PROSPECTS FOR THE DEVELOPMENT OF ENVIRONMENTAL SCIENCES RESEARCH INFRASTRUCTURES IN UKRAINE

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Abstract. The scientific potential regarding the human resources in Ukraine is high to support global scientific research activities, though, there are insufficient levels of provision for material and technical base of scientific and high academic degree institutions. To increase the competitiveness of scientific research, scientific-technical developments and improve the state of the national economy and the life quality of citizens, Ukraine needs to find new additional sources of funding for carrying out research activities and update the material and technical base from the scientific institutions. To achieve this, closer cooperation between scientific institutions and the European research infrastructures is required. Research infrastructures, including the European Open Science Cloud, and technology infrastructures are the key elements of research and technological innovation, and the main drivers of multidisciplinary science in the EU. Today, Europe has a high-developed research infrastructure, which could be essential for Ukraine to take part in. Smart investments will be required now and in the future for stimulating the development of new research infrastructures to fill knowledge gaps, support emerging needs and scientific breakthroughs, and respond to new challenges, particularly in the context of green and digital technologies. Research in the field of renewable energy and environmental science should be highlighted among current research areas of particular interest.

Key words: research infrastructure, scientific research, Horizon Europe, international cooperation, Ukraine's European integration

1. INTRODUCTION

The research infrastructure (RI) is built on the collection of facilities, resources and associated services used by the scientific community for conducting research activities at the highest level, covering critical scientific facilities and sets of instruments or equipment, knowledge-based resources (collections, archives, depositories or data banks of scientific information), infrastructure based on communications technology (grids, computers, software and network communications) and other structures of a unique character (Law, 2015).

RI can be placed locally, virtual or distributed as an organized public or private network of resources, which can also be part of international networks (Kokhan, 2022).

Research infrastructures may include centers for the collective use of scientific equipment, national scientific centers, state key laboratories, structures of a unique character, including scientific objects that constitute a national heritage.

Today in Ukraine there is a significant competitiveness drop in the scientific research domain and scientific-technical (experimental) developments, which negatively affects the national economy and the life quality of the citizens. One of the important reasons for this process is the lack of a systematic state policy for the development of research infrastructures along with many years of underfunding the capital expenditures which support and update the technical base of scientific materials and the educational institutions.

Thus, in 2019, the financing of science in Ukraine from the gross domestic product was 0.43 %, while in Poland – 1.03 %, Slovakia – 0.88 %, Turkey – 1.00 %. The current level of science funding in Ukraine does not allow investing in the development of research infrastructures.

The scientific potential of human resources in Ukraine is high for conducting global scientific research activities, even though there are insufficient levels of provision of material and technical base of scientific and higher education institutions. Over the past five years, the number of researchers in Ukraine has decreased by almost half – from 101,440 people in 2014 to 51,121 people in 2019. From the total employed population in 2018, the scientific workers represent only 0.54 %, including researchers - 0.35 %. This is caused by the departure of scientists abroad, where the level of development of RIs is much higher than in Ukraine.

In 2021, to create the necessary organizational, legal, and financial conditions for the development of a RIs system in Ukraine, for increasing its competitiveness, as well as developing the areas of scientific and innovative activities in advanced RIs in the European Union, the "Concept of the State Target Program for the Development of Research Infrastructures in Ukraine for the Period until 2026" was developed and adopted (Order CMU, 2021).

The main objective of the Concept is to systematize RIs, assess their compatibility with European RIs, provide priority funding for their further development and consistency with "Roadmap for the development of European research infrastructures", approved by the European Strategic Forum for Research Infrastructures (ESFRI).

Based on the analysis of options for improving the competitiveness of scientific research and scientific-technical developments in Ukraine, it is proposed to develop and gradually implement a legal, organizational, and financial mechanism for the development of RIs (Lyubchych, 2022).

Also, in 2021, the Ministry of Education and Science of Ukraine developed a "Roadmap for the integration of the scientific and innovative system of Ukraine into the European research space", which should ensure the harmonization of policies in the field of science and innovation in accordance with EU standards and regulations; expanding access to EU science and innovation programmes; development of Ukrainian RIs and their integration into EU research infrastructures; implementation of open science principles and implementation of EU open access instruments; development of innovation infrastructure taking into account best European practices; internationalization of research and innovation outside the EU (Order MES, 2021).

The purpose of the study is to analyze trends in the development and the induction of the Ukrainian research infrastructures in the European landscape of environmental research sciences infrastructures.

2. EUROPEAN UNION INITIATIVES

Research infrastructures, including the European Open Science Cloud (EOSC), and technology infrastructures are the key enablers for research and technological innovations, and drivers of multidisciplinary and intensive science in the EU.

Today there are twenty-eight RIs that have been established as European Research Infrastructure Consortia (ERIC), a legal form enshrined in the EU law and a single EU regulation within the European Research Area (ERA), ensuring the co-financing and integration of resources between Member States and associated countries, guaranteeing their commitment to continued support. The European Union and Member States jointly invest in RI also through the Cohesion Policy, developing research capacity at regional and national levels with the aim of publishing research results to the industry.

ERA member countries, EU countries and associated countries jointly develop policies for the development of RIs within the framework of the forum ESFRI. Ukraine can participate in this group with the right to vote (Vapniarchuk *et al.*, 2022).

At the pan-European level, the development of a strategy for the development of RIs began with the founding in 2002 of an informal organization – the European Strategic Forum on Research Infrastructures (ESFRI). Its main objectives were to ensure a consistent approach in developing policies in the field of pan-European scientific infrastructure; stimulating international initiatives aimed to improve the use of existing and creating new RI at European and global levels.

The ESFRI in 2006 developed a roadmap of new pan-European RI facilities for a 10–20-year period; in 2008, the list was revised to include 44 projects of pan-European importance. European RIs play a critical role in Europe's ability to create new knowledge and innovation to understand and solve environmental, social and economic problems (Nazarenko, 2017).

Another EU initiative is the Horizon Europe Programme, which aims to promote and maintain a stable RI at a pan-European level, open and accessible to the best researchers from Europe and beyond, and to strengthen the capacity of RIs to support scientific progress and innovation. This is the ninth European Framework Program for Research and Innovation for 2021-2027, which is an evolution of the Programme Horizon 2020 and includes three main and one cross-section entitled "Widening participation and strengthening the European Research Area".

Nowadays, Europe has a rich RI, a developed experience which is suitable for Ukraine to implement. Smart investments will be needed now and in the future to stimulate the development of new RIs to fill knowledge gaps, support emerging needs and scientific breakthroughs, and respond to new challenges, particularly in the context of green and digital technologies. Research in the field of renewable energy and environmental science should be highlighted among current and areas of research interest. Environmental RIs are essential to provide systematic and coherent datasets needed for research addressing topics regarding climate, natural resources, health, food security, biodiversity, and sustainable use of the marine, freshwater and soils.

At the moment, about 50 European RIs have already been registered in the fields of energy, environmental conservation, health and food safety, physical sciences and engineering, social and cultural innovation (ERA-UA, 2024).

Consequently, the European landscape of RIs (ESFRI, 2021) in the field of renewable energy and environmental sciences includes (Fig. 1): EURO-ARGO ERIC European contribution to the international Argo Programme (entered the operational stage in 2014), IAGOS In-service Aircraft for a Global Observing System (2014), ICOS-ERIC Integrated Carbon Observation System (2015), ECCSEL-ERIC European Carbon Dioxide Capture and Storage Laboratory Infrastructure (2016), EMSO-ERIC European Multidisciplinary Seafloor and water-column Observatory (2016), LifeWatch ERIC e-Infrastructure for Biodiversity and Ecosystem Research (2017), EU-SOLARIS European Solar Research Infrastructure for Concentrated Solar Power (2022), EPOS-ERIC European Plate Observing System (2023), EISCAT_3D Next generation European Incoherent Scatter radar system (2023).

Currently in the implementation phase: DANUBIUS-RI International Centre for Advanced Studies on River-Sea Systems (planned entry into the operational stage in 2024), ACTRIS Aerosol, Clouds and Trace Gases Research Infrastructure (2025), DiSSCo Distributed System of Scientific Collections (2025), eLTER RI Integrated European Long-Term Ecosystem, critical zone and socio-ecological system Research Infrastructure (2026), MARINERG-i Marine Renewable Energy Research Infrastructure (2030), IFMIF-DONES International Fusion Materials Irradiation Facility - DEMO Oriented Neutron Source (2033).

An example is DANUBIUS-RI (DANUBIUS-RI, 2024), which is currently underway in transition from the Implementation Phase to DANUBIUS-ERIC and will offer an agile pan-European RI in order to support the Research and Innovation needed to achieve healthy River-Sea Systems: enabling state-of-the-art, holistic, R&I from river source to sea and providing the integrated knowledge to manage River-Sea Systems, utilizing a source-to-sea perspective to understand their evolution and functioning.

DANUBIUS-RI will offer services integrating capabilities from: remote and in-situ observation platforms, experimental facilities, laboratories, modelling tools and resources for Knowledge Exchange along the river source to sea continuum. DANUBIUS-RI comprises components (Hub, Data Centre, Nodes, Supersites (living labs), e-Learning Office and Technology Transfer Office) distributed across Europe.

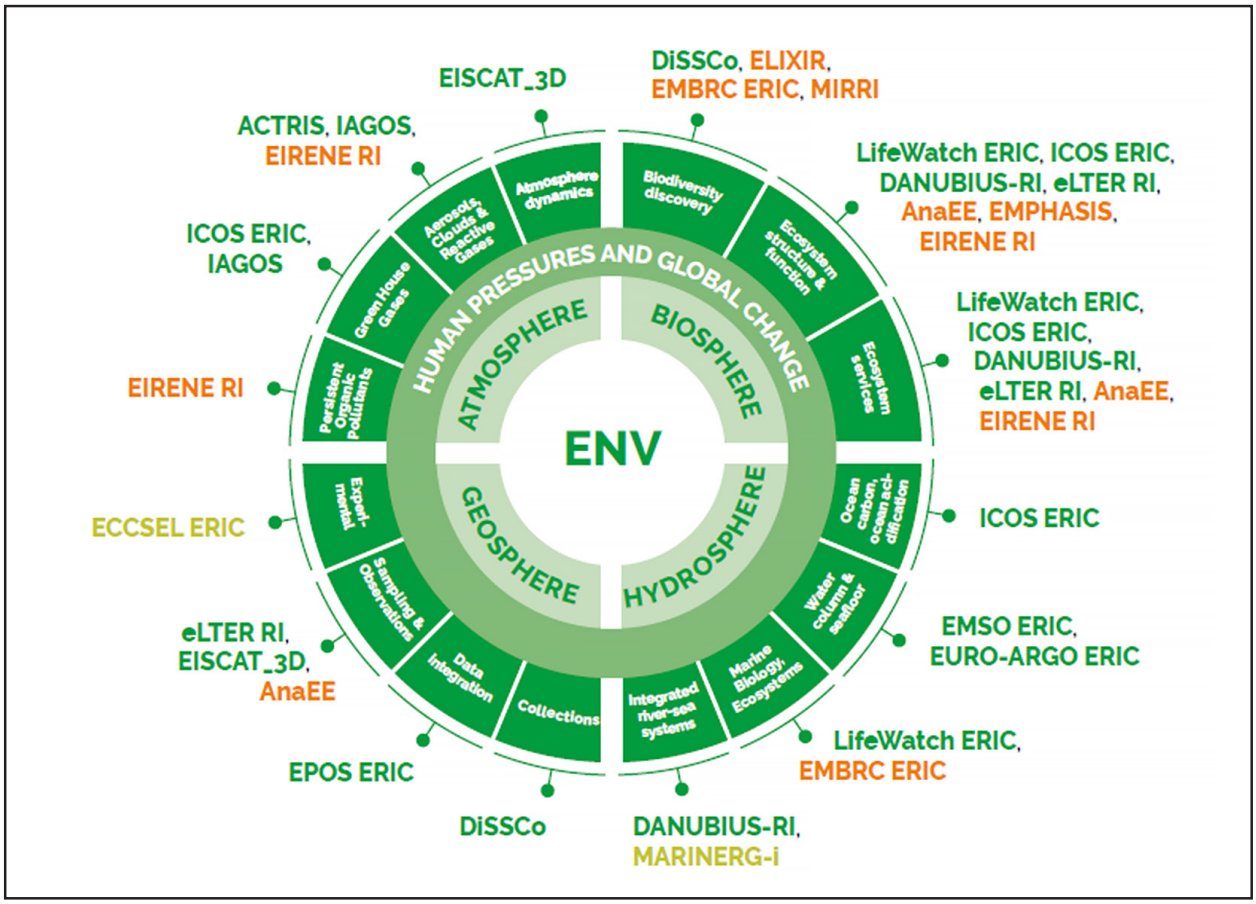

Fig. 1. The Landscape of the Environment domain of the European RIs. In dark green is the environment sector RIs are shown, light green in the renewable energy sector, and orange in the health and food sector (ESFRI, 2021).

Harmonized regulations, methods, procedures and standards will be achieved through the DANUBIUS Commons to ensure that outputs are comparable, and transferable. DANUBIUS-ERIC (under negotiation) will be the legal entity providing the governance framework to coordinate, manage and communicate the work of the RI.

3. PROSPECTIVE DEVELOPMENTS OF RIs IN UKRAINE

Currently in Ukraine there are more than 16 research organizations that are members of the National Academy of Sciences of Ukraine, carrying out research studies in the field of Earth Sciences, having an extensive material and technical base and resources. Among them there are leading research organizations such as: Institute of Geological Sciences, State Scientific Institution „Center for Problems of Marine Geology, Geoecology and Sedimentary Ore Formation", Ukrainian Scientific Research Institute of Ecological Problems, Ukrainian Hydrometeorological Institute, etc. It is worth mentioning that in the field of Earth Science, professional and scientific personnel are trained in 19 academic institutions of Ukraine, which also conduct active scientific and research labor, leading scientific and educational organizations.

The long-term development of RIs in Ukraine involves solving the following interrelated tasks (Vapniarchuk *et al.*, 2022):

1. Monitoring the development of the general RI of world science and separately in priority sectors of science and technology in Ukraine; analysis of forecasts for the future development of RI.
2. Carrying out an inventory of equipment, resources, databases (including those in need of modernization) assigned to national research organizations, and preparing informed proposals for their development, decommissioning, modernization, etc.
3. Generating of a list of foreign RIs, which is necessary to be accessed for Ukrainian researchers for carrying out scientific research and achieve scientific results.
4. Marking the most relevant objectives for the development of the Ukrainian scientific and technical sphere for the next 10-20 years, based on the results from the analysis of the first three points of the research profession object list,
5. Rule development for the collective usage of RIs potential by Ukrainian scientists on the territory of Ukraine, including regulations for scientific results.
6. Increasing the active participation of Ukraine in the system of various types of RIs and various organizational and legal forms to gain more experience, to use the necessary equipment and other resources for completing scientific studies.

It should be noted the EU's support for the development and preservation of Ukraine's RI. Therefore, in June 2024, the "Consolidating and developing the landscape of European research infrastructures by supporting research infrastructure policy in Ukraine (2024)" was initiated by the 'HORIZON-INFRA-2024-DEV-02 Programme: Assessing the state of research infrastructures in Ukraine' with a budget of 2 million euros (Horizon, 2024).

Project results are expected to contribute to all the following expected outcomes:

- roadmap identifying a clear path and plans for recovery and enhancement of the Ukrainian RI landscape, in line with the green and digital transition;
- sufficient information is available for guiding the EU reconstruction support for Ukrainian RIs; increased integration of Ukrainian RIs in the EU RI landscape;
- upscaled skills and knowledge of Ukrainian RI staff.

4. CONCLUSIONS

To increase the competitiveness of scientific research and scientific-technical developments and thus improve the state of the national economy and the life quality of citizens, Ukraine needs to find new additional sources of funding for carrying out research activities and update the material and technical base of scientific institutions. To achieve this, closer cooperation between scientific institutions, RIs owners with European RIs is required.

It is necessary to systematize existing RIs, assess their compatibility with European RIs, provide priority funding for their further development and its consistency with Roadmap for the development of European research infrastructures, approved by the European Research Infrastructures Strategic Forum.

In Ukraine, there is a significant potential for research and educational institutions in the field of Earth Sciences, which can be involved in the European Union RI landscape. This will contribute to the development of modern science, create new opportunities for Ukrainian and European scientists and will support the transition from Ukrainian RI to the European research space.

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