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Analysis of the challenges in the field of innovation diffusion and digitalisation, and a proposal for focusing the priorities of the National RIS3 Strategy after 2025

Final report - short version

August 2024

Co-funded by the European Union

MINISTRY OF REGIONAL DEVELOPMENT CZ

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The report was prepared for the Ministry of Industry and Trade under the contract 'Analysis of Challenges in the Field of Innovation Diffusion and Digitalisation, and a Proposal for Focusing the Priorities of the National RIS3 Strategy after 2025.' This work was implemented within a project funded by the Operational Programme Technical Assistance, entitled 'Update of Analyses and Extraction of EDP Process for the Upgrade of the National RIS3 Strategy,' with the registration number CZ.07.01.01/00/22_005/0000013.

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1 Introduction

The aim of the study prepared by the Technology Centre Prague (TCP) for the Ministry of Industry and Trade (MIT) under the contract "Analysis of challenges in the field of innovation diffusion and digitalisation, and a proposal of the focus of priorities of the National RIS3 Strategy after 2025" is to identify significant technological and societal challenges that the Czech Republic will face in the future and to assess the relevance of these challenges for the National Research and Innovation Strategy for Smart Specialization of the Czech Republic 2021-2027 (National RIS3 Strategy, NRIS3) [1]. The conclusions of the analysis will be used in particular to update of NRIS3 and serve as a valuable resource for defining further missions to be included in the strategy after 2025, or in the subsequent NRIS3 for the next European Structural and Investment Funds (ESIF) financial period

The analyses were prepared using the most recent statistical data and other data from publicly available databases and information sources as well as from commercial databases to which TCP has access. The data were matched to grand societal challenges (GSCs) and advanced technologies using sets of keywords. Certain findings from the literature review were incorporated to address the study's topics. The results of the analyses were subsequently discussed in two workshops with experts specializing in advanced technologies.

This document is an abridged version of the final report, encompassing the most pertinent information and findings derived from the analyses and various activities conducted under the contract. Chapter 2 provides a concise characterization of the grand societal challenges (GSCs) currently facing the Czech Republic, as well as those anticipated in the near future. Additionally, it offers an overview of advanced technologies that have the potential to address and resolve these challenges.

In the Chapter 3 the trends in publication and patenting activities in advanced technologies and state support provided for R&D of advanced technologies in the Czech Republic are analysed. In this chapter, the links of advanced technologies to the identified GSCs are also evaluated.

In the Chapter 4 the most important results of the analysis of stakeholders active in R&D in the field of advanced technologies and the analysis of the links between the entities involved in such projects are presented. In Chapter 5 the international position of the Czech Republic in advanced technologies is assessed. Furthermore, the contribution of individual advanced technologies to the solution of the identified GSCs is assessed.

Chapter 6 presents an overview of the key findings from the analyses along with a set of recommendations, incorporating insights from experts at the closing workshop. Chapter 7 provides a summary of the most relevant information sources. Detailed results from all analyses are available in the full version of the final report on public procurement titled "Analysis of the challenges in the field of innovation diffusion and digitalisation, and a proposal for focusing the priorities of the National RIS3 Strategy after 2025" [2], and in its annexes.

2 Great societal challenges and advanced technologies

2.1 Great societal challenges

To identify the great societal challenges (GSCs), we conducted a review of strategic and conceptual documents addressing this topic, compiled in recent years both within the Czech Republic and at the European Union level. The key documents included in this review were:

- Outputs of the project FUTURE-PRO: Megatrends and Grand Societal Challenges[1] supported by the Technology Agency of the Czech Republic (TA CR) in the years 2020 - 2021, which was carried out by the Czech Priorities, z. ú. [3], [4].
- The report Long-term challenges for Czech society (LTCs) [5], prepared in 2023 by the Technology Centre Prague. It was commissioned by the Office of the Government of the Czech Republic within the project "Conceptual and analytical support to the Research, Development and Innovation Council (RDIC)" related to the preparation of new National Priorities of Oriented Research (NPOR) [6].
- National Research and Innovation Strategy for Smart Specialization of the Czech Republic 2021-2027 (National RIS3 Strategy, NRIS3) prepared by the Ministry of Industry and Trade in 2021 [1]. The search included mainly information on two missions, which are in Annex 1: Cards for thematic areas (version 4, December 2022).
- Horizon Europe (HE) Framework Programme [7]. In particular, the work programmes for Pillar II "Global Challenges and European Industrial Competitiveness" and the relevant documents setting out the focus of the missions in the HE Framework Programme were included in the search.

Using these documents, six GSCs relevant to the Czech Republic at present and in the near future were identified. An overview of these is given in Table 1 in the first column with blue underlining. As can be seen in the table, the challenges identified in this document always include several GSCs from the FUTURE-PRO project (second column of the table), and at the same time correspond to some extent to the global challenges of the HE Framework Programme and the missions defined in this programme (third and fourth columns of the table). Two of the GSCs correspond in their focus to two missions in the current NRIS3 [8] listed in the last column of the table.

[1] https://www.tacr.cz/20projekt-future-pro-megatrendy-a-velke-spolecenske-vyzvy/

Table 1 Comparison of societal challenges and missions defined in the Long-term challenges for Czech Society [5], Megatrends and Grand Societal Challenges relevant to the Czech Republic [2][3], the Horizon Europe Framework Programme [7] and the NRIS3 National Research and Innovation Strategy for Smart Specialisation of the Czech Republic 2021-2027 [1]

Long-term challenges for Czech society	**GSC defined in FUTURE-PRO**	**Global challenges in HE**	**Missions in Horizon Europe**	**Missions in the current NRIS3 2021-2027**
Adaptation to climate change	GSC 1 - - Crucial, yet vulnerable cities GSC 2 - Insufficiently addressed climate crisis GSC 23 - Water scarcity GSC 8 - Adverse effects of humans on the environment GSC 9 - Equal access to high-quality and nutritious food GSC 16 - Unsustainable use of natural resources and ecosystem services (part) GSC 21 - Sustainable consumption (part) GSC 22 - Ensuring sustainable economic growth (part)	Climate, energy and mobility–(part) Food, bioeconomy, natural resources, agriculture and environment	Adaptation to climate change including social transformation *New European Bauhaus*[3]	
Preparedness for demographic change and an ageing population (abbreviated as Preparedness for demographic change)	GSC 6 - Unpreparedness for the new nature of work GSC 11 - New ethical dilemmas and cultural challenges GSC 12 - Poor health and mental discomfort	Health	Cancer	
Energy transformation and a sustainable future (abbreviated as Energy Transformation)	GSC 7 - Low-emission energy production and consumption GSC 21 - Sustainable consumption (part) GSC 22 - Ensuring sustainable economic growth (part)	Climate, energy and mobility(part)	Climate-neutral and smart cities	Making the economy more material, energy and emissions efficient

[2] The grand societal challenges from the FUTURE-PRO document are taken from Annex 2: Identification of MTs/GSCs - Names of MT cards and GSC
cards

[3] The "New European Bauhaus" is HE's upcoming mission connecting the Green Deal and "living spaces"

Trust in democracy, societal resilience, security and defence (abbreviated as Trust in Democracy, Societal Resilience)	GSC 3 - Democracy under pressure GSC 10 - Geopolitical tension GSC 13 - Increasing inequality within states GSC 14 - Infrastructure failure risks GSC 15 Insufficiently addressed migration GSC 17 - Poverty and risk of falling into poverty GSC 19 - Unpreparedness for the new nature of security threats GSC 20 - Social instability	Culture, Creativity and Inclusive Society Civil security for society		Strengthening society's resilience to security threats
Technological and digital transformation of society (abbreviated as Technology and Digital Transformation)	GSC 4 - Impacts of digitisation and automation on work and society GSC 18 - Extensive breadth and speed of technological change	Digital, industry and space		

2.2 Advanced technologies

The selection of advanced technologies is based primarily on those defined in the European Commission's Advanced Technologies for Industry (ATI) project [9], [10]. Key Enabling Technologies (KETs [11], [12], [13]) used in NRIS3 to identify domains of research and innovation specialisation and R&D topics with potential for application in industries ([1], [8]) were also considered in the selection process. Emphasis was placed on the area of digital technologies, which are increasingly applied in a number of technological areas and contribute to their dynamic development, often in a disruptive way.

For analytical purposes, the advanced technologies were categorized into six broad technology areas, as shown in the leftmost column of Table 2. Each of these broad areas encompasses several specific advanced technologies listed in the second column. The final column details the Key Enabling Technologies (KETs) that are associated with each advanced technology area. Depending on the objectives, the analyses were conducted either at the level of broad technology areas (indicated by dark blue shading) or at the level of specific technologies (indicated by light blue shading).

Table 2 Advanced technologies included in the analysis. Source: ATI project ([9], [10]), European Commission

Advanced technologies - areas	**Advanced Technologies - ATI**	**KETs**
Advanced manufacturing technologies	Advanced manufacturing Robotics[4]	Advanced manufacturing technologies
Advanced material technologies	Advanced materials Nanotechnology Micro- and nanoelectronics Photonics	Advanced materials and nanotechnology Photonics and micro-/nanoelectronics
Biotechnology	Biotechnology[5]	Biotechnology
Digital technologies	Artificial Intelligence Augmented/virtual reality Big Data Blockchain Cloud computing	Artificial Intelligence - part Digital security and connectivity - part
Information and communication technologies	Connectivity Internet of Things (IoT) Cyber security	Digital security and connectivity - part
Other advanced technologies	Quantum technologies	Artificial Intelligence - part

[4] Robotics in this analysis includes robotic devices that are autonomous or use artificial intelligence for their operation

[5] "Biotechnology" includes industrial biotechnology as well as medical and life sciences technologies (as in the updated version of the KETs)

3 Analysis of technological trends in relation to identified societal challenges for the Czech Republic

3.1 Trends in advanced technologies and the dynamics of their development

Publication and patent activity in most advanced technologies is increasing. This is evident in Figure 1, which compares the change in the number of publications and priority patent applications in each of the advanced technologies over two two-year periods - for publication activity between 2017-2018 and 2021-2022, and for patent activity between 2016-2017 and 2020-2021[6]. The horizontal dashed red line in the figure represents the change in the total number of priority patent applications over the period under review, and the vertical line represents the change in the total number of publications. If the technology is to the right of the vertical red line, the increase in the number of publications in that advanced technology is higher than the increase in total publication activity, and vice versa. The same is true for patent activity.

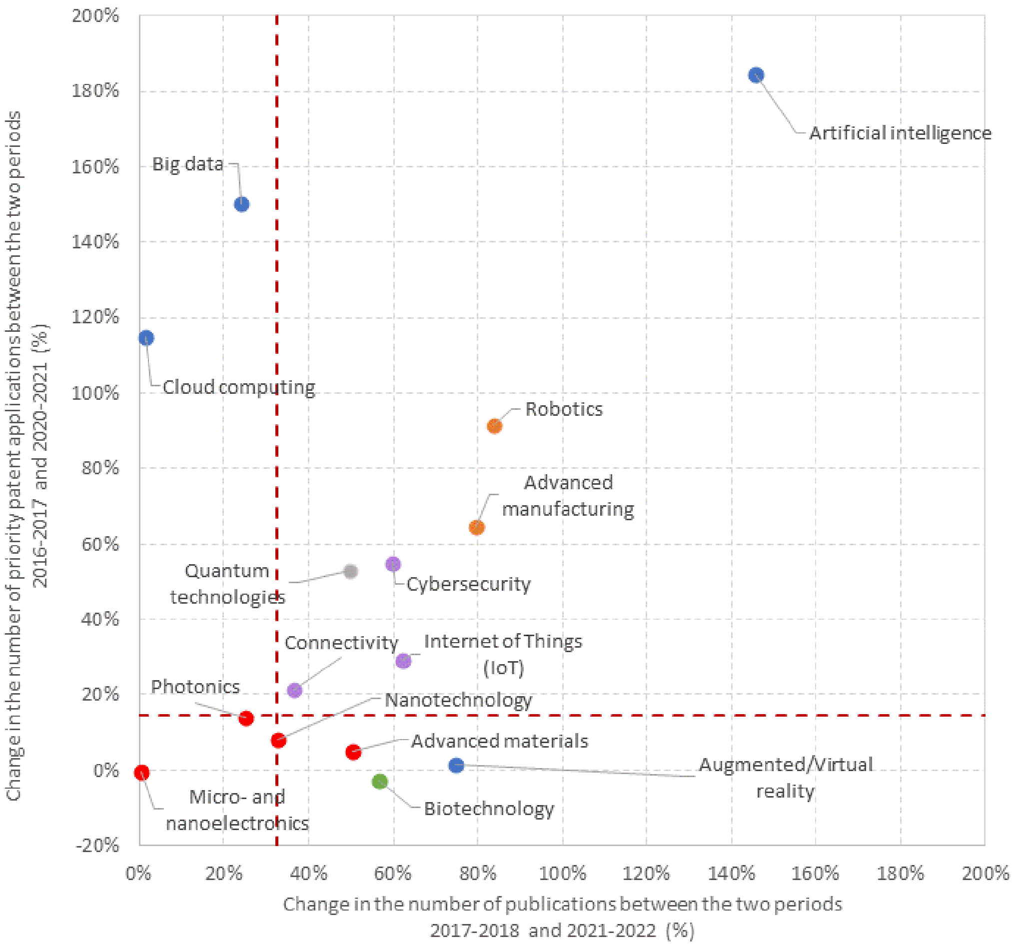

Figure 1 Comparison of trends in publication and patent activity in advanced technologies. Further information on the figure is provided in the text. Source: Clarivate Web of Science, PATSTAT, Autumn 2023

Simultaneously, these technologies in the right upper corner are experiencing a more rapid increase in patenting activity compared to other fields, indicating their expected rise in practical applications.

[6] The shifted time period for patent activity is related to the fact that even in the latest PATSTAT database from autumn 2023, the data from 2022 are not yet complete

Among these, artificial intelligence (AI) stands out as having the highest potential for further development and broader application. Positioned in the top right corner of Figure 1, AI shows significant promise. The textual analysis of patent applications showed that neural networks, deep learning and training are currently gaining importance in AI, and the application of AI in the Internet of Things (IoT), clouds and blockchain is also growing. AI is a prominent topic in technology media, permeating various sectors beyond digital technology to encompass a wide range of research activities.

Advanced manufacturing technologies - robotics and advanced manufacturing, where the number of publications and patent applications is increasing more than in other technological areas, have a significant potential for development. This increase may to some extent be 'driven' by the dynamic development of AI used in these technologies (e.g. autonomous robots, automation and digitalisation of manufacturing technologies, etc.). Machine vision and recognition (of objects, images, faces, and behaviour, etc.) are becoming increasingly important in advanced manufacturing technologies.

Technologies with above-average growth in publication and patent activity also include information and communication technologies (ICT, see Figure 1). Cybersecurity has the highest potential of these technologies, with publications and patent applications increasing by around 60% more than the average, which seems to be related to the increasing cyber threats. The application of cybersecurity is increasing in the areas of networking, blockchain and data storage.

For some advanced technologies, while publication activity is not growing much, the possibilities of their application are increasing significantly (patent activity is increasing significantly, well above the average rate). These technologies, located in the upper left quadrant, include big data and cloud computing. In big data, there is an increasing emphasis on real-time data processing and storage, forecasting and early warning. In both technologies, the use of AI, among others, is increasing.

Augmented/virtual reality, biotechnology and advanced materials, on the other hand, are among the technologies where research activity is more concentrated compared to other technologies, but patent activity is increasing moderately compared to other technologies (see Figure 1, bottom right quadrant). In the future, however, research activities and their results may help to extend the 'capabilities' of these technologies and thus increase their application.

Photonics, nanotechnology and micro- and nanoelectronics classified in the group of advanced material technologies in Figure 1 are located in the lower left quadrant. This means that research activities have been shifting to other areas in recent years. Despite the decline, these technologies are finding considerable application as the number of patent applications is still high.

3.2 Trends in state support of R&D in advanced technologies

State support for R&D projects in the most advanced technologies is on the rise, mirroring trends seen in publication and patent activities (see Figure 2). The total budgets for projects in advanced manufacturing and robotics, categorized as advanced manufacturing technologies, have notably increased between 2016 and 2023, particularly in terms of non-state funding. Conversely, project budgets for most technologies classified under advanced materials have remained stagnant or slightly declined over the same period. An exception is photonics, which has seen a significant rise in funding, especially in 2023. The scenario is markedly different for digital technologies. Project budgets in this sector have been growing consistently from 2016 to 2023, fuelled by both state and non-state funding. The most pronounced growth has been in artificial intelligence, with an accelerating rate of increase, particularly in non-state funding (R&D expenditure on artificial intelligence is assessed in Chapter 3.3). Cloud computing and blockchain have also shown strong growth, especially in the latter years of the review period.

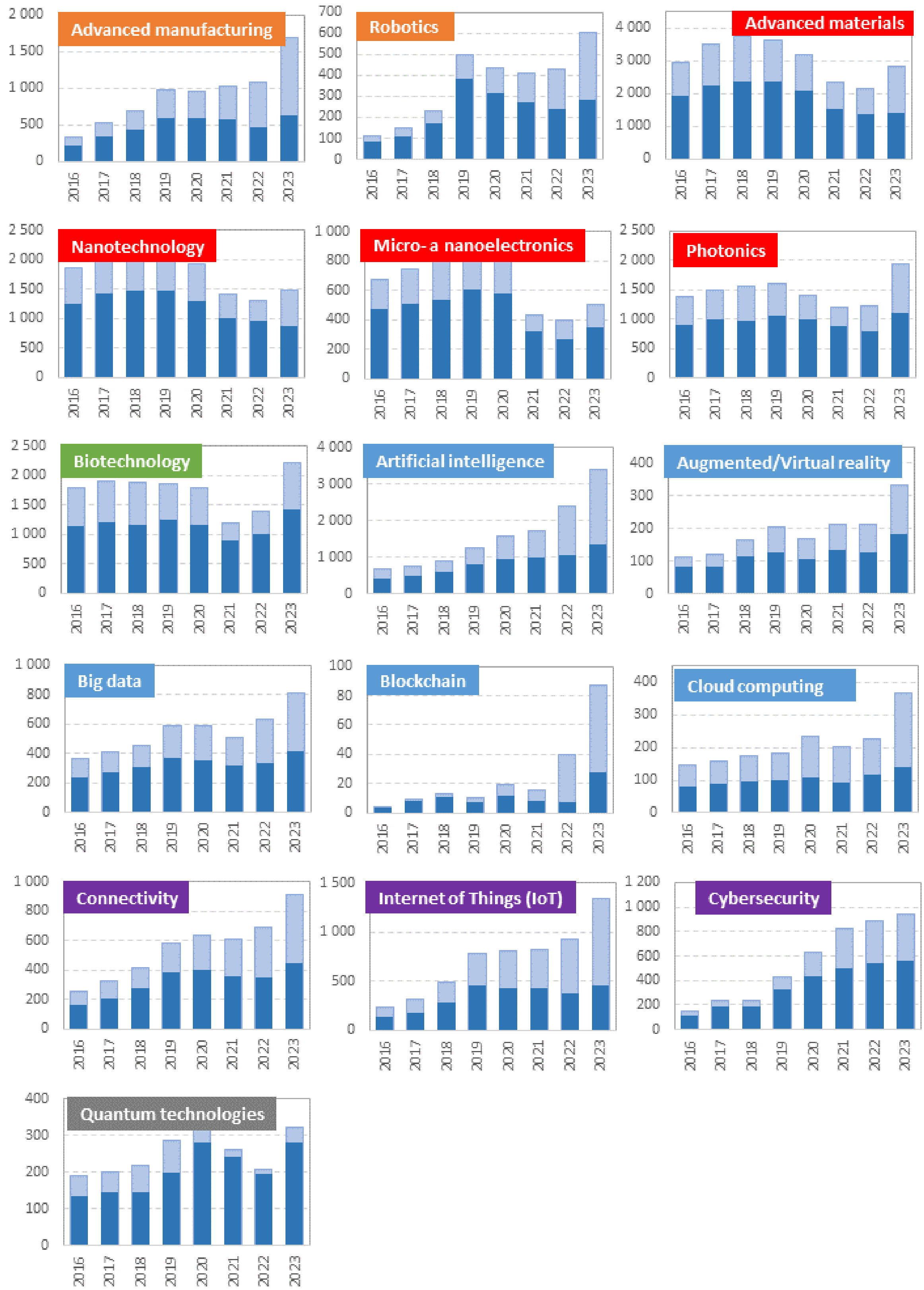

Figure 2 Evolution of total costs and state support of projects focused on individual advanced technologies in 2016-2023. The dark blue bars indicate the amount of state support in total project costs (excluding infrastructure projects). Figures are in millions of CZK. Source: R&D&I Information System

In ICT, state and non-state funding is also growing significantly. The highest growth is seen in the Internet of Things, which also shows the highest increase in the non-state funding. During the period under review, there has been a substantial increase in spending on projects focused on cybersecurity issues. Similarly, there is noticeable growth in quantum technologies. However, a significant portion of the budget for quantum technology projects comes from state support. This is due to the complexity of the research and the fact that the results of the research and development are still far from being in the market application level.

3.3 Financial Investment into AI in the Czech Republic

The study [14] shows that more than eight hundred projects addressing AI have been initiated from the beginning of 2017 until about mid-2023[7] . By 2028, the support from the state budget of the Czech Republic provided for these projects should exceed CZK 11 billion and their total cost should reach approximately CZK 15 billion. Almost a thousand participants from various sectors are involved in the projects (see Table 3). A total of 818 projects have carried out R&D aimed at the development of AI or its use in specific applications (research projects). These projects will receive approximately CZK 8.8 billion in support from the state budget by the end of their implementation and their total cost will reach almost CZK 15 billion. 29 projects supported the development of R&D infrastructure in the field of AI. The total costs and state support provided to these projects amounted to around CZK 2.7 billion.

Table 3 The number of projects launched since 2017, the state budget support that will be awarded to these projects from 2017 to 2028 and their total cost (after 2023 this is the projected figure). The last column shows the number of participants in these projects. Source: Research and development in the field of artificial intelligence in the Czech Republic [14]

	Number of projects	Support from the state budget (CZK million)	Total costs (CZK million)	Number of participants
Projects found using keywords, of which:	847	11 441.5	17 586.4	956
- research projects	818	8 794.6	14 805.4	628
- projects supporting the development of research infrastructure	29	2 646.9	2 781.0	328

A more detailed analysis prepared in the study [14] showed that approximately 15% of the projects conducted basic AI research. Less than 20% of the projects dealt with applied AI research. The majority of projects were related to AI (e.g. the use of AI in specific technological areas). Ethical and legal aspects of AI were addressed in less than 4% of projects. The remaining projects dealt with the development of R&D infrastructure or only touched on AI issues.

3.4 Links of advanced technologies to identified MSCs

Advanced technologies are used in projects aimed at GSCs solutions. This can be seen in Table 4, which shows the linkages of advanced technologies to GSCs in projects supported by the HE Framework Programme. The values in the table indicate the proportion of projects assigned simultaneously to a given GSC and to a given broader area of advanced technologies ('intersection') out of the total number of projects assigned to that GSC. Advanced technologies have been used most frequently in the HE programme in projects addressing the GSCs Trust in Democracy, Societal Resilience, Security and Defence, Technological and Digital Transformation of Society, and Energy Transformation and

[7] The evaluation was carried out in mid-2023

Sustainable Future. The uptake of advanced technologies is somewhat lower in the Adaptation to Climate Change and Preparedness for Demographic Change and Ageing GSCs (see first column of the table).

Table 4 Links between advanced technologies and grand societal challenges. Data are for projects supported by the Horizon Europe Framework Programme. Source: e-CORDA

Projects supported in the Horizon Europe Framework Programme ------------------------------------ **Grand Societal Challenges (abbreviated)**	Advanced technologies	Advanced manufacturing technologies	Advanced material technologies	Biotechnologies	Digital technologies	Information and communication technologies
Trust in democracy, societal resilience	65%	8%	16%	7%	37%	37%
Adaptation to climate change	35%	1%	10%	8%	16%	10%
Energy transformation	61%	8%	34%	12%	20%	12%
Technological and digital transformation	65%	11%	13%	6%	43%	31%
Preparedness for demographic changes	29%	2%	5%	3%	18%	8%

Digital Technologies and ICT play a crucial role in addressing the GSCs. Their most significant applications are in the GSCs Trust in Democracy, Societal Resilience, and Technology and Digital Transformation. This high adoption rate in Trust in Democracy and Societal Resilience is likely due to the need for enhanced security against cyber threats and the integration of digital technologies within government and business sectors. Additionally, digital technologies demonstrate a substantial impact on Energy Transformation. Advanced material technologies have the greatest influence on the Energy Transformation GSC, while advanced manufacturing technologies show a notable impact in the Technology and Digital Transformation GSC. They also play a significant role in Energy Transformation and Trust in Democracy, Societal Resilience GSCs (refer to Table 4). Similar connections between advanced technologies and GSCs have been observed in projects undertaken in the Horizon 2020 (H2020) framework programme and in targeted R&D support initiatives funded by the Czech Republic's state budget. A more detailed analysis showed that there are significant links between specific advanced technologies and areas of GSCs. An assessment of these can be found in the full version of the final report [2]. The results of this analysis were used to quantitatively describe the impact of advanced technologies on GSCs in Chapter 5.3.

4 Stakeholder analysis and networking of research and innovation actors

4.1 Stakeholder analysis

A high number of actors from all sectors were involved in projects focused on R&D of advanced technologies. In the R&D of advanced manufacturing technologies and their applications, the faculties and departments active in the field of mechanical engineering, electrical engineering and ICT as well as some more general faculties and departments were the most involved from the higher education institutions (HEI) sector. Some institutes of the Czech Academy of Sciences (CAS) were also frequent participants in such projects. Faculties and departments of universities were most involved in projects focused on advanced material technologies. The focus of these faculties/departments was quite broad, which is related to the use of these materials in various products and sectors. The faculties and departments were active in physical, material and life sciences as well as in engineering, construction, electrical engineering, ICT and healthcare, where, in addition to R&D of advanced materials, attention is also paid to their use in applications in various sectors.

Faculties and institutes working in the field of (bio)chemical, natural and health sciences were most involved in projects focused on biotechnology. The faculties most involved in projects focused on digital technologies and ICT were electrical engineering faculties, faculties focused on ICT and faculties focused on natural and physical sciences.

An overview of the most important participants in the R&D support programmes in each broad area of advanced technologies is given in Table 5. For each area of advanced technologies, the table shows the ten entities with the highest number of projects implemented in targeted R&D support programmes from 2019 to the present. Also listed are the entities that have participated in ten or more projects in the H2020 and HE framework programmes since 2019. The entities are ranked in descending order of the number of projects in the state R&D support programmes.

Table 5 Overview of the most important stakeholders in each broad field of advanced technologies. Source: R&D&I Information System, e-CORDA

Advancet technology / Institution (abbreviated)	National programmes		H2020 and HE	
	Number of projects	Support (CZK Mill.)	Number of projects	Support (€ thous.)
Advanced manufacturing technologies				
CTU in Prague - Faculty of Mechanical Engineering	45	228.0	0	0.0
Brno University of Technology - Faculty of Mechanical Engineering	40	284.6	1	718.8
CTU in Prague - Faculty of Electrical Engineering	36	651.8	2	36.8
CTU in Prague - Czech Institute of Informatics, Robotics and Cybernetics	24	329.8	8	11 769.8
University of West Bohemia in Pilsen - Faculty of Applied Sciences	22	258.4	2	650.8
Brno University of Technology - Central European Institute of Technology	21	130.0	10	5 980.8
BUT in Brno - Faculty of Information Technology	20	153.8	5	1 512.5
BUT in Brno - Faculty of Electrical Engineering and Communication	18	97.7	1	415.0
COMTES FHT a.s.	16	94.3	0	0.0
University of West Bohemia in Pilsen - Faculty of Mechanical Engineering	15	165.4	0	0.0
Advanced material technologies				
Institute of Physics of the CAS, v. v. i.	210	3 669.0	23	18 496.4
Charles University - Faculty of Mathematics and Physics	128	586.4	8	5 099.4
UCT - Faculty of Chemical Technology	122	498.8	10	1 987.4
Institute of Macromolecular Chemistry of the CAS, v. v. i.	118	347.9	2	188.0
BUT - Central European Institute of Technology BUT	116	904.6	24	7 349.7
Czech Technical University in Prague - Faculty of Civil Engineering	101	399.3	5	2 082.5
J. Heyrovsky Institute of Physical Chemistry of the CAS, v. v. i.	96	384.9	8	1 977.1
Palacký University in Olomouc - Faculty of Science	89	707.7	7	2 177.1
Brno University of Technology - Faculty of Civil Engineering	71	315.9	0	0.0
Brno University of Technology - Faculty of Mechanical Engineering	68	409.3	2	1 097.8
Argotech a.s.	3	7.813	13	5 751.4
UPOL - Czech Advanced Technology and Research Institute	13	51.5	11	8 297.8

Advancet technology / Institution (abbreviated)	National programmes		H2020 and HE	
	Number of projects	Support (CZK Mill.)	Number of projects	Support (€ thous.)
Biotechnology				
Institute of Microbiology of the CAS, v. v. i.	84	541.2	3	3 469.3
Biological Centre of the CAS, v. v. i.	41	223.2	4	611.6
UCT - Faculty of Food and Biochemistry. Technology	38	212.2	2	643.3
Charles University - Faculty of Science	34	310.8	3	652.7
MU - Central European Institute of Technology	30	709.9	12	6 916.5
Masaryk University - Faculty of Science	29	92.0	7	10 646.9
USB in České Budějovice - Faculty of Science	22	164.2	1	150.4
UP in Olomouc - Faculty of Science	20	240.9	2	265.0
Institute of Biotechnology of the CAS, v. v. i.	20	173.7	1	419.1
Veterinary Research Institute, v. v. i.	19	140.3	2	743.5
Digital technologies				
CTU in Prague - Faculty of Electrical Engineering	93	734.8	9	2 690.7
BUT - Faculty of Electrical Engineering and Communication	73	253.9	3	1 810.9
Charles University - Faculty of Mathematics and Physics	63	436.5	20	10 408.5
Brno University of Technology - Faculty of Information Technology	55	332.5	13	3 395.0
University of West Bohemia in Pilsen - Faculty of Applied Sciences	42	208.2	4	694.7
VSB - TUO - Faculty of Electrical Engineering and Computer Science	34	171.1	0	0.0
CTU in Prague - Czech Institute of Informatics, Robotics and Cybernetics	32	432.4	15	13 887.9
Brno University of Technology - Central European Institute of Technology	25	161.9	11	6 336.2
Institute of Information Theory and Automation of the CAS, v. v. i.	25	84.2	4	671.0
VSB - TUO - IT4Innovations	24	951.3	18	7 402.9
Masaryk University - Faculty of Informatics	13	203.0	13	6 666.9
CESNET, zájmové sdružení právnických osob	14	1 575.7	10	3 020.2
Information and communication technologies				
BUT in Brno - Faculty of Electrical Engineering and Communication	74	386.9	3	1 848.1
CTU in Prague - Faculty of Electrical Engineering	52	188.1	3	1 029.2
BUT in Brno - Faculty of Information Technology	31	212.2	12	3 001.2
IMA - Institute of Microelectronic Applications	25	60.4	8	974.7
BUT in Brno - Faculty of Electrical Engineering and Communication	23	148.1	7	1 816.7
CESNET, zájmové sdružení právnických osob	20	1 374.4	7	2 181.4
CTU - Faculty of Transportation Sciences	20	60.4	0	0.0
VSB - TUO - Faculty of Electrical Engineering and Computer Science	19	117.3	0	0.0
Charles University - Faculty of Mathematics and Physics	19	87.9	3	683.2
Masaryk University - Faculty of Informatics	17	144.9	3	2 073.9
Quantum technologies				
Palacky University in Olomouc - Faculty of Science	44	229.2	5	1 522.4
Charles University - Faculty of Mathematics and Physics	31	95.3	3	2 243.1
Institute of Physics of the CAS, v. v. i.	23	233.0	4	2 587.6
CTU in Prague - Faculty of Nuclear Sciences and Physical Engineering	13	94.9	0	0.0
BUT - Central European Institute of Technology	11	166.9	2	578.1
J. Heyrovsky Institute of Physical Chemistry of the CAS, v. v. i.	9	60.8	0	0.0
Institute of Scientific Instruments of the CAS, v. v. i.	8	237.4	1	211.3
Masaryk University - Faculty of Science	7	18.7	2	644.3
Czech Metrology Institute	7	12.0	0	0.0
Institute of Organic Chemistry and Biochemistry of the CAS, v. v. i.	6	12.1	1	145.0

A total of 28 institutions were contacted to inquire if they would be willing to nominate a vetted researcher in accordance with the EU 2022/2065 Digital Single Market Regulation [15]. These included selected faculties and departments of universities, as well as institutes of the CAS involved in R&D in the fields of digital technology and ICT. Additionally, institutions active in the social sciences and humanities, which are likely to assess the impact of AI and other digital technologies, potential threats to their deployment, and their effects on society, were also contacted. Out of the 11 responses received, nine institutions indicated their willingness to nominate vetted researchers as required by the Regulation.

4.2 Networking of research and innovation actors

There is a well-developed cooperation between the participants in projects focused on advanced technologies. In the cooperation maps[8] in national programmes for R&D on advanced technologies, the role of research organisations is evident. Faculties of engineering at universities (Czech Technical University in Prague, Brno University of Technology, University of West Bohemia, VSB-Technical University of Ostrava) can be considered as knowledge centres in advanced manufacturing technologies. Faculties and centres active in electronics, electrical engineering, computer science and robotics, which are related to the application of digital technologies and artificial intelligence in manufacturing, also play an important role in cooperation.

In the field of advanced materials technology, several research institutions specializing in this area play a crucial role in fostering national collaboration. The main knowledge centres include faculties and centres of universities, institutes of the CAS (in particular the Institute of Physics of the CAS, the Institute of Macromolecular Chemistry of the CAS and the Institute of Physical Chemistry of the CAS) and research centres from the business sector (e.g. COMTES and SVÚM).

In the field of biotechnology, chemically and natural science-oriented universities and faculties (University of Chemistry and Technology, Prague, Faculty of Science of Charles University and others) and some institutes of the CAS focused on biological sciences act as knowledge centres (for example, the Institute of Microbiology of the CAS and the Biological Centre of the CAS).

In the field of digital technologies, the dominant role is played by electronics-oriented university faculties and research centres. The key knowledge institutions in this area of advanced technologies include the Faculty of Electrical Engineering and Communication Technologies at Brno University of Technology, the Faculty of Electrical Engineering at the Czech Technical University in Prague and the Faculty of Electrical Engineering and Informatics at VŠB-Technical University of Ostrava. The situation is similar in the field of ICT, where the most important role is played by the faculties and departments of universities such as the Faculty of Electrical Engineering and Communication Technologies of Brno University of Technology, the Faculty of Electrical Engineering of the Czech Technical University in Prague and the Faculty of Information Technology of Brno University of Technology. Some centres, such as the Central European Institute of Technology (CEITEC) in Brno, also play an important role in cooperation. For a more detailed assessment of cooperation in projects focusing on advanced technologies in national R&D support programmes and EU Framework Programmes, it is possible to use the internet version of the cooperation maps (https://svizualizace.tc.cas.cz/NRIS3/en.html).

[8] For the evaluation of cooperation between the subjects, the cooperation maps established from projects supported in national programmes of targeted R&D support and in EU framework programmes were used.

5 Mapping and empirical analysis

5.1 Assessment of the position of the Czech Republic in advanced technological fields

The Czech Republic has a good position in international comparison in terms of publication activity - the share of publications in most advanced technologies in the total number of publications in the Czech Republic is higher than in the world (see Table 6). The only exception is digital technology, where the Czech Republic lags behind the world, the EU-28 average and all countries included in the international comparison (i.e. research activities are less focused on this technological area in the Czech Republic than in other countries).

The position of the Czech Republic in patent activity in advanced technologies is somewhat different. The share of advanced technologies in the total number of priority patent applications in the Czech Republic is lower than in the world in most advanced technologies. The only exception is advanced material technologies, where their share is higher in the Czech Republic than in the world. On the other hand, the Czech Republic is lagging behind the world in digital technologies (see Table 7).

Table 6 International comparison of publication activity of the Czech Republic, EU-28 and selected EU Member States in individual areas of advanced technologies. The values in the table show by what percentage the representation of publications in advanced technologies in the total publication output of a given country (group of countries) and in the world average differs. The figure is for the number of publications between 2019 and 2023. Source: Clarivate Web of Science

Country	Advanced manufacturing technologies	Advanced material technologies	Biotechnologies	Digital technologies	Information and communication technologies	Quantum technologies
EU-28	-6.2%	-18.1%	-0.3%	5.5%	20.8%	-12.3%
Czech Republic	14.1%	22.9%	2.2%	-14.4%	9.9%	21.8%
Denmark	-35.8%	-28.5%	52.6%	0.1%	95.5%	-36.2%
Finland	20.6%	-11.0%	8.4%	46.2%	255.2%	-8.1%
Netherlands	-39.1%	-36.0%	-6.3%	6.7%	84.1%	-19.0%
Austria	24.0%	-12.6%	12.2%	14.7%	148.2%	-9.8%
Germany	29.6%	3.6%	-3.7%	23.5%	114.4%	14.0%
Ireland	14.1%	-23.0%	29.5%	36.9%	207.9%	-26.1%
Portugal	48.0%	-2.8%	54.3%	31.8%	176.8%	-31.1%
Slovenia	6.1%	4.1%	4.3%	4.3%	82.5%	-100.0%
Italy	20.2%	-16.1%	-17.8%	13.6%	143.6%	-1.8%

Table 7 International comparison of patent activity of the Czech Republic, EU-28 and selected EU Member States in individual areas of advanced technologies. The values in the table show the percentage difference in the representation of priority patent applications in advanced technologies in the total number of priority patent applications in a given country (group of countries) and in the world average. The figure is for priority patent applications filed between 2018 and 2021. Source: PATSTAT, Autumn 2023

Country	Advanced manufacturing technologies	Advanced material technologies	Biotechnologies	Digital technologies	Information and communication technologies	Quantum technologies
EU-28	-66.5%	-61.8%	-64.9%	-68.9%	-64.2%	-51.1%
Czech Republic	-42.5%	36.2%	-43.4%	-77.1%	-33.1%	-57.3%
Denmark	-49.6%	-47.4%	8.7%	-64.5%	-69.7%	-56.1%
Finland	-73.0%	-40.2%	-42.5%	-20.0%	112.9%	104.7%
Netherlands	-46.5%	5.9%	-36.2%	-36.5%	-49.2%	34.8%
Austria	-78.2%	-34.4%	-78.3%	-90.1%	-88.6%	-41.7%
Germany	-74.2%	-84.8%	-88.4%	-77.5%	-81.0%	-74.8%
Ireland	-8.4%	-17.0%	-39.1%	174.6%	0.6%	110.3%
Portugal	-76.0%	-63.2%	13.5%	-77.8%	-76.0%	-100.0%
Slovenia	-48.2%	-12.0%	205.6%	-88.0%	-90.3%	-100.0%
Italy	-90.0%	-87.7%	-90.5%	-95.5%	-93.8%	-100.0%

5.2 The Czech Republic's position in digital technologies

Comparison of the Czech Republic with the EU average and its individual Member States in the composite indicator Digital Economy and Society Index 2022[9] (DESI 2022) [16] can be found in Figure 3. The Czech Republic ranks nineteenth out of 27 countries, which is five places below the EU average. The index value for the Czech Republic is roughly at the level of Italy and Cyprus. Among the new EU Member States, all the Baltic countries, Slovenia and Malta are also ahead of the Czech Republic (the DESI 2022 index value is based on the values of individual indicators, usually from 2021).

[9] From 2023, the DESI index will be included in the Digital Decade Status Report.

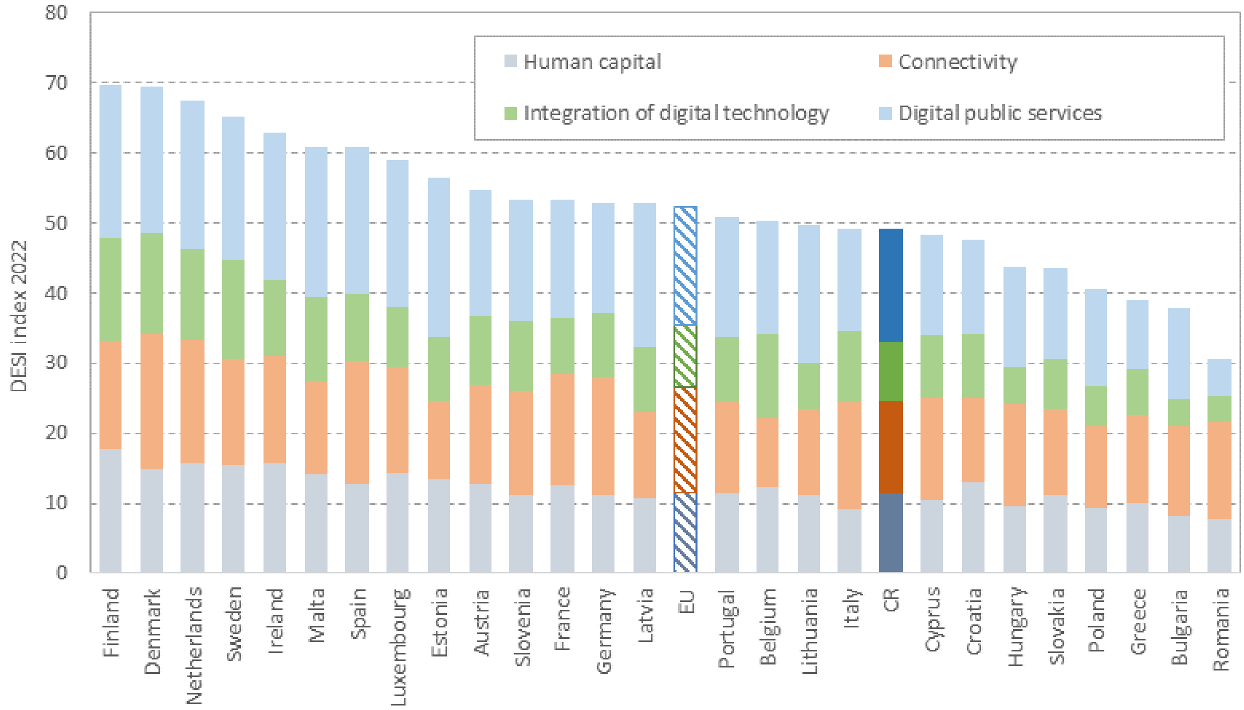

Figure 3 Comparison of the Czech Republic with the EU average and individual Member States in the Digital Economy and Society Index 2022 (DESI 2022). Source: DESI 2022 [16]

Figure 4 compares the position of the Czech Republic with the average of EU Member States in particular dimensions. The Czech Republic is approximately at the EU average in the Human Capital dimension. In the other dimensions, the Czech Republic is below the European average, most notably in the Connectivity dimension (about 12% below the EU average). In the Digital Technology Integration dimension, the Czech Republic is about 6% below the EU average, and in the Digital Public Services dimension, the Czech Republic is about 4% behind the EU average. The Czech Republic's position is evaluated in more detail in Table 8.

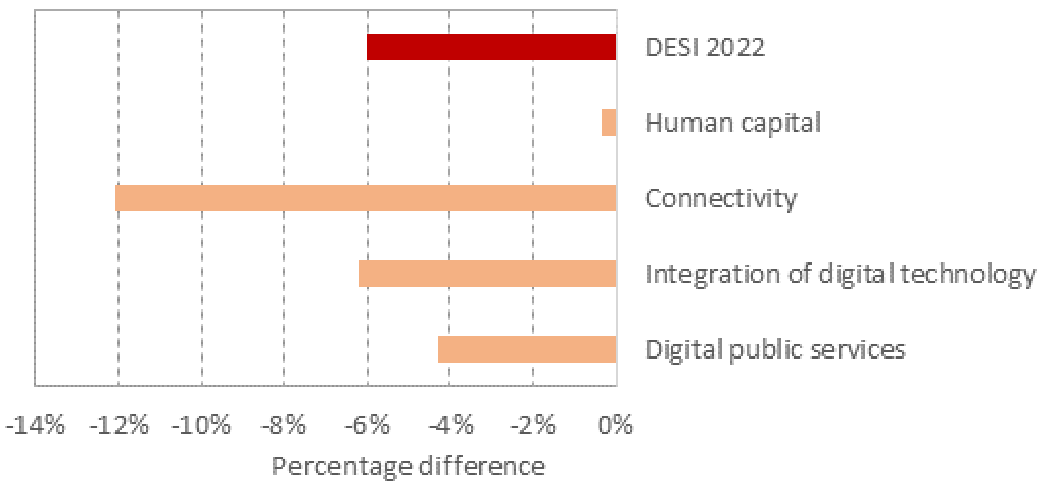

Figure 4 Comparison of the Czech Republic and the EU in the four dimensions tracked in DESI 2022. Data are from the last year tracked in DESI 2022. Data for the determination of values are generally from 2021. Source: DESI 2022 [16]

Given the inclusion of DESI in the Digital Decade Status Report in 2023 [17] the methodology and indicators monitored have changed, Table 8 shows a comparison of the Czech Republic with the average of the Member States making use of the indicators currently monitored in DESI 2023 (see the DESI 2023 methodology document [18] and DESI 2023 dashboard [19]). The indicators are divided in the table into dimensions and subdimensions monitored in DESI 2023.

In some dimensions of DESI 2023, the Czech Republic is at the EU average, in some it is above the European average and in others it is far below the average of the EU Member States (see Table 8). In majority of the indicators included in the Digital Skills dimension, the Czech Republic is at the level of the EU Member State average. It is slightly above average in the share of people with basic digital skills, including the representation of women. However, the Czech Republic falls significantly below the EU average in the number of female ICT specialists. When it comes to digital infrastructure, the country meets the European average in mobile broadband across all monitored indicators. In contrast, for the indicators concerning fixed broadband, the Czech Republic remains well below the EU average (see Table 8).

In the dimension of digital transformation for businesses, the Czech Republic significantly lags behind the average EU Member States in most indicators within the sub-dimension of Digital Technologies for Enterprises, with the notable exception of cloud computing. Given the growing importance of digital technologies for enhancing competitiveness, it is alarming that Czech enterprises are considerably underutilizing digital technologies such as artificial intelligence and big data compared to their European counterparts, even considering the critical role these technologies play in addressing current challenges. However, the Czech Republic does score above average in the e-commerce sub-dimension. Revenue from electronic transactions in the Czech Republic is approximately 50% higher than the EU average (see Table 8). This surge in e-commerce activity may be linked to the increased adoption driven by COVID-19 containment measures.

In the last dimension, Digitalisation of public services, the Czech Republic is at the EU level in digital public services for citizens and businesses (above average in the number of users). On the contrary, it falls below average in indicators characterising the user environment and user-friendliness. The Czech Republic is also below the average of the Member States in access to electronic health records (see Table 8). Additional details regarding the Czech Republic's advancements in digital technologies, as they pertain to the objectives of the Digital Decade, are available on the DESI 2023 dashboard [19] and in the report on the status of the Digital Decade goals [17].

Table 8 Comparison of the current values of the indicators monitored in DESI 2023 in the Czech Republic and the average of the EU Member States. The last column shows the percentage difference between the Czech Republic and the EU. Indicators are grouped according to the DESI 2023 dimensions and sub-dimensions. Source: DESI 2023 [19]

Dimension	Sub-dimension	Indicator	Czech Republic	EU	Percentage of EU
Digital skills	Internet user skills	Internet use	89.7	88.6	1%
		At least basic digital skills	59.7	53.9	11%
		Above basic digital skills	24.1	26.5	-9%
		At least basic digital content creation skills	65.9	66.2	0%
		Enterprises providing ICT training	23.1	22.4	3%
		Females having at least basic digital skills	59.7	52.3	14%
	Advanced skills and development	ICT specialists	4.5	4.6	-2%
		ICT graduates		4.2	
		Female ICT specialists	10.9	18.9	-42%
Digital infrastructure	Fixed broadband	At least 100 Mbps broadband take-up	31.0	55.1	-44%
		At least 1 Gbps broadband take-up	1.3	13.8	-91%
		Fixed Very High Capacity Network (VHCN) coverage	53.2	73.4	-28%
		Fibre to the Premises (FTTP) coverage	37.4	56.5	-34%
	Mobile broadband	Mobile broadband take-up	85.4	86.5	-1%
		Overall 5G coverage	82.6	81.2	2%
		5G spectrum	66.7	68.2	-2%
Digital transformation of businesses	Digital intensity	SMEs with at least a basic level of digital intensity	68.0	69.1	-2%
	Digital technologies for businesses	Electronic information sharing	37.7	38.0	-1%
		Social media	24.0	29.3	-18%
		Big data	9.1	14.2	-36%
		Cloud	40.0	34.0	18%
		AI	4.5	7.9	-43%
		e-Invoices	12.2	32.2	-62%
	e-Commerce	SMEs selling online	22.8	19.1	19%
		e-Commerce turnover	17.2	11.3	52%
		Selling online cross-border	11.2	8.7	29%
Digitalisation of public services	e-Government	e-Government users	86.0	74.2	16%
		Digital public services for citizens	76.2	77.0	-1%
		Digital public services for businesses	83.8	83.7	0%
		Pre-filled forms	41.9	68.2	-38%
		Transparency of service delivery, design and personal data	57.3	64.7	-11%
		User support	68.0	83.6	-19%
		Mobile friendliness	80.1	93.3	-14%
	e-Health	Access to e-health records	47.4	71.7	-34%

5.3 Quantitative description of the impact of advanced technologies on identified societal challenges

For this evaluation, data from the analysis of the links of advanced technologies to GSCs were used. The weight of contribution was assessed at four levels, ranging from zero contribution (no stars) to high contribution (three stars). The evaluation results are clearly summarized in the following tables: Table 9 shows the contribution at the level of broader areas of advanced technologies, while Table 10 provides a more detailed assessment of the contribution of digital technologies and ICT to the GSCs solution.

As demonstrated in Table 9, digital technologies constitute the primary means of addressing GSCs, being extensively utilized in projects aimed at all identified GSCs. Furthermore, ICTs have a substantial contribution in projects related to the Technology and Digital Transformation of Society, Energy Transformation and Sustainable Future, and Trust in Democracy, Societal Resilience, Security, and Defence GSCs. Specifically, within the GSC of Energy Transformation, ICTs are predominantly employed to decentralize the energy sector. Concerning the GSC of Trust in Democracy and Societal Resilience, ICTs are chiefly used to enhance infrastructure security and the security of emerging technologies. In the Technology and Digital Transformation GSC, ICTs are applied comprehensively across all sectors.

In the same GSCs, advanced material technologies are also highly applicable. In GSC Energy Transformation, advanced materials are applied in the context of decarbonisation and the circular economy. In GSC Trust in Democracy, Societal Resilience, their application is particularly related to environmental security and ensuring the functioning of the economy. In GSC Technological and Digital Transformation, materials are mainly used to upgrade production and service processes.

Table 9 Quantitative assessment of the contribution of advanced technologies to solving major societal challenges relevant to the Czech Republic. The contribution is evaluated at four levels - high contribution (three stars, deep green shading), medium contribution (two stars, medium deep shading), low contribution (one star, light shading), no or negligible contribution (no star, light grey shading). Quantum technologies are not included in the table. Source: e-CORDA, own calculations

GSC / Advanced Technologies	Advanced manufacturing technologies	Advanced material technologies	Biotechnology	Digital technology	Information and communication technologies
Adaptation to climate change	*	**	**	***	**
Preparedness for demographic change and an ageing population	*	**	*	***	**
Energy transformation and a sustainable future	**	***	***	***	***
Trust in democracy, societal resilience, security and defence	**	***	**	***	***
Technological and digital transformation of society	***	***	**	***	***

Biotechnology finds its most significant application within the Energy Transformation GSC, specifically in energy production via biomass and in promoting sustainable development, including recycling initiatives and the utilization of environmentally friendly materials (see Table 9). Under the GSC Trust in Democracy, Societal Resilience framework, biotechnology plays an important role in enhancing environmental security. Advanced manufacturing technologies are particularly relevant to the

Technology and Digital Transformation GSC, where they are used in optimizing production and service processes.

The impact of each digital technology on the GSC solution has been assessed in see Table 10. It is evident that AI-based technologies make the highest contribution, playing a pivotal role in projects that address all GSC related issues. Cybersecurity also ranks highly in its contribution to the GSC domains of Technological and Digital Transformation of Society, Trust in Democracy, Societal Resilience, Security and Defence, a necessity driven by the increasing frequency of cyber-attacks. Similarly, connectivity is crucial in tackling these challenges effectively.

Big data technologies exhibit extensive applicability, contributing across a wide range of economic sectors to address all identified GSCs. The Internet of Things also demonstrates a significantly high contribution, as the intercommunication between technological devices facilitates the resolution of multiple GSC issues (see Table 10).

Table 10 Quantitative assessment of the contribution of digital technologies and information and communication technologies to solving major societal challenges relevant to the Czech Republic. The contribution is assessed at four levels - high contribution (three stars, deep green underlining), medium contribution (two stars, medium deep underlining), low contribution (one star, light underlining), no or negligible contribution (no star, light grey underlining). Source: e-CORDA, own calculations

GSC / advanced technology	Artificial Intelligence	Augmented/virtual reality	Big Data	Cloud computing	Blockchain	Connectivity	Internet of Things	Cyber security
Adaptation to climate change	***	*	**	*		*	*	**
Preparedness for demographic change and an ageing population	***	*	**			*	**	*
Energy transformation and a sustainable future	***		**	*	*	**	**	*
Trust in democracy, societal resilience, security and defence	***	*	**	*	**	***	**	***
Technological and digital transformation of society	***	**	***	**	**	***	***	***

6 Key findings and draft recommendations

6.1 Overview of the most important findings

6.1.1 Grand societal challenges and advanced technologies

Based on the analysis of strategic and conceptual documents developed both in the Czech Republic and at the EU level, a total of five grand societal challenges relevant to NRIS3 were identified:

- Adaptation to climate change;
- Preparedness for demographic change and an ageing population;
- Energy transition and a sustainable future;
- Trust in democracy, societal resilience, security and defence;
- Technological and digital transformation of the economy and society.

In addition, advanced technologies have been identified that can help address these GSCs with the contribution of research and development. Advanced technologies have been grouped into six broad technology areas:

- Advanced manufacturing technologies;
- Advanced material technologies;
- Biotechnology;
- Digital technologies;
- Information and communication technologies;
- Other advanced technologies.

6.1.2 Trends in advanced technologies and their use in GSCs

The analysis of publication activity revealed that the number of publications in most advanced technologies is globally on the rise. The highest growth is seen in digital technologies, particularly in artificial intelligence (AI), blockchain and augmented/virtual reality. Publication activity is also growing significantly in advanced manufacturing technologies and biotechnology. There is also an increase in publication activity in ICT. The situation is the opposite in advanced material technologies - publication activity is stagnating in most of the technologies included in this area, while it is slightly decreasing in micro- and nanoelectronics.

Similar trends are evident in patent activity. The number of patent applications in most advanced technologies is increasing, some very significantly. Patent activity is increasing significantly in most digital technologies. The biggest increase is seen in AI. High growth is also evident in advanced manufacturing technologies, particularly robotics. Patent activity is stagnating in material technologies and biotechnology. This means that research activity has been concentrated in recent years in the area of digital technologies and information and communication technologies, so we can expect to see an expansion of their capabilities in the future as well as their increased use in various applications.

Advanced technologies are used in R&D projects focused on GSCs - most notably in the GSC *Technology and Digital Transformation of Society*, *Energy Transformation and Sustainable Future* and *Trust in Democracy, Societal Resilience, Security and Defence*. In particular, digital technologies (mainly AI), ICT (cybersecurity) and material technologies (advanced materials, nanotechnologies) are highly applicable.

The application of specific technologies in GSCs depends on the nature of the challenge and the focus of its sub-areas. In the *Energy Transformation and Sustainable Future* GSC, advanced material technologies, biotechnologies, AI and some ICT (in particular the Internet of Things, IoT) are most applicable. In the GSC *Confidence in Democracy, Resilient Society, Security and Defence*, technologies such as cybersecurity and AI are most applicable. Connectivity and big data also have higher applications.

In the GSC *Adaptation to Climate Change*, the issue of AI and biotechnology is often mentioned in the projects addressed. Material technologies and cyber security are also highly applicable in some specific areas. The use of AI, robotics and IoT is often mentioned in projects addressing the GSC *Preparedness for demographic change and ageing*. In the *Technology and Digital Transformation of Economy and Society* GSC, digital and information and communication technologies such as AI, connectivity, cybersecurity, big data and IoT are expected to be used the most.

6.1.3 R&D of advanced technologies in the Czech Republic

Research and development (R&D) of advanced technologies is relatively well developed in the Czech Republic. A high number of entities from all sectors are involved in projects focused on advanced technologies. Faculties and institutes of higher education operating in the fields of mechanical engineering, electrical engineering and ICT play a significant role in the R&D of advanced manufacturing technologies. A wide range of faculties and departments of higher education institutions (HEIs) and a high number of research institutes are involved in advanced material technology R&D, which is related to the wide use of materials in various products and sectors. R&D in the field of biotechnology mainly involves faculties and institutes active in the field of (bio)chemical, natural and health sciences. Electrical engineering faculties, ICT faculties, science and physics faculties and research institutes active in digital technologies are most involved in digital technology and ICT projects.

Businesses are also involved quite intensively in projects focusing on advanced technologies. The highest participation of enterprises is visible in projects focused on advanced material technologies and advanced manufacturing technologies. Enterprises are least involved in projects on quantum technologies.

In the projects supported in the programmes of targeted R&D support, cooperation between research organisations (ROs) and subjects from the application sector is developed. An important role in this cooperation is played by technology-oriented faculties of universities, some institutes of the Czech Academy of Sciences and research centres supported by the European structural and investment funds (especially European Centres of Excellence).

Major HEIs are involved in EU Framework Programme projects, which demonstrates their potential for conducting internationally competitive research. In the EU Framework Programmes, entities from the Czech Republic cooperate with a number of research teams from abroad, including teams from leading foreign research institutes.

6.1.4 The Czech Republic's position in advanced technologies

The international position of the Czech Republic in R&D of advanced technologies is quite satisfactory. Research in the Czech Republic is more focused on advanced technologies than in other countries. In this comparison, the Czech Republic is also above the average of EU Member States. The Czech Republic is in the best position in advanced materials technologies, where domestic research focuses significantly more than in other countries. The situation is somewhat worse in digital technologies, where the Czech Republic lags behind the world and EU average.

The weakness of the Czech Republic is low patent activity in advanced technologies. The proportion of patent applications focused on advanced technologies in the total number of patent applications is lower in the Czech Republic than in the world (except for advanced material technologies). Although patent activity is influenced by several factors related to the environment in the Czech Republic and differences between industries, the low number of patent applications may result in lower use of R&D results in business innovation.

The Czech Republic's position in digital technologies is not very satisfactory. In the composite indicator "Digital Economy and Society Index", the Czech Republic ranks nineteenth out of 27 EU countries, which is five places below the EU average. The current values of the indicators monitored in DESI 2023 show that the Czech Republic has a relatively satisfactory position in digital skills in European comparison, which creates good conditions for the use of digital technologies in society. In this context, it is favourable that mobile broadband in the Czech Republic is at a higher level than the EU average. The willingness of society to use digital technologies is also reflected in the above-average number of enterprises using e-commerce. It is also positive that the Czech Republic has a satisfactory position in the digitisation of public services in European comparison.

A significant weakness, however, is the digital transformation of enterprises, where the Czech Republic is still lagging far behind the EU average. Given the growing importance of these technologies, it is alarming that Czech enterprises are making far less use of digital technologies such as artificial intelligence and big data compared to European enterprises, even in the context of their high application to address current GSC.

6.2 Draft recommendations

The proposed recommendations aim to enhance the strengths and address the weaknesses of the Czech Republic in advanced technologies concerning the GSCs. These recommendations are structured according to the priorities outlined in the National Research and Innovation Strategy for Smart Specialisation of the Czech Republic 2021-2027 (NRIS3).

6.2.1 NRIS3 cross-cutting priorities

6.2.1.1 Corporate research, development and innovation

The use of AI and other digital technologies will contribute to increasing the efficiency of domestic businesses, boosting their competitiveness and shifting supply chains. In addition to stimulating businesses to adopt these technologies, other tools need to be created to help businesses become more competitive, including the creation of an enabling business environment. Well-developed links between research organisations and businesses can also contribute to strengthening the competitiveness of enterprises in the field of advanced technologies. These links need to be exploited in advanced technology R&D programmes, where enterprises will work together with HEIs in relevant sectors.

As the segment of advanced technologies is still developing and their use in practice is gaining importance, it is necessary to stimulate and support the creation of new companies based on R&D results in these technological areas. At the same time, it is necessary to create a suitable environment for the initial development of start-up companies.

6.2.1.2 Public research and development

In the Czech Republic, the results of public R&D are not sufficiently used in the commercial sphere. For this reason, the use of public research results focused on advanced technologies in applications and business innovation needs to be stimulated in all programmes aimed at addressing R&D.

Research centres equipped with cutting-edge infrastructure and application-oriented centres supported by the ESIF, with which a significant number of entities from the public and business sectors cooperate, play an important role in R&D focused on advanced technologies. It is essential to take advantage of this when formulating programmes and public competitions aimed at addressing GSCs, where entities from both sectors can cooperate in R&D projects covering all phases of the innovation process.

6.2.1.3 People and smart skills

Although the Czech Republic is at the EU average in most of the indicators monitored in the Digital Economy and Society Index (DESI 2023) in its Digital Skills dimension, it lags behind the European average in advanced skills. As these skills are crucial for the implementation of digital technologies, there is a need to stimulate students to study these fields and develop their skills. Efforts to develop digital skills and boost the number of ICT graduates must begin well ahead of time.

6.2.1.4 Digital agenda

The Czech Republic lags behind the EU average in a number of indicators monitored in DESI 2023. The lag is particularly evident in fixed high-speed connections. Although the Czech Republic is above the EU average in mobile high-speed connectivity, it is necessary to improve the quality and speed of fixed connections, which in some cases is essential. The Czech Republic faces a challenging situation regarding the adoption of digital technologies by enterprises. This lag in digital transformation could become a significant constraint on the future application of these technologies in addressing GSCs. In addition to incentives towards the digital transformation of enterprises, there is also a need to improve the transparency of digital services provided by the state and their user support. Significant improvements should also be made in access to health data.

6.2.2 Vertical priorities NRIS3

6.2.2.1 Domains of research and innovation specialisation

Based on the results of the analyses, it is recommended to consider expanding the current definition of key enabling technologies (KETs), specifically "Artificial Intelligence" and "Digital Security and Connectivity," in NRIS3. The analyses indicate that other digital technologies, such as big data, cloud computing, augmented/virtual reality, and blockchain, are increasingly being used to address mission (or GSC) issues. Therefore, it would be appropriate to broaden the KETs to include "Other Digital Technologies," thereby incorporating these advanced technological applications.

Likewise, the use of advanced technologies encompassed in the current KET "Digital Security and Connectivity" is on the rise. In the future, this KET could be divided into two distinct categories, each differing in nature and mission-specific applications – “Connectivity and IoT” and “Cyber Security”.

6.2.2.2 Social challenges

The two missions "Making the economy more material, energy and emission efficient" and "Strengthening the resilience of society to security threats" included in the current NRIS3 should be expanded to include the remaining three GSCs that are relevant for the Czech Republic at present and in the near future - Adaptation to climate change, Preparedness for demographic change and ageing and Technological and digital transformation of society.

Given the cross-cutting nature of most missions, it is essential to develop R&D programmes in close cooperation of all relevant funding providers. Experts from different sectors should actively participate in designing and focusing these programmes. In order to implement R&D programmes that address the issues outlined in the NRIS3 mission, it is essential to utilise the resources of the relevant funding providers in a synergistic manner. For R&D programmes that do not have specific focus on missions, it is appropriate to launch open calls for projects that will address specific challenges of the mission corresponding to the focus of the given programme. When selecting projects, priority should be given to those that utilise advanced technologies, as these are more likely to make a significant contribution to addressing the challenges outlined in the mission

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As the current two NRIS3 missions and the three newly proposed missions are global in nature, it would be appropriate to leverage resources from multiple countries to address them, for example through specifically targeted bilateral or multilateral programmes. At the same time, projects that meet the objectives of NRIS3 missions and have successfully passed the evaluation process in the Horizon Europe Framework Programme, the Digital Europe Programme[10] and other European programmes but have not been funded due to limited call budgets (Seal of Excellence[11]), should be supported.

[10] https://digital-strategy.ec.europa.eu/en

[11] https://commission.europa.eu/funding-tenders/find-funding/seal-excellence_en

7 The most important data sources

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