CHAPTER 13

Transforming Ukraine's research and development to become a driving force of reconstruction

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EXECUTIVE SUMMARY

The full-scale Russian invasion of Ukraine has heavily affected country's research and development (R&D) sector. In particular, it has caused considerable damage to research infrastructure and forced researchers to leave their homes, ruined many research teams and paralysed their work, and stopped funding and implementation of many research projects. All these devastating consequences of the full-scale war have piled on top of the existing problems and challenges of Ukrainian science and deepened its long-term crisis.

Recognition and analysis of these systemic challenges implies that the reconstruction of the Ukrainian R&D sector cannot be seen simply as physical rebuilding of the damaged research infrastructure. It is essential to transform the R&D sphere itself and build ways for science to benefit the economy and society. To enable the 'build back better' principle of Ukraine's reconstruction, science, technology and innovation should be the cornerstone of the national reconstruction strategy, and their transformation should be seen as an essential part of the EU accession. This implies that, first, the agency responsible for Ukraine's reconstruction should have a dedicated unit supervising the R&D sector. And second, Ukraine's R&D sector should be reformed as early as possible. At the same time, its reforms need to be systemic, accurately designed and appropriately supported. If supported by appropriate resources, the National Council on Science and Technology can start designing these reforms right away.

A crucial and urgent task is helping researchers (who have mostly stayed in Ukraine) remain researchers, that is, ensuring that they do not leave for other sectors. To this end, we suggest that the government, together with international donors, provides stipends to researchers selected on merit-based principles. Furthermore, it is important to support the development of networks and partnerships at different levels - among Ukrainian researchers; among Ukrainian and foreign researchers; among researchers, businesses and local governments. These networks and partnerships will be essential for the future reconstruction of Ukraine.

For the long-term transformation of the science sphere, we suggest the introduction of performance-based funding; the gradual transition of the most capable research teams under the new research societies (created in parallel with existing academies of sciences) with a simultaneous increase in their funding; intensifying European integration of Ukrainian science, including integration of research infrastructure; and data-driven R&D policy development, the foundation for which has been already laid. Closing the gap between education and research is also one of our key recommendations.

1 INTRODUCTION

To achieve sustainable recovery and development, Ukraine needs to prioritise its research and development (R&D) sector,[1] which implies both substantial investment and a fundamental policy shift.

This is a formidable task, as the sector is plagued by the Soviet legacy of weak links between research, education and business, mistrust among principal stakeholders, insufficient state capacity and a lack of coherent strategy. Before the war, Ukraine had been neglecting R&D, focusing instead on its strong but aged and carbon-intensive industry. The war has caused an acute threat to key human capital, driven by the drastic reduction of research funding, paused international collaborations and growing damage to research infrastructure. Post-war recovery, along with the EU accession, which implies green and digital transformation, will pose modernisation challenges, leaving no other way but to embrace R&D as the driving force of the transformation. This chapter provides an overview of the pre-existing problems in this sector and Ukrainian science policy (Section 2) and the impact of the war (Section 3). It also outlines key actions necessary to ensure its survival in a short-term perspective and to lay down the seeds of the large-scale transformation in the long run. Finally, Section 5 concludes.

1 In this chapter we use the terminology following OECD (2015), so that research and experimental development (R&D) comprises creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge. It contains basic research, applied research, and experimental development.

2 PRE-WAR STATE OF R&D IN UKRAINE

2.1 Statistics and trends

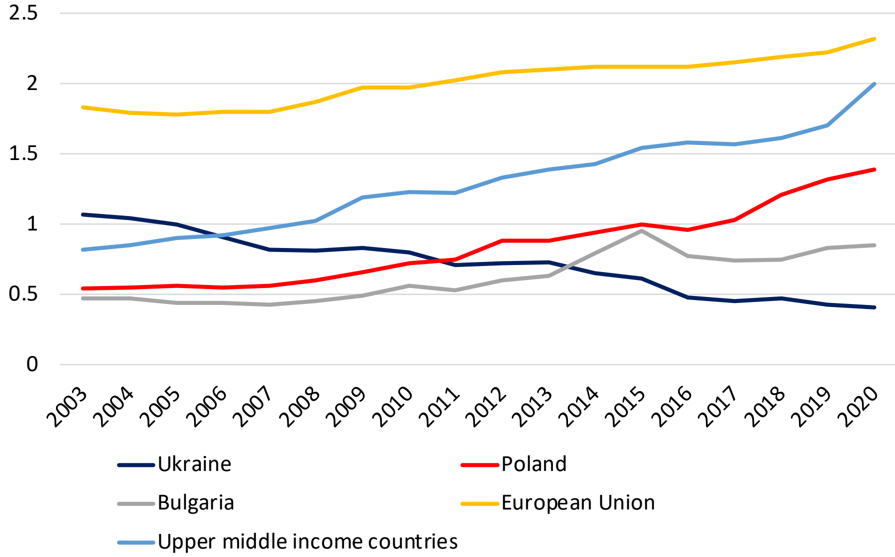
Ukraine's gross domestic expenditure on R&D (GERD),[2] a key indicator in the analysis of R&D, decreased from 1.19% of GDP in 1997 to 1.07% of GDP in 2003 and to 0.41% in 2020, according to the UNESCO Institute of Statistics.[3] This significant drop in the GERD-to-GDP ratio caused, among other things, a decline in the total number of researchers – from 1,475 per million people in 2006 to 846 in 2020. The number of young researchers[4] is also decreasing rapidly (at the National Academy of Sciences of Ukraine, it dropped by 27% by 2020 compared to 2017).[5]

In the 2022 Global Innovation Index (GII),[6] Ukraine ranks 57th out of 132 economies, which is a decline compared to its 49th place in 2021, 45th place in 2020 and 47th place in 2019, although there is some variation across categories of this index (see Figure 2). In particular, Ukraine ranks 49th in "Human capital and research" (44th in 2021), 59th in "R&D" (58th in 2021), 36th in "Knowledge and technology outputs" (33th in 2021) and 27th in "Knowledge creation" (29th in 2021). Ukraine ranks 4th among the 34 lower middle-income group economies and 34th among the 39 European economies in the index. However, according to the GII analysis, relative to GDP, Ukraine's performance is above expectations for its level of development.[7] This illustrates that, despite insufficient R&D funding and weak incentives from the state, Ukraine has considerable potential in the innovation sphere.

In comparison to its peers, Ukraine's scientific resources have declined significantly over the last 20 years. In 2003, Ukraine's GERD as a share of GDP was higher than average for upper-middle-income economies (Figure 1). In particular, it was much higher than the GERD of Poland and Bulgaria. Since then, the situation has changed dramatically, and Poland (since 2011) and Bulgaria (since 2014) now have significantly higher GERD-to-GDP ratios. In 2017, the average GERD/GDP for the upper-middle-income economies was 1.57% and for low-income economies it was 0.53%; for Ukraine it was 0.45%. In 2020, the average GERD/GDP for the upper-middle-income economies was five times higher than in Ukraine.[8]

2 As defined in the OECD's *Frascati Manual* (OECD 2015).
3 uis.unesco.org
4 According to the Law on Science and Technology, a young researcher is defined as a researcher younger than 35 with at least a master's degree, or younger than 40 with a Doctor of Sciences degree. The Ukrainian system has two levels of scientific degrees: Candidate of Sciences and Doctor of Sciences. Attaining Candidate status usually takes at least three years, while a Doctoral degree can take much longer.
5 https://files.nas.gov.ua/text/YoungMessage/Komisiya/Komisiya_Zvit.pdf (in Ukrainian).
6 www.wipo.int/global_innovation_index/en/2022/. The 2022 Index uses data from 2021 or earlier.
7 www.wipo.int/edocs/pubdocs/en/wipo_pub_2000_2022/ua.pdf
8 According to the UNESCO Institute of Statistics.

FIGURE 1 **RESEARCH AND DEVELOPMENT EXPENDITURES (% OF GDP)**



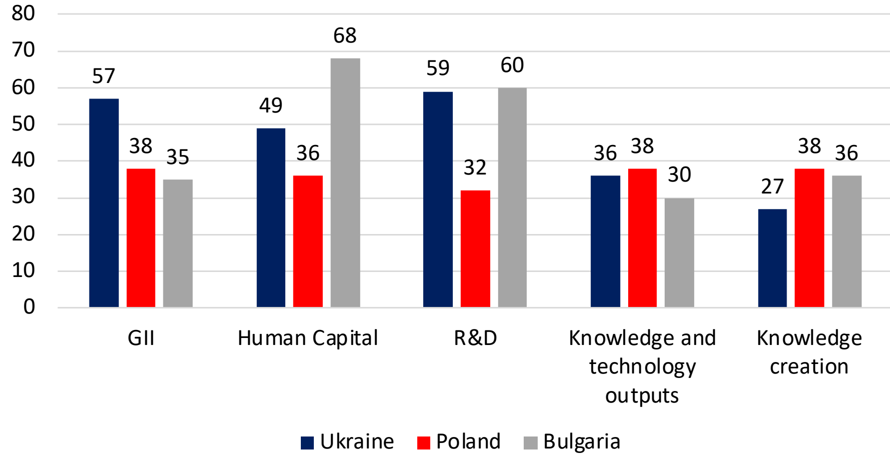
Source: World Bank

Other indicators paint a similar picture. In absolute numbers, Poland was 20th in the world in terms of R&D spending in 2020 (US$18.1 billion in current PPP dollars), according to the Congressional Research Service (2022).

In 2006, the numbers of researchers per million people in Ukraine, Poland, and Bulgaria were comparable – 1,475, 1,553 and 1354, respectively – and almost half the EU average (2,691). By 2020, Ukraine's number had nearly halved (846), while those of its peers had almost doubled (3,288, 2,402, and 4,257 for Poland, Bulgaria and the EU average, respectively).[9] As mentioned above, in the Global Innovation Index 2022 Ukraine ranked 57th out of 132 economies, while Poland ranked 38th and Bulgaria 35th (GII-2022: Ukraine, Poland, Bulgaria). According to the European Innovation Scoreboard 2022, Ukraine, Poland and Bulgaria belong in the lowest category of "Emerging Innovators", with scores at 31.0%, 60.5% and 45.2% of the EU average, respectively.[10]

9 Ibid.
10 https://ec.europa.eu/assets/rtd/eis/2022/ec_rtd_eis-country-profile-ua.pdf; https://ec.europa.eu/assets/rtd/eis/2022/ec_rtd_eis-country-profile-ua.pdf; and https://ec.europa.eu/assets/rtd/eis/2022/ec_rtd_eis-country-profile-bg.pdf

FIGURE 2 **GLOBAL INNOVATION INDEX 2022: UKRAINE, POLAND AND BULGARIA**



Source: Global Innovation Index 2022.

There has been certain progress in linking Ukraine's R&D sector to global research. For example, since 2016 Ukraine has participated in the EU Horizon 2020 and EURATOM Research & Training (2014–2020) programmes as an associated country. Under Horizon 2020, Ukrainian researchers have participated in 230 projects involving 323 participants for a total funding request of €45.5 million. In EURATOM R&T (2014–2020), Ukrainian entities received approximately €4.9 million for fusion and fission activities.[11] Among 16 associated countries, Ukraine was in the top seven by amount of money received and project winners. Foreign-funded R&D as a share of GERD in Ukraine was 20.7% in 2012–2014 and 21.6% 2015–2017 (UNESCO 2021, Chapter 12).

A summary of governance and organisation of the R&D sphere in Ukraine is presented in Table 1. An acute problem with the governance in the sector is the limited capacity of the Ministry of Education and Science (MoES) to develop and implement data-driven policy in the sphere. Limitations are present in all stages of this process, from data collection (very poor quality R&D data), to data analysis (poor analytical capacity within the MoES, strained capacity within the National Council on Science and Technology), to development of strategy and policy solutions (no clear vision, widely distributed responsibility, a large number of stakeholders for whom R&D is not a priority).

11 https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/europe-world/international-cooperation/ukraine_en

TABLE 1 **RESPONSIBILITIES, POWERS AND CONSTRAINTS FOR MAIN STAKEHOLDERS**

Stakeholder	Responsibilities/powers	Constraints
Ministry of Education and Science (MoES)	• Develops and implements policies in the R&D sphere, forms budgetary requests, makes decisions on the distribution of institutional funding to state-owned higher educational institutions and appoints their rectors. • Runs its own system of project-based funding aimed exclusively at universities.	• Does not have a strategy for the development of science. • Has very limited capacity for analytics and policy development. • Has no political power and capacity to coordinate the development and implementation of horizontal policies.
Other ministries and state agencies	• Many ministries (including the Ministry of Health, Ministry of Internal Affairs and Ministry of Energy) have their own 'branch' research institutions.	• R&D is a low priority for the respective ministries, and many of the 'branch' research institutions are not capable of producing high-quality research.
National Council on Science and Technology of Ukraine (NCST)	• Advisory body on science and technology policy to the Cabinet of Ministers created to provide effective interaction between researchers, government, and the real economy sector for the development and implementation of national science and technology policy; headed by the Prime Minister. • Has an Administrative Committee with 24 members (minister of education and science, deputy ministers, presidents of the national academies of sciences, etc.) and a Scientific Committee with 24 independently elected top-level researchers working on a voluntary basis.	• Should, but does not, have regular (quarterly) meetings and is not operational without them. • The government has not really used it as an instrument for getting advice and horizontal coordination. • Does not have a proper back-office to support its activities.
National Academy of Sciences of Ukraine (NASU) and five 'branch' National Academies of Sciences (medical, agricultural, pedagogical, law, arts)	• Each academy is self-governed, controls its own system of research institutes, approves their research programs, makes decisions on the distribution of funds inside its research institutions network, and appoints their directors and key personnel (starting from the level of department heads).	• Strong vertical hierarchy, research groups have very limited autonomy, strict financial control within their research institutions. • Mechanisms of fund distribution between research institutions and departments are not transparent.

Stakeholder	Responsibilities/powers	Constraints
National Research Foundation (NRFU)	• Provides grants for research projects irrespective of the affiliation of the scientists involved in the team. • Has generous pay scale caps that enable decent salary levels for grantees. • Implements bottom-up funding as well as topical calls. • Foreign experts are involved in the evaluation of project applications.	• Legislation limits the scope of projects that can be funded (currently, no individual grants and no institutional grants can be awarded). • The share of funds distributed by NRFU is still low (less than 10% of the total R&D funding). • Budgetary restrictions limit development of its organisational capacity, not allowing it to modernise its digital infrastructure and compete for the best staff.
Other state funding agencies: Ukrainian Startup Fund and the Fund of the President of Ukraine for the support of Education, Science, and Sports.	• Ukrainian Startup Fund provides grants to small-scale innovation projects that can be completed within a short period (1-2 years). • The Fund of the President of Ukraine is focused on providing individual mobility and study grants (e.g. for study abroad), but can provide grants for research projects as well. • These organisations have high political support and flexibility.	• Ukrainian Startup Fund had not been focused on science-based startups and deep tech innovations, therefore researchers who had an idea for a startup were unlikely to get funding. During the war, some programmes of this type were launched. • The Fund of the President was established in 2019 but has not completed its organisational phase and has not yet funded anything. Despite that, during 2020-2021 it had a planned budget of more than 1 billion hryvnia that could have been allocated to operating R&D organisations such as the NRFU.
Research institutions	• Conduct research. • Nearly all research institutions are state-owned, the absolute majority belong to NASU. • Some research institutions do not conduct research but rather perform analytical or organisational duties for the ministries and national academies of sciences.	• Lack of financial autonomy. • The infrastructure is very aged, its maintenance is energy- and cost-consuming. • Fixed state-prescribed pay scales for researchers' jobs make them non-competitive.
Higher education institutions (HEIs)	• Provide education and conduct research. • Have wide autonomy rights (self-government) but rectors of state-owned institutions are appointed by the MoES. • Nearly all HEIs are state-owned.	• Education remains the primary task of HEIs; research still plays a minor role in their evaluation and funding. • The legacy distribution of employees into teaching personnel (faculty) and scientific personnel (pure research) is limiting the integration of research. • Funding for research personnel is exclusively project-based (no institutional funding) and thus unstable.

Source: Compiled by authors.

2.2 Challenges

R&D in Ukraine has faced numerous systemic challenges that are briefly outlined below. Most of these problems existed long before the Russian full-scale invasion, and therefore represent perennial impediments to R&D development. The war has not only exacerbated these challenges but also created new ones, such as severe funding cuts, destruction of research facilities and outflow of researchers.

General problems of state policy in the R&D sphere
One of the basic challenges is the absence of a coherent state strategy for the development of science. There is practically no continuity of state policy in the field. Science is viewed as a heritage rather than an integral part of the general economic strategy. Thus, the resources provided for science development are very limited, as they are considered expenses or losses rather than investments. Consequently, there are few to no incentives for science to solve specific problems of the economy and society. On the other hand, while the government cannot design and implement mission-oriented policies based on R&D, it expects to obtain 'useful' research products. As a result, the legislation does not provide incentives for investment in science or R&D, and state support for innovative activities is insignificant.

Problems of governance and policymaking in R&D
The legal framework in general is outdated and contradictory, having suffering from scattered, inconsistent revisions. It needs to be rewritten from scratch, but the lack of strategy prevents this. There is little effective coordination inside the government (between ministries and the National Council on Science and Technology Development). At the same time, the functions of forming and implementing government policy in the R&D sphere are not clearly delineated between the Ministry of Education and Science, other ministries, the national academies of sciences, the National Research Foundation (NRFU) and the central executive authorities.

The MoES is mainly responsible for policy development, but lacks qualified personnel or the ability to recruit/train such personnel. Thus, its ability to formulate policy goals, develop policies and estimate their effect is limited. Faulty data-collection procedures and very few digital instruments for this do not allow for the implementation of evidence-based policymaking.

The legacy system of so-called 'branch science' (nearly every ministry has some scientific institutions or departments belonging to its administrative domain) cannot generate high-quality research.

The scientific community has weak self-organisation and is unable to maintain high standards of research and academic integrity. The management of scientific organisations is inefficient – it is a mixture of hierarchical and collegial management bodies, with no clear division of duties and responsibilities and neither incentives nor

opportunities for training of quality scientific managers. There are conflicting criteria for evaluating scientists and administrators and lack of transparent accountability tools. Faulty promotion mechanisms result in age and gender imbalances in management of research organisations.

Challenges involving the connection between science and the economy

The low-tech structure of the economy implies a limited need for R&D, which results in low innovative activity of businesses. Instead of forming demand for research products, businesses prefer to purchase ready-made solutions from abroad. Consequently, research funding by the private sector is low. However, even if the private sector were willing to invest into R&D, legal and financial limitations imposed by the status of a 'budgetary institution'[12] (shared by nearly all research institutions) makes this cooperation rather complicated. Communication between the R&D sphere and industry is insufficient and results in low levels of mutual trust and cooperation.

The share of applied research (including defence- and security-related research) is disproportionately low because it requires a lot of resources, which the government does not provide.

Problems with funding instruments

The existing management and funding instruments are not tailored to the specific needs of different types of research. Defence-related, applied, commercial and basic research each require different financial instruments and the involvement of different players and organisations in their management. Existing budgetary legislation and the way it has been implemented, as well as the the legacy system of the national academies of sciences, are not up to this task.

There are no effective and transparent procedures ensuring and stimulating the quality of research. There is neither performance-based research funding nor an underlying system of research evaluation. Instead, the 'historical' block funding is preserved, and salary supplements for researchers are based on formal titles rather than real research achievements. Consequently, there are few incentives to improve research quality. The share of competition-based funding and the absolute amount of this funding are low. As a result, many research competitions are just a substitute for basic funding. Only a small part of the public research funding is spent on research needs (equipment, materials, etc.), with the main part covering salaries and utilities.

The NRFU has limited financial flexibility and cannot provide the full spectrum of funding opportunities. Its opportunities for capacity building are highly limited by legislation and its budget.

12 The status of a budget institution does not allow financial flexibility for scientific institutions (for example, changes in pre-planned purchases of equipment, personnel changes and transfers between expenditure items are problematic).

Problems with human capital and education

Currently, careers in research are based on scientific titles (mostly inherited from Soviet times) and set false priorities that stimulate imitation of science and violations of academic integrity, which have become a systemic and mass phenomenon in some fields. Low salaries for researchers prevent academic mobility within Ukraine and internationally, making the Ukrainian academic job market very local and fragmented. This results in low social prestige for the profession of scientist, which makes it unattractive to ambitious young people. As a result, researchers quit for other fields or move abroad, which constantly decreases the number of scientists and the share of young scientists.

The higher education system has been losing the capability to train researchers to the appropriate, globally competitive level. Brain drain during bachelor's and master's studies decreases the number of students and competition at the next levels of education. Insufficient numbers of talented students willing to pursue an academic career decreases training quality at the PhD level.

The connection between higher education and research in many disciplines is weak. Many universities have failed to build research-oriented educational programmes because they did not have qualified personnel or sufficient funding. There are no state programmes supporting cooperation between research institutions and universities. Therefore, existing initiatives are bottom-up and rarely sustained.

Research institutions do not have the resources to attract professional staff who could provide additional necessary services, such as public communication, partnership development, interaction with business, international cooperation, fundraising or training scientists in additional skills.

Research infrastructure problems

The country's outdated and insufficient research infrastructure (from buildings to equipment) requires significant funds for modernisation, which has been very sporadic over the last 30 years. There is neither detailed data on the state of existing research infrastructure nor an infrastructure development strategy supported by the necessary resources or mechanisms for collective use and management of the research infrastructure. In our view, research infrastructure should be based on regional development (i.e. smart specialisation) strategies. Digital research infrastructure is also underdeveloped and lacks tools, resources and qualified personnel for its development.

Problems of international cooperation and integration into the global and European research space

The government has neither the resources nor the capacity to implement the "Roadmap for Ukraine's Integration into the European Research Area", which has still not been adopted as the government-level document. Nor does it have a nationwide strategy for the internationalisation of Ukrainian R&D that would foresee systematic work to attract foreign research funds and build partnerships or involve the Ukrainian scientific diaspora in domestic research projects.

Ukrainian researchers have a low level of English language proficiency, and thus English is not the primary language for obtaining and spreading knowledge among the majority of researchers. Many research areas are detached from the global scientific process and thus do not have the appropriate level of quality to interest international partners.

The incompatibility of the regulatory framework, as well as bureaucratic and financial restrictions, repel international partners or deter Ukrainian research institutions from developing institutional-level international cooperation. Moreover, there are no resources for implementing research using foreign research infrastructure.

2.3 Previous reforms/policies

Establishing new policy and funding instruments

The new Law on Scientific and Technological Activity (hereafter, 'the Law'), which came into effect in 2016, tried to address the problems outlined above. One of the main goals of the first stage of the reform was establishing evidence-based policymaking in the R&D sector.

However, implementation of the Law was a challenge. The Law promised to increase GERD to 1.7% of GDP from 2020, which was never implemented, and stipulated the possibility to provide funding to higher education institutions and research institutions based on their performance (state attestation), which was never implemented either.[13] The Law created two new institutions: the National Council on Science and Technology (an advisory body to the Cabinet of Ministers headed by the Prime Minister) and the National Research Foundation of Ukraine. The former was meant to provide the government with first-hand advice on R&D policies, and the aim of the latter was to introduce some competition among researchers and support the best ones, who would then become agents of change in the next iteration of science reform. However, due to the limited state capacity and the absence of political leadership for this reform, these institutions were established with a large delay and their impact was limited.

13 Thus, research institutions get 'historical' funding, while universities until 2021 had no institutional research funding at all (only project-based). The NASU applies its own methodology of research evaluation since 2016 (it is based on German best practices), while the government adopted two distinct methodologies for state attestation of research activity of universities (2018) and state research institutions (2017) that are problematic to implement. Upon results of "state attestation" universities in 2021 received an opportunity to get additional funding, but it was again project-based rather than institutional funding.

The Council was intended to be a platform for dialogue between the research community and government officials, to bring scientific advice and an evidence-based approach to policymaking, and to enable horizontal coordination and evaluation of science and technology policies. Due to limited administrative capacity and political ignorance, the Council convened for the first time only in 2018 and until 2022 it met annually rather than quarterly as prescribed by the Law. Despite that, the Scientific Committee of the Council has been providing its opinion on drafts of all government acts on science and innovation policy.

The NRFU was established to provide individual, team and institutional grants for fundamental and applied R&D projects.[14] It has a multi-level governance model, ensuring transparent decision making. The NCST acts as its Supervisory Board; it also has an elected Scientific Council (academic board) and a Directorate headed by the executive director (elected by the Scientific Council, approved by the Supervisory Board and appointed by the prime minister). The NRFU's procedures are transparent, minimise conflict of interests and utilise independent expertise. However, it has insufficient funding for its institutional development, which limits its impact. The NFRU issued its first call for proposals in 2020 and awarded some grants in 2021. With the start of the full-scale invasion its budget for grants was entirely cut, so those projects are now at risk. On the other hand, since February 2022 it has significantly increased its international cooperation, becoming a member of Science Europe, and it remains in active dialogue with decision-makers worldwide.

Integrating into the European Research Area

The ERA represents the ambition to create a single, borderless market for research, innovation and technology across the EU that was articulated in 2000 and has been developing since then.[15] The ERA Roadmap 2015-2020 became a basis for a coordinated effort of member states to demonstrate visible progress on ERA priorities: (1) effective national research systems; (2a) jointly addressing grand challenges; (2b) making optimal use of public investments in research infrastructures; (3) an open labour market for researchers; (4) gender equality and gender mainstreaming in research; (5) optimal circulation and transfer of scientific knowledge; and (6) international cooperation.[16]

As an associated country, Ukraine was supposed to actively integrate into the ERA. However, the "Roadmap for Ukraine's Integration into the European Research Area" was only adopted by the MoES in 2021. There is neither a commitment to implement it at the Cabinet of Ministers level nor the necessary resources. In 2021, the European Commission presented a new ERA Policy Agenda for 2022-2024, but Ukraine has not

14 Even though the Law allows supporting infrastructure development, academic mobility, and science popularization, bylaws currently enable only support of research projects.

15 https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/our-digital-future/european-research-area_en#what

16 https://era.gv.at/era/era-2000-2021/era-roadmap/european-era-roadmap-2015-2020/

yet reacted to this. However, in October 2022 the government adopted the National Plan for Implementing Open Science (an approach to the scientific process that focuses on spreading knowledge as soon as it is available using digital and collaborative technology which is embedded into the ERA Policy Agenda).[17]

In 2016-2020 Ukraine was fully associated with Horizon 2020, the EU's research and innovation EU funding programme. Unfortunately, the country did not fully exploit the opportunities of this programme. In 2016, the Ukrainian government established a Coordination Centre for Horizon 2020, but the panel for the centre was only approved in 2018 and the centre held its only meeting in the same year. The Ukrainian government showed very little involvement in the programme; it provided very few resources to the network of National Contact Points of Horizon 2020, and ministries (including the MoES) showed little willingness to solve bureaucratic problems. This undermined the efficiency of Ukraine's participation in program and its integration into the ERA (EU-Ukraine Civil Society Platform 2017). Ukraine is now an associated country in the follow-up programme, Horizon Europe (2021-2027), but the problems with engagement and resource provision remain. Integration into the ERA is not seen as a priority by the government and is permanently absent in communications with the EU.

One tangible result from this cooperation was that the Horizon 2020 Policy Support Facility implemented peer review of Ukrainian R&D in 2016 (European Commission 2016). This provided 30 recommendations and three key messages: (1) raise the quality and relevance of the science base;[18] (2) open up the research and innovation system to the world and enhance international collaboration, (3) build a conducive framework for an innovation-driven economy in Ukraine. These recommendations were partly implemented by R&D stakeholders, but the national plan for their implementation was never adopted. Therefore, the majority of recommendations remain valid.

In July 2020, the Ukrainian government announced the country's readiness to contribute to the European Green Deal (Holovko 2021). As research and innovation play a crucial role in achieving the Green Deal goals, the European Commission has been using framework programmes[19] on research and innovation as tools to empower green transition. Thus, under Horizon 2020, the Green Deal call[20]– the largest research grant call for €1 billion – was launched. Under Horizon Europe, over 35% of funds are allocated to addressing climate change. At the moment, the Ukrainian government does not envisage R&D as a crucial part of Ukraine's green transition, so there is no national programme to support dedicated research projects.

17 https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/our-digital-future/open-science_en
18 This implies, among other things, raising the quality and relevance of science and technology through competitive funding, developing talent and capacity, and increasing the efficiency of research organizations.
19 https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/environment-and-climate/european-green-deal_en
20 https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/environment-and-climate/european-green-deal_en

Cooperation with local governments as an opportunity

The decentralisation reform launched in 2014 lays much more responsibility for the wellbeing of people on local governments. Local governments should draft regional development strategies ('roadmaps') for the development of infrastructure for people and businesses.

In 2017, some Ukrainian regions started developing their 'smart specialisation strategies' (S3s).[21] Smart specialisation is an industrial and innovation framework that shows how, taking into account the initial conditions of a region, public policies – especially R&D and innovation policies – can influence the economic, scientific and technological specialisation of a region and consequently its productivity, competitiveness and economic growth path (OECD 2013). S3s are based on an analysis of the strengths and potential of a regional economy and on an 'entrepreneurial discovery process' with a wide stakeholder involvement, including research organisations, universities, and science parks. During the entrepreneurial discovery process, stakeholders find out what is feasible based on their combined capabilities and agree upon their joint priorities. Thus, research and higher educational institutions find their place in the specialisation and knowledge-based development of a region by (1) performing research that is later utilised by local businesses, the government and the community, (2) preparing proper human capital and (3) providing expertise. Since 2021, smart specialisation is a mandatory part of regional development strategies (S3Ua)[22] and it can be used for sustainable reconstruction of Ukraine.[23]

Smart specialisation was recognised as one of the global methodologies in the Science, Technology, and Innovation (STI) for Sustainable Development Goals Roadmaps (United Nations 2021). Ukraine joined the UN Global Pilot Program on STI for SDGs Roadmaps in March 2021 (Matusiak et al. 2022).

3 IMPACT OF THE WAR

3.1 Estimates of damage

Estimation of damages to research infrastructure is complicated because of the need to assess it case-by-case (for example, equipment, types of specialised buildings and rooms and supplies all have different value). Furthermore, as a national database of research infrastructure items is absent, all estimates are preliminary and based on the information provided by damaged research institutions and universities.

21 Today the European Commission is already discussing with stakeholders a possible transformation of S3 into smart specialisation strategies for sustainability (S4) (Nakicenovic et al. 2021).

22 https://s3platform.jrc.ec.europa.eu/ukraine

23 https://s3platform.jrc.ec.europa.eu

The MoES reported that 15% of the research infrastructure of higher educational institutions has been damaged. According to the NASU, damages to research institutions amounted to around 0.5 billion hryvnia (nearly $13 million) as of 25 October 2022. However, the damage to unique infrastructure makes any assessment very imprecise. For example, Russian shelling damaged the buildings of the National Science Centre of the Kharkiv Institute of Physics and Technology (NSC KIPT), where a 'neutron source' subcritical nuclear reactor is located.[24]

3.2 Human capital

Following the onset of the full-scale war, 73% of respondents to a survey on "Ukrainian Researchers in Times of War"[25] said they have been unable to perform research activities as before the war. Among these are people who live in heavily affected (Kharkiv, Sumy) and occupied (Kherson) regions, internally displaced persons, and those who have lost their teams. Other reasons for inability to work are destroyed or damaged infrastructure, problems with Internet connection, lack of supplies, and psychological or medical issues.

Budget cuts are also affecting researchers significantly: in April–May 2022, 84% of respondents to the same survey said their financial situation had worsened compared to pre-war times. In particular, recipients of NRFU grants – i.e. the teams conducting excellent science research – had lost their funding. International cooperation is at risk as Ukrainian researchers cannot implement research as planned under existing grants and can hardly guarantee the fulfillment of their obligations under prospective ones. Competitive international instruments such as the Horizon Europe calls were only available to a minority of Ukrainian researchers even before the war. Most opportunities for scholars are available only for researchers who can flee the country, which is problematic as men in the 18–60 age bracket are generally not allowed to cross the border. Due to the dire economic situation, investments in R&D from businesses will probably decrease dramatically, and joint projects of business and research institutions/universities will be terminated or frozen. Thus, direct results of the full-scale war are the deteriorating financial situation of individual researchers, a growing tendency for disintegration of teams, and the termination of project-based collaborations between different organisations within and outside Ukraine.

On the other hand, teams and institutions with relevant organisational capacity or international collaborations established before the full-scale invasion have managed to extend their interactions. For example, the NRFU became a member of Science Europe, the organisation representing major public institutions that fund or perform ground-breaking research in Europe.[26]

24 As reported by the State Nuclear Regulatory Inspectorate of Ukraine on 25 June 2022.
25 www.uascience-reload.org/2022/07/05/ukrainian-researchers-in-times-of-war-results-of-survey/
26 www.scienceeurope.org/news/nrfu-and-mta-new-members-of-science-europe/

3.3 War-related challenges

Wartime budget cuts have led to a large-scale termination of funding for existing projects and to significant job cuts among the researchers and staff of scientific institutions and universities. This pushes more people out of the R&D sphere, aggravating the already dire situation. The government is prioritising war-related research, but many researchers cannot switch quickly to a completely different topic.

The growing damage to research infrastructure and loss of data, collections, archives, assets and so on has forced many research projects to stop. A large number of displaced scientists cannot continue their research at their new place of work. Many senior researchers have decided to stay abroad, and it will be difficult to get them back.

Suspension of joint international research projects and international academic mobility due to travel restrictions, as well as suspension of financial contributions to international scientific organisations, threaten to increase the isolation of Ukrainian science (although the European Commission has waived around €20 million in financial contributions for participation in Horizon Europe that would have been due in 2021 and 2022).

The war has caused many enterprises to shut down, significantly reducing the funds available for investing in high-risk projects and thus further weakening the already weak ties between science and business.

Low prioritisation of security-related R&D in previous years significantly hampered the development of modern weapons and military technologies in Ukraine, which has become a critical problem since the full-scale Russian invasion. The war laid bare that the organisational structure of defence-related R&D (limited flexibility and speed of reaction, insufficient scientific and technological level, non-compliance with EU/NATO standards) does not meet the needs and challenges of the sphere, which prevents scientific support for the implementation of modern military technologies, including those provided to Ukraine by partners.

4 RECONSTRUCTION

Reconstruction of the Ukrainian R&D sector cannot be seen simply as physical rebuilding of damaged research infrastructure; it should include policies to transform the sector and make science the foundation for a thriving economy and society. Development and utilisation of R&D for achieving high-level strategic goals such as the green and digital transitions should be seen as a part of integration into the EU, strengthening Ukraine's national security and enabling sustainable development and modernisation, as well as the reconstruction of Ukraine.

Timing is crucial. Starting reconstruction of Ukraine's R&D cannot wait until after the war ends. Ensuring the survival and development of human capital, building networks and enabling the transfer of expertise, building the capacity of R&D sector stakeholders, and helping them to maintain the dialogue with businesses, local authorities, and the state are among the key interventions that should enable survival, perseverance and development both during the war as well as in the after-war transformation of the R&D sector.

We suggest three basic reconstruction principles with respect to R&D:

1. Science, technology and innovation are essential to the Ukrainian future, so they need to have a proper place in the national reconstruction strategy, supported by appropriate resources. In particular, the reconstruction agency should have a dedicated unit supervising the R&D sector.
2. Systemic reforms in the R&D sector are crucial for its recovery. These reforms should be accurately designed, appropriately supported and implemented in time. Any urgent actions and partial solutions should fit the overall architecture of changes.
3. Preserving, developing and engaging human capital is the most urgent short-term goal, but is also critical for long-term recovery. The development of networks and partnerships should be enabled, encouraged and supported.

In the next two sections, we suggest short-term and long-term policies based on these principles. Implementation of these policies will ensure not only the preservation but, more importantly, the transformation of Ukraine's R&D sphere.

4.1 Short-term actions

In designing the short-term instruments of support, it is crucial to take into account differences in the Ukrainian situation compared to other recent situations of science at risk. Specifically, the majority of Ukrainian researchers are still in Ukraine – only 15% of the 2,173 respondents to the ""Ukrainian Researchers in Times of War" survey have fled the country.[27] However, 38% of respondents have changed their place of residence within Ukraine, which limits their ability to implement research if they have lost access to materials or equipment. Thus, the emergency response should ensure that funding and opportunities are available on the needed scale for Ukrainian researchers who are still in Ukraine. In some sense, this can be seen as an extension of the experience gained by governments during the COVID-19 pandemic, when remote positions and

27 www.uascience-reload.org/2022/07/05/ukrainian-researchers-in-times-of-war-results-of-survey/

international cooperation became possible. To mitigate the brain drain, any instruments focused on Ukrainian researchers who have left the country should include opportunities to cooperate with Ukrainian teams in order to preserve research groups and funding and to increase the chances of their return after the war.

In other words, support should focus on **preserving and developing human capital in science**. Instruments should focus on enabling researchers (selected by merit) to remain as researchers, even if they are highly limited in their ability to perform research as usual. Equally important is project-based support of capable research teams that would allow to preserve collective expertise.

The war has provided Ukrainian researchers with more opportunities to collaborate globally and build networks of expertise. The government should encourage these networks, the most successful of which can be institutionalised and become 'agents of change' in Ukrainian science. We suggest developing the following instruments for implementation of these ideas.

- **A national system of researcher fellowships.** Ukraine should establish a programme of merit-based individual support for researchers to help them through the hardships of the war and thus prevent brain drain to other sectors. The NRFU could provide fellowships based on researchers' track records for the last 5–10 years, regardless of their current ability to carry out research. The criteria for track record performance should be developed by international expert panels and tailored to broadly defined fields (natural sciences, life sciences, social sciences, etc.). Fellowships can differ by experience levels and should be awarded for 1–2 years, with the possibility of renewal. Total programme duration should be no less than three years. The estimated annual cost for supporting 10,000 researchers (about 10% of all researchers, including those in universities) is €34.8 million.[28] International donors and the Ukrainian state could decide on the distribution of this sum among them. These fellows could form the core pool of personnel for the new research establishments discussed further.
- **Support for competitive project funding via the NRFU.** Ukraine should ensure that the NRFU remains an active funding channel supporting excellent science and mission-oriented projects. The aim is to preserve existing research teams and 'scientific schools', to provide meaningful career development paths (especially for young researchers) and to support and develop the NRFU as an institution and funding instrument. The estimated total annual cost for this is €25 million (based on the pre-war 2022 NRFU budget) with an initial commitment for two years.

28 For example, 2,000 researchers could receive €400/month, 5,000 researchers €300/month, or and 3,000 researchers €200/month

- **A special EU programme to integrate Ukrainian science into the European Research Area.** The first stage of this programme, which could start immediately, could focus on (1) founding *research networks* that foster information exchange, organising online and hybrid workshops, seminar and lecture series, mutual short visits; and (2) embedding Ukrainian research groups within existing research projects ('outsourcing' certain research tasks, preparation of joint research proposals). The programme should provide the possibility to fund research physically conducted in Ukraine (*'non-residential fellowships' or 'remote work'*) whenever this is compatible with the nature of the performed research. The second stage, designed for a longer-term impact (but which could start already during the war) could help institutionalise these networks (e.g. establishing *joint doctoral schools*).

  Research networks and joint doctoral schools will form 'seeds' for future centres of excellence. The establishment of such centres can be modelled on the German initiative "Establishing German-Ukrainian Excellence Centers (CoE) in Ukraine",[29] which unfortunately was not completed before start of the full-scale war. Centres of excellence should be established as joint labs of European and Ukrainian institutions based on the most successful research teams and networks. The preparatory and organisational phases can be launched during the war, but the actual launch of the centres will involve substantial investment into infrastructure and will have to wait until after the war.

  The programme can be implemented jointly by one of the European funding bodies (e.g. the European Research Executive Agency, or the European Research Council) and the NRFU, as well as by special instruments of Horizon Europe. Wider formats involving other countries/funders would bring additional benefits. The estimated total annual cost for the first stage is €500,000 (supporting around 20 research networks), with an initial commitment for a two-year funding cycle; for the second stage the estimated annual cost is €1 million (supporting around five doctoral schools), with an initial commitment for a four-year cycle.

- **Informational support and matchmaking for the international transfer of expertise** could create many decentralised opportunities and cover those interested in finding experts and colleagues worldwide. International donors can support the implementation of the corresponding module in the National Electronic System of Scientific and Research Information URIS.[30] This online platform has been in development since 2019. When fully developed, it will contain information on all institutions, research groups and researchers, as well as metadata on publications.

29 www.bmbf.de/bmbf/shareddocs/bekanntmachungen/de/2019/12/2743_bekanntmachung (in German).
30 https://nauka.gov.ua

For now, it includes useful information for Ukrainian researchers, such as FAQs on publications, opportunities for fellowships, conferences, and so on. When the system is finalised, it will become the main source of R&D data in Ukraine and an instrument for developing networks both within Ukraine and internationally.

Unfortunately, current budget restrictions do not allow for developing the URIS system to its full potential, so it must rely on donor support. An investment of as little as €100,000 would allow a module to be launched for providing support to Ukrainian scientists, which is currently offered by many research institutions worldwide.

- **Programmes supporting the utilisation of science for national security, reconstruction, economy, and policymaking.** Engaging researchers in helping the country during the war and in its recovery is crucial. As many needs and efforts are bottom-up and local, it will be more efficient to support networks and partnerships between researchers, businesses and local authorities who are prepared to build smart solutions for urgent war-related and reconstruction problems. The NFRU, with the help of international donors, could fund joint R&D-intensive projects implemented by businesses, NGOs and local authorities in cooperation with research organisations. The estimated cost is up to €3 million annually (two-year cycle), and it could be launched as early as 2023. After the war, these instruments could be transformed into co-funding schemes, supporting the smart specialisation approach to the regional development of Ukraine. At that time, the EU instrument for pre-accession assistance can be used. The NFRU should be provided with sufficient resources not only to provide grants but also to strengthen its organisational capacity so that it can manage various R&D support programmes, including those discussed here.
- Finally, **capacity building for developing reforms in the R&D sector should be supported immediately.** Limited government capacity in the R&D sphere has been a long-term constraint on its reform and evolution, integration to ERA, and on providing value to the economy and society. Today, poor governance threatens the survival of the R&D sphere and crisis response by it, and it will definitely limit reconstruction. The actions proposed here will require a lot of effort for their implementation, and there are few resources to do it.

The optimal way to address this problem is to establish a Science and Technology Policy Office as a support team for the National Council on Science and Technology.[31] This office, working with the Scientific Committee of the Council, could develop comprehensive and well-aligned evidence-based policy proposals and drafts of the legislation needed for the transformation and reconstruction of Ukraine's R&D sector.

4.2 Long-term actions: Policy for science

Ukraine needs a major policy shift to embrace R&D as an economic driver of, and a key factor in, sustainable recovery. Before this becomes possible, the R&D sector itself has to transform. Here, we outline our vision of this transformation, being fully conscious that there is no consensus between the key stakeholders on the desired architecture.

Our key recommendations are as follows:

1. Introduction of a performance-based research funding system (PBRFS).[32]
2. Implementing dual-track replacement of academies of sciences by two new research societies managing basic and applied science.
3. Integrating education and research.
4. Strengthening the integration of Ukrainian research into the European Research Area (ERA).
5. Transforming governance and policymaking in the R&D sphere (in particular, strengthening the National Council on Science and Technology and National Research Fund, creating a DARPA-like agency that would provide project-based funding, and creating an Evaluation Office that would evaluate research institutions and help distribute institutional funding).

Below, we develop these recommendations in turn.

The introduction of a performance-based research funding system requires the creation of a transparent and effective quality assurance and evaluation system for the R&D sector based on international best practices and expertise. Instead of the MoES, evaluation of the scientific activity of research institutions and universities should be performed by a dedicated independent institution – an Evaluation Office. The evaluation should be tailored to the type of research (basic, fundamental, development) the research area and the type of institution, and it should take into account the

31 This would require an investment of about €100,000, which is not a large sum in the context of Ukraine's reconstruction but could be a game-changer for Ukrainian R&D.

32 A good description of performance-based research funding systems in different countries can be found in Jonkers and Zacharewicz (2016).

evaluated organisations' missions. Digitalising this process is important to make it more transparent and less time-consuming; compliance should not be a burden. Evaluation should be done at the research unit level (research group, laboratory, department) to be useful for further organisational transformations.

The evaluation would aim to select research groups that either (1) produce high-quality scientific output and are competitive globally, or (2) engage in research areas that are strategic priorities for Ukraine and are competitive nationally. The evaluation would need to be performed with the help of independent experts, of which no fewer than 80% should be international experts. It will be important to involve a sufficient number of high-profile international scientists as evaluators to ensure that the selection process is transparent and is perceived as fair by the research community.

Funding instruments should be quality-based and support different types of missions. There should be different complementary funding types:

- Basic funding allocated directly to research institutions and higher educational institutions according to a formula based on the evaluation results, with re-evaluation every five years. The share of basic funding should not be a goal or KPI, but it should be compatible with the specific profile of each organisation.
- Competitive funding provided via different channels: bottom-up (provided to any research topic, with the only criterion being excellence), priority areas (provided within state priority programmes[33] and key laboratories) and individual (provided via the national system of researchers, scholarships/awards for researchers at various career stages). Competitive funding should be distributed via grants by NRFU or other funding agencies.
- State contracts (defence, security, critical technologies, healthcare, other strategic issues) issued by a DARPA-like state agency; research groups engaged in those tasks would remain affiliated with their societies.
- Co-funding by business.
- International funding, in particular for the development of joint research infrastructure.

Performance-based basic funding should be available for any state-owned research institution or HEI, and all other channels should be open to any research groups irrespective of their affiliation, including private non-profit organisations. Every research group should have an opportunity to draw on several funding sources.

33 The establishment of state priority programmes for R&D, which has been blocked for the last eight years, should be re-installed and equipped with proper independent expertise and transparent governance models.

Besides establishing the multichannel funding scheme, the government should encourage 'scientific outsourcing', first of all by removing administrative barriers to research institutions implementing commercial R&D projects. Ideally, an office providing legal support and consulting for joint projects between research institutions and business should be established, while the initial matching of research groups and businesses can be realised via a dedicated module on the URIS digital platform.

The changes outlined above will require a significant overhaul of the current legislation, redefining nearly all existing financial regulations governing the R&D sector, including (1) the salary grid (for state-owned research institutions, a new salary scale should be introduced with the upper limit competitive at the European level to allow these institutions to attract and retain talent), (2) the legal status of research institutions (which should change from state budgetary organisations to a new, more flexible status that would better fit the missions of research institutions, would make attracting external funding easier and would allow for the introduction of multi-year budget planning and allocations), and (3) the R&D reporting and data collection system. Given the sheer scale of this task, work must begin as soon as possible.

These changes in the funding instruments should be accompanied by a significant overall increase in the funding amount. Right after the war ends, the state should commit to gradually increasing GERD within its R&D strategy. Past attempts to introduce new competitive funding instruments simply by reducing basic funding turned out to be counterproductive since academies of sciences proportionately reduced funding to all research institutions rather than supporting the best ones. Therefore, our next recommendation is the transformation of the research system. We suggest a dual-track approach for this.

Transformation of the organisational structure of the research system

The existing system should be gradually (over five or so years) transformed into two smaller excellence-based research societies based on the most capable research groups of the national academies of sciences. One of the new research societies/academies – modelled on the Max-Planck Society – would host world-class groups focused on basic science, while the other – modelled on the Fraunhofer Society – would unite groups engaged in applied research. Each of the two new societies should have a lean umbrella management structure consisting of a board of directors (executive level) and an internationally composed advisory board (policy-setting level). The only priority for the academy of basic research should be excellent science, while the priorities for the academy of applied research will be formed in close interaction with its donors from the private sector. These two new research academies will be able to incorporate internationally funded centres of excellence to ensure a high-quality research environment.

The organisational and legal form of the new research societies should provide much greater financial flexibility than is the case now for a standard budget institution. The academy of applied science needs to become a convenient partner for cooperation with business; its long-term goal should be funding a substantial share (up to 70%) of relevant research projects from non-public sources.

The proposed new structure should be created in parallel to the existing academies of sciences. The research groups that pass the selection process outlined above will be offered the opportunity to join the new structures and will receive additional resources (increased salaries, extra hiring power, modern office and lab space, some equipment, etc.). Over a certain transition time interval (say, 2–3 years), all research groups capable of producing high-level scientific output and/or pursuing research along strategically important lines will be accumulated inside the new research societies, which will implement administrative functions with respect to these research groups.

The remaining groups or institutions will be either transformed into new institutions according to their activity type (e.g. analytical centres, technical units, state-owned enterprises) or dissolved. The existing national academies of sciences may remain active as high-level professional associations of individuals, funded by membership fees and grants, involved in advisory and expert roles at the state level, but will be relieved of their management and fund distribution roles.

Such a structural reform should only be done after a proper evaluation of research groups to ensure that highly qualified human capital, capable networks and research infrastructure are preserved. Similarly, the transformation of 'branch' research institutions that are currently under the ministries should be done after their proper evaluation. When performing this structural transformation, Ukraine can take into account both positive and negative experiences of states that have undergone similar processes, such as eastern European countries or eastern Germany.

Supporting integration of research and education
From the very beginning, the new research societies should be mutually affiliated with universities. Contracts of key personnel (group leaders and senior-level researchers) should include an obligation to teach (up to a comfortable amount) at a specific university/department, and research groups should be involved in PhD programmes of affiliated universities. Rectors of affiliated universities should be included on the boards directors of the new research societies, and directors of affiliated institutes should reciprocally be included on the executive boards of universities. Existing integration initiatives such as the Kyiv Academic University[34]. built on the basis of the National Academy of Sciences should be supported and scaled up.

34 https://kau.org.ua/

At the same time, higher education institutions themselves will obtain access to performance-based research funding as described above, which will allow and motivate them to have resources for establishing permanent research units and engaging professors in research. All the funding instruments which we propose are quality-based, thus universities will have incentives to open research-intense positions on a competitive basis, increase academic mobility, and pursue academic integrity. As a result, capable HEIs will get resources, staff, and infrastructure to integrate research and education and become research universities.

At the level of secondary education, it will be crucial to develop and implement a strategy for engaging enough well-trained STEM[35] teachers in schools and for providing access to needed equipment and interaction with active researchers and innovators as a part of school STEM curricula. School teachers of all specialties should undergo professional training to familiarise themselves with the scientific mindset, the latest developments in science and methodologies for teaching science-related issues and scientific methods at schools. At the same time, curricula for researchers should include soft skills, communication and project management components adapted for R&D.

As a part of efforts to engage youth in science, we suggest supporting grass-roots initiatives that work with school-level initiatives, engaging children in science, implementing science in school education, and popularisation of science. Talented research-oriented youth should be supported nationwide by different instruments, from school to the PhD level.

European integration and internationalisation are an essential part of the transformation

An ERA Roadmap should be adopted as a government-level document and backed up by sufficient funding. Its implementation should be treated as part of Ukraine's EU accession path, with a view to developing Ukrainian research infrastructure as a part of European research infrastructure. There should be serious efforts towards science diplomacy on the Ukrainian side, sending to the ERA-related and Horizon Europe committees representatives capable of communicating and promoting the state-level position. To that end, the needed capacity should be provided by developing a dedicated sub-unit in the MoES and a working group in the National Council on Science and Technology, and establishing a well-trained and supported Horizon Europe national infrastructure (points of contact, support office, e-portal, communication strategy).

A general strategy for internationalisation should be developed, which would include: (1) engagement of the Ukrainian science diaspora in research programmes, projects, institutions building, and transformation of the sector; (2) providing incentives for reintegration of outstanding diaspora researchers; (3) turning 'brain drain' into 'brain circulation' using various instruments; (4) establishing remote international partnerships

35 Science, technology, engineering and mathematics.

so that Ukrainian researchers can use research infrastructure worldwide; (5) consistent promotion of English as the basic working language for researchers (e.g. introducing English-language education programs at HEIs and stimulating the influx of foreign students); and (7) removing legal barriers to international cooperation.

As Ukraine is now a candidate country to the EU, instruments available from the European Commission should be actively used for supporting R&D during and after the war and reconstruction of research infrastructure. Instruments of pre-accession assistance, which were effectively used by Turkey for innovation development support, could be used for this purpose.[36]

For the reconstruction of research infrastructure, European Structural Funds would appear to be the preferable instrument if it is possible to use them at the stage of Ukraine's candidacy. For example, in 2007–2013 European Structural Funds accounted for 51% of Poland's GERD. The second largest amount of EU funding for 2014–2020 in Poland was allocated to the Operational Programme Smart Growth.[37] This was the largest programme funding research, development and innovation in the EU, with a budget of €10.5 billion for 2014–2020 (76% spent) including €8 billion aimed at R&D support (European Commission, 2017).[38] Enterprises (in particular SMEs), research units, consortia of enterprises and research units, as well as business environment institutions were eligible to apply for this programme.

To ensure the proposed massive changes, policymaking capacity within the Ukrainian government should be strengthened considerably, and functions and interactions of different government agencies should be clearly defined and implemented.

Transformation of governance and policymaking in the R&D sphere

The role of the MoES should be limited to policy development, while implementation functions should be distributed between other actors. In particular, the Ministry should not distribute funding. Appropriate training and technical assistance should be provided to the Ministry staff responsible for policy development. Enabling data-driven policy development requires high-quality data on the R&D sector. Currently, research-related data are collected by the Ukrainian Institute on Scientific and Technical Information, which is a Soviet-era legacy institution that de facto accumulates only formal 'research reports' and other meaningless data. It should be transformed into a new institution capable of efficient data collection and providing meaningful analytics. As noted above, the national electronic system of scientific and research information, URIS, if properly developed, can be used both for policymaking and establishing communication between different stakeholders.

36 www.avrupa.info.tr/en/regional-competitiveness-262
37 See www.poir.gov.pl/en and https://ec.europa.eu/regional_policy/en/atlas/programmes/2014-2020/poland/2014pl16rfop001
38 https://cohesiondata.ec.europa.eu

The NRFU (and other similar funding agencies) and the advisory boards of research societies should be responsible for the allocation of funding and evaluation of the progress of projects. The institutional evaluation role should be delegated to a separate independent entity – an Evaluation Office.

The National Council on Science and Technology should be allocated enough resources (including a capable back-office) to implement its functions of horizontal policy coordination, providing scientific advice and setting priorities for the science and technology policy at the governmental level. Organisational changes to the NCST are also needed. The current setup, with the Council headed by the prime minister and the Administrative Committee filled by officials whose primary responsibilities lie elsewhere, leads to highly formal and inefficient operation. We recommend introducing the position of vice-prime minister (VPM) responsible for science, technology and innovation policy, who will coordinate the efforts of all ministries with respective responsibilities and programmes. The dedicated VPM should head the Council (instead of the prime minister) and ensure its dynamic and effective work and enforcement of its recommendations and decisions. We recommend the introduction of dedicated deputy ministers and units at least in those ministries that coordinate R&D activities in their sectors. These will become meaningful members of the Administrative Committee of the Council. Other stakeholder representatives that enter the Administrative Committee should also be directly responsible for policy development or coordination.

One of the functions of the NCST will be to design the strategy (masterplan) for research infrastructure development, as discussed next.

Strategic approach to the development of research infrastructure

The National Council on Science and Technology will design the strategy of research infrastructure development. Strategy design should be based on verified data on the existing capacity (both equipment and human capital), its geographical distribution, regional development strategies and smart specialisations. It should take into account international collaborations and be viewed as a part of integration into ERA, with joint utilisation of European research infrastructure and developing Ukrainian research infrastructure as a part of it.[39] The government should adopt this strategy and oversee its implementation. The development of research infrastructure should be viewed as both complementing and driven by the development of human capital. Therefore, the primary targets for research infrastructure development projects should be the newly established centres of excellence (concentrating the best personnel and providing intensive international cooperation). The infrastructure development projects can be implemented at the third stage of the programme for integration of Ukrainian science in the ERA, after supporting networks and doctoral schools as discussed above.

39 The strategy should take into account the European Research Infrastructure Roadmap (https://roadmap2021.esfri.eu/) and experience of other countries such as Poland (www.gov.pl/web/science/polish-roadmap-for-research-infrastructures) or Estonia (https://etag.ee/en/funding/infrastructure-funding/estonian-research-infrastructures-roadmap/).

4.3 Long-term actions: Science for policy

Strengthening the role of scientific expertise in government workflow and decision-making processes

The Scientific Committee of the NCST, if provided with suitable resources, can become an effective platform to deliver professional scientific advice to the government (the model of the US Office for Science and Technology Policy[40] can be used here). The organisational transformations of the Ukrainian research landscape envisioned in Section 4.2. will strengthen research institutions and their associations and provide them with the capacity to develop policy advice for the government or technologies for industries. Special programmes for training professionals in science communication, analytics and government relations should be established to ensure that needed talent is available.

The government should provide grant support to *professional organisations of researchers* to develop their capacity to produce scientific advice for policymakers and establish professional standards within their sectors. Similarly, grants should be available for grass-roots initiatives, NGOs and think tanks focusing on R&D to create a market of well-developed ideas, products, and projects.

5 CONCLUSIONS

Ukraine needs a major policy shift to embrace R&D as an economic driver of, and key factor in, its sustainable recovery. Reconstruction offers a unique opportunity to initiate long-term sectoral transformation by 'seeding' new and supporting existing structures and instruments that will define the direction and become the driving force of future changes, at relatively low investment cost. International support in the R&D sphere during the active war phase should be primarily aimed at protection and development of human capital, as well as supporting capable teams and networks. A considerable increase in R&D funding should be accompanied by reforms based on the following principles:

1. Make funding more competitive and predictable so that scarce resources flow to the most productive uses and teams (e.g. fund merit-based individual stipends to help researchers stay in the academy; basic funding should be distributed transparently according to past performance over a 5–10 year period; introduction of a multi-layer funding scheme with different layers targeting different types of research and career stages, creating clear promotion paths and opportunities; establish/fund joint centres of excellence, operating virtually during the war).

40 www.whitehouse.gov/ostp/

2. Give more autonomy – financial and managerial – to research organisations and encourage growth of new institutions or mergers of research organisations to overcome the Soviet legacy (e.g. research organisations should be more free to raise external funding, including from businesses; organisations' boards, rather than state auditors, should review financial results; the National Research Foundation, with the help of international donors, should be allowed to provide grants to research projects implemented by research institutions together with businesses, NGOs or local authorities).

3. Integrate Ukrainian science into global science (e.g. establish non-residential fellowships, exchange lectures, workshops etc.; fund research networks and joint doctoral schools; evaluation of Ukrainian research organisations should heavily involve international experts and scientists; instruction in English should become standard).

4. Integration of research and education is a key objective to ensure that cutting edge technology and expertise are transferred to new generations of researchers (e.g. universities should be not only teaching institutions but also research organisations; joint appointments across research institutes and universities should become the norm).

5. Strengthen the role of scientific expertise in government workflow and decision-making.

The war and reconstruction offers a once-in-a-lifetime opportunity to radically and systemically reform Ukraine's science sector. These reforms should commence immediately.

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