ukrainian technological capabilities is inadequate. Instead, Ukraine should prioritize the development and consistent implementation of state-targeted programs that support R&D at all stages—ranging from fundamental and applied research to prototyping, testing, and scaling production.

Ukraine needs an integrated innovation system similar to that used by the U.S. Department of Defense, including the creation of DARPA-like entities to support new technologies – from research to the industrial adoption of innovative products. Standardizing production, ensuring component interchangeability, and developing state production of key elements are crucial, especially during wartime.

When shaping the system of targeted programs, it is advisable to utilize foresight methods to assess existing potential across various research directions. This will allow for

9 Proposed updates to priority directions for scientific development, which received the highest relevance scores from experts surveyed during the 'Ukrainian Scientific and Technological Foresight' project. Dobrov Institute for Scientific and Technological Potential and Science History Studies of the NAS of Ukraine, 2024. Available at: https://stepscenter.org.ua/archives/3690 focused efforts on areas with the highest potential for technological breakthroughs. Immediate attention is also required for identified weaknesses within the national science and technology system. Addressing these weaknesses is crucial for preserving research teams and capacities, ultimately ensuring strategic resilience and capability.

This study gathered expert opinions on priority research directions, providing valuable guidance for shaping long-term science and technology policy. The assessments of relevance and potential for each research direction can be used not only to determine their prioritization but also in the development of program structures, as well as in the formulation of measures aimed at the balanced development of the country's scientific potential.

When engaging in detailed planning of science and technology programs, it is advisable to utilize a combination of foresight methods, such as Delphi surveys, along with program-forecast methodologies aimed at maximizing and optimizing the involvement of all scientific and technological talent within the country. The goal is to achieve the fastest and most effective solutions for defined scientific and technological challenges (e.g., creating a domestically produced ballistic missile with specific range and cost parameters). Such methods can quickly identify technologies currently unavailable in Ukraine but necessary for solving critical challenges. Additionally, they can help determine optimal development pathways, leveraging the full potential of Ukrainian developers.

Recently, the President of Ukraine enacted[10] the decision of the National Security and Defense Council of Ukraine "On the Strategy of Maritime Security of Ukraine," which mandates foresight research to identify the most promising (priority) objectives for each research cluster within maritime research.

We advocate for the expanded and active application of foresight methods, particularly program-forecast methodologies, across all scientific disciplines. This is especially pertinent for prospective research in national security and defense, as well as for addressing the challenges associated with post-war recovery.

10 *Decree of the President of Ukraine dated July 17, 2024 No. 468/2024*

SCIENTIFIC PUBLICATION

NATIONAL ACADEMY OF SCIENCES OF UKRAINE

DOBROV INSTITUTE FOR SCIENTIFIC AND TECHNOLOGICAL POTENTIAL AND SCIENCE HISTORY STUDIES OF THE NAS OF UKRAINE

PROJECT TEAM

ORGANIZATIONAL AND METHODOLOGICAL GUIDANCE AND RESULTS SYNTHESIS:
Oleksandr Popovych – Scientific Supervisor,
Oleh Mishchuk, Zakhar Popovych, Olena Kostrytsia

WORK WITH EXPERTS (ORGANIZATIONAL AND METHODOLOGICAL GROUPS FOR RESEARCH TOPICS):

Fundamental Research in Emerging Areas of Mathematics and Natural Sciences	**Lidiia Kavunenko, Oksana Chernogaeva**
Research and Development for National Security and Defense Needs, Dual-use Technologies	**Alla Lytvynko, Yuriy Mushkalo**
Information and Communication Technologies, Digital Technologies, Artificial Intelligence, Robotics, Cybersecurity	**Vitaliya Klimenkova, Maksym Shumakov**
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Aksynia Kurina – Media and Communications
Karyna Chmelyuk – Project Website Development
Yevhen Mishchenko – Data Processing and Visualization
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THE PROJECT TEAM EXPRESS THEIR SINCERE GRATITUDE TO ALL EXPERTS WHO CONTRIBUTED TO THE FORECAST AND ANALYTICAL STUDY "UKRAINIAN SCIENCE AND TECHNOLOGY FORESIGHT".

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ABOUT THE STUDY

The «Ukrainian Science and Technology Foresight» is a comprehensive analysis of key research directions in the scientific and technological development of Ukraine. Using the Delphi method, over 500 experts were surveyed to form a strategic vision that considers current challenges and global trends.

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