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Special Issue: Opportunities and challenges of EU farm-to-fork strategy

Research and innovation challenges for better policies in food systems and bioeconomy transitions – evidence from Poland

RESEARCH ARTICLE

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Abstract

Climate changes and depleting natural resources call for the urgent sustainability transition of the economy. This also refers to food systems, which are a vital part of the economy directly linked to the nature. The first step in creating better forward-looking policies for the transition of food systems is identification of knowledge gaps to target R&D spending. In the paper we focus on the presentation and analysis of research directions that constitute future challenges for the transformation of research and development in Poland. The methodology of research applied in the study is based on participatory action research philosophy. The approach to determine the research challenges and needs included round tables and focus groups under the BIOEAST initiative. The results show that the most important weakness is low level of R&D expenditure in bioeconomy sectors, while the strength is a large number of new active entities for implementation of innovations, supporting bioeconomy and science-practice cooperation. The key recommendation is increasing the R&D spending and prepare national bioeconomy strategy to make use of the large potential of the Polish bioeconomy sector.

Keywords: value chain, food systems, SWOT analysis, research and innovation, BIOEAST, CEEC, Poland

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1. Introduction

Climate changes and depleting natural resources call for the urgent sustainability transition of the economy to meet Sustainable Development Goals (Sachs, 2012). This also refers to food systems, which are a vital part of the economy directly linked to the nature. Introducing new sustainable and circular processes in the food system requires intense R&D activities to create new solutions that ensure tackling the triple challenge facing food systems: food security and nutrition, livelihoods and environmental sustainability (OECD, 2021). The transition is an opportunity to improve the functioning of the food systems. The first step in creating better forward-looking policies for the transition of food systems is identification of knowledge gaps to target R&D spending where it is most needed (De Vries, 2021; McCarthy *et al.*, 2013).

The complexity of food systems, value-based dilemmas related to them and the necessity to answer long-term questions related to functioning of different elements of food systems call for deliberative process for public decision making as they are best suited for such problems (Chwalisz, 2020). This can help in creating policies that are accepted by a wide range of stakeholders. The challenge of transition of food systems and bioeconomy requires innovative approach that offers effective and inclusive empowerment of different stakeholder groups in process of shaping better policies. This is due to the nature of the bioeconomy, which is based on knowledge (and human resource) based production and the use of biological resources to provide products, processes and services in all sectors within the frame of a sustainable economic system. Food systems are a major contributor to the development of the bioeconomy, as they are the main provider of biomass as a material base and energy source for the economy. Nowadays, these two elements are closely interlinked, responding to the challenges of a changing climate and the need to implement a sustainable growth model.

In the context of the implementation of EU policies, including in particular those related to the implementation of the Farm-to-Fork strategy, research on research capacities as well as mapping of research and innovation needs for the positive transformation of food systems is crucial (Sonnino *et al.*, 2020).

In the paper we focus on the presentation and analysis of research directions that constitute future challenges for the transformation of research and development in Poland, in the context of the development of the whole macro-region of Central and Eastern Europe (Chmieliński *et al.*, 2021). The paper is structured as follows. The introduction addresses the main issues related to the subject of the study, the methodological part shows the collective approach and the logic behind the analysis presented. The analytical part includes on the one hand a general background indicating the potential of the sectors related to bioeconomy and food systems in Poland, and the characteristics of the research and innovation related sectors in the light of international statistics, followed by the results of own study, based on participatory approach for SWOT (strengths, weaknesses, opportunities and threats) analysis as well as a set of priorities for the development of the research and innovation (R&I) sector in Poland, identified by the multi-actor group of experts. The results of the study are followed by the conclusions.

2. Data sources and methodology

We used a mix-method design of our study. The methodology of research applied in the study is based on participatory action research philosophy often applied in social sciences (Bergold and Thomas, 2012; Masson *et al.*, 2021; Sautier *et al.*, 2017). It is a reflexive process, where the next step is conducted after a critical analysis of both results and process leading to these results. This approach also helps to bridge the gap between theory and practice (Moote *et al.*, 1997).

The approach to determine the research challenges and needs included round tables and focus groups organised by the Thematic Working Group on Food Systems under the BIOEAST initiative (Chmieliński *et al.*, 2021; Horváth, 2019; Vásáry, 2019), with the participation of the representatives of Polish Ministry of Agriculture and Rural Development and Ministry of Science, as well as research institutes, NGOs and other entities (n=187). The analysis of research and innovation needs in Poland was a summary of consultations among

a group of researchers and experts representing Polish Research Institutes and departments in particular public administration units. Similar studies conducted in other central and eastern European countries (CEECs) under the H2020 BIOEASTsUP project¹ allow not only to identify challenges from a multi-actor perspective, but also allow comparisons of the results with other countries of the region. The application of the participatory method to the countries of our region not only allows for a better identification of the problems and challenges facing food systems in the future, but also makes it possible to relate these problems to other research conducted at EU level. Such work results in the inclusion of the most pressing problems in EU research programmes, and it is with this intention that the survey described in this study has been conducted.

The systemic approach to identify challenges and problem themes for future research and innovation in CEECs, including Poland, involved a triangulation of research methods based primarily on the participatory method. Developing future topics that will advance the transformation of food systems, as well as bioeconomy is a task based primarily on the experience of various expert groups, including not only the administration shaping public policy, but primarily scientists and representatives of practice and entrepreneurs (Juhász and Vásáry, 2017).

The study was conducted in stages. In the first stage involved the analysis of the strategic documents, as well as documents developed by Polish administration and scientific units, mapping the themes and research needs for R&D in agriculture and bioeconomy sectors for joint strategic planning in CEEC macro-region, and also as a Poland's and BIOEAST inputs, as a suggested topics for the Horizon Europe Work Programme 2021 – *Cluster 6 'Food, Bioeconomy, Natural Resources, Agriculture and Environment* (Ministry of Agriculture and Rural Development (MARD), 2016). The approach to defining the topics involved a group of experts, who made a first, preliminary catalogue of research and innovation issues, and then agreed with representatives of the Polish research institutes working in the field of agriculture, rural development and food systems. In February 2021 a validation meeting among Poland's research institutes and representatives of ministries, experts and practitioners (n=187) was organised to discuss and prioritize specific SWOT elements and to identify Research and Innovation Needs for food and bioeconomy sectors in Poland. Finally, a subsequent expert workshop (with active participation of 81 experts and direct input from 58 participants) identified key characteristics to prioritise and rank challenges and opportunities and to sort out the different food systems related R&D characteristics (Chmieliński, 2021). The distribution of respondents according to the type of institution/entity they represented was as follows:

- industry / business or business association – 13.8%;
- academia/research institution – 63.8%;
- government – 19.0%;
- other – 3.4%.

The study included a synthesis of other activities aimed at mapping research and innovation needs for the formulation of national guidelines for EU framework programmes, and research to identify challenges for science and practice in agriculture and food systems. The main research material was obtained by conducting interactive online workshops using the interview method and structured online questionnaires (used in discussion, for structured collection of opinions and information in real time), thus bypassing the organisational problems associated with COVID-19.

¹ Project 'Advancing Sustainable Circular Bioeconomy in Central and Eastern European Countries' is a project funded through the European Research and Innovation programme, Horizon 2020, for the duration of three years (October 2019 to September 2022), see: www.bioeast.eu.

3. Results and discussion

3.1 Agriculture and food sector in Poland

Food sector is an important part of the Polish economy, while the strength of the food economy is based on cooperation in the food chain, although agriculture plays a key role here in terms of organisation and structure of biomass production. With economic development, the share of agriculture in the structure of the national economy in Poland is decreasing in favour of non-agricultural sectors, especially industry and services. The development possibilities of agriculture result to a smaller and smaller extent from endogenous conditions of this sector, and depend more and more on the general economic situation and the macroeconomic policy. This is mainly due to the changing role of the food sector in national economies. The productive and non-productive functions of agriculture for the economy, society and natural environment require close interactions of this sector with other sectors of the economy. Moreover, the supply and prices of agricultural products are subject to stronger fluctuations than most other products on world markets. This process has been intensified as a result of globalisation processes (MARD, 2019).

The share of agriculture in the creation of GDP and employment in economically developed countries has decreased to 1.4% (in Poland the share of agriculture in the creation of GDP amounts to 3%, and in employment in the agri-food sector to about 10%).

The productivity of Polish agriculture is increasing, decreasing the gap in relation to the results obtained in the EU, however, structural problems in this respect include mainly the fragmentation of Polish agricultural holdings, the average size of which in 2020 amounts to slightly more than 11 ha. Despite significant progress, the productivity of Polish agriculture is lower than in leading EU countries, e.g. the yield of Polish cereals per 1ha is equal to the level that France and Germany achieved in the 1970s (MARD, 2019). Opportunities for improvement in this regard are associated with the possibility of scientific and technological progress and the degree of absorption of innovations in the food sector.

Agriculture is naturally an important part of the Polish food system. After the EU accession the Polish agriculture started to develop rapidly (Table 1). This is reflected also in the increase of the Polish share in the EU agri-food export. In 2008 it amounted to 3.4%, while in 2018 it reached 5.7% (Wigier *et al.*, 2021). However, the share of meat – 17.3% and dairy products – 8.3% (Figure 1) can be a barrier for further growth with the changing consumer preferences and the European Green Deal leading to include agriculture in the effort of reducing GHG emissions.

The food industry in Poland is one of the most successful in the period of social and economic transformation and Poland's membership in the EU. Food manufacturing companies have made numerous investments to bring their plants up to world standards and to reduce the technology gap. These activities have turned the food industry from traditional and labour-intensive to modern. The high technological level of food processing makes the Polish food industry considered to be one of the most modern in the EU. The food industry (including the tobacco industry) in Poland generates about 3% of the GDP and employs about

Table 1. Output of the Polish agricultural industry – basic and producer prices (in million Euro) and change 2019/2009 (in %) (Kowalczyk, 2021).

Year	Value
2009	17,461
2013	23,669
2019	26,358
2019/2009	151

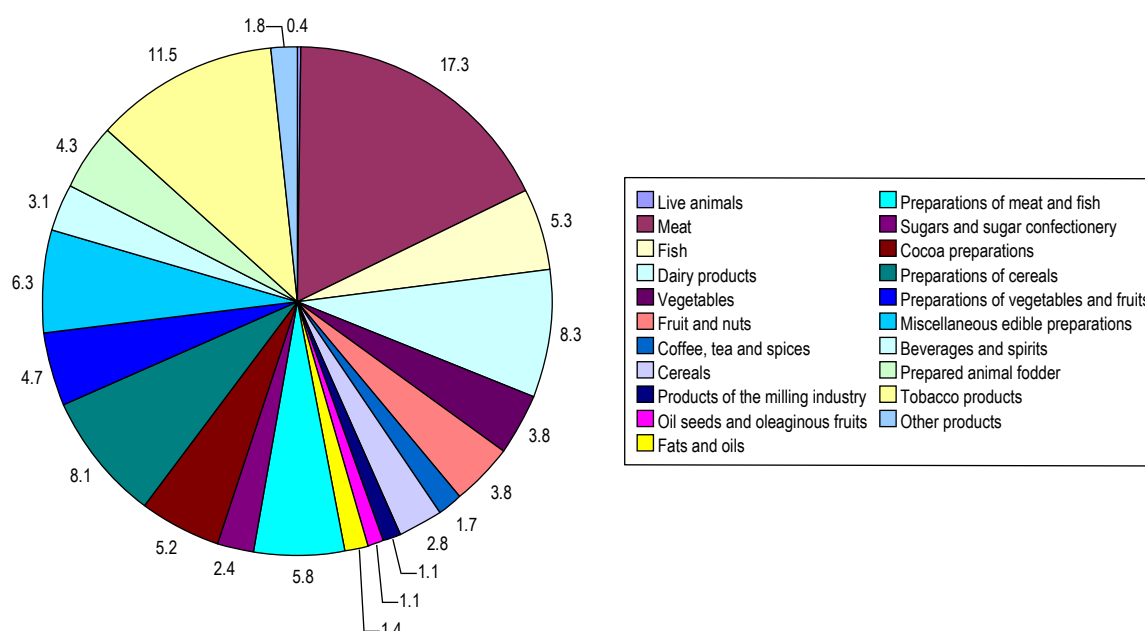


Figure 1. Commodity structure of the Polish agri-food exports (based on Kowalczyk, 2021).

420,000 people (full-time equivalents), which constitutes about 18% of the labour resources in industrial processing in the country. It should be emphasized that the value of sold production of the food industry in 2004-2018 more than doubled in current prices (to about 62 billion Euro), and in constant prices it increased by almost 80%. Its growth rate (in current prices, 6.2% per year on average) was higher than GDP, but slightly lower than industrial production (6.8%). The food industry is one of the few sectors of the economy with a positive balance of trade exchange, which has been successively increasing after Poland's accession to the European Union. Already over 40% of articles produced in the domestic food industry are directed for export (Szczepaniak *et al.*, 2020).

The production capacity far exceeds the needs of the Polish market. The Polish food industry is among the most modern in the EU. Therefore, it exports much to other EU countries as well as to third countries. In 2019 export amounted to app. 44% of the value of sold production of the Polish food industry with the level of production capacity utilization at 80% (Szczepaniak *et al.*, 2020). The concentration in the sector is relatively small. In 2018, among app 16.9 thousand companies 91.8% were micro and small companies. However, their share in sales amounted only to 16.8% (Szczepaniak *et al.*, 2020). Poland is an important producer of food in the EU. In 2018 its share in the value of sold production of the food industry in the EU-28 amounted to 9.1% and its share in the employment in food industry reached 9.4% (Wigier *et al.*, 2021).

Polish food system needs development of e-services in agri-food trade. Much needed is also development of programmes to raise awareness and educate agricultural producers on the principles and elements of a circular economy.

3.2 Research, development and innovation expenditure in food and bioeconomy sectors

Poland suffers from a low level of R&D expenditure in food and bioeconomy sectors. The situation further deteriorated in the COVID-19 pandemic and even in the highly-developed food industry the level of investment was in 2020 significantly lower than in 2019 (Szczepaniak *et al.*, 2020). Ensuring sustainable food production requires human and financial investment – innovation, skills and technological change.

The position of Poland in the region and in the EU is shown by the European Innovation Scoreboard (European Commission, 2020), according to which innovation performance is improving in all EU countries. On average, EU innovation performance has increased by 12.5 percentage points since 2014 (BIOEASStsUP, 2021). In terms of regional variation in innovation indicators, the phenomenon of convergence persists in the EU, with lower-performing countries growing faster than better-performing countries, thus narrowing the innovation gap. According to the Regional Innovation Scoreboard (European Commission, 2021), this trend also applies to innovation in individual EU regions. Based on the results obtained, EU countries are divided into four groups, depending on the value of the synthetic indicator: Innovation leaders, Strong innovators, Moderate innovators, Emerging innovators. Sweden remains the EU innovation leader, followed by Finland, Denmark and Belgium, all with innovation scores well above the EU average (Lopes *et al.*, 2021).

Poland was among the emerging innovators and strengths include digitalisation, intellectual assets and the use of information technology. Among the top three indicators are design applications, population with higher education and environmental technologies. In contrast, Poland has an above-average share of non-innovators without a propensity to innovate and scores below average on indicators related to climate change.

Data from the RIS (2021) show that five Member States have improved their score by 25 percentage points or more (Cyprus, Estonia, Greece, Italy and Lithuania). Four Member States recorded an improvement in performance of 15-25 percentage points (Belgium, Croatia, Finland and Sweden). In eight Member States the performance improved by 10-15 percentage points (Austria, Czech Republic, Germany, Latvia, Malta, the Netherlands, Poland and Spain). The remaining 10 Member States recorded an improvement of 10 percentage points or less.

On a regional basis, innovation performance has increased in 225 regions out of 240 EU regions since 2014. The most innovative region in Europe is Stockholm in Sweden, followed by Etelä-Suomi in Finland and Oberbayern in Germany. Hovedstaden in Denmark is fourth and Zurich in Switzerland is fifth. In Poland the most innovative regions are Warsaw Capital Region (Moderate Innovator) and Małopolska (Moderate Innovator). There has been a process of convergence of regional performance over time, with differences in performance between regions narrowing.

Globally, the EU still performs better than its competitors, such as China, Brazil, South Africa, Russia and India, while South Korea, Canada, Australia, the USA and Japan maintain their lead over the EU. Comparing the EU average with selected global competitors, South Korea is the most innovative country, scoring 36% higher than the EU in 2014 and 21% higher than the EU in 2021.

The European Innovation Scoreboard 2021 (European Commission, 2021) already includes elements that are important for both the development of food systems and the overall transition towards a bioeconomy. These include new indicators on digitalisation and environmental sustainability, bringing the scoreboard more in line with EU priorities outlined in the European Green Deal and Farm to Fork Strategy.

Research and development activity of Polish enterprises is considered low and cooperation between enterprises and science is underdeveloped. This is true for all sectors of the Polish economy in general, but especially for the food and beverage industry, where R&D expenditure in relation to value added is 0%.

Poland has the status of ‘moderate innovator’ in the European Innovation Scoreboard (European Commission, 2020) with innovation performance below the EU average and ranking 24th among the 27 EU countries in 2019. Poland has an innovation performance advantage over Romania, Bulgaria and Croatia and an innovation performance gap with the other seven CEE EU countries.

In 2018, Polish R&D intensity was 1.21% of GDP, which is less than half of the EU Europe 2020 target of 3% and almost half of the EU27 average (2.2%). There is a need to increase both public and private investment in R&D in order not to lag behind in the EU’s green transformation process.

In Poland, gross expenditure on research and development (GERD) as a share of GDP (commonly referred to as national R&D intensity) is increasing from 0.64% in 2000 to 1.21% in 2018. This share is significantly lower than the 3% target set by the Europe 2020 strategy for the EU28 as a whole and lower than Poland's planned target of 1.7%. R&D intensity in Poland is almost half lower than the EU27 average (2.2%) and is significantly lower compared to innovation leaders with developed innovation systems, such as Sweden (3.3%), Denmark (3.0%) or Finland (2.8%). In the group of Central and Eastern European countries, Poland is also below the average of other countries in terms of R&D intensity: Slovenia (1.9%), Czech Republic (1.5%), Hungary (1.5%) and Estonia (1.4%) (EUROSTAT, 2021).

Within the reported industries classified as fully or partially bioeconomy (Figure 3), Polish business R&D activity is low in all reported fully and partially biomass and biobased industries in terms of the ratio of R&D expenditures to value added (business sector R&D intensity) – ranging from 0% in the production of food and beverages to 0.50% in the production of paper and paper products excluding pharmaceuticals (14.9%) in 2017. Significantly lower business R&D expenditures per value added (less than 0.1%) were recorded in industries such as manufacture of wood and wood products (0.03%), textiles, clothing and leather (0.04%), manufacture and supply of electricity, gas and water (0.07%), manufacture of furniture (0.08%). The highest increase in R&D intensity is observed in the manufacture of paper and paper products (from 0.08% in 2010 to 0.50% in 2017). In some industries, such as the production of food and beverages, agriculture, forestry and fishing, the production of chemicals and pharmaceuticals, R&D intensity decreased.

The Polish R&D and innovation system has seen rapid development over the past two decades. In real terms, between 2000 and 2018, the total expenditure on R&D (GERD) increased significantly – from PPS 2,486.3 million to PPS 9,107.5 million (in constant 2005 prices). It should be pointed out that over the long term (2000–2018), R&D expenditure grew at an annual rate of 7.48%, compared to 2.8% in the EU27 (BIOEASTsUP, 2021).

In terms of the share of product and/or process innovation enterprises involved in the cooperation with scientific partners, the cooperation of business with science in Poland was the most active in the field of production, transmission and distribution of electricity (35.9%) and production of gas and distribution of gaseous fuels (20%). A slightly different situation occurs in the case of cooperation with governmental or public scientific entities. The highest cooperation is shown by enterprises dealing with gas production and distribution of gaseous fuels (20%), pharmacy (11%) and production, transmission and distribution of electricity (10.3%). The lowest cooperation of enterprises with universities is observed in the production of furniture (2.6%) and in the production of food, beverages and tobacco products (2.4%). The cooperation in the production of food products, beverages and tobacco products is also relatively low (1.8%).

The relative importance of factors preventing or hindering innovative activities of enterprises varies within Polish industries, which are wholly or partially included in the bioeconomy. According to the 2016 Community Innovation Survey (CIS) – the last one for which data is available – fully bioeconomy industries are most often hampered by lack of external funding, low market demand and lack of collaboration partners. These factors are also most important for the production of chemicals and electricity, gas, steam. The biggest constraint in the production of textiles, clothing, leather is the lack of good ideas. In the production of pharmaceuticals, in addition to the lack of external funding, the other most important constraint is uncertainty due to legislation/regulation (BIOEASTsUP, 2021; Szczepaniak *et al.*, 2020).

Transformation of the Polish food systems requires changes in every element of the food chain. This also applies to consumers and their dietary habits and preferences. The above analysis provided the background for a participatory approach involving researchers, practitioners, experts and representatives of public administration to work together to identify good and weak points as well as opportunities and threats for the development of a research and innovation system in Poland in the field of food systems, as part of creating a bio-economy.

3.3 Poland's bioeconomy and food systems related research and innovation

The analysis of Poland's bioeconomy-related research and innovation included the SWOT analysis as well as identification of actions necessary to overcome weaknesses (internal factors) and threats (external factors) and recommendations boosting for bioeconomy related RDI in Poland. The process of preparing the SWOT table was preceded by an analysis of the development characteristics of agricultural and food systems in Poland, going beyond a simple approach to food production, but as an element of a broader approach to supporting the development of bioeconomy sectors.

In the area of strengths, a growing number of actors in the economy were identified and pointed out, both on the part of businesses seeking new areas of activity, but above all a growing number of representatives of the civil society sector (NGOs) and consumer representatives, actively supporting food transformation from the point of view of changing food composition, production techniques and its assortment so as to respond to the growing need for dietary change among consumers (Table 1). The potential in terms of active actors in the food chain as well as pro-consumer organisations (including short and alternative supply chains) is complemented by a growing scientific capacity, its participation in EU research programmes, which results in a sustained contribution to the pan-European debate on the food systems of the future (De Vries, 2021). This has a very practical dimension, as the investment gap in this area – discussed in more detail earlier – creates new opportunities to fund new directions for research and innovation. This is reflected in the programmes implemented in Poland for the development of bioeconomy and food systems. One of them is BIOSTRATEG, the programme aimed in increasing of innovation and competitiveness of Polish economy, particularly in agricultural-food and forestry and related industries (Chylek, 2014). The program covered five strategic problem areas in line with the priority research directions currently carried out in the European Union and worldwide. These areas are:

- food security and food safety;
- rational management of natural resources with particular emphasis on water management;
- prevention and adaptation to climate change, with particular emphasis on agriculture;
- protection of biodiversity and sustainable development of agricultural production space;
- forestry and wood industry.

The scientific policy also supports the expansion of technology transfer units and serves to improve the situation at the level of primary production, including in particular the access of farm managers to specialised knowledge offered by agricultural advisory services.

Weaknesses include the still low investment in research and development, especially in modern areas of the food economy, which currently need increased investment in research and innovation. Differences in this respect reflect the gap that CEE countries in general have in comparison with western EU countries. The low level of internationalisation of research and the emphasis on the commercialisation of research results still characterise the Polish R&I sector, which is why there is both a decreasing number of scientists in general and a relatively large group emigrating to countries that offer better salary conditions and a more modern approach to the area of development and research on sustainable food systems.

The opportunities for the development of the research and development sector include above all a fundamental shift in EU policies towards the implementation of the European Green Deal paradigm. It should be emphasised here that for countries with a relatively traditional structure of agriculture (with a large share of small and medium-sized farms), the change of philosophy based on economies of scale to one in which natural resources (and land) are substituted with modern technologies, is a chance to change with the use of existing resources (mainly biomass) or with activities related to agriculture, e.g. aiming at the production of clean energy or ecological products.

In this respect, cooperation is important, not only between the scientific community at home and internationally (such as within the Horizon Europe programme), but also within the food chain. Producers are getting

Table 2. SWOT analysis of Poland's bioeconomy and food systems related research and innovation (R&I).¹

Strengths	Opportunities
<ul style="list-style-type: none"> • A large number of new active entities for implementation of innovations, supporting bioeconomy and science-practice cooperation. • Strategic documents, roadmaps, policies on bioeconomy. • Strategic programmes related to bioeconomy financed from public funds. • Highly qualified scientific personnel. • Knowledge of advisory services and scientists. • Highly qualified and experienced personnel in business. • Potential to develop R&D laboratory facilities. • Strong private and commercial technology transfer units. • High innovative potential of Polish ICT companies. 	<ul style="list-style-type: none"> • Increasing level of implementation of new solutions for biomass production and use in Poland. • Increasing global demand for innovations in new products of bioeconomy sectors. • Creating new measures of development in the light of the Green Deal paradigm. • Increasing business expenditure in science, technology and innovation. • New AKIS developed under the new CAP. • New EU policies, including the CAP and policy changes related to Green Deal and Farm-to-Fork Strategy. • Growing number of cooperation initiatives between science and policy makers – hub, technology centres, clusters. • International initiatives in which Poland participates (e. g. BIOEAST). • New education programmes (new university courses and training modules for adults). • Promoting and enhancing cooperation between entities involved in knowledge creation process, e.g. cooperation platforms, Horizon 2020, research networks. • Demand from practice for specialists and new skills in bioeconomy. • Participation in international cooperation and new exchange programmes in science and education at all levels. • New additional sources of EU funding for research development under Green Deal. • Global climate programmes and initiatives (such as FAO, Paris Agreement, etc.) • Cooperation with new actors in bioeconomy. • Increase the internationalisation of research.
Weaknesses	Threats
<ul style="list-style-type: none"> • Low level of R&D expenditure in bioeconomy sectors. • Low overall spending on R&D. • Decreasing human resources in R&D. • Insufficient cooperation of science with business environment institutions. • Lack of direct commercialisation support projects. • Low level of commercialisation of research results. • Relatively low internationalisation of research. 	<ul style="list-style-type: none"> • Lower (price) competition for production in bioeconomy-related sectors compared to conventional production. • Global economic slowdown. • Wrong measuring of country's development (using traditional categories, such as GDP). • Changing national policy priorities with regard to bioeconomy sectors. • Low level of public spending related to research. • Low recognition of universities and research institutions in the international arena. • Strong negative influence of agricultural lobby organisations on political decisions. • Lack of experienced and skilled central public administration representatives (policy makers). • Lack of setting the bioeconomy development as a main goal of strategic programming. • Persistent restrictions in national spending on scientific activities. • Unfavourable demographic trends. • Limited number of high-quality researchers meeting high standards of scientific work. • Failure to increase the level of internationalisation of research and participation in research consortia.

¹ CAP = EU common agricultural policy; AKIS = agriculture knowledge and innovation systems.

closer to consumers, and other actors in the chain are increasingly including sustainability and food in their marketing strategy in line with a healthy diet, but also biobased products and policies against food waste. In this case, the approach in Europe is not regionally differentiated, unlike in the academic research and development sector, companies act uniformly in terms of their response to environmental and climate challenges. This is linked to consumer awareness and demand oriented towards providing specific added value to solve global challenges.

The realization of the vision and assumptions of the transformation of food systems, as well as the whole economy, towards their sustainability faces a number of risks, identified in the research process (Table 2). One of the fundamental threats is to remain on the hitherto path of development, which we developed after World War 2, and which traditionally perceives the food economy only as functions of cheap food production, with limited concern for the environment, as a public good requiring valuation and inclusion in production costs. This may happen if consumer awareness and the quality of food demand do not result in a transformation of the supply side, i.e. of each element of the food chain. Apart from consumer awareness and willingness to pay for public goods and access to better quality food, the most important is the public policy framework, both at the EU and state level, promoting the paradigm of sustainable food systems, modern use of biomass with emphasis on reducing food waste, adulteration eggs and waste management. At the same time, it is important to pursue a skillful scientific policy promoting the internationalization of research, cooperation with business towards dissemination of implementations, as well as basic research on the limits of development, resources and intensification of work on the possibilities of solving global problems at the local level.

3.4 Recommendations boosting for bioeconomy related R&I in Poland based on SWOT and needs

The SWOT analysis allowed, in the next stage, to define the main areas in which intensive efforts should be made to actively support the development of research and innovation for food systems and economic development (Table 3).

Financing research and innovation is the main factor supporting positive transformation of food systems not only in Poland, but in all countries of the region. CEECs constitute a group of countries in which expenditure on science has always been significantly lower than in other EU countries. Furthermore, the promotion of research that goes beyond a sectoral approach to the perception of the economy may contribute to a more comprehensive approach to food production and use, as well as to the various possibilities of using non-food biomass in non-agricultural sectors of the economy. The definition of the bioeconomy points to going beyond a sectoral approach, which may contribute to facilitating the development of interdisciplinary research that looks at economic, social and environmental systems holistically.

According to the participants in the study greater attention is recommended for the preparation of a national strategic research and innovation agenda in the area of primary production, food chains, consumer education and research infrastructure could help to boost bioeconomy sectors. This includes both understanding of the bioeconomy at business, scientific, governmental and consumer levels, better use of the education system at all levels, as well as concrete actions to support new business models, innovation, digitalization of processes in sectors related to agriculture, forestry and fisheries.

Above all, a positive transformation requires an absolute increase in investment in research, strengthening human resources while promoting the best and the young. Equally important is AKIS' focus on supporting the development of agriculture as a provider of biomass, the guarantee of rural resilience and the equitable distribution of benefits from the modern value chain.

Table 3. The assessment of the factors of the development of food systems and bioeconomy-related research and innovation (R&I) in Poland.¹

Bioeconomy-related research and innovation needs (research sector and organisation)	Average (score 1-5)
Increased investment in R&D in bioeconomy sectors	4.5
Promoting interdisciplinary research and development cooperation	4.4
Increase understanding of the bioeconomy at business, scientific, governmental and consumer levels, better use of the education system at all levels	4.3
Optimise processing technologies, reducing food waste	4.3
Methodologies and technologies to reduce biomass and waste losses in production	4.3
Development of knowledge and technology for the creation of new, high quality local products	4.2
Methods of digitising production processes in agriculture and public services in rural areas	4.2
Coherent and planned research funding, based on long-term strategic planning	4.0
Develop programmes to raise awareness and educate agricultural producers on the principles and elements of a circular economy	4.0
Programmes to attract young people to science and advisory services	4.0
Promotion of commercialisation of research results	4.0
Ensure sustainable food production through human and financial investment – innovation, skills and technological change	4.0
Putting into practice state-of-the-art preservation technologies (with special attention to environmentally friendly packaging, storage conditions, etc.) to extend the shelf life of raw materials and the durability of final products.	4.0
Methods for developing and mapping sustainable short food chains, initiatives and new green business models in food processing, wholesale, retail and food service	4.0
Better use of the opportunities offered by the European Research Area by universities, institutes and companies	3.8
Develop incentive schemes for advice and science to increase commitment to general knowledge transfer and voluntary data sharing	3.8
Promote the development of bio-clusters, development of cross-sector collaboration initiatives and multi-level science and practice	3.7
Effective transfer and adoption of digital technologies in agriculture and rural public service infrastructure	3.7
Development of principles for effective implementation of crop diversification technologies	3.7
Development of e-services in agri-food trade	3.5
Research to reduce digital exclusion among farmers and the rural population	3.5
Integrated bioinformatic system for the management of genetic resources of livestock breeds and crop varieties	3.5
Development of data bases for decision support systems for climate change adaptation in rural areas	3.4
Increasing funding and improving the status of public research institutes	3.4
Identify and identify opportunities for dissemination of ICT solutions for actors in bioeconomy sectors	3.3
Focus on business models and governance using digital tools, artificial intelligence and robotics along the bio-product value chain	3.2

¹ Own compilation based on responses (n=58).

4. Conclusions

Food sector and bioeconomy are an important part of the Polish economy. Therefore, their future prospects to a large extent determine the long-term economic situation of Poland. Strengthening public and private R&D is necessary for a successful transition of the food systems and bioeconomy in Poland and other CEECs. Further promotion of co-operation between business and science as well as international co-operation is also vital for bioeconomy's development.

We argue that greater attention is recommended for the preparation of a national strategy in the area of agriculture and other bioeconomy sectors with the aim to strengthen the development of RDI sector. This includes both understanding of the bioeconomy at business, scientific, governmental and consumer levels, better use of the education system at all levels, as well as concrete actions to support new business models, innovation, digitalization of processes in sectors related to agriculture, forestry and fisheries. A systemic approach to the formation of bioeconomy sectors, with a particular focus on food systems development, will require investment in the creation of correct institutions based on human capital and knowledge transfer. The development of innovation and knowledge systems (and AKIS in particular) is an opportunity for primary producers, who gain not only as providers of biomass to different sectors of the economy, thus creating a sustainable basis for the local economy, but also allows for an equitable distribution of benefits from the modern value chain.

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