ISSN 2300-5599

ACTA INNOVATIONS

CENTRUM
BADAŃ I INNOWACJI
PRO - AKADEMIA
RESEARCH AND INNOVATION CENTRE

no. 33

October 2019

Acta Innovations

quarterly

no. 33

Konstantynów Łódzki, Poland, October 2019

ISSN 2300-5599

Original version: online journal

Online open access: www.proakademia.eu/en/acta-innovations

Articles published in this journal are peer-reviewed

Publisher:

Research and Innovation Centre Pro-Akademia
9/11 Innowacyjna Street
95-050 Konstantynów Łódzki
Poland

Editor in Chief:
Ewa Kochańska, Ph.D.

The tasks “Creation of the English versions of the *Acta Innovations* articles”, “Selection & contracting of the renowned foreign reviewers for the assessment of received manuscripts”, “*Acta Innovations* digitalization in order to provide an open access by the Internet” and “Maintenance of the anti-plagiarism system” are financed by an agreement 605/P-DUN/2018 from the resources of Polish Ministry of Science and Higher Education dedicated to the activity popularising the science.

Zadania „Stworzenie anglojęzycznych wersji artykułów w Acta Innovations”, „Dobór i kontraktacja uznanych zagranicznych recenzentów do oceny zgłaszanych manuskryptów”, „Digitalizacja Acta Innovations w celu zapewnienia otwartego dostępu poprzez sieć Internet” i „Utrzymanie systemu antyplagiatowego” finansowane w ramach umowy 605/P-DUN/2018 ze środków Ministra Nauki i Szkolnictwa Wyższego przeznaczonych na działalność upowszechniającą naukę.

Ministerstwo Nauki
i Szkolnictwa Wyższego

ACTA INNOVATIONS

no. 33

October 2019

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THE ASSESSMENT OF UKRAINE'S READINESS FOR INNOVATIONS IN THE CONDITIONS OF THE SPREAD OF TECHNOLOGIES OF THE NEW INDUSTRIAL REVOLUTION

Abstract
The article is devoted to the topic of Ukraine's readiness for innovations in industry 4.0. The article also discusses the concept of the 4th industrial revolution. The proposed methodology for assessing readiness for innovations is based on the annual ranking of The Global Innovation Index of Cornell University, the French Business School and Research Institute (INSEAD), the World Intellectual Property Organization (WIPO) and official EU statistics. An analysis was carried out of Ukraine's readiness for innovation in comparison with EU countries in the area of "The Conditions for Creating Innovative Potential, Level of Innovation Potential, Conditions for Realization of Innovative Potential, Realization of Innovative Potential". A cluster analysis of countries regarding the level of preparedness for innovation based on the indicators was also made. The strengths and weaknesses of Ukraine as an innovative country are highlighted, practical recommendations are also given for improving the level of innovative development in the country.

Keywords
Industry 4.0, Industrial revolution, Innovations, innovative potential, readiness for innovations.

Introduction

Today, in the context of the new industrial revolution, the scientific and innovative development of any country determines its competitiveness in the upcoming decades. According to the founders of the World Economic Forum, the fourth industrial revolution is spreading at an explosive pace. At the same time, humanity has never encountered such large-scale and complicated changes, while the changes themselves will affect all groups and layers of population, all professions, manufacturers and services [1-3].

The Fourth Industrial Revolution (Industry 4.0) is the transition to fully automated digital production, controlled by intelligent systems in real time, in constant interaction with the external environment, going beyond the boundaries of one enterprise, with the prospect of joining the global industrial Network of Things and Services [2-3].

In a more narrow sense, Industry 4.0 is the name of one of the 10 projects of the state Hi-Tech strategy of Germany until 2020, which describes the concept of smart manufacturing based on the global industrial network of the Internet of Things and Services.

In a broader sense, Industry 4.0 characterizes the current trend of the development of automation and data exchange, which includes cyber-physical systems, the Internet of Things and cloud computing. It represents a new level of organization of production and value chain management throughout the entire life cycle of products manufactured [2-5,9].

The renowned Swiss economist, Dr. Klaus Schwab, founder and leader of the World Economic Forum, stated: "This fourth revolution comes on us like a tsunami. The speed is not to be compared with last revolutions and the speed of this revolution is so fast that it makes it difficult or even impossible for the political community to follow up with the necessary regulatory and legislative frameworks.". He also said: "My fear is, if we are not prepared... and we have a concentration of jobs in the high level, more innovative areas and in the low service areas, this could lead to a new problem of social exclusion, which we absolutely have to avoid"[5].

The Fourth Industrial Revolution sets forth new frontiers for economic prosperity, future jobs and policies that will lay the foundation for future competition between companies. In the globally saturated market and spread of the consequences of the fourth industrial revolution, there has been a rethinking of the behavior of leaders and personnel of enterprises from the standpoint of maintaining their competitiveness. This was evidenced by the annual EFQM Forum, held in Milan in August 2016. The main keynote points from the speeches of the leaders of the most successful European organizations were as follows [2,3]:

- the need for operational excellence, quality process execution; stable production of quality products is no longer enough for sustainable success;
- ISO 9001, kaizen, lean manufacturing, etc. have become well-known; their presence is no longer a sufficient condition for success in a globally saturated market;
- it is no longer sufficient to only fulfill the requirements of interested parties.

In reply to the question "What should I do?" The following answers were put forth at the forum:

- strive not only to meet the requirements of consumers, but also to cause them to be delighted;
- to not only attract staff for improvement, but also be a source of happiness and pride for them;
- to not only engage in corporate social responsibility, but also actively build a future in which the organization is able to develop steadily;
- to not only build flexible management systems, but also recognize the inevitability of unforeseen changes and build systems that are resistant to them.

As for Ukraine and its enterprises, in the context of the approaching industry 4.0, the following key points can be distinguished regarding the current state of the Ukrainian economy and how competitive it is in comparison with other more developed countries, in particular with the EU countries. On November 9, 2016, participants of the Scientific and Practical Conference discussed the topic: "Ukraine is paving the way to the EU: how to achieve competitiveness of enterprises and the economy". After hearing and discussing the reports, the attendees noted the following [6-8]:

- the state of the economy of Ukraine is extremely unsatisfactory and continues to deteriorate;
- the situation is aggravated by the fact that with the modern development of world science and technology, the competition for goods (services) in Ukraine is losing momentum, while the competition between models and control systems is becoming increasingly fierce;
- Ukrainian business circles do not adequately meet the requirements of a saturated global market. Their business culture, in particular business excellence, was formed during the years Ukraine has undergone total financial collapse and significantly lags behind the economies inherent in other developed nations;
- the quality of public administration in the country is low and does not contribute to the development of a competitive economy or significant improvement in the lives of the citizens of Ukraine.

Thus, in order to understand how the Ukrainian economy will survive and assume its role in the era of Industry 4.0, an assessment of Ukraine's readiness for innovations in the conditions of the spread of technologies of the new industrial revolution was made. This study should help to identify the strengths and weaknesses of Ukraine as an innovator country in order to eliminate existing shortcomings and develop a strategy for the development and creation of innovations in the country and find the most favorable ways to apply them. The assessment was carried out in comparison with the EU countries.

Methods of research

To assess the level of readiness of EU countries and Ukraine for innovation, the following methodology was proposed: determining which indicators the different countries' readiness for innovation were to be evaluated; distribution of selected indicators into four groups, namely [6]: The Conditions for Creating Innovative Potential (CFCIP), Level of Innovation Potential (LIP), Conditions for Realization of Innovative Potential (CFRIP), Realization of Innovative Potential (RIP); the assessment of countries' readiness for innovation by these indicators; classification of countries according to the level of their readiness for innovation, based on the indicators. A diagram of the methodology can be seen in Fig. 1 below.

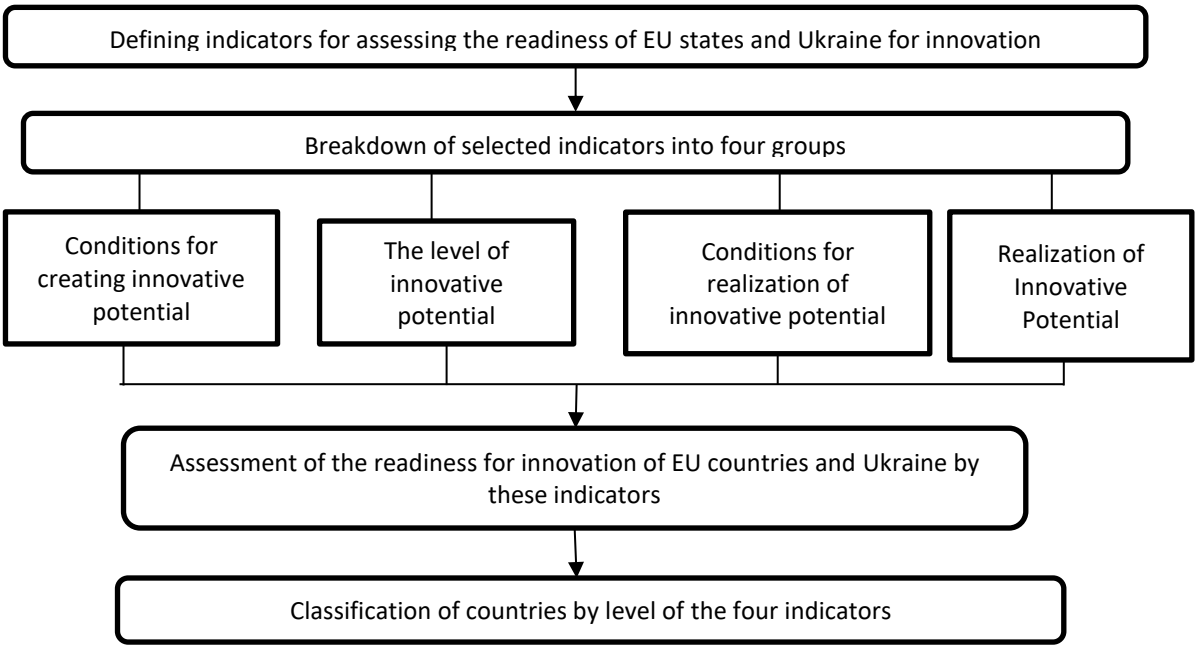

Figure 1. Methodology for assessing countries' readiness for innovation
Source: Author's

The study was based on the annual ranking of The Global Innovation Index of Cornell University, the French Business School and Research Institute (INSEAD), the World Intellectual Property Organization (WIPO) and official EU statistics. In total, 25 indicators were used. The raw data used for the study can be seen in tables 1, 2, 3 and 4.

Indicators for assessing the conditions for creating innovative potential were divided into two sub-groups, namely: conditions for creating educational potential and conditions for creating institutional potential. The following indicators were used to assess the conditions for creating educational potential: expenditure on education, school life expectancy and ICT access. Indicators of ease of obtaining credit, ease of protecting minority investors and state of cluster development were used to assess the conditions for creating institutional potential [6,10-11].

The indicator of the level of innovation potential was accordingly divided into the level of educational potential and the level of institutional potential. Assessment of educational potential was based on the following indicators: population aged 20-24 with upper secondary education, population aged 30–34 with tertiary educational attainment of graduates in science and engineering, new doctoral graduates aged 25-34. The following indicators were used to assess the level of institutional potential: number of researchers, QS university ranking, quality of scientific research institutions and innovation capacity [10-11].

Assessment of Conditions for Realization of Innovative Potential was based on such indicators as: gross expenditure on research and development, ICT use and employment in knowledge-intensive activities.
Finally, the assessment of the realization of the innovative potential also took place in two stages: the first was the assessment of the realization of R&D potential on the basis of indicators of number of trademark applications and the number of international patent applications filed by residents; the second was to assess the commercial realization of the potential on the basis of indicators such as: knowledge-intensive services export, high-tech and medium high-tech output, high-tech exports, ICTS and business model creation, SME with product or process innovations and creative goods exports [10-11].

Table 1. Indicators for assessing the level of Conditions for creating innovative potential

Country	The conditions for creating innovative potential					
	Conditions for creating educational potential			Conditions for creating institutional potential		
	expenditure on education, % of GDP	school life expectancy, years	ICT access	ease of obtaining credit	ease of protecting minority investors	state of cluster development
1	2	3	4	5	6	7
Austria	5.5	16.3	8.5	55	68.3	5
Belgium	6.6	19.7	8.1	65	61.7	4.9
Bulgaria	4.1	14.8	7	65	68.3	3.8
Hungary	4.6	15.1	7.8	75	50	3.8
United Kingdom	5.5	19	9.3	75	75	5.2
Greece	4	17.9	8	50	66.3	2.9
Denmark	7.6	19.1	8.3	70	66.7	4.8
Estonia	5.2	16.1	8.2	70	56.7	3.7
Ireland	3.8	18.8	8.1	70	75	4.6
Spain	4.3	17.9	8	60	70	4.3
Italy	4.1	16.2	7.4	45	58.3	5.5
Cyprus	6.4	14.6	8	60	66.7	3.8
Latvia	5.3	16.2	7.4	85	66.3	3.8
Lithuania	4.2	16.5	7.4	70	66.7	3.5
Luxembourg	3.9	14.2	9.4	15	48.3	5
Malta	5.3	16.9	9.1	35	61.7	4.2
The Netherlands	5.4	18	8.8	45	58.3	5.4
Germany	4.8	17.1	9	70	58.3	5.5
Poland	4.8	16.4	7.4	75	66.7	3.8
Portugal	4.9	16.3	8	45	60	4.3
Romania	3.1	14.3	7.1	80	60	3.1
Slovakia	4.6	14.5	7.4	70	53.3	3.8
Slovenia	4.9	17.4	8.1	45	70	3.8
Finland	7.1	19.3	7.4	65	58.3	4.9
France	5.5	15.5	8.3	50	66.7	4.8
Czech Republic	5.8	16.8	7.2	70	58.3	4
Croatia	4.6	15	7.6	55	66.7	2.8
Sweden	7.6	18.8	8.3	55	68.3	5.1
Ukraine	5	15	6.7	75	58.3	3.3

Source: [10-11]

Table 2. Indicators for assessing the level of of innovation potential

Country	The level of innovation potential							
	The level of educational potential				The level of institutional potential			
	Population aged 20-24 with upper secondary education, %	Population aged 30–34 with tertiary educational attainment, %	Graduates in science and engineering, % of total graduates	New doctoral graduates aged 25-34	Researchers, per million population	QS university ranking average score of top 3 universities	Quality of scientific research institutions	Innovation capacity
1	2	3	4	5	6	7	8	9
Austria	88	40.7	30.3	1.4	5.4	42	5.5	5.5
Belgium	84.8	47.6	17.1	1.5	4.9	54.2	5.7	5.4
Bulgaria	86	33.7	19.7	0.6	2.1	4.7	3.9	4.2
Hungary	85	33.7	22.8	0.6	2.9	20.5	4.7	3.8
United Kingdom	85.9	48.8	26.3	2	4.3	95.2	5.4	5.5
Greece	93.9	44.3	28.2	0.6	3.1	21.9	4	3.9
Denmark	74.5	49.1	21	2.2	7.9	57.1	5.7	5.3
Estonia	82.6	47.2	27.6	0.8	3.5	21.6	5.4	4.9
Ireland	94.4	56.3	25.2	1.4	4.3	47	5.4	5.2
Spain	72.7	42.4	23.9	1.2	2.9	47	4.7	4.3
Italy	81.1	27.8	23.3	1.1	2.3	47.6	4.9	4.9
Cyprus	91.5	57.1	15.9	0.4	1.2	0	4.3	3.7
Latvia	88.3	42.7	20.5	0.2	1.8	13.1	4.3	4.2
Lithuania	92.1	57.6	23.8	0.7	3	19.8	4.4	4.8
Luxembourg	76.8	56.2	17.9	1.3	4.6	0	5.2	5.6
Malta	77.4	34.7	18	0.4	2	0	4.2	4.7
The Netherlands	82.5	49.4	14.1	1.9	5	68.1	6.2	5.8
Germany	77.4	34.9	36	2.1	5	69.1	5.7	5.9
Poland	91.2	45.7	22.9	0.4	3	25.4	4.3	4.1
Portugal	80.8	33.5	29	0.8	4.3	30.3	5.3	4.7
Romania	81.7	24.6	28.8	1.1	0.9	0	4.1	3.8
Slovakia	89.4	37.7	21.1	1.5	2.8	13.8	3.8	4.5
Slovenia	91.5	42.7	25	1.2	4.4	10.5	5	4.9
Finland	87.4	44.2	29.5	1.1	6.7	48	5.8	5.6
France	88.1	46.2	25.6	1.4	4.4	69.3	5.8	5.7
Czech Republic	89.5	33.7	23.5	1.2	3.7	25.4	5.1	5
Croatia	96.2	34.1	25.3	0.6	1.8	4.7	3.8	3.4
Sweden	84.5	52	26.6	1.5	7.2	59.1	5.7	5.9
Ukraine	97	63	24.2	2.1	1.1	22	3.9	4.3

Source: [10-11]

Table 3. Indicators for assessing the level of Conditions for realization of innovative potential

Country	Conditions for realization of innovative potential		
	gross expenditure on research and development, % of GDP	ICT use	employment in knowledge-intensive activities %
1	2	3	4
Austria	3.2	7.5	40.6
Belgium	2.6	7.6	47.6
Bulgaria	0.8	6.6	31.4
Hungary	1.4	6.4	34.3
United Kingdom	1.7	8.3	48.6
Greece	1.1	6.3	29.8
Denmark	3.1	9	46.3
Estonia	1.3	8	45.5
Ireland	1	7.8	42.5
Spain	1.2	7.7	33.2
Italy	1.4	6.5	36.1
Cyprus	0.6	8	35.3
Latvia	0.5	7.5	42.1
Lithuania	0.9	6.8	41.8
Luxembourg	1.3	8.2	55.9
Malta	0.5	7.8	42.5
The Netherlands	2	8.5	44.7
Germany	3	7.7	46.8
Poland	1	7	38.6
Portugal	1.3	6.7	36.1
Romania	0.5	6.2	23.4
Slovakia	0.9	6.9	32
Slovenia	1.9	6.6	43.1
Finland	2.8	8	47.4
France	2.2	8	45.1
Czech Republic	1.8	7	38
Croatia	0.9	6.3	36.3
Sweden	3.4	8.7	52.3
Ukraine	0.4	4	36.9

Source: [10-11]

Table 4. Indicators for assessing the realization of the innovative potential

Country	The realization of the innovative potential							
	The realization of the R&D potential		The commercial realization of the potential					
	Number of trademark applications, per billion PPP$ GDP	Number of international patent applications filed by residents at the Patent Cooperation Treaty, per billion PPP$ GDP	Knowledge -intensive services export	High-tech and medium high-tech output, % of total output	High-tech exports, % of total export	ICTs and business model creation	SME with product or process innovations	Ccreative goods exports, % of total export
1	5	6	7	8	9	10	11	12
Austria	53.3	3.2	43.7	0.4	7.5	5.4	45	0.9
Belgium	45.8	2.4	68.7	0.4	8.1	5.5	47.3	1.6
Bulgaria	98.6	0.4	37.6	0	3.8	4.5	16.3	0.8
Hungary	40.5	0.5	47.7	0.6	12.5	4.9	18	6.1
United Kingdom	56.2	1.9	82.1	0.4	9	5.8	38	2.9
Greece	0	0.4	52.9	0.1	2	4.2	44.4	1.1
Denmark	44.7	4.8	74.9	0.4	5.2	5.5	33.3	1.6
Estonia	81.3	1.1	50	0.2	8.6	5.5	41.4	1.4
Ireland	0	1.6	94	0.7	9.9	5.6	37.8	1.3
Spain	52.8	0.8	33.8	0.4	3.9	5.5	18.6	0.9
Italy	47.3	1.4	51	0.4	5.3	5	40.7	2.2
Cyprus	97	1.2	68.7	0.2	0.4	4.5	28.6	0.5
Latvia	72.3	0.5	51.5	0.1	7.4	5	18.7	3.1
Lithuania	53.7	0.4	23	0.2	5.9	5.2	37.9	2
Luxembourg	102.9	5.9	92.3	0.1	0.6	5.8	40.4	0.1
Malta	119.8	2.2	53.8	0.1	3.8	5.6	22.5	0.2
The Netherlands	53.9	4.3	78	0.3	11.2	6	48.5	4.1
Germany	65.2	4.5	75.5	0.6	11.5	5.7	41	2.2
Poland	38.2	0.3	40.8	0.3	6.5	4.6	14.8	4.4
Portugal	98.4	0.8	38.5	0.3	2.7	5.7	56	1.5
Romania	43.1	0.1	45.5	0.4	4.2	4.6	4.6	0.7
Slovakia	55.7	0.3	38.3	0.6	9.2	5	19.5	8.5
Slovenia	111.2	1.5	36.5	0.3	4.5	5.1	25.9	1
Finland	44.7	7.1	71.7	0.3	4.4	6.1	54.2	0.5
France	97.9	2.7	62	0.5	12.8	5.6	38	1.7
Czech Republic	61.9	0.5	42.7	0.6	17.1	4.9	33	10.1
Croatia	46.8	0.4	19	0.2	3.1	4.5	30.8	0.8
Sweden	55.6	7.7	71.5	0.5	7.3	5.9	38.4	1.8
Ukraine	128.6	0.4	46.9	0.2	2	3.9	7.4	0.2

Source: [10-11]

To calculate the integral indicators of The Conditions For Creating Innovative Potential and Level of Innovation Potential and Conditions for Realization of Innovative Potential and Realization of Innovative Potential, an additive method of convolution of normalized partial indicators based on the simple mean used for characterization of a hierarchical series of components was applied [6].

Standardization of partial indicators was carried out by the formula:. $z_{ij} = \frac{x_{ij}}{x_{\max j}}$,

where z_{ij} – the normalized j-th partial indicator of the i-th country;

x_{ij} – the value of the j-th partial indicator of the i-th country;

$x_{\max j}$ – the maximum value of the j-th partial indicator.

Results of research

The results of calculating the Indicator of The Conditions For Creating Innovative Potential (CFCIP) in 2018 using the above methodology can be seen in Fig. 2 below:

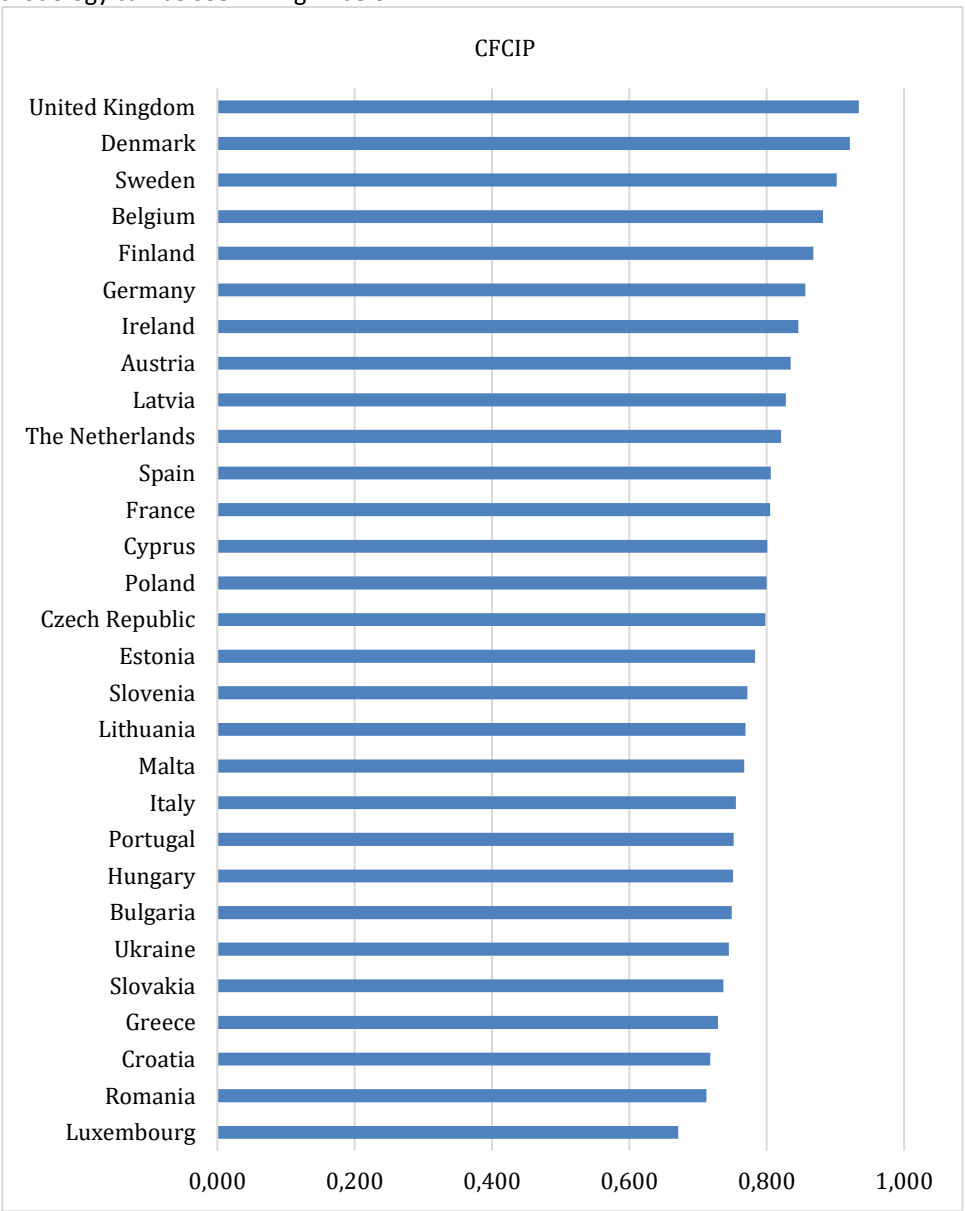

Figure 2. The value of the indicator of conditions for creating innovation potential of EU countries and Ukraine in 2018. Source: Author's

The figure shows that the leaders in the Indicator of The Conditions For Creating Innovative Potential are the UK, Denmark, Sweden, Belgium and Finland. The lower rankings are held by countries such as Slovakia, Greece, Croatia, Romania and Luxembourg.

Ukraine is in 24th place, ahead of the aforementioned countries, but behind all others, including Bulgaria and Hungary. In more detail, it can be said that the result of Ukraine is due to the fact that in the country there is a low level of access to ICT and the development of clusters is also low. There are also problems with ease of protecting minority investors indicator and the school life expectancy is much lower compared to EU countries. The expenditure on education and the ease of getting credits are at average level.

The next step was to consider the results of calculating the Level of Innovation Potential (LIP) in 2018, which can be seen in Fig. 3 below:

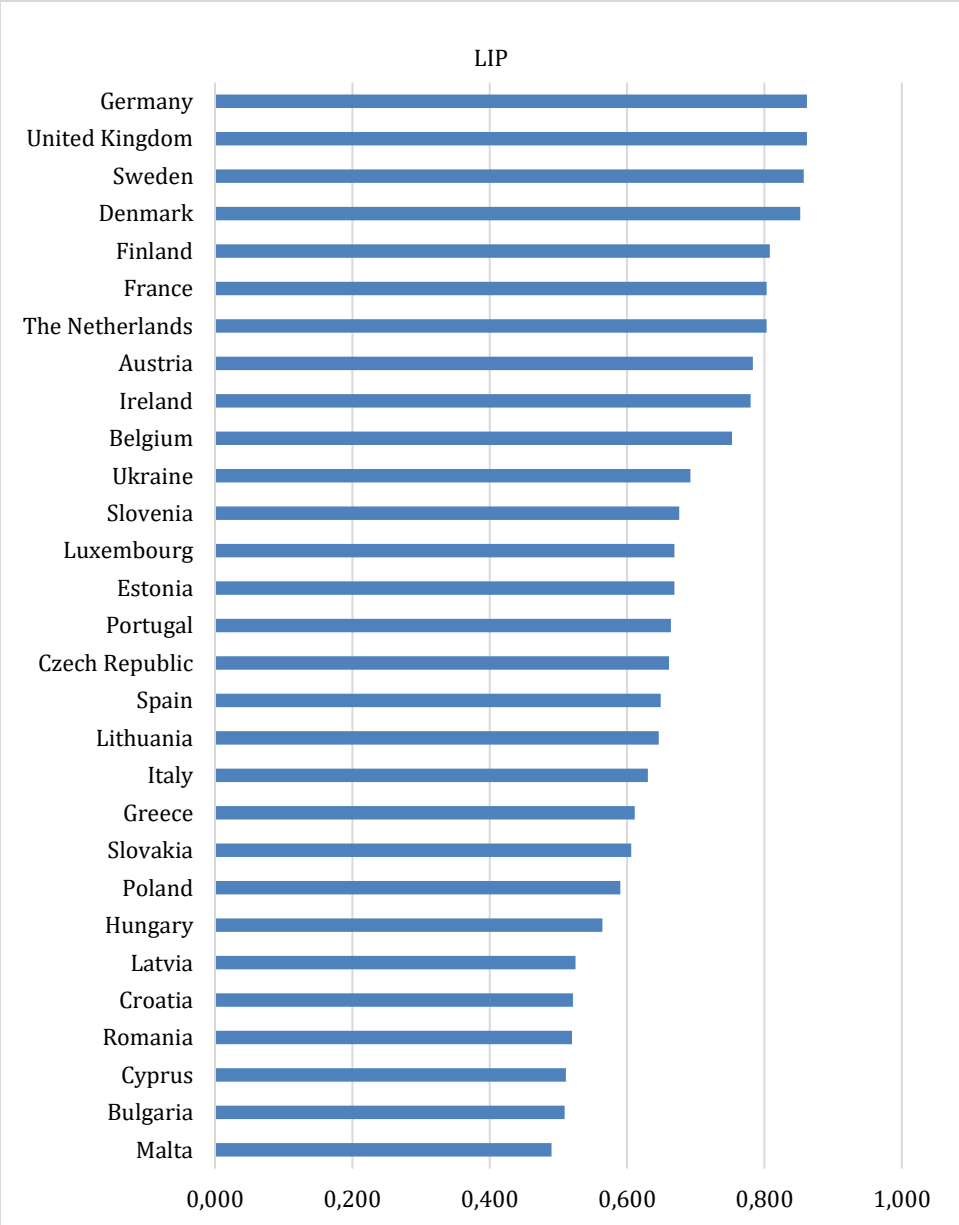

Figure 3. The value of the indicator of level of innovation potential of EU countries and Ukraine in 2018. Source: Author's

As can be seen from the figure, the leaders in the calculation of the indicator of the level of innovation potential are Germany, Great Britain, Sweden, Denmark and Finland. The countries with the lowest rates are Croatia, Romania, Cyprus, Bulgaria and Malta.

Ukraine ranks 11th in this indicator and is ahead of such countries as Slovenia and Luxembourg but has results lower than Belgium and Ireland. This result is due to the fact that Ukraine is the leader on the indicator of population aged 20-24 with upper secondary education and with tertiary educational attainment. This means that there is a rather high level of educational potential in Ukraine. However, the level of institutional potential remains low. The number of researchers in Ukraine is one of the lesser among EU countries, as is the quality of scientific research institutions.

We then we proceeded to the analysis of the results of the calculation of the indicator of the conditions for realization of innovative potential (CFRIP) of the country. The results of the calculation are shown in Fig. 4.

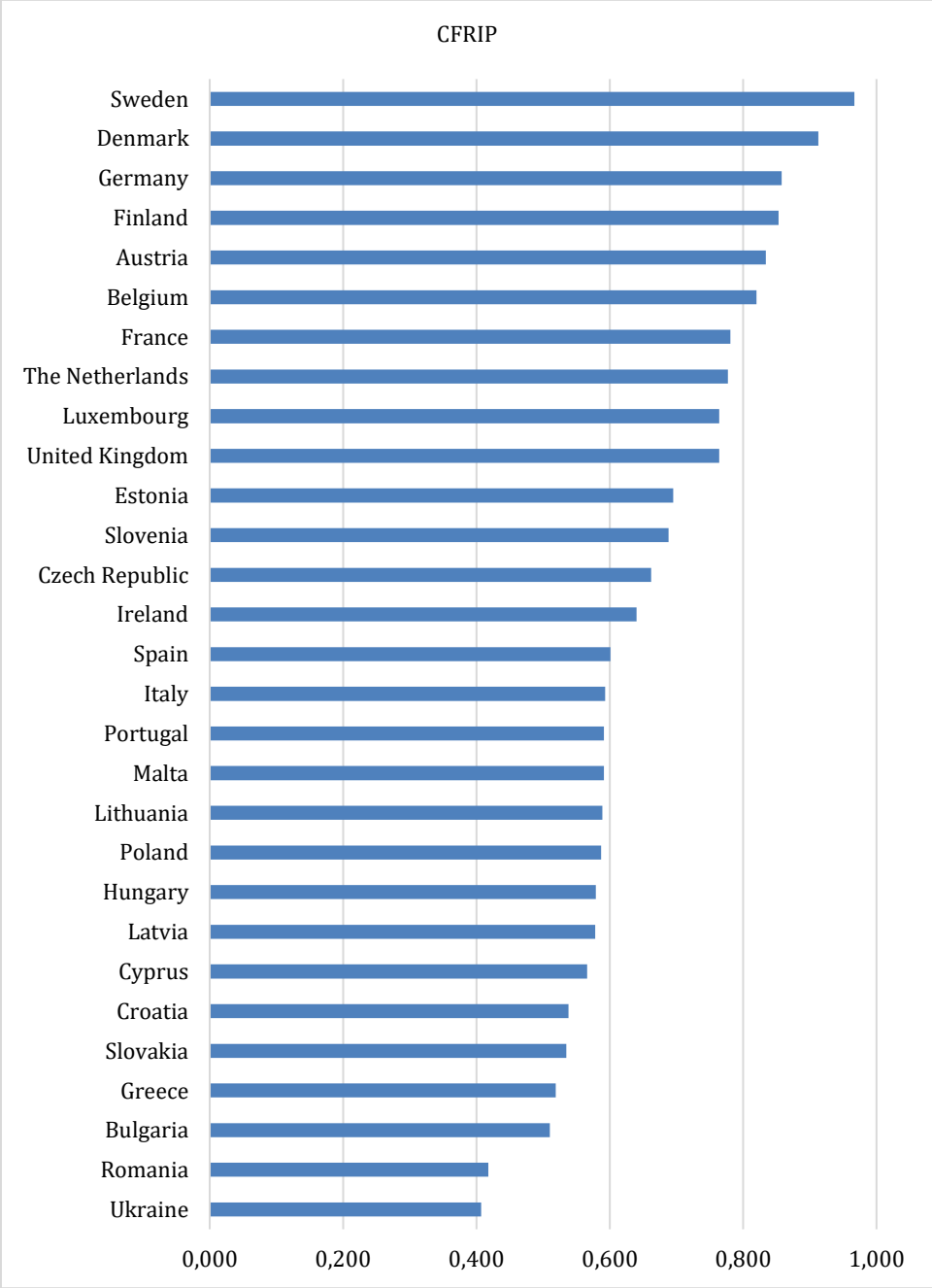

Figure 4. The value of the indicator of the conditions for realization of innovative potential of EU countries and Ukraine in 2018.
Source: Author's

As can be seen from the image, Sweden, Denmark, Germany, Finland and Austria are the leaders on the indicator of the conditions of realization of innovative potential (CRIP). The countries with the lowest URIP are Ukraine,

Romania, Bulgaria, Greece and Slovakia. Ukraine ranks last in CRIP among all countries. This can be explained by the fact that Ukraine has the lowest expenditure on R&D and poorest ICT use.

The next step is to consider the results of calculations of the indicator of realization of innovative potential (RIP). The results can be seen in fig. 5.

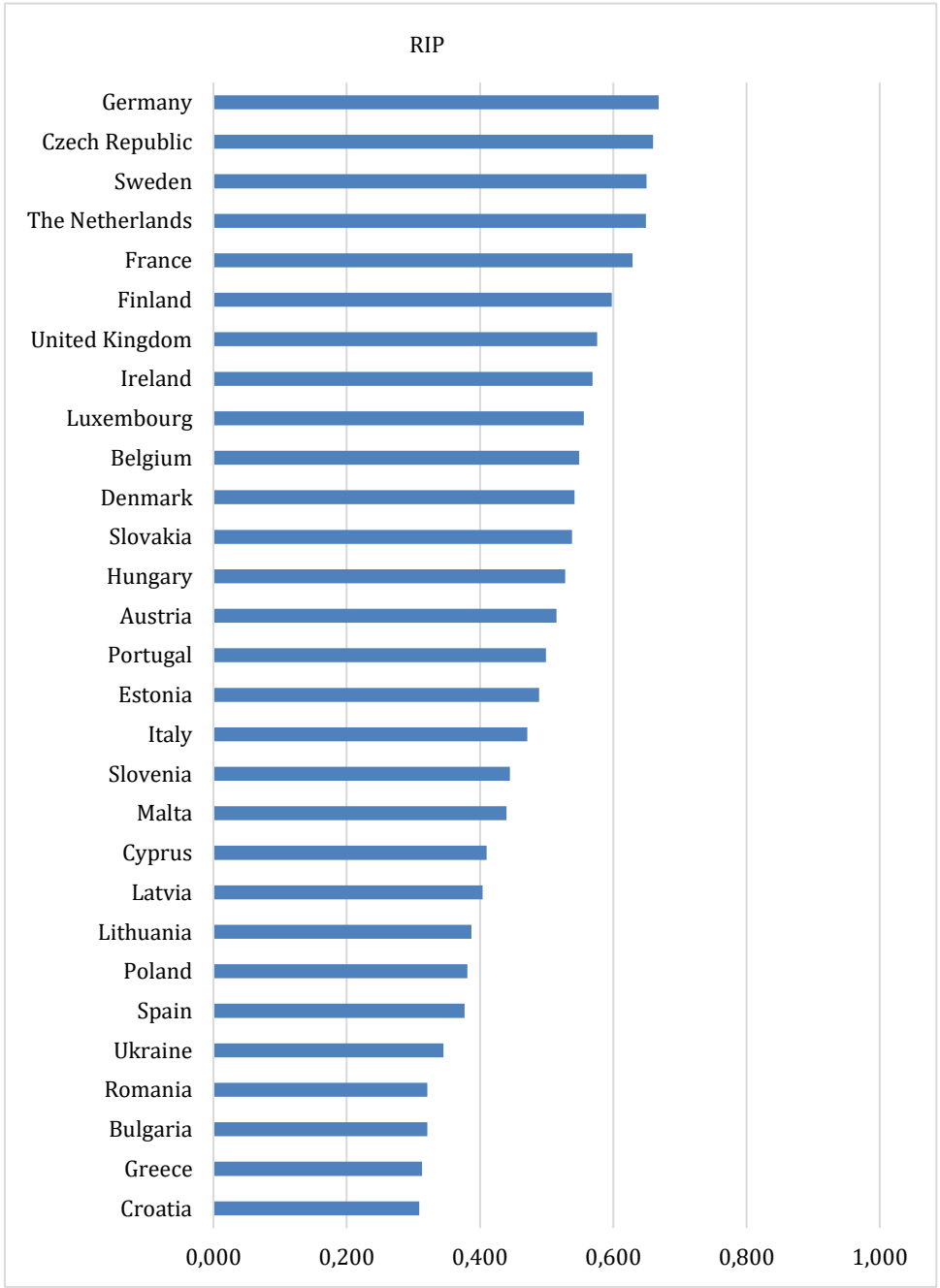

Figure 5. The value of the indicator of the realization of innovative potential of EU countries and Ukraine in 2018. Source: Author's

The figure shows that Germany has been most successful in realization of its innovation potential, followed by such countries as the Czech Republic, Sweden, the Netherlands and France. These countries have one of the highest scores of all indicators used to assess the Realization of Innovation Potential.

The last positions are occupied by the following countries: Croatia, Greece, Bulgaria, Romania. Ukraine is 5th place from the end, behind Spain and Poland. Ukraine has low results on indicators of high-tech exports, ICTS and business model creation, SME with product or process innovations and creative goods exports.

After analyzing the results of calculations of all four indicators of The Conditions for Creating Innovative Potential (CFCIP), Level of Innovation Potential (LIP), Conditions for Realization of Innovative Potential (CFRIP), Realization of Innovative Potential (RIP) it was possible to distinguish obvious leaders on the level of development of innovative potential and willingness to innovate. These countries are Sweden, Denmark, Finland, the United Kingdom and Germany. Countries with clearly low levels of innovation potential and willingness to innovate in comparison with all other EU countries are Romania, Croatia and Bulgaria.

However, in order to determine exactly how the countries were positioned relative to each other and where Ukraine's place among other EU countries is according to the studied indicators, additional analysis was needed. This was done by comparing the analyzed indicators with the help of the cluster analysis method (k-means method).

The graph below shows the final cluster centers to see which calculation results of each indicator are most typical for each cluster.

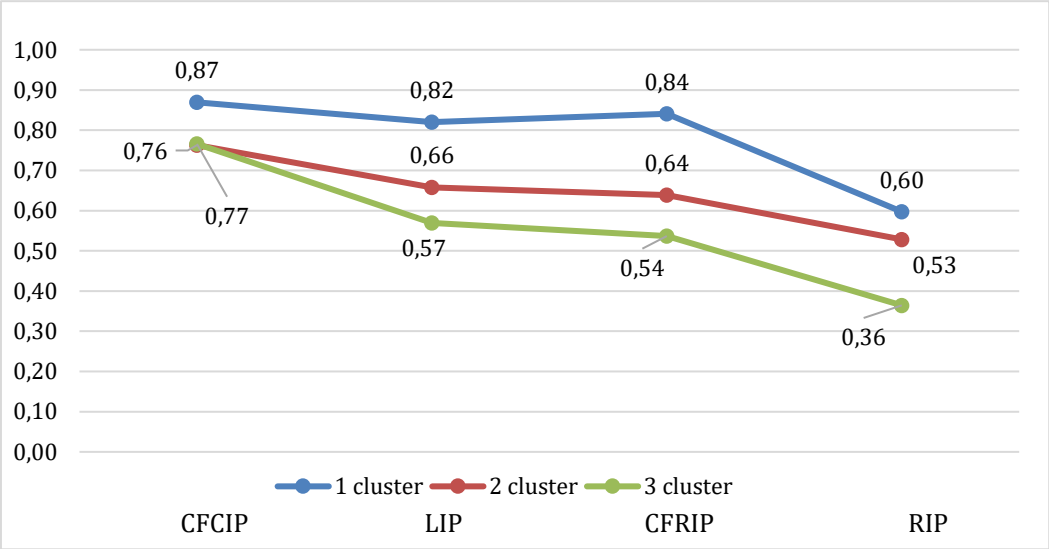

Figure 6. Final Cluster Centers
Source: Author's

From this figure it can be seen that the first cluster includes countries with high indicators of The Conditions for Creating Innovative Potential, Level of Innovation Potential, Conditions for Realization of Innovative Potential and Realization of Innovative Potential; the second cluster includes countries with average indicators of The Conditions for Creating Innovative Potential, Level of Innovation Potential, Conditions for Realization of Innovative Potential, Realization of Innovative Potential; the third cluster includes countries with average indicators of The Conditions for Creating Innovative Potential, moreover, this indicator is even higher than in the countries of the second cluster, but the indicators of the Level of Innovation Potential, Conditions for Realization of Innovative Potential and Realization of Innovative Potential have a low level. These results testify to the relevance of further study of this topic, namely: why countries with the same level of conditions for innovation potential have different results in its implementation.

The breakdown of the countries studied according to the indicators into three clusters can be seen in the table below.

I Cluster	II Cluster	III Cluster
		Bulgaria
Austria	Hungary	Greece
Belgium	Italy	Cyprus
United Kingdom	Portugal	Latvia
Germany	Slovenia	Lithuania
Denmark	Czech Republic	Poland
The Netherlands	Estonia	Romania
Finland	Ireland	Spain
France	Luxembourg	Croatia
Sweden	Slovakia	Ukraine
		Malta

Figure 7. Breakdown of the countries clusters
Source: Author's

As seen from the table, as a result of the cluster analysis, the countries were divided into clusters as follows: the 1st cluster included 9 countries, among them the Scandinavian countries and the countries of Western and North-Western Europe; the second cluster includes mainly the countries of Southern and Central Europe; the 3rd cluster includes the countries of Eastern and Southeastern Europe, to which Ukraine belongs.

Discussion the other scientists and papers

In his work [12], M. Kyzym considered the problems of assessing Ukraine's readiness for innovative transformations, although he assessed the possibility of forming innovative clusters even before the concept ofa new industrial revolution appeared. In her work, V. Khaustova [13] also assessed the possibility of creating innovative clusters in the Ukrainian economy using the example of enterprises in the electrical industry operating in the Kharkiv region. I. Yegorov, I. Odotiuk and O. Salihova [14, 15] considered the possibility of implementing high technologies in the Ukrainian economy and evaluated the development indicators of ICT, biotechnology, nanotechnology, new materials and nuclear technology. Moreover, in the studies of all these authors there was no comprehensive analysis of the technological readiness of the country as a whole. L. Fedulova [16] also used a number of indicators of innovation to justify the national priorities of social and economic development of the country on an innovative basis, although she determined only the technological contours in the Ukrainian industry without taking into account the factors of the new industrial revolution. However, these authors did not have a comprehensive approach to the development of a methodology for studying Ukraine's readiness for innovation in the conditions of Industry 4.0.

Uncertainty and impact of research results

The conducted analysis of indicators has shown the expediency of further research of innovative potential of countries and willingness to innovate in the area of 'The Conditions for Creating Innovative Potential, Level of Innovation Potential, Conditions for Realization of Innovative Potential, Realization of Innovative Potential'. In the future, these indicators will allow to study and analyze in more detail the level of innovation development of the EU and Ukraine, develop a strategy of innovation development and implementation of innovations for the more backward countries and to find ways to increase the competitiveness of the economies of the countries by realizing their innovative potential. Presently, this is very relevant for Ukraine because the EU's high innovation potential is one of the most powerful and motivating factors for Ukraine's European integration choice.

Therefore, it can be stated, that Ukraine is not yet ready for innovations in the conditions of the spread of technologies of the new industrial revolution. This also means that the country has many ways to improve the central element of industry 4.0 and any innovation will be among its people, not technology, and as was mentioned previously, Ukraine has a high level of educational potential, which means, that there can be professionals that will lead the country towards the needed progress.

Summary and conclusions

Based on the results of the study, the following conclusions can be drawn about Ukraine's readiness for innovation in the conditions of Industry 4.0:

- Ukraine is 24th in the Indicator of The Conditions For Creating Innovative Potential because of its low level of access to ICT and the development of clusters;
- Ukraine ranks 11th in the indicator of Level of Innovation Potential due to the fact that Ukraine is the leader of the indicator of Population aged 20-24 with upper secondary education and with tertiary educational

attainment. There is as high level of educational potential in Ukraine. However, the level of institutional potential remains low;
- Ukraine ranks last in CRIP among all countries because Ukraine has the lowest expenditure on R&D and poorest ICT use;
- Ukraine has low results on indicators of high-tech exports, ICTS and business model creation, SME with product or process innovations and creative goods exports.

So, taking into account the fundamental importance, complexity and systematic nature of this problem to ensure the competitiveness of Ukrainian enterprises and the economy in a global saturated market, and taking into account the rapid spread of the consequences of the 4th industrial revolution, there is a need for Ukrainian Government to:
- make raising business excellence a priority in work and personally initiate urgent measures aimed at significantly improving the quality of public administration, in particular, by using the best practices in terms of system management and the corresponding refinement of the Strategy for Public Administration Reform;
- to develop and adopt a concept of state policy in the field of system management, providing for active assistance on the part of the authorities to domestic enterprises in improvement based on modern approaches and best practices;
- to develop and adopt a concept of state policy in the field of quality of products (works, services), including in it such areas of activity as standardization, technical regulation, metrological support and market supervision;
- promote the introduction of digital technology in all areas of production and contribute to computer literacy among the population.

Conflict of interest
There are no conflicts to declare.

Acknowledgements
The authors would like to express his appreciation towards to M.O. Kyzym, Professor, Dr.Sc. of Economics. His knowledge and experience was invaluable during the above work.

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ANALYSIS OF SELECTED RISK FACTORS IN TRADE FAIR DECISIONS OF EXHIBITORS

Abstract
In the process of managing participation in fairs, a long-term vision, taking into account a number of non-financial dimensions of the assessment, makes it more complex and risky and, consequently it requires more attention. The article presents the parameters of the process of managing participation in fairs by the exhibitors studied, analyses the relationships between them and identifies key risk factors in trade fairs activity of exhibitors. The article describes the respondents' behaviours in the studied area and highlights the importance of non-financial elements determining the readiness of exhibitors to participate in the fair. The decisions to participate in fairs are more and more often made based, for example, on the assessment of cooperation with organizers. The possibility of achieving non-sales goals during the event is also becoming more and more important, even if the company has difficulty assessing the degree of their implementation.

Keywords
trade fairs, exhibitors, stakeholders, B2B.

Introduction

The role of trade fairs has been evolving very intensively since the very beginning of their presence in the economic reality [30]. Their initial provision nature changed several times to, at first, result in an increase in the importance of the promotional role of trade fairs and, at a later stage, to lead to an increase in the importance of their informational and educational function [21, 23]. The process of shaping experiences and building relationships also involves tasks that contemporary companies successfully implement as part of participation in trade fairs [22].

The growing importance of other-than-sales trade fair goals of contemporary exhibitors [16] results in the fact that these goals become a permanent element of marketing communication for representatives of many industries [11, 34]. Exhibitors and organizers are constantly striving to optimally use the exhibition space by all stakeholders. They want to minimize the risk of mischoosing the place and way of presentation during the fair. It is difficult to determine the criteria for the choice of the event and the unambiguous way of defining the possibility of using these events in the communication policy of enterprises [9].
The purpose of this article is to describe the behaviour of exhibitors participating in the KOMPOZYT-EXPO 2018 and FASTENER POLAND fairs and present an attempt to identify key factors affecting risks in the trade fairs decisions determining their fair activity and a level of satisfaction with participation in fair events. The multiplicity of acceptable solutions (also in the communication area) makes decisions in this area increasingly risky and entrepreneurs need to work on improving their procedures and looking for new criteria of decision-making.
It was established which of the selected factors in the area of preparation and implementation of the fair policy of exhibitors and the observed effects of participation in fairs affect the level of satisfaction with the event and readiness to increase involvement in participation in these events.
The character of analyses and considerations was determined by the stakeholder theory [15], which as one of the first concepts of today's business showed the need to look at the activities of enterprises in the context of a broad impact, in the long-term and taking into account multidimensional market relations.

The basis for the conclusions drawn is a critical review of the literature on the stakeholder theory and contemporary trade policy as well as the results of 198 exhibitors participating on 17-19/11/2018 in fairs KOMPOZYT-EXPO 2018 and FASTENER POLAND.

The stakeholder theory and the objectives of market activities of modern enterprises

Developed since the 1970s of the 20th century [36], the stakeholder theory, since its presentation by R. E. Freeman [6], has changed the philosophy of the understanding of the functioning of a company. Its basic

assumption is that the market activity of an enterprise is connected with the existence of the so-called stakeholders, or groups of entities that remain in various types of multifaceted relations with it, and thus affect its functioning [4].
More precisely, term stakeholders is understood [33] as persons or groups of people, institutions and organizations that are both directly and indirectly interested in the activity of the enterprise and include, for example, employees, media representatives, suppliers, co-operators and clients who can both influence the company or be influenced by it. The stakeholder theory is a management concept, the essence of which is building long-term and lasting relationships with all entities [36].
Originally, the business activity of enterprises was primarily focused on production and in subsequent periods was increasingly focused on the purchasing behaviours of customers. The stakeholder theory claims [12] that in the process of building and implementing the strategy [3], one must also take into account other market participants and a longer time span both in the area of impact on the people affected by the activities and their reaction to the tools used. The attention of managers should also be paid to the relations with entities not directly involved in the production process, such as, local community, local government, media, own staff, competition and a number of others, because their character affects the final result of the activity [20].
From the very beginning, the theory has become very popular among researchers dealing with the enterprise management, but quite quickly it turned out that there is also a number of different directions of its understanding and interpretation [25].
It is used both in the business sector, government administration, as well as in the social sector [8, 33]. The multidimensionality of looking at own activity has become a necessity in every area of modern reality. The stakeholder theory is also quite present in modern marketing [17, 36]. Other concepts and marketing paradigms draw from it, i.e. relational marketing, or holistic marketing or experience marketing. There is an increasing interdependence of individual market participants in both the financial and organizational area. At the same time, analysing the prosumer behaviour of today's buyers of the offer, you can see that they not only want to have more and more influence on what they buy, but also when making market decisions are more and more prepared and use many non-standard information and communication channels. They become more and more involved in their purchasing decisions and have the courage to change them very dynamically so as to fully meet their needs.
Hence today's entrepreneurs, focusing on the basic market goal of the enterprise, which is the duration and development, are looking for new areas of impact on the target market and try not to forget about other stakeholders [14].

In this context, the question becomes whether exhibitors planning their participation in fairs take into account multi-faceted relations with their stakeholders and how this affects their market behaviour.

Evolution of defining exhibitors' trade fair goals

The popularity of the business approach in accordance with the stakeholder theory resulted in the fact that the exhibitors' trade fair goals are subject to modification [35]. The recipients of activities are also changing - their list is rapidly growing and the diversity of their specifics is increasing [26]. At the same time, exhibitors place more and more emphasis on information [1, 2, 29], promotion and educational purposes of participation in fairs [13, 27]. In the case of the majority of large trade fairs, it can be observed that the sales activity of both exhibitors and visitors is marginalized, and the pressure of a fast and high sales result has ceased to be so clearly visible [31]. Today's presence of exhibitors at the fairs involves greater financial and organisational commitment to a single event, and thus the decision to participate in it will be fraught with greater risk. And that's why there are also more thought-out activities of both exhibitors and visitors who plan their trade fairs and prepare for them earlier – which is the result of companies' efforts to reduce the risk level associated with participation in trade fairs. This also results in the fact that in trade relations (especially at large B2B events) there is less intrusiveness in presenting the offer and fewer accidental meetings [7, 8].

In today's market practice, one can notice difficulties in validating the results of the company's participation in fairs (especially the smaller ones) [10, 32], but on the other hand, the intuitive need to engage in this type of event is the result of the development of relationship marketing and the awareness of entrepreneurs about the need to use it [28].

Uncertainty and risks in companies' trade fairs policy

From the point of view of the level of knowledge of the entity concerned, the effects of its actions shall be taken under the conditions:

- certainty (the entity's belief that a specific sequence of events occurs without interference),
- risk (all possible results of the action and the likelihood of each of them are known)
- uncertainty (the probability of action results is unknown or it makes no sense to talk about them).

Uncertainty is a multidimensional cognitive category, the essence of which is the inability to determine the likelihood of possible development options for a given situation. On the one hand, uncertainty is synonymous with threats and a source of conflict, and on the other, it encourages caution and helps minimize losses [19].
The greater the uncertainty range, the greater the risk range. The risk, unlike uncertainty, is measurable and occurs when it is possible to estimate the likelihood of a specific outcome of the activity [24]. The risk is also a danger of making a misdecision and failure of a particular action. It is measurable uncertainty, it is characterized by the possibility of prior identification and measurement and the possibility of managing it [5].
The dynamic nature of fair events makes it impossible to implement the objectives of participation in the fair without any disruption, and in practice it is also difficult to determine all possible results of this activity. Closed events with a rigid, precisely planned formula, in which it is easier to predict the future are the exception. Trade fairs decisions are most often taken in conditions of uncertainty, the source of which are visitors, other exhibitors and interactions between all participants in the fair.
In order to eliminate losses and estimate potential benefits, companies seek to describe sources of uncertainty, which should ultimately lead to quantification of the existing risks and the development of the risk management system. A well-designed risk management system should integrate knowledge of individual risks in the organization, and by supporting business decision-making, increase the effectiveness of achieving goals. One of its elements is to analyse the sources of uncertainty and risk in the process of trade fairs participation management and the ability to minimise their impact on the company's fair results.

Method of research and characteristics of the studied population

The research subject was the fair behaviour of the exhibitors participating in the KOMPOZYT-EXPO 2018 and FASTENER POLAND fairs organized by Targi w Krakowie Sp. z o. o. on 17-19/11/2018. The research took the form of a direct questionnaire conducted during the aforementioned events. 198 research questionnaires filled out by exhibitors participating in the fair were used. Analyses of connections between selected variables were made on the basis of the Spearman's rank correlation coefficient (r_S), assuming that at least one of the analysed variables is of a qualitative character, but which allows for sorting by strength. The numerical parameters of the studied population are presented in table 1.

Table 1. Parameters of the studied population (N of valid -198)

List of parameters	Mean	Median	Lower quartile	Upper quartile
The year the company was founded	1988,16	1996	1986	2006
The year of the first participation in the fair	2005,75	2010	1998	2016
Number of trade fairs in which the company took part the last year	4,98	3	2	5
Distance of the company's headquarters from Krakow (exhibition place)	1612,73	340	163	1500
Number of employees employed in the company	164,93	38	12	140
Number of employees at the trade fair stand	3,43	3	2	4
Rented exhibition space	18,52	12	9	18

Source: Author's.

The dominant legal form among the surveyed entities was a limited liability company (47%), with quite a large proportion of participants coming from foreign markets and it was not always possible to precisely determine their legal or organizational status. Over 53% of respondents spend less than 20% of their marketing budget on participation in fairs, only 7% of respondents spend more than 60%.
The most frequent sources of information on potential exhibition venues are invitations of trade fair organizers (61.62% of respondents), followed by their own experiences (49.49%), industry brochures (44.44%), customer suggestions (24.25%), intensive search in industry media (22.22%), daily general information in the media (16.16%) and competition monitoring (15.16%).

Analysis of research results of exhibitors participating in The KOMPOZYT-EXPO 2018 and FASTENER POLAND fairs

The surveyed exhibitors declared a number of different goals for participation in the fair event examined. The detailed distribution of answers is presented in table 2.

*Table 2. The trade fair goals of the exhibitors analysed**

Declared goals	Number of cases	Percentage of indications
presentation of the company's offer	192	96.97
increase in sales after the fair	132	66.67
collecting information about customers' expectations	104	52.52
gathering information about the possibilities of cooperation	100	50.50
increase in market share	92	46.46
improvement of the image of the company on the market	82	41.41
collecting information about the current situation of the market	80	40.40
improvement of relations with market participants	72	36.36
comparison of own offer with a competitive offer	42	21.21
seeking intermediaries	28	14.14
sale of products at the fair	24	12.12
others	4	2.02

* multiple choice question.

Source: Author's.

The presentation of the company's offer (96.97% of respondents) was the most important for the surveyed exhibitors. The next important goal was to increase sales after the fair (66.67%) and gather information on customer expectations (52.52%). These results are a confirmation of the global trends in fair policy, linked to the decline of the sales role of the trade fair for this marketing (communication) role. The fair objectives of the exhibitors participating in the study differ from one another, which determines how these entities function during the event, which in turn makes it difficult to compare the market activity of the respondents. The factors that differentiate the functioning also include the demographic parameters of the respondents. When planning the research project, the researchers were looking for a factor which would be a common denominator of the respondents' attitudes to the fairs regardless of their size or trade fair assumptions. The declarations of exhibitors on their involvement in the fair in the future were considered the most appropriate parameter (and relatively easy to obtain as part of the direct questionnaire). A similar approach was presented, among others in study [18].

Table 3. Declarations of exhibitors regarding their future fair activity

Declared attitude regarding their future fair activity	Number of cases	Percentage of indications
Raising trade expenses and participating in more trade fair events	54	27.27
Raising trade expenses and maintaining or reducing the number of events in which they will participate	28	14.14
Lowering trade expenses and maintaining the number of events in which they will participate	12	6.06
Lowering trade expenses and reducing the number of events in which they will participate	10	5.05
Maintaining the current level of trade expenses and the number of events in which they will participate	98	47.48

Source: Author's.

Only a dozen or so percent of respondents declare (tab. 3) that they intend to reduce the level of expenditure on participation in fairs, while as many as 27% of respondents plan to increase their involvement in participation in such events. This testifies to the very positive attitude of exhibitors to the fair as an institution and their belief in the usefulness of this business tool in the company's activity.

The question relevant to the future of the entire exhibition industry is "what factors influence the growth of this positive attitude, and what factors will be the limitation for it?". In model [17], the assessment of cooperation with the organizer (operator) in connection with participation in the fair (satisfaction with organizers) was considered one of the most important factors.

Therefore, in this case it was also decided to examine the potential links between the declarations of exhibitors participating in the fair in the future and the assessment of cooperation with the organizer. The areas of evaluation of this cooperation and the results obtained are presented in tab. 4.

Table 4. Evaluation of the quality of cooperation with the trade fair organizer (N of valid: 198)

Criterion for assessing the quality of cooperation with the trade fair organizer:	Mean	Median	Mode	Cardinality of mode
quality of information about the event (website and other sources)	5.66	6	7	62
quality of fair infrastructure	5.62	6	6	68
quality of fair service	5.53	6	6	60
communication during the reservation of the stand and preparations for the fair	5.82	6	7	74
possibility of promotion at the fair	5.37	5	5	52
promotion of trade fairs in the media	5.00	5	4	68
help in evaluating the results of the fair	4.87	5	4	60
comprehensive assessment of the quality of cooperation	5.50	5	5	72

* The exhibitors' assessment was on a scale from 1 (quite bad, I was disappointed with cooperation with the organizer) to 7 (very good, the organizer met all my expectations in this area).

Source: Author's.

The respondents assessed the organizers in the categories of "communication during ..." and "quality of trade fair information ...", while the lowest score was given to the organizers for help in assessing the results. The basic statistics quoted above indicate that cooperation with the organizer is evaluated very positively.
The analysis of Spearman's correlation between the declaration of the future participation in the fair and the assessment of the quality of cooperation with the organizers did not show any significant correlation. Only in three cases (the possibility of promotion at trade fairs, promotion of trade fairs in the media, overall assessment of cooperation quality), there was a statistically significant correlation (at $p<0.05$) with a variable showing trade fair plans of exhibitors, but also the obtained values of the coefficient are below the value of 0.2 and have a negative value. This indicates that companies less satisfied with cooperation with the organizer in the above-mentioned areas are more likely to increase their participation in fairs. One of the reasons may be the belief that the fair is a useful tool, but one needs to better choose the place of presentation, which is associated with additional expenses and commitment.

Analysing the level of correlation between the variable presenting declarations about the future participation of exhibitors in the fairs and the variables showing the distribution of other elements of exhibitors' fair trade policy, statistically significant relations of the variable showing the aforementioned declarations with the following variables can be noticed:

- as part of searching for information on potential exhibition venues - "intensive search in the specialized industry media" (value of the correlation coefficient at the level of $r_S=0.34$ at $p<0.05$)
- "The use of external advertising during the fair" (value of the correlation coefficient at the level of $r_S=0.27$ at $p<0.05$)
- "Using surveys among visitors (the value of the correlation coefficient at the level of $r_S=0.21$ at $p<0.05$)
- "Establishing individual e-mail contact after the fair in relation to the interests of the visitor to the stand" (value of the correlation coefficient at the level of $r_S=0.26$ at $p<0.05$).

There is also a statistically significant relationship between the declaration on the future participation in the fair and the observed positive results of participation in these events. The exhibitors who observe the increase in the number of formal inquiries after the fair ($r_S = 0.26$ at $p <0.05$), increase in sales ($r_S = 0.16$), increase in offer inquiries ($r_S = 0.21$) and increase in the number of positive opinions about the company on the market ($r_S = 0.25$) more often think about increasing the expenditure on the participation in the fair.

Directions to minimise the level of risk in fairs activity of respondents surveyed

The fair trade activity of exhibitors is a very complex phenomenon and as such is fraught with a high risk of total failure or suboptimal solution. For the purposes of this article, only a few parameters were selected, which control would reduce the risk of missed trade fairs presentations for exhibitors. In the analysis of research results obtained, it was agreed that readiness to increase the intensity of participation in fairs in the future:

- is higher among enterprises that are more involved in the preparation process by, for example, a more intense search for potential exhibition venues or the preparation of marketing research to be carried out during the event itself;
- is also higher among those exhibitors who observe positive results of participation in the fair in the form of an increase in the number of offer inquiries;
- is lower among those who make a higher overall assessment of cooperation with the organizers;
- does not show a statistically significant relationship with variables illustrating the detailed assessment of cooperation with the organizers;
- shows a statistically significant relationship with the following goals of the fair exhibitors: gathering information on customer expectations (0.22), seeking intermediaries (0.25), improving the company's image on the market (0.18).

Analysing the obtained results, we can conclude that the exhibitors who are more fully involved in their trade activities are interested in participating in the fair and increasing their market activity. As a result, they are able to better use their potential. Increasing commitment to preparing for the fairs reduces the risk of a missed trade fairs presentation.
Looking for strategic implications for, for example, organizers of events interested in increasing the number of participants in their events, one can suggest introducing additional services to potential participants who will be better prepared to participate and will be more active during the trade fair itself and after the event.

Conclusions
Exhibitors' activity is endowed with high risk, which can be controlled and effectively reduced. When analysing the fair behaviour of the exhibitors, one can notice that their market activity is not addressed to all stakeholders. Of course the decline in popularity of "selling goals" of trade fairs, while increasing the importance of presenting the company's offer during event and increasing interest in the search for various types of information during the fairs shows the extension of the stakeholder group, to which the fairs presentation of exhibitors is addressed. So this is no longer perceived as a one-dimensional relationship with the client, but still not all groups of stakeholders are addressed by the fair policy of exhibitors. The exhibitors' awareness of this could help improve the results of the participation in the fair.
Looking for factors that influence the decision of exhibitors to participate in subsequent trade fairs, it was found that the most important element is their own activity in the search for new places of presentation and involvement in managing their participation in the fair. Especially in the case of small businesses, this is associated with a very large effort (both financial and organizational), which should be a signal for the organizers to create tools, applications and procedures to help exhibitors perform all activities beyond the basic rental of space. It can be presumed that today's exhibitor is mentally ready to carry out these additional tasks, but they may have problems with planning and implementing them alone. The comprehensive and ready-made management programs for the fair policy of the company would be particularly valuable.
Relatively low correlation indices and their small number may be the result of too small a research sample. In order to obtain more reliable results, a larger sample of exhibitors should first be tested. It would be good to choose bigger event then these ones organised by Targi w Krakowie. Obviously, the improvement of these indicators will also be supported by the professionalization and greater commitment of exhibitors and the improvement of the quality of trade fair guests.

Conflict of interest
There are no conflicts to declare.

Acknowledgment
This research was financially supported by AGH University of Science and Technology in Krakow (subjective grant for maintaining research potential).
Paper funded by the statutory AGH, no contract: 11/11.200.349.

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CORDUNUM PISTONS INCREASE DIESEL ENGINE ECONOMY AND RELIABILITY

Abstract
Taking into account the oil resources depletion the requirements to fuel consumption of internal combustion engines are now increasing as well as to their reliability and durability. With the continual increase in the number of internal combustion engines in operation, along with the problem of parts of the cylinder piston group wearing out has caused exhaust from such engines to be one of the main source of harmful pollutant emissions in cities. Therefore, environmental requirements have in turn increased dramatically. The engine resource and its efficiency largely depend on the process of fuel combustion in the combustion chamber. Experimental studies aimed to improve the working process on diesel engines by piston insulation have shown an effective decrease in fuel consumption by reducing heat loss and more complete fuel combustion. When oxide ceramic coatings were used on the piston and cylinder head, the maximum power increased and the specific fuel consumption decreased. However ceramic coatings are not widely used due to their peeling. We have developed a technology for the galvanic plasma treatment of pistons, which made it possible to obtain on the pistons surface made of aluminum alloys a ceramic corundum layer with high adhesion to the base metal that does not peel and has electret properties. In 1993, pistons with a corundum surface layer were installed in a shunting diesel locomotive and life-time running tests were conducted. Such pistons increased wear resistance, reduced the wear of cylinder liners, increased the strength of the annular jumpers, and were not prone to burnouts and scuffing. They provided an increase in the resource of the cylinder-piston group of the diesel engine by more than 125 thousand engine hours. The paper provides an analysis of the effect of corundum pistons thermal insulation on significant increasing the, engine power and fuel consumption reduction. Basing on experimental bench studies of a gasoline engine, a tractor diesel engine and long-term operational life tests of diesel engines, an attempt had been made to explain the reasons for the improvement in the engines' efficiency.

Keywords
Diesel, engine, locomotive, piston, corundum, layer

Introduction

There is a fleet of approximately 1000 diesel shunting ChME-3 currently in service in Ukraine. The problem of improving the efficiency and economy of this fleet's performance is important in the context of the annual reduction of the fleet of shunting locomotives. Replacing worn-out power units with imported ones requires considerable financial expenditures. Every year the fleet of shunting diesel locomotives decreases, and the volume of shunting operations increases. To maintain the performance characteristics of shunting diesel locomotives at the proper level, it is necessary to frequently repair of diesel engines with replacement the cylinder-piston group parts. Currently the reduction of repair and operation cost of shunting diesel locomotives is one of the important problems faced by Ukrainian Railways. They are trying to solve this problem by replacing the existing K6S310DR diesel engines with Caterpillar diesel engines, however it is rather expensive. Another more economical solution is to refurbish the engines of the current fleet. To limit the heat loss of the working fluid through the walls of the combustion chamber, heat insulating overlays, heat rings, screens are used as well as cermets or ceramic coatings which have high heat resistance, hardness and wear resistance and do not require changes in the design of parts. It lets to reduce the impact of thermal loads on the life cycle and reliability of the

engine. Several companies have tried using ceramics in engines/The Japanese company Kyoto Ceramic [1] had manufactured almost entirely ceramic engine made of sintered silicon oxide. Such ceramics were used to make the cylinders, pistons, firing bottom of cylinder head, pusher, rocker arm, bar tips and plugs of piston fingers. Cummins Engine Co (USA) [2] has developed the turbocharged diesel engine with ceramic outer cylinder insulation, ceramic piston plate, ceramic cylinder head bottom, ceramic plate on the exhaust valve plate, ceramic insert in the exhaust duct. However, ceramic parts break when the bolts are pulled, when they fall, or when the heat is uneven. The use of cermets to isolate parts has also been investigated by Fiat [1]. In order to improve the efficiency of the internal combustion engines. For the first time, partially-dynamic thermal insulation of the combustion chamber was used. The modification of the working surfaces of pistons was made using aluminum alloys to form heat-insulating corundum layer with electret properties. A rational thickness of the heat insulating layer was established, which reduced the heat flow to the piston, increased the temperature of the gas near the upper dead point, led to more complete and faster combustion of fuel, increased power, reduced fuel consumption and emissions of harmful gases and increased the resource of engine. The repairs of on-line diesel engines K6S310DR in CHME-3 type locomotives with pistons that had undergone galvanoplasma surface treatment with the formation of a corundum layer is much cheaper. It helps to solve the problem of diesel engines performance characteristics improvement in shunting locomotives of the CHME-3 type after repairs. The purpose of the publication is to inform about the benefits of the proposed piston corundum technology for internal combustion engines.

Methodology for combustion chamber thermal insulation efficiency study

To solve the problem of fuel consumption and emission of harmful gases reduction, the results of previous studies on the use of ceramic coatings and heat insulating linings on engine pistons were analyzed. Experimental studies on workflow improvement in diesel engines equipped with pistons with a ceramic coating of 0.2–0.9 mm thickness demonstrated the effective fuel consumption decreasing by 6–8 g/(kW·h). For the 1ChN18/22 diesel engine the decreasing was 7–9 g/(kW·h) [3]. For 1ChN18/20 diesel engine with an aluminum piston coated with aluminum oxide with a thickness of (0.25-0.3)mm at optimum ignition timing angle ϕ=14-14,5°in nominal mode, the effective fuel consumption decreased by 2.7 g/(kW·h), for diesel engine 2ChN 21/21, with n = 1200 min^{-1} and ϕ=36-38 °, the decreasing was 5.44 g/(kW·h). Aluminum oxide coating with a thickness of (0.2–0.25)mm on the piston of a low-speed diesel engine 1ChN24/36 with volumetric mixture formation caused a decrease in the effective fuel consumption for loads less than 45% of effective power by 2.5–13 g/(kW·h) [4]. When using oxide ceramic coatings with a thickness of about 0.06 mm, obtained by anodic microarc oxidation on a piston and cylinder head, the maximum power of a two-stroke internal combustion engine was increased by 6% and the specific fuel consumption was decreased by 3.2% [5]. However, thermal insulation coatings were not widely used due to their peeling, which led to engine seizure. The use of insulating pads [6,7] led to the complexity of the design of the pistons, weight gain and reduced the reliability of the piston. Experimental study by G.Woschni et al.[8] of heat transfer in internal combustion engines using a piston with a head covered with a layer of ceramics “Nimonic-80A” with a thermal conductivity of 2 W/m·K was carried out for a single-cylinder diesel engine with an undivided combustion chamber having the diameter and piston stroke of 125 and 140 mm, respectively, with turns of 2,200 min^{-1} . It was concluded that the use of thermal insulation of the combustion chamber surface in the piston leads to an increase in fuel consumption. Making such a conclusion for heat insulation thicknesses from 2mm to 20mm, Woschni, nevertheless, showed that with small thicknesses of heat insulation there is a decreasing in fuel consumption and an increasing in engine efficiency. However, studies with the thickness of the heat-shielding layer less than 1mm had not been carried out [8]. During the development of the adiabatic engine by Professor N.F. Razleitsev the idea was proposed that the temperature of the wall should change during the cycle in accordance with the change in the temperature of the gas in the combustion chamber, that was later proved by British scientists. As a result of studies of thermal insulation materials for adiabatic engines by H. Valland,G.K. Wyspianski , F.J. Wallaces et al., University of Bath, UK [6,7] it was concluded that in order to obtain the most favorable thermodynamic indices, the duty cycle of the engine must be purely adiabatic, i.e. the temperature of the combustion chamber walls should change following the changing the gas temperature throughout the cycle. In the process of organizing the combustion of fuel in the cylinder of a diesel engine, a complex heat exchange process takes place, with a variable temperature field on the parts of combustion chamber surface. Calculations of piston thermal insulation, which were carried out taking into account the thermal inertia of zirconium $3.5x10^6$kg /s^4·K at n turns 3000 min^{-1}, showed the amplitude of the temperature change was 100^0C.Based on the analysis of these and other research results, a general conclusion was made: a purely adiabatic mode of engine operation cannot be achieved with any real construction of the combustion chamber walls. In addition, a significant increasing in efficiency (up to 10%) may be obtained with partial thermal

insulation of the combustion chamber [8]. Attempts to create adiabatic engines failed and further work in this direction was ceased. It was pointed out on the positive effect of the hot surfaces of the combustion chamber on the performance of the diesel engine and that there are optimal temperatures for the parts of the combustion chamber that provide obtaining the most beneficial workflow for the cycle. Studies carried out by A. Pischiuger [9],O.V. Leonov and E.P. Kamzolov. [10], V.F. Ermakov [11] had shown that for combustion chambers with film and volume-film mixing and working on diesel fuels the temperature of the combustion chamber surfaces should be in the range of 320-380^{0}C. With such temperatures of the combustion chamber walls the specific fuel consumption for a diesel engine is Ch10.5/13 with the smallest vortex chamber [12]. The greatest effect in efficiency improvement was reached by the piston coating with the aluminum alloy, which consists of aluminum oxide, with a thickness of (0.2 - 0.5)mm [4]. Such a heat-insulating ceramic surface can be obtained by microarc oxidizing the surface of a aluminium alloy made piston. The establishing of optimal temperatures can be achieved by changing the thermal resistance of the surface through the thickness of the heat insulating layer change. It can ensure a decrease of heat flow from the gas to the parts of the combustion chamber, but also from parts to the fresh charge. It is known that in order to obtain the most favorable thermodynamic indicators, the duty cycle of the engine must be purely adiabatic, i.e. the temperature of the walls of the combustion chamber should change following the change in gas temperature throughout the cycle [13]. However, this is an ideal case and it is not yet possible to achieve it .As a result of a series of simulation and experimental studies for engines of various types, a rational thickness (0.12-0.16)mm of a ceramic corundum layer was determined at which the growth of the full fluctuation of the piston firing surface temperature occurs. In this case, the maximum instantaneous temperature of the cycle increases from 320°C to (380-390)°C and the minimum instantaneous temperature of the cycle decreases from 315°C to 305°C. The depth of penetration of the temperature wave into the body of the piston decreases and the rate of change of the temperature of the piston surface increases. The calculated values of the temperature change on the piston firing surface during the cycle are shown in Fig.1.

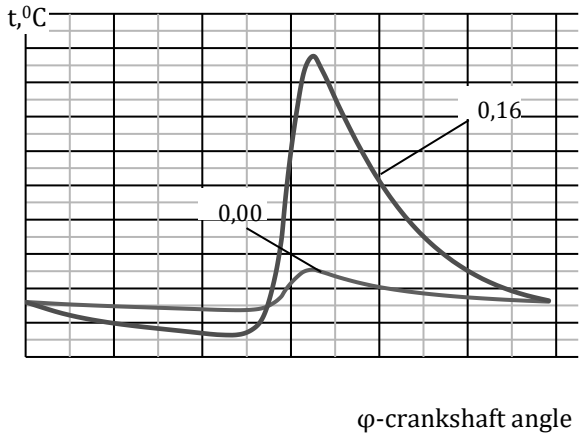

Figure 1. Temperature change on the piston firing surface during the cycle.
The figures at curves indicate the thickness of the corundum layer in mm
Source: Authors

The minimum value of the surface temperature of the standard piston was 313^{0}C, and on the corundum surface 306^{0}C. The maximum temperature on the surface of the standard piston was 325^{0}C, and on the corundum surface it was 387^{0}C, so the amplitude of temperature fluctuations was increased by 69^{0}C and was reached 81^{0}C.The calculations of the unsteady temperature state of the surface of the piston with a corundum layer were confirmed by experimental studies of the 4CHN12 / 14 engine equipped with pistons with a corundum surface layer.

Methodology of work efficiency of diesel engines with corundum pistons study.
Experimental research of the 4ChN12/14 engine were carried out on a motor stand with removal of indicator diagrams in two versions: for a diesel engine with a usual piston and for an engine with a piston having electret corundum layer on the surface in the zone of the combustion chamber. When the cylinder is filled with fresh charge, the heat flux from the wall of the combustion chamber is directed to the working fluid. The small thickness of the low heat conductive surface layer causes a decrease in its temperature to the level of the working fluid temperature. The layer temperature becomes lower than the temperature of the piston base material, the

pressure drops, and the cylinder filling ratio increases. During the filling process, the surface temperature of the corundum layer of the piston decreased by 80 ° C working fluid into the wall of the combustion chamber, the layer temperature increases and becomes higher than the temperature of the piston base material [9]. The heat flux from the working fluid to the surface of the combustion chamber is reduced. The temperature of the working fluid increases and the period of delaying the auto-ignition of the fuel decreases. The pressure rise rate (dp / dφ) max during combustion for fuel supply process is higher when corundum pistons are used in almost the entire range of operating modes of the diesel engine. It may be explained by the combustion rate of the fuel increasing. The part of fuel that has fallen on the wall of the combustion chamber in the piston due to the increased temperature of the wall surface is evaporated more efficiently. The high temperature of the combustion chamber surface during combustion of the fuel and expansion of the working fluid causes the reduction the heat flux to the piston wall and, accordingly, the coefficient of relative heat loss to the wall decreasing (Fig. 2).

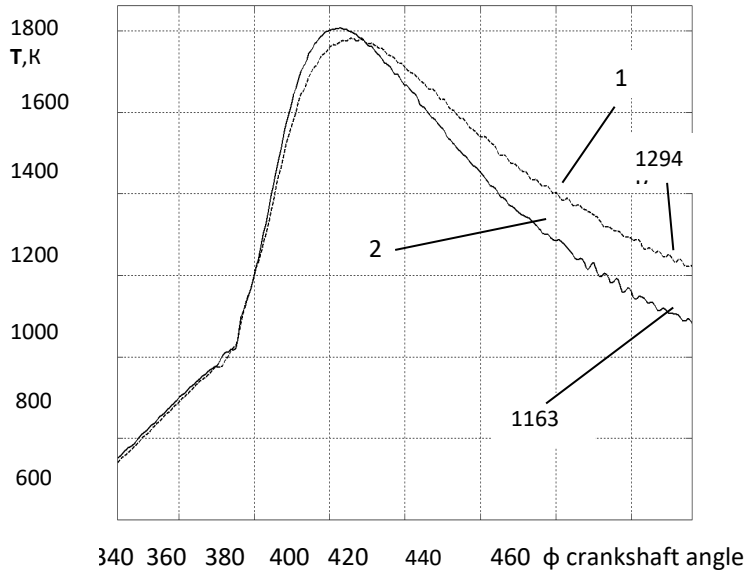

Figure 2. Gas temperature: 1 — standard pistons, 2 — experimental pistons, n = 2000 min⁻¹, pe = 0.95 MPa
Source: Author

As the thickness of the corundum layer increased, the heat flow to the piston decreased, and after the thickness of the layer 0.12mm, the heat flow decrease ceases. The rational thickness of the heat-insulating layer provided a reduction in the maximum value of the specific heat flux in the piston by 16% compared to the non-heat-insulated piston, which led to a decrease in heat loss. With the removal of load characteristics and operation of the engine with pistons with a corundum layer, the maximum cycle pressure increased by 0.5 MPa. The self-ignition process was started earlier, with less amount of injected fuel and therefore, at the first flash, the maximum value of the heat release rate decreased by 12.5%. This conditioned the soft work of the engine. The maximum value of the heat release rate in the combustion chamber with the piston having the corundum layer during the second flash increased by 8.35%. An increase the maximum value of the combustion rate in the region of the second maximum and its approximation to the top dead center improves the efficiency use of the heat of combustion use, which leads to effective power of the diesel engine increase and fuel consumption decrease. From the point of view of the conventional combustion theory, the improvement of the combustion process can be explained in the following way. The corundum layer on the piston fire surface, formed by galvanoplasmic processing, being a corundo electret with a negative surface charge of -3.9×10^{-8} Cl / cm^2, leads to the acceleration of the combustion process. That is, it is a catalyst and affects the fuel combustion process. When the fuel is injected into the electric field of the corundoelektra, electrostatic spraying takes place, which leads to earlier beginning of fuel molecules decomposition with the formation of free radicals. The appearance of a cold flame is accelerated, the time of the beginning of the process of chain self-acceleration of the reaction is reduced and the heat evolution is improved. Due to the partially dynamic heat insulation of the combustion chamber during the period of diffusion combustion, an increase in the temperature of the gas occurs. The temperature of the gas in the combustion chamber is increased by about 30 K, and on the corundum surface of the piston by about 60 K, which makes it possible to obtain a plasma with an increased concentration of ionizing action [9].The excess gas charge is basically positive, and the excess charge of corundolectret is negative. Gas molecules

attraction to the corundum surface is intensified, their velocities are significantly increased, that leads to an increase in the impact of molecules on the corundum surface and the destruction of the molecule itself. There is a destruction of large molecules into small fragments. The activation energy of the beginning of the chain reaction of the decay of molecules is reduced [12]. The maximum value of the temperature of the gas in the engine with the corundum piston increases and shifts towards the upper dead center, which results the faster and more complete combustion of the fuel. It causes the engine efficiency improvement. The power of the engine increases and, accordingly, the fuel consumption decreases. It leads to the reduction of harmful gases emission. After the tests, usual pistons had a charge on the head in the thickness from 20 to 160 μm. The higher temperature of the corundum surface of the piston bottom lets to achieve the more complete combustion of fuel and significantly reduce of carbon deposits. After the tests of the engine with corundum pistons on the heads of the pistons there was no scum. This has led to a reduction in emissions of harmful gases. Comparison of mass and average operating specific emissions of solid particles of the 4ChN12/14 tractor diesel engine was carried out with standard pistons and pistons with a corundum layer Δ = 0.12 and 0.24 mm thick. Corundum layer was formed on the bottom of the piston, the side surface of the piston (up to the upper compression ring) and on the surface of the combustion chamber in the piston. As a result of the tests, a reduction in mass emissions of solid PTm particles with exhaust gases of 4ChN12/14 diesel was defined by (19-30)% [13].
Experimental studies of the 4ChN 12 / 14 engine, equipped with experienced corundum pistons, allowed to establish the results. The standard pistons after testing had a soot on the head with a thickness of 20 to 160 μm, and after testing the engine with pistons having the corundum layer on the heads of the pistons there was no soot. The higher temperature of the corundum surface of the piston bottom led to more complete combustion of the fuel and a significant reduction in carbon. Partial-dynamic thermal insulation of the piston firing surface with a corundum layer with thickness δ ≈ (0.12-0.16 mm) allowed to obtain fluctuations in the temperature of the thermally insulated surface of the piston within 60–80 ° C following the changes of gas temperature. This ensured a reduction of the maximum value of the specific heat flux to the piston by 16% compared to a piston without thermal insulation. It led to the following consequences: the decreasing of heat loss and the surface temperature of the corundum piston layer by 8 ° C during the filling process compared to the temperature of the usual piston, the increasing of the maximum range of the temperature wave by 60 ° C, the decreasing of the maximum heat release rate during auto-ignition by 12.5%.The use of corundum pistons leads to decrease the mass emission of solid particles with diesel exhaust gases by 19 - 30% and CO_2 in the environment.

Results of the research

Wearing of pistons and cylinder's well in the process of operational resource tests
One of the most important indicators of internal combustion engines is its resource, which is largely determined by the wear of engine parts and especially, the piston-cylinder group. The resource of the new cylinder-piston group with standard pistons installed in the diesel engine of the ChME-3 diesel locomotive during routine maintenance is about 35-40 thousand hours. During the following maintenance repairs, the pistons and sleeves that were out of order were replaced . In February 1993, when maintenance was carried out in the Kharkiv-Sorting locomotive depot, two shunting diesel locomotives with diesel engines K6S310DR, manufactured in 11.1989, were selected for performance service tests with installation of new experimental corundum pistons and new liners. In the second diesel locomotive, new standard pistons and liners were installed. The tests were carried out for 19 years. During each routine repair (in 1994, 1997, 1999, 2002, 2005, 2008 and 2011), the dimensions of the parts of the piston-piston group — cylinder liners, upper grooves of the piston rings, and the cylindrical part of the pistons — were measured and their wear was determined. In the process of rheostat tests, fuel consumption and rheostat power were measured. Controlled diameter is a diameter located at a distance of 50 mm from the cut of the skirt. Here the most piston wear out took place. As a result of diesel locomotive operation from 03/01/1993 to 12/20/2012, the maximum wear out of the monitored part of the pistons after operating time of 125 thousand hours does not exceed 0.2 mm. On December 2011 during routine maintenance it was found that the piston sizes are within the allowable values, the width of the first annular grooves on all pistons was within tolerance, the working parts of cylinder liners had a mirror surface without longitudinal scratches and visible wear out . Figure 3 shows the wear out values of the monitored part of the pistons for experimental CHMI-3 diesel engine after operating for 125 thousand operating hours. After pistons installation with a corundum layer in the diesel engine of ChME-3, the wear out of pistons and cylinder liners was reduced (Fig. 4).

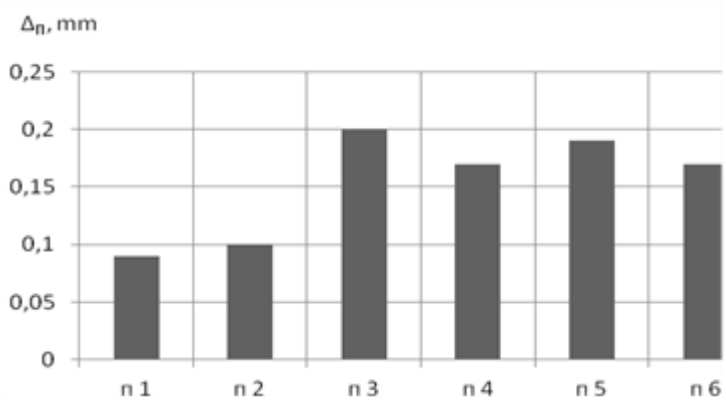

Figure 3. The wear out value of the controlled part of the pistons in the diesel engine ChME-3 after the operating time of 125 thousand hours
Source: Authors

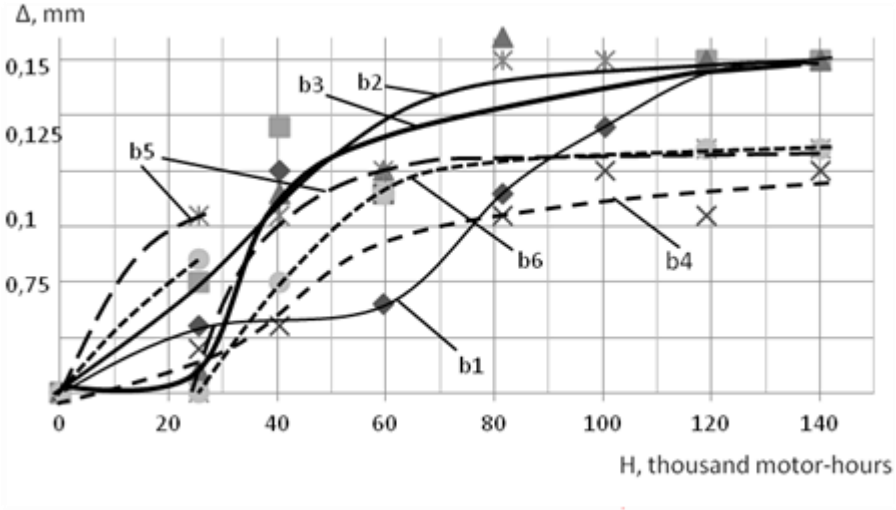

Figure 4. Wear out of diesel liners with corundum pistons during operation
b1 – b6: cylinder liners Nos.
Source: Author

When a diesel engine works with standard pistons, the resource of liners is approximately 35-40 thousand hours, and due to the large wear out, they are replaced during routine repairs. Therefore, the modernization of diesel locomotive with the installation of pistons having the corundum layer allowed to increase the life cycle of the cylinder-piston group more than a three time. During the tests of the Belarus tractor diesel D240 with a corundum piston worked for 15 thousand engine hours without replacement of the cylinder-piston group. After the 36-hour motor tests of the 4ChN12/14engine with standard pistons, the cylinder liners had longitudinal scratches, and after testing the engine equipped with corundum pistons with the liner there were no scratches, they had a mirror surface. A corundum layer on the cylindrical surface of the piston, with a high hardness and fine-grained structure let the surface of the liner to be smoothed. The low friction coefficient and porosity of up to 10-12% of the corundum layer ensured in friction reduction and the reduction in of the liner surface wear out.

Research of the efficiency of the heating diesel working with corundum-electric pistons

The rheostat tests of diesel engines with new pistons and sleeves with corundum layer showed the conformity of performance characteristics to the technical conditions. During rheostat tests, the parameters of diesel locomotive engines were measured according to diesel locomotive characteristics. Comparison of the characteristics of the experimental and existing diesels with the new pistons and sleeves, after the technical

repair, show that an experimental diesel engine with corundum pistons develops significantly more power than a existing. After new corundum piston installation, prior to operational tests on mode 8, the test engine developed a maximum rheostat power N equal to 1040 kW at turns 750 min^{-1}, and standard Nc = 634 kW at turns 680 min^{-1} (Fig.5).

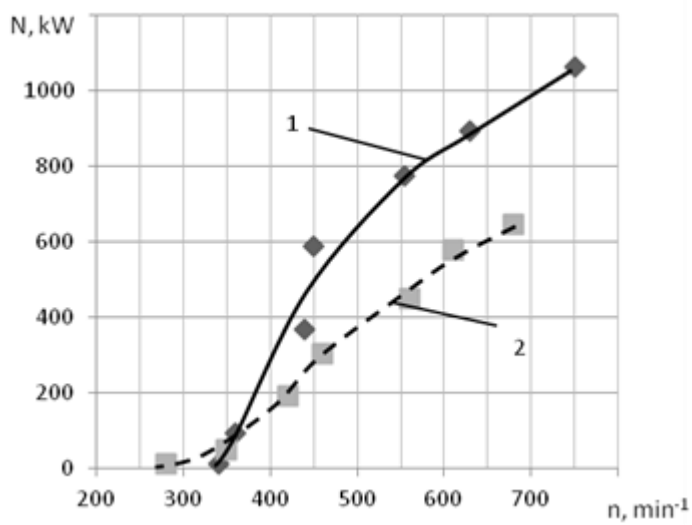

Figure 5. Characteristics of diesel locomotive engines after major overhaul and replacement of the cylinder of the piston group: 1 - diesel locomotive No. 6830 with pistons with corundum layer;
2 - diesel locomotive №6835 with standard pistons
Source: Authors

Rheostat tests of diesel engines performed at the depot Kharkov-Sorting for 20 years showed a significant reduction in diesel fuel consumption of locomotive with corundum layered pistons were installed. In the process of rheostat tests, fuel consumption was measured using the AIRT-2 device developed by the Ukrainian State Academy of Railway Transport and the RECORD Company Attorney of the State Enterprise "Kharkivstandart-Metrology" (Certificate No. 3383 dated July 09, 2008). According to the results of rheostat tests, the specific effective fuel consumption of a diesel engine with serial and corundum pistons was estimated. The specific fuel consumption of a diesel engine with pistons having a corundum layer decreased by 10% (Fig. 6).

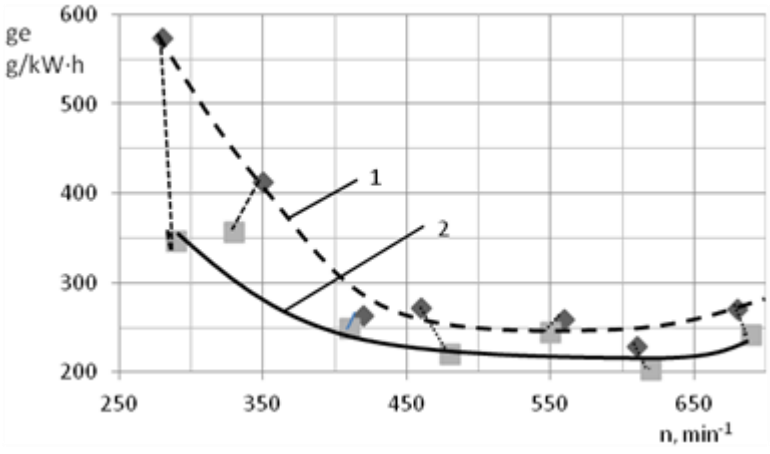

Figure 6. Specific effective diesel fuel consumption: 1 - with standard pistons; 2 - with corundum pistons
Source: Authors

The improvement of the combustion process is confirmed by the absence of carbon deposits on the bottom of the piston with a corundum layer. After testing, standard pistons had carbon deposits on a head with a thickness of 20 to 160 µm, and after testing engine with corundum pistons, there was no deposit on the piston heads. The maximum value of the rheostat (traction) efficiency of a diesel locomotive ChME-3 with pistons having the corundum layer reaches 36%, and a diesel locomotive with standard pistons 31%). In almost 5 to 8 modes,

the traction efficiency of a diesel engine with pistons with a corundum layer is 5% higher. In 2011, an analysis was made for the diesel locomotive equipped with a corundum piston and diesel locomotives equipped with standard pistons operating in approximately the same conditions and with almost the same annual mileage. The fuel consumption and mileage of diesel locomotives for each month of work is taken into account by the form of TCT 5. Basing on the test data, the results of fuel consumption and mileage of the indicated locomotives for 2005–2010 years are presented in the table 1.

Table 1. Actual average annual specific fuel consumption of diesel locomotives CHME3 in kg per km of run (2005-2010 years)

No. of locomotive	2005	2006	2007	2008	2009	2010	Consumption for 35 thousand km
6830	1,9	1,96	1,91	1,90	2,22	2,13	66,56tons
4384	2,7	2,7	2,62	2,57	2,56	2,78	90,1(23,5)
5820			2,1	2,35			82,56 (16,0)
5822				2,34			81,9 (15,3)
5833			2,2	2,2			77 (10,4)
6835			3,37	3,27			114,6(48,1)
7321			4,3	4,2			145,8 (79,2)
7323			2,16	2,71			94,86 (28,3)

The values in brackets indicate fuel overrun by diesel locomotives with a run 35 thousand km
Source: Authors

During 2005 - 2006, the mileage for diesel locomotives with pistons with corundum layer and with standard pistons was almost the same, and the fuel consumption of diesel locomotives with standard pistons was more. From table 1 it is clear that the average annual fuel consumption per 1 km of diesel locomotives with standard pistons is higher than the fuel consumption of a diesel locomotive with corundum pistons. It becomes obvious that with a run of 35 thousand km the best diesel locomotive with standard pistons consumes 10.437 tons more fuel than a diesel locomotive with pistons having the corundum layer. Of course, such a comparison of fuel consumption is not entirely correct, since diesel locomotives have different operating time after technical repair and work with different loads, different downtime and distance of runs for certain operations are different and so forth. However, to some extent such an assessment allows, to some extent, to evaluate the efficiency of a diesel engine and to conclude that the installation of pistons with a corundum layer in diesel engines of shunting diesel locomotives significantly reduces fuel consumption by shunting diesel locomotives.

Discussion with the other papers

An experimental study by German scientists G. Woschni et al. of heat transfer in internal combustion engines using a piston with a head coated with a Nimonic-80A ceramic layer, ZrO2 5 mm thick allowed to conclude that it is practically impossible to obtain a reduction in fuel consumption by thermal insulation of the combustion chamber walls [8]. Making such a conclusion for thermal insulation thickness from 2 mm to 20 mm, Woschni, however, showed that with small thermal insulation thickness, fuel consumption is reduced and engine efficiency is increased. However, studies for the thickness of the heat-shielding layer less than 1 mm were not carried out [8]. As a result of studies of heat-insulating materials for adiabatic engines obtained by scientists H. Valland et al. from the University of Bath, United Kingdom [6], it was concluded that to obtain of the most favorable thermodynamic parameters, the duty cycle of the engine should be purely adiabatic, i.e. the temperature of the walls of the combustion chamber should change following a change in gas temperature throughout the cycle. Based on the analysis of these and other research results, a general conclusion was made: a purely adiabatic mode of operation of the engine cannot be achieved with any real design of the walls of the combustion chamber. However, an increase in efficiency (up to 10%) can be obtained with partial thermal insulation of the combustion chamber [6].The technology of galvanic-plasma processing developed by authors made it possible to create a ceramic corundum layer on the firing surface of the pistons of a diesel shunting diesel locomotive with an optimum thickness of (0.12-0.16) mm. Such thickness lets to obtain temperature fluctuations on the piston surface within 80-100^{0}C following a change in gas temperature during the cycle. In addition, the electret corundum layer has a negative surface charge $–3.9•10^{-8}$ C / cm^2 and, being as catalyst, accelerates the process of fuel combustion. This improved the efficiency of fuel combustion heat use, increased the effective diesel power, reduces fuel consumption and reduces the emission of harmful gases. So the significant technical and economic advantages of pistons with a corundum layer use in internal combustion engines are shown in the

paper. It allows to reduce the specific fuel consumption per unit of work and to low the level of CO_2 emissions to environment.

Impact of research results on science, economy, environment and society

Conducted scientific studies have shown the possibility of obtaining a partially-dynamic thermal insulation of the combustion chamber to increase the efficiency by using the heat of combustion of fuel. The optimum thickness of the corundum layer was determined, which allowed to obtain a change in the temperature of the walls of the combustion chamber following a change in gas temperature throughout the cycle. The increase in engine force is accompanied by an increase in mechanical and thermal loads on the parts and affects the resource and reliability, which mainly depend on the wear of the crankshaft necks, cylinder liners and piston damage. As the temperature of the piston increases, the mechanical properties of the piston material deteriorate, and the uneven temperature field in the various sections of the piston causes considerable thermal stresses and uneven deformation, which is the main reason for the shortening of the service life of the piston and piston rings. The pistons crack the edges of the combustion chambers, there is wear and tear of the ring jumper, melting of the piston head and the appearance of burrs on the cylindrical part and clutch with the cylinder sleeve. Generally, engine life and technical and economic and toxicity indicators depend on the performance of the parts of the cylinder-piston group. Therefore, the use of pistons with a corundum layer made it possible to increase the engine resource by more than 3 times. The corundum layer, being a catalyst, accelerates the process of fuel combustion. Engines with standard pistons have significantly worse combustion quality. The consequence of this is an increase in fuel consumption and a decrease in diesel power. In engines with pistons with a corundum layer, the combustion process proceeds almost in the design mode. This provides the calculated parameters for the specific fuel consumption and power during the operation of the engines. Furthermore, this positive effect becomes greater with increasing operating time of internal combustion engines. This reduces fuel consumption and reduces the emission of harmful gases. The creation of engines with a 15-20% lower fuel consumption will reduce the consumption of fuel for transport, reduce greenhouse gas emissions of CO2 into the environment and reduce operating costs due to a significant increase in the resource of the cylinder-piston group.

Summary and conclusions

Based on the inspection and measurement results within the operation period from March 1993 to December 2012, we can make the following conclusions. The use of pistons with a corundum layer permits to increase the operating life of the cylinder-piston group of a diesel engine of a ChME-3 diesel locomotive engine by more than three times. The pistons with a corundum layer and cylinder liners had worked from March 1993 to December 2011 for more than 125 thousand running hours; as for the diesel locomotive with commercial pistons, the cylinder-piston groups had been replaced three times over the same period. As a result of the analysis of previous studies on the use of ceramic coatings and heat-insulating linings on engine pistons, the technology of galvanic-plasma processing of pistons has been developed. The modification of the working surfaces of pistons made of aluminum alloys was performed with the formation of a heat-insulating corundum layer on the firing surface of the piston, which made it possible to obtain fluctuations in the temperature of the piston surface following a change in gas temperature during the cycle. For the first time, partially-dynamic thermal insulation of a combustion chamber was used to reduce heat loss during fuel combustion. The rational thickness of the ceramic corundum layer was determined, which ensures a decrease in the heat flux into the piston, an increase in the gas temperature near the upper dead center, and more complete and faster combustion of the fuel. As a result of experimental studies of a tractor diesel engine, it has been established that a diesel engine with corundum pistons reduces the mass emission of solid particles with exhaust gases by 19 - 30% and to a reduction in the smokiness of exhaust gases by 15 - 20%. As a result of 19 summer rheostatic tests, it was found that the maximum rheostatic power of a diesel locomotive with corundum pistons exceeds the power of a control diesel engine with serial pistons by more than 20%. Almost traction efficiency of a diesel engine with pistons with a corundum layer was increased by 5% in comparison to a diesel engine with standard pistons. The specific effective fuel consumption of a diesel engine with pistons with a corundum layer decreased by 10%. The installation of pistons with a corundum layer in a diesel shunting diesel engine allowed to reduce the average annual fuel consumption by 25-30%.On December 25, 2012, the Technical Council for the Main Directorate of the Locomotive Economy resolved: “Given the positive results of testing corundum-coated pistons, the Technical Council considers it advisable to recommend corundum-coated pistons to railways for widespread implementation when the locomotives carry out technical repairs and overhauls”. In accordance with this decision, 42 shunting diesel locomotives have already been modernized.

Conflict of interest
There are no conflicts to declare.

Acknowledgment
The support of the State Administration of Ukrainian Railways and collaboration of Kharkiv State Railway Academy are sincerely acknowledged.

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INFLUENCE OF OSH MANAGEMENT SYSTEM ON THE QUALITY AND SAFETY OF WORK

Abstract
The concept of occupational health and safety is not defined in Polish law. The only place where such a definition can be found is PN-N-1801:2004. Nevertheless, according to the Act on standardisation, the application of Polish Standards is voluntary. Activities in the field of occupational health and safety should be an integral part of business management. Companies from countries which are members of the European Union, in accordance with Directive 89/391/EEC, are obliged to implement standards related to occupational health and safety. The most commonly used and recognised standard for occupational health and safety management systems, in line with the specifics of each company, is the OHSAS 18001 international management system, while in Poland it is the PN-N-18001 standard. The study examined the scope of OHS at work among Research and Innovation Centre Pro-Akademia employees. The employees were subjected to surveys. The results obtained show that employees appreciate the importance of OHS regulations, but they do not always consciously comply with them. One of the tools that enabled author to prepare this article is analytic method called desk research. Desk Research is a research method that boils down to analyzing the records of available data sources, including in particular their compilation, mutual verification and processing. Such analysis is the basis for drawing conclusions about the examined problem. For example - the effect of the Desk Research analysis proceeded as part of the labor market survey is the diagnosis of the state of the labor market in the studied area, the characteristics of all its component groups as well as a description and verification of the actions taken by the institutions operating within it.

Keywords
management system, organisational culture, occupational health and safety, risk assessment, risk management, procedures

Nomenclature, Abbreviations
- OHS - Occupational Health and Safety
- OHS management system - part of the overall company management system
- Organizational structure - the arrangement of positions and the organisational units consisting of them (departments or other separate units) inside the organisation and the relationships between them (information flows, formal division of responsibilities, affiliations, etc.)
- Procedures - in other words: a way of conducting (type of activity);
- Processes - in organisation and management, it is most often defined as a set of activities, interrelated with each other, the implementation of which is necessary to obtain a specific result

Introduction
An indispensable element of managing the occupational health and safety (OSH) management system in a company is the need for extensive documentation. The bureaucracy associated with the proper performance of OHS obligations causes many problems for both business owners, managers and employees. Keeping health and safety documentation is not an easy task and often raises many doubts. This is due to two things, namely:
- the lack of a specific form and scope of mandatory data that should be documented as part of a given issue
- the lack of direct legislative requirement for the issue

Due to the possibility of control, people responsible for occupational health and safety must often demonstrate that they fulfil the obligations arising from the entrusted function and document almost everything. This is a simple task in case of a small business with a negligible risk to employees. Challenges arise when a company consists of a large number of employees and, as a result, the work risk is greater.

The occupational health and safety management system is an element of the superior company management system, which consists of:
- organisational structure

- planning
- responsibility
- rules of conduct
- procedures, processes and resources

The above elements are components necessary to develop, implement, review and maintain occupational health and safety policy, and thus to manage occupational risk in the work environment in connection with the work performed in individual departments and teams.

OHS management systems are all legal, technical and organisational measures, which are aimed at protecting people in the process of their work, against threats arising from the material work environment as well as against occupational diseases and accidents at work (B. Dołęga, 2008).
The OHS system, which aims to permanently strive for continuous improvement, should be based on the guidelines and requirements of Polish standards:

- PN-N-18001: 2004 "Occupational Health and Safety Management Systems. Requirements."
- PN-N-18004: 2000 "Occupational Health and Safety Management Systems. Guidelines."

Method of research

Desk research is a technique for obtaining information that already exists. In other words, it is an analysis of existing sources and documents. As the name suggests, the test is performed from behind the desk. Sources of available data are primarily the Central Statistical Office (GUS), statistical data, trade press, all information obtained from legal available sources.
Desk research is most often practiced at the beginning of the research to gain insight into the subject and obtain information necessary for further actions.
Reliable analysis of existing data is the basis for a well-conducted next part of the research process. Data analysis is also a selection of available information. Not everything that is available is valuable from the point of view of the subject of the study. The main purpose of carrying out desk research is to select information and give the right direction to further actions. In addition, thanks to the analysis of documents, the researcher is able to verify and specify knowledge on a given topic.
The reliability of the information obtained depends on two factors:

- availability of existing documents and appropriate selection of sources;
- proper data processing.

As a rule, the existing data analysis is an introduction to the comprehensive research process. However, there are situations where desk research is the main study. It is possible when the existing sources provide sufficient information and when the reliability of the research will be compared to other research results obtained using other techniques. In addition, when there are no other techniques to collect data in this research process. It may also be the researcher's decision to exclusively use existing data analysis for organisational, legal or economic reasons. Another technique used in the study is a survey. Researchers say that it is a form of an interview. However, it is different from an actual interview as regards three features: 1) the degree of standardisation of questions asked; 2) the scope and "depth" of the issue and 3) the principles of the study, and hence the distance that is minimised during the interview.
"Therefore, the survey is a technique of gathering information consisting in completing, usually by the respondents themselves, special questionnaires, mostly with a high degree of standardisation, in the presence of an interviewer or, more often, without the interviewer."(T. Pilch, 2001)
This is the most common tool for collecting information. Surveys are used to conduct research on a representative group for a given population, which results in the possibility of generalising them in relation to the entire population.
The following table presents the advantages and disadvantages of conducting research using the survey.

Table 1. Advantages and disadvantages of research conducted with the use of survey

Advantages	Disadvantages
▪ the research can cover a large population ▪ a survey can be anonymous, which is an important information for respondents	▪ no possibility to deepen the question ▪ no possibility to further clarify the answer ▪ no researcher's control over the answers given (e.g. perfunctory statements) ▪ no personal contact with the respondent

▪ it does not generate relatively high costs of the research ▪ it makes it possible to reach a large number of people in a relatively short time ▪ compilation of results and analysis of studies is not problematic for researchers	▪ the need to adjust the language of the survey so that it is clear and understandable to each of the potential respondents

Source: own elaboration

The basic tool in surveys is a questionnaire. In the introduction, the researcher should explain the purpose of the study, its aim and subject. It is also necessary to include a brief instruction on how to complete the questionnaire. This makes it easier for respondents to give answers as well as for the researcher to compile data.
At the stage of constructing the questionnaire, the researcher must ensure that the questions in the questionnaire are logically ordered. Their order is very important. General questions should be asked first, and then the more specific ones. It is also important to organise the questions thematically in case the survey is multi-threaded.
Depending on the researcher's decision, a metric should be placed at the beginning or end of the study. It should include, for example, questions about age (in ranges), size of the place of residence, education, occupation and other, if required for the study.
The most commonly used types of surveys are:

- postal survey - consisting in sending questionnaires to respondents via traditional mail, together with an instruction attached
- online survey - delivery of survey questionnaires takes place e.g. via e-mail or by posting questions on the website
- auditorium survey - completed "in the room"/"in the auditorium," in which the participants of the study are gathered.

The survey was conducted among employees of the Research and Innovation Centre Pro-Akademia. The anonymous survey consisted of questions regarding the OHS system and compliance with its principles, as well as OHS training. The vast majority of respondents are employees with 3-4 years' experience. This indicates that the Research and Innovation Centre Pro-Akademia team is young and is made up of scientists involved in research and development projects.

Research results

What should an OSH management system look like in a company?
Management can be understood as the planned and organized impact of the management system on the managed system, which includes everything that leads directly to meeting the requirements. The indicated approach to the management process can also be referred to the area and specifics of occupational health and safety 45020: 2009., 2009). The basic requirements for the OHS management system in a company arise from the provisions of law, according to which it is the duty of each employer to carry out occupational risk assessment and to use the resulting protection measures, as well as to train and inform employees about hazards at the workplace. The effective implementation of these and other legal requirements may be facilitated by the implementation of the OHS management system, the model and elements of which are described in the Polish standard PN-N-18001: 1999 "Occupational health and safety management systems. Requirements." The OHS management system presented in this standard consists of:

- management commitment and occupational health and safety policy
- planning
- implementation and functioning
- monitoring, auditing and corrective actions
- review carried out by the management and continuous improvement of the OHS management system.

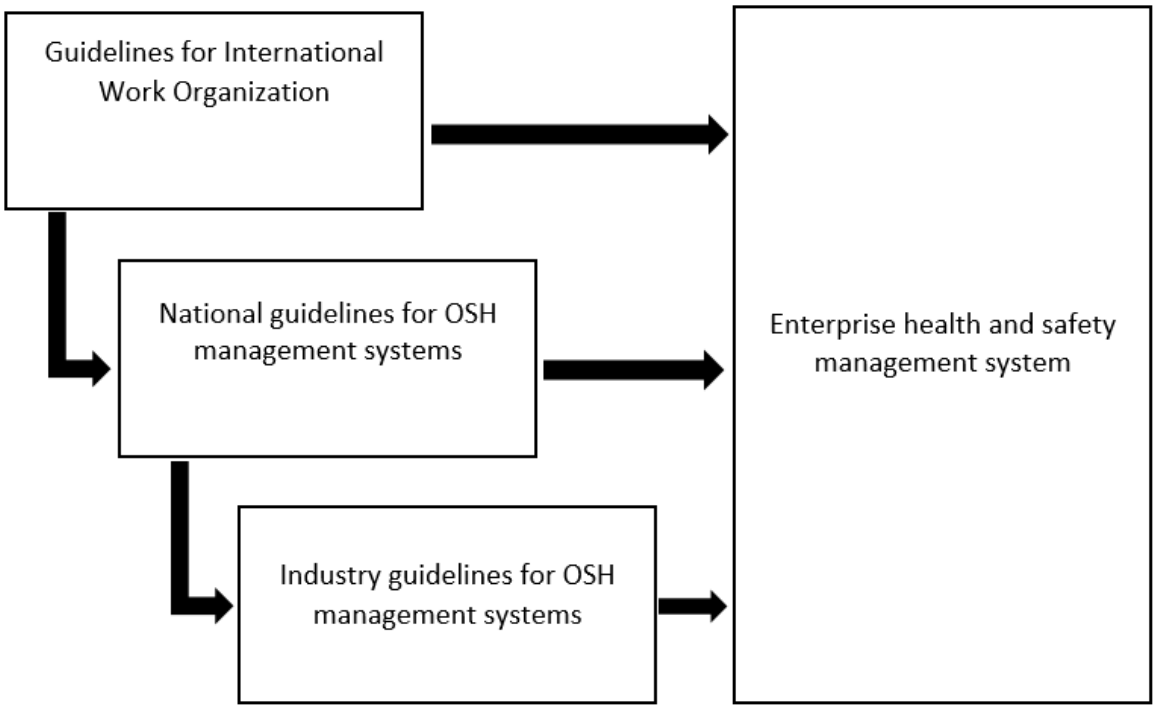

Figure 1. Elements of occupational health and safety management system structures
Source: International Labour Organization (ILO) guidelines

The main emphasis in the management system should be put on the process of permanent improvement of both the company and the management system, and thus security policies. Deming cycle (also referred to as PDCA cycle: Plan-Do-Check-Act, or PDSA cycle: Plan-Do-Study-Act) - a diagram illustrating the basic principle of continuous refinement (continuous improvement, Kaizen), created by William Edwards Deming, an American specialist in statistics working in Japan.

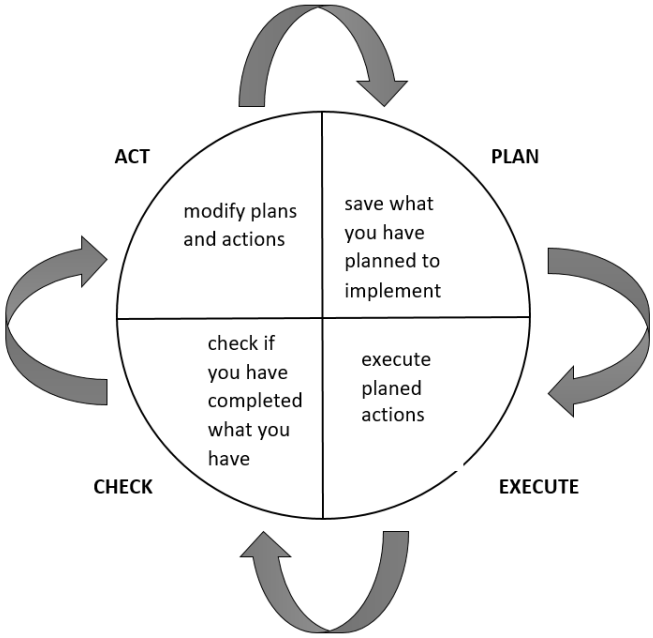

Figure 2. Deming Cycle
Source: Cf. i.a. A. Hamrol, Zarządzanie jakością z przykładami [eng. Quality management with examples], PWN, Warsaw 2005, p. 156

The system approach implemented in occupational health and safety management seems to be perfect. The implementation of system solutions makes it possible to implement security development processes similar to the neighbouring areas of company management (quality, environment, information, finance, etc.). The use of a system approach in managing work safety is associated with the fact that many characteristic management issues (areas) should be taken into account. One of them is the area of shaping pro-humanistic requirements, making it possible to adapt the existing working conditions to the needs and expectations of the interested people. Their inclusion in the management process makes it possible to increase the efficiency of the work performed and minimise the adverse burdens associated with professional tasks (A. Górny, 2015).

The application of the system approach in shaping work safety requires covering all areas of the company's operations with the conducted activities. These areas can be identified as:

- management commitment in development of occupational health and safety policy, taking into account the participation of employees in undertaking system activities
- planning the implementation of appropriate actions
- identification of legal and normative requirements
- defining general and specific goals and planning their implementation
- defining the structure, responsibility and authority relevant to functioning of the system
- providing necessary resources, including competent and responsible employees
- defining the rules of communication
- development of system documentation, along with identification of rules of supervision over documents and records conducting occupational risk assessment and options of performing work
- proper planning and organization of works associated with significant risks
- ensuring the possibility of operational control related to readiness to take appropriate responses to accidents at work and serious failures
- development of purchasing processes, taking into account aspects of security of goods and services purchased
- checking the functioning of the system and testing its compliance with the law,
- indication of non-compliance, together with taking corrective and preventive actions (Dahlke, 2000).

Results of the research

Human factor in occupational health and safety management

There is no doubt that the human factor is the most important link in the entire occupational health and safety management chain.

It is the very core of the management system. These are people that are the basic unit determining the effectiveness of implemented tasks. Due to the above, the nature and scope of tasks assigned to employees should be treated as extremely important. From a system perspective, an additional aspect to which attention should be paid is whether the possibility of performing an action resulting from the implementation and functioning of the system has been provided (A. Górny, 2015).

Taking action can be equated with managing people. Ensuring the efficiency of performing system tasks requires:

- Determining the competences of persons performing activities affecting occupational health and safety,
- Ensuring the implementation of trainings and instructors, thanks to which employees acquire knowledge and skills necessary to perform the scope of duties,
- Taking care of ensuring staff awareness regarding the implementation of tasks,
- Possession of records confirming education, training, skills acquired and staff experience (Karczewski T., 2009).

The state of occupational health and safety can be treated as one of the basic indicators of assessing satisfaction that affects the level of satisfaction with the work environment (A. Górny, 2015).

Figure 3. Company security culture - aspects of evaluation
Source: Milczarek, 2002

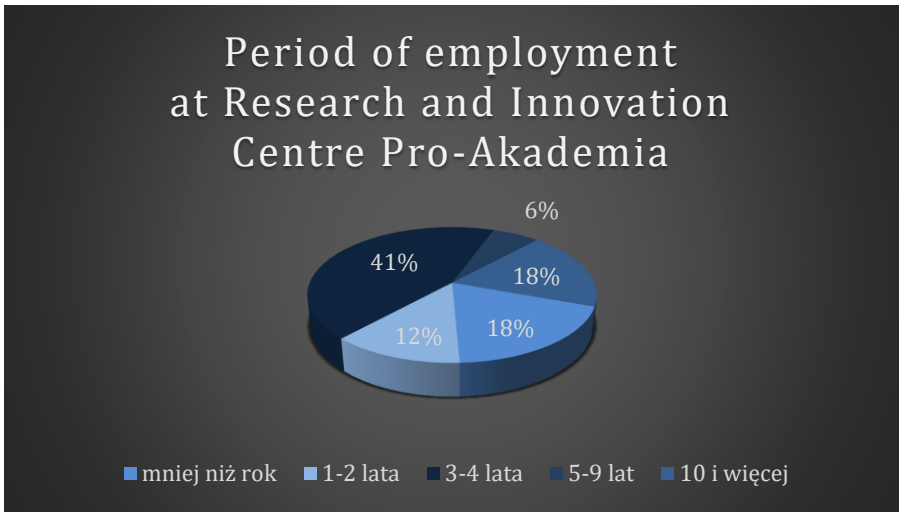

Chart 1. Period of employment at Research and Innovation Centre Pro-Akademia
Source: own elaboration based on a survey

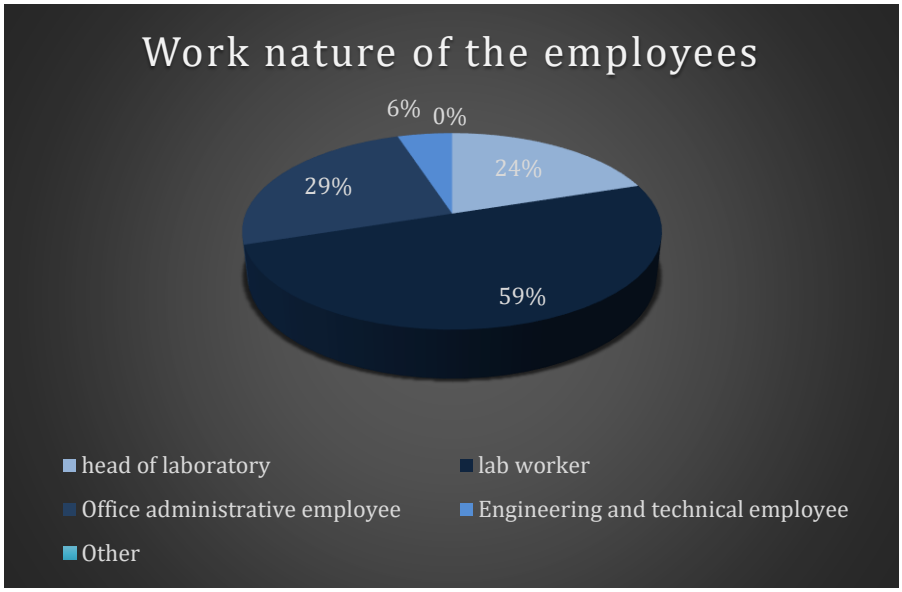

Chart 1. Work nature of the employees
Source: own elaboration based on a survey

Based on the survey, it was found that 35% of respondents admitted to working without the recommended collective or personal protective equipment. The most frequently mentioned reasons why this happens include: rush, overconfidence, lack of awareness of the threat.
Actions that should be taken to minimise the phenomenon of work without personal protective equipment are the increased attention of laboratory managers and the person responsible for occupational health and safety. Increased inspections in the laboratory work rooms and trainings reminding about the effects of the lack of personal protective equipment.

Chart 2. Work without protective equipment
Source: own elaboration based on a survey

Respondents assessed the usefulness of OHS training as useful on a five-point scale (1 - least useful, 5 - very useful). 47% of them marked the answer 5 and 29% - answer 4.
It was found that for almost half of the employees training is useful. However, it is worth noting that OSH training is not an unpleasant obligation for both the instructor and the new employee. OSH training is the first duty, the first task to perform and also the first contact with other employees. In view of the above, every effort should be made to ensure that the training is a source of information provided to employees in the most possible attractive form.

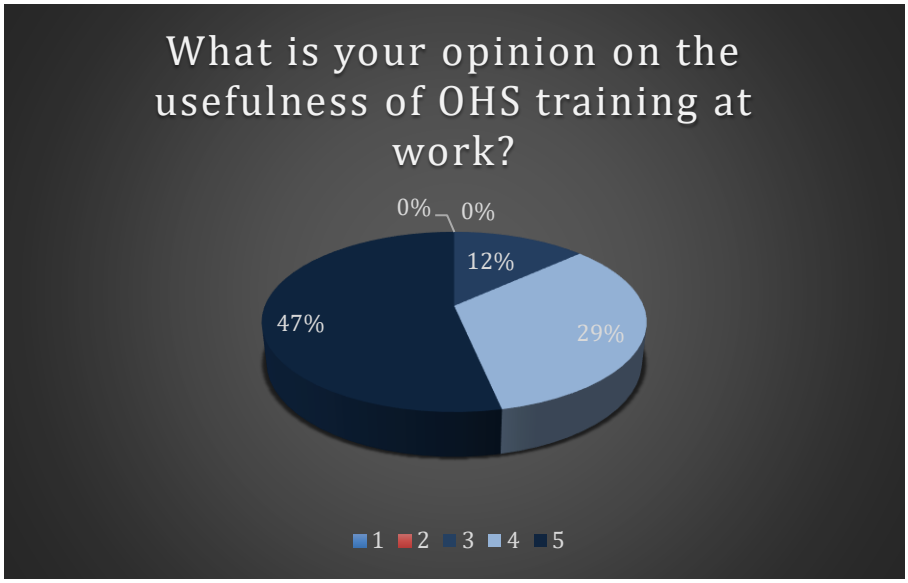

Chart 3. The usefulness of OHS training at work
Source: own elaboration based on a survey

Almost half of the employees of the Research and Innovation Centre Pro-Akademia assess their knowledge of OSH as very good. 29% of respondents selected level 3 on a five-point scale.
Such data forces us to analyse methods and techniques that are currently used in OHS training for people working in laboratories. One needs to choose the right content and the way it is transmitted. Changes in the initial and periodic training will allow more employees to become aware (both those who have some knowledge in this field after the initial training and those who will take it for the first time).

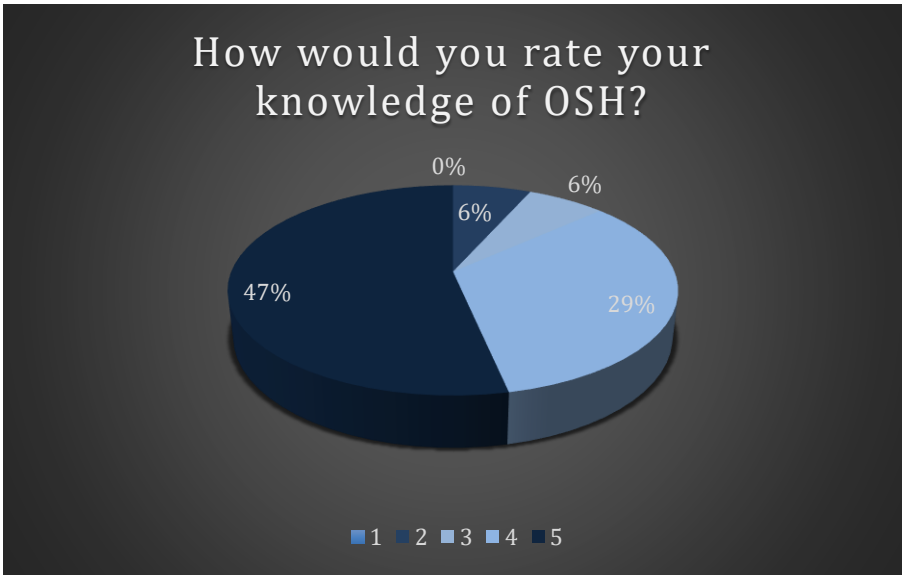

Chart 4. Knowledge of OSH
Source: own elaboration based on a survey

The most frequently mentioned reasons for disregarding OSH regulations include: routine and lack of awareness of the threat. The intentional non-compliance, overconfidence and stress answers were indicated by 24%, 29% and 35% of respondents respectively.

https://doi.org/10.32933/ActaInnovations.33.4 • ISSN 2300-5599 •

Chart 5. Reasons for disregarding OSH rules
Source: own elaboration based on a survey

According to 82% of respondents, the knowledge provided during OHS training is sufficient to be able to work safely.

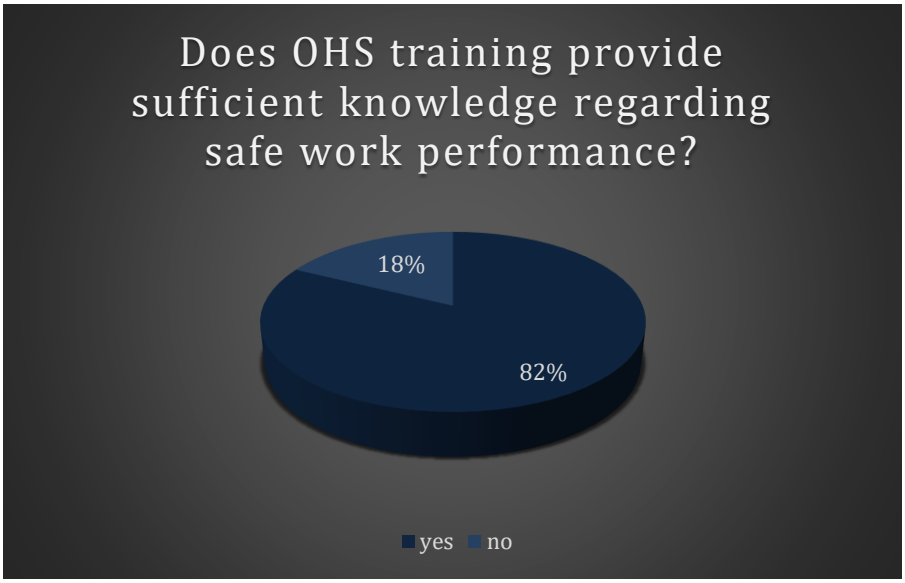

Chart 6. The usefulness of OHS training
Source: own elaboration based on a survey

OHS procedures are clear and transparent for every employee. Employee self-assessment in terms of understanding OHS procedures is very high. However, the question should be asked whether this translates into the way the duties are performed. The answers given to the above questions lead to the question of whether or not every procedure is clear. The OHS system is constructed primarily for the needs of employees, so that they can refer to it at any time and adhere to the rule while performing their duties. At the time of change, it is a ready collection of documents, based on which we are able to update and improve what was not perfect in the past.

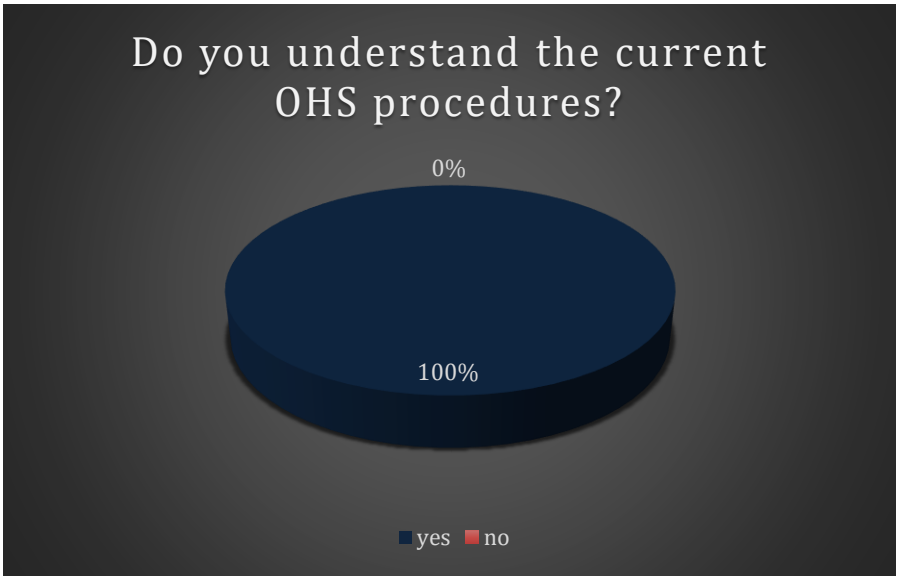

Chart 7. Transparency of OSH rules
Source: own elaboration based on a survey

According to 24% of respondents, OHS procedures are an element that hinders the daily performance of duties. This assessment of the situation may result from the lack of knowledge about the necessary safeguards. A situation when the rush will decide what actions employees will manage to perform and which ones they will skip cannot occur. The employer's task is to make people aware of the threat and the importance of the need to follow procedures. Internal regulations are built by the team, so if a given procedure does not apply in practice, then the issue should be discussed in a larger group of people and the necessary corrections to the system should be made.

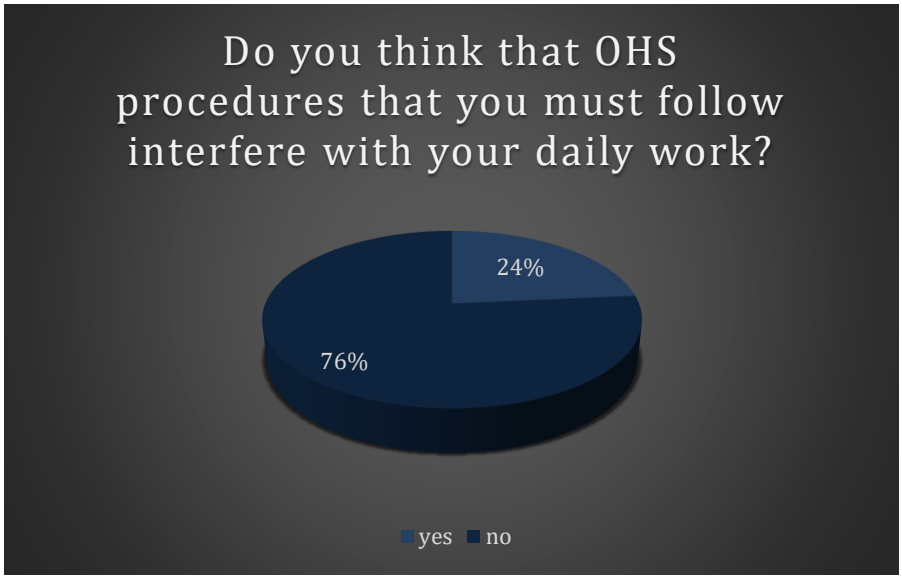

Chart 8. OHS procedures as a hindrance to everyday work
Source: own elaboration based on a survey

On the other hand, according to 12% of respondents, not all procedures are needed at the workplace.

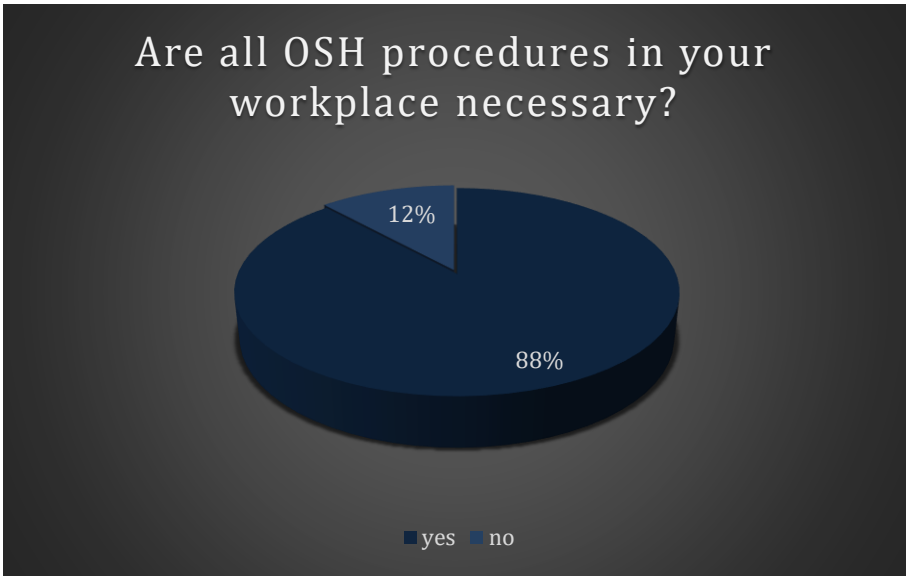

Chart 9. Usefulness of OHS procedures
Source: own elaboration based on a survey

All employees participating in the survey declare that they know the procedure to be followed in an emergency or accident. It is very difficult to predict how people will behave in an emergency situation under stress, worrying about their and their colleagues' life and health. In view of the above, it should be remembered that knowledge of the theory is the indispensable minimum to be able to assess situations and react appropriately in an emergency. The employer, making every effort to ensure that responses in emergency situations are appropriate, should ensure the appropriate frequency of refresher training in first aid.

Chart 10. Response to an emergency or accident
Source: own elaboration based on a survey

Discussion with the other scientists and papers

The occupational health and safety system is part of a broader company management system. The research shows that the employees of the Research and Innovation Centre Pro-Akademia are aware of how standards and regulations work. They are familiar with OHS rules and know what behaviours are appropriate in an emergency. Unfortunately, despite understanding the legitimacy of the regulations, they believe that there are such rules that interfere with everyday work or are unnecessary at all. The approach to OHS training also needs to be

considered because, despite employees' declarations that the training is a sufficient source of knowledge, there are cases of non-compliance with occupational health and safety regulations. The answers to the question of what this results from were spread out among all the options. The reasons for non-compliance with OHS regulations are: routine, overconfidence, stress, lack of awareness of the danger and/or the intentional disregard of regulations.
The issue of participation is especially important in the context of the integration of Poland with the European Union and the implementation of its directives. One of them is Framework Directive 89/391/EEC, in which cooperation and employee involvement in activities related to ensuring safety and health protection at work are emphasised. The system should be based on co-decision and consultation training. A system approach to OHS issues in a company is presented in the book OHS Management System. A Tool for Continual Improvement very carefully. According to Frick K, the OHS management system cannot be treated as a panacea for ensuring a stable and sustainable work environment. The implemented systems have their strengths and weaknesses, while the effectiveness depends on how the system is understood and implemented in the company. According to OHS Management System. A Tool For Continual Improvement, excessive document production is a weakness. The amount and legitimacy of documentation should be controlled because it can make us forget about the most important thing, which are people, and focus on the production of documentation instead. (Frick K., Jesen PL, Quilian M, 2000)
Although OHS management systems are currently being implemented by companies around the world, there is still no universally agreed consensus in the field of OHS management, as emphasised by Nielsen (European Agency for Safety and Health at Work EU-OSHA, 2010).

OHS management systems are obviously not a well-defined set of management systems. There are no clear boundaries between OSH activities, OSH management and OSH management systems. A "system" consists of many parts or components connected together that interact in an organised way (K. Nilsen, 2000).
According to one definition, the OHS management system is "a set of related or interacting elements for determining the principles and objectives of OHS and achieving those goals. These elements may include OHS policy, planning, organisational structure and accountability, communication and training, risk management, monitoring as well as corrective and preventive actions. Continuous improvement is one of the most important elements of successful system operation and is closely related to performance assessment and is based on the well-known Plan-Do-Check-Act (PDCA) model, also known as the Deming cycle. (WE. Deming, 1982)

The study shows that, despite many areas that have been well assessed, the works on improving the conditions and management of the OHS system at Research and Innovation Centre Pro-Akademia should not be stopped. A great example are the answers to the question about the reasons for non-compliance with OHS regulations, where routine was mentioned quite often. As Nils K. states, one must not forget about the human, the essence of the organisation, as well as the participatory approach of each participant in the management process, regardless of their position level.
The perfect conclusion seems to be the need to remember about the Deming cycle, the essence of which is continuous: planning - write down what you should do; doing - do what you planned; checking - check if you did what you planned; and acting - modify plans and actions.

Uncertainty and impact of research results on science, economy, environment and society
Living in a world of norms and regulations, we are forced to organize work spaces in a certain way. It should be remembered that following the letter of the law and introducing standards for the daily performance of duties is intended to guarantee safety in everyday life. The approach to standards should be based on the belief that they are intended to secure opportunities, and not limit them.
Lack of detail as to how the OHS documents should be created should be seen as an opportunity to build one's own company management system. The general scope described in the legislation and standards is the basis for developing one's own occupational health and safety management system. Obligations related to OHS service documentation are a very broad topic. The manner of fulfilling the obligation related to keeping documentation has been signalled by stating that it is necessary to keep records, complete and store documents regarding the working conditions for an appropriate period, identify occupational diseases and suspicions of such diseases, store test results and measure factors harmful to health in the work environment. The field for self-organisation of the OHS system allows the inclusion of all participants to create internal rules and procedures. As a result of discussions with each employee, there is a chance to create internal rules understandable for each system participant. Most importantly, each employee then becomes the author of the regulations, not just their

follower. This translates directly into the ability to move among regulations and procedures as well as their understanding and legitimacy. The implementation of an OHS management system in a company may not only facilitate compliance with applicable law, but also enable the achievement of measurable benefits related to the improvement of OHS level. An effective OHS management system makes it possible to:

- reduce the number of accidents at work, occupational diseases and related losses
- reduce absence of employees caused by sickness
- increase productivity and improve the quality of work.

Both OHS status and actions taken to improve it should be monitored. Proactive monitoring, including checking the degree of implementation and effectiveness of plans, procedures, as well as preventive and protective measures against accidents at work and occupational diseases, is of basic importance in the OHS management system. It should lead to the detection of threats and the use of appropriate preventive measures to prevent such events. Analysing the causes of accidents at work, including non-traumatic accidents and occupational diseases, are elements of reactive monitoring, which may indicate deficiencies and shortcomings in the occupational risk assessment and the use of preventive measures.

Summary and conclusions

Global trends and willingness to prove oneself against the background of not only domestic competition, but also European and global one, are conducive to designing and implementation of occupational health and safety management systems in a company.

Contemporary organisations operating in dynamically changing conditions are forced to find solutions improving individual areas of operation. What is more, efforts are being made to integrate activities in various areas contributing to increasing their efficiency and reducing own costs. The benefits of implementing an occupational health and safety management system are as follows:

- organization of formal and legal status - compliance or greater probability of compliance with legal requirements
- easier compliance with work safety requirements
- quick detecting and removing any potential non-conformities by preventing, and not correcting them
- raising team awareness about the essence of OSH
- reducing the number of accidents by supervising potentially accidental events and introducing preventive actions based on them
- a smaller number of employees exposed to harmful factors after identifying threats and taking appropriate actions (a smaller number of employees affected by occupational diseases)
- reducing the level of occupational risk
- building the company's image as socially responsible
- increasing the company's credibility
- improving the company's image
- confirmation of the importance of occupational health and safety in the company's activities
- meeting customer expectations
- improving relations with working conditions supervision bodies.

Conflict of interest

There are no conflicts to declare.

Acknowledgments

This research has not been supported by any external funding.

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PRODUCTION OF AGRICULTURAL BIOGAS FROM WASTE – AN ELEMENT OF SOCIALLY RESPONSIBLE ACTIONS IN THE FOOD SECTOR

Abstract
The agricultural and food sector accounts for substantial volumes of organic waste (such as livestock excreta, meat offals) considered as onerous on the environment. The above decomposes formulating methane, carbon dioxide and hydrogen sulphide in anaerobic conditions. Methane produced in digester chambers of a biomass plant (called biogas) may be applied for the production of electricity and heat, powering of vehicles as well as injections into gas networks. Biogas is one of the renewable sources of energy. In the light of the EU's sustainable development and climate neutrality policies, increasing the share of renewable sources in overall energy consumption is a priority for the Member States. For this reason, the article examines one of the renewable energy sectors in Poland, which is agricultural biogas production. The main attention was focused on agricultural biogas plants. Most often used substrates for biogas production, the dependence of biogas plant location on the population living in particular regions (voivodships) and the development of agriculture in their territories were analysed. The main purpose of the article was to indicate the reasons for the failure of the agricultural biogas plant construction program in Poland. Literature and document analysis were performed, interviews with waste producers as well as owners of agricultural biogas plants were carried out, and SWOT analysis was prepared.

Keywords
renewable energy, organic waste, agri-food sector, agricultural biogas, biogas plants, SWOT analysis

Introduction

Statement that *„decisions and actions undertaken by an organization always have an impact on the environment, regardless of the location of a given organization. Such impacts may be related to the use of resources, placement of organization actions, emission of pollutants as well as the impact of organization's activities on natural habitats"* [1], draws reference to all human activities. Direct hazardous aspects of this activity include:

- emission of greenhouse gases (carbon dioxide, sulphur dioxide, nitrogen oxides, methane) and dusts into earth's atmosphere;
- discharges of waste water into surface waters;
- waste created in the course of production and consumption which constitute a secondary source of pollution emitted into the atmosphere and waters.

Carbon dioxide is deemed as being a particularly harmful gas, the content of which in the atmosphere continues to grow as a result of combustion of increasing volumes of fossil fuels. Since its share in increasing the earthly temperature is considered to be the largest of all (which leads to climate changes) actions are undertaken with the goal of decreasing its emission through processing power from renewable [2] and alternative sources. The

latter group encompasses biogas, obtained from waste treatment plants and landfills and produced by biogas plants from agricultural and food waste.
Substantial volumes of waste which subsequently turns into the potential source of pollution emitted into air and surface or ground waters are created within the food chain originating from agriculture and ending with consumption [3]. The majority of them may however be used in production of biogas called "agricultural biogas". China and India are the leading producers of this gas, using non-complex installations. Asia – Japan and South Korea and in Europe – Germany possess more advanced technologies for production of biogas and these particular countries indicate the most significant dynamics of growth in its production [4]. Biogas consists of a blend of methane, carbon dioxide, nitrogen and hydrogen sulphide, whilst the latter one must be eliminated prior to combustion in CHP units. It is possible to extract biogas from municipal water treatment plants, organized landfills (the so called landfill sites) and produce it in biogas plants. There are several types of biogas plants which, depending on the applied substrates, may be divided into: rendering, agricultural-rendering and agricultural [5]. The Act on Renewable Energy Sources (from 20 February 2015) [6] defines agricultural biogas as *„fuel generated in the process of methane fermentation from agricultural raw materials, agricultural by-products, liquid or solid livestock effluents, by-products or residues from the processing of products of agricultural origin or forest biomass, with the exclusion of gas obtained from the raw materials generated by water treatment plants and landfills "*. Agricultural biogas is generated by biogas plants formed by a complex of built structures adjusted to transforming the above specified raw materials (substrates) into biogas [7]. The substrates, as a result of the process of methane fermentation, are transformed into biogas (blend of: methane 40-85%, carbon dioxide 16-48% and nitrogen 0,6-7,5%) as well as digestate [8]. The obtained biogas, upon prior elimination of hydrogen sulphide, carbon dioxide and water vapor, is most frequently combusted in cogenerators as a result of which electricity and thermal energy are produced. The efficiency of cogeneration aggregates amounts to approx. 90% – electricity 40%, whilst thermal energy – 50%. Approx. 30% of thermal energy is used for sustaining the processes inside the bioreactor. Provided there are no major issues related to the sale of electricity, the sale of thermal energy is not at all times possible, which translates into a decreased investment profitability. Actions targeted at using biogas for vehicle powering [4] and injecting it to natural gas networks [5] are ongoing. The by-product released in the course of biogas production from agricultural and food waste is digestate which, post drying and sterilizing, may be used as a high quality organic fertilizer.

The objective of the hereby article was to identify the reasons behind the failure to realize the programme specified within the document of the Council of Ministers [9] as well as to indicate actions which might accelerate its subsequent realization.

Method
The designated goal was achieved within the article through conducting a critical analysis of the subject literature as well as statistical data gathered from the National Support Centre for Agriculture (NSCA), Towarowa Giełda Energii (TGE) and Central Statistical Office (CSO). Direct interviews with the owners of agricultural biogas plants and landfills as well as the inhabitants, further to data obtained from the subject literature [10] and analysing legal regulations [6, 11, 12] contributed to the conduct of SWOT analysis for agricultural biogas plants.

Results
Among the European countries the sector of agricultural biogas has acquired the most advanced form in Germany, where in 2018 as many as 9.5 thousand biogas plants were in operations [13]. In Poland, natural conditions are relatively alike in comparison to those experienced by our western neighbours and thus the development of biogas plant network would surely be a successful venture [2]. At present, our country holds 99 agricultural biogas plants (status as at 25.08.2019) which operate primarily on the basis of the German technology. Their total annual capacity equals 424 739 201 m^3 of agricultural biogas, which constitutes less than 10% of its estimated potential (let us recall that the estimation amounted [9] to 5 billion m^3). The total electric power of the installations in place equals 104,865 MWe [14].

Within the territory of Poland, agricultural biogas plants are unevenly scattered (compare table 1). The majority of biogas plants may be found in the following voivodeships: West Pomerania – 13, Greater Poland – 11, Lower Silesia – 10, Warmia-Masuria – 10, Podlaskie – 9, Pomerania – 9, whilst the least of them are located in: Świętokrzyskie – 1, Opolskie – 1, Lesser Poland – 2, Silesia – 2. Voivodeships with the largest number of this type of objects are distinguished by a substantially lower than average density of population (with the exception of Lower Silesia) and the location of ample larger agricultural farms which are involved in plant cultivation and

https://doi.org/10.32933/ActaInnovations.33.5 • ISSN 2300-5599 •

farm animal breeding (caws, pigs, poultry) continuing the activity of former state-owned agricultural holdings from before 1990.

Table 1. Number of agricultural biogas plants in Poland divided into voivodeships

Voivodeship	Population density [persons/ km^2]	Number of biogas plants	Annual capacity [Thousand m^3/year]		Installed power [MW$_e$]	
			Total	Per installation	Total	Per installation
Lower Silesia	**146**	10	34,491	3,449.1	10.41	1.041
Kujawy-Pomerania	116	6	29,679	4,946.5	7.991	1.332
Lubelskie	85	7	36,100	5,157.1	9.859	1.408
Lubusz	73	4	11,100	2,775.0	2.792	0.698
Łódź	**137**	4	21,913	5,478.2	5.057	1.264
Lesser Poland	**222**	2	20,946	10,473.0	4.899	2.449
Masovia	**150**	6	5,370	1,074.0	1.150	0.230
Opole	106	1	8,000	8,000.0	2.000	2.000
Podkarpackie	119	3	10,948	3,649.3	2.498	0.833
Podlaskie	59	9	31,458	3,495.3	7.596	0.844
Pomerania	**126**	9	47,968	5,329.7	10.159	1.129
Silesia	**371**	2	6,400	3,200.0	1.596	0.798
Świętokrzyskie	107	1	2,464	2,464.0	0.800	0.800
Warmia-Masuria	60	10	38,883	3,888.3	8.464	0.846
Greater Poland	117	11	38,253	3,477.5	10.678	0.970
West Pomerania	75	13	52,081	4,006.2	11.690	0.899

Source: Own elaboration based on the materials from the National Support Centre for Agriculture [11].

The most advantageous conditions for production of agricultural biogas from cow faeces have been reported in the following voivodeships: Greater Poland, Warmia-Masuria, Kujawy-Pomerania, Masovia and West Pomerania. On the other hand, with regards to production of biogas from pig faeces the most advantageous conditions have been noted in the following voivodeships: Greater Poland, Lower Silesia and Lubelskie, whilst in the case of poultry: Masovia, Greater Poland and Łódź. Thus, the most advantageous conditions for production of agricultural biogas from animal faeces may presently be found in Greater Poland Voivodeship which is on the second place when it comes to the number of agricultural biogas plants [15].

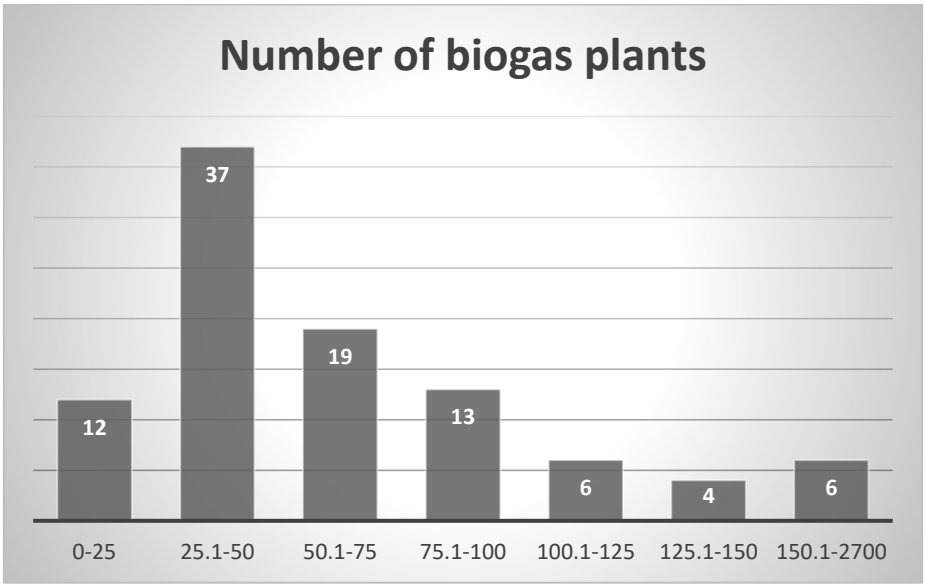

Figure 1. Dependence of the number of biogas plants on population density (persons/km^2) in municipalities
Source: Own elaboration based on [11]

Almost all agricultural biogas plants (81.83%) are located in municipalities with population density below 100 persons/km^2 (compare Fig. 1), whilst the largest number of such objects (37.38%) may be found in municipalities with population density between 25 and 50 persons//km^2.
In Poland, agricultural biogas plants use organic waste as substrates – 73.65% (i.e. manure, slurry, chicken slurry, silage from grass and corn) and targeted cultivation – 26.35% (that is cultivated with a designation for production of electricity and/or thermal energy) [16). The most frequently encountered however are: slurry, fruit and vegetable leftovers, distillery grains and silage from corn [17]. Data concerning the use of individual fractions of waste in production of biogas in Poland (in the years 2011, 2013, 2016) have been presented in table 2.

Table 2. Raw materials used for production of agricultural biogas in the years 2011, 2013 and 2016

Substrates	Years					
	2011		2013		2016	
	thousand Mg	%	thousand Mg	%	thousand Mg	%
Slurry	266	56.7	456	29.0	775	24.0
Fruit and vegetable leftovers	11	2.3	269	17.1	665	20.6
distillery grains	30	6.4	35	22.6	476	14.8
Silage from corn	109	23.2	287	18.2	439	13.6
Marc	7	1.5	102	6.5	222	6.9
Technological sediments from agricultural and food industry	6	1.3	14	0.9	125	3.9
Dairy industry waste	2	0.4	13	0.8	89	2.8
Manure	12	2.6	30	1.9	86	2.7
Green fodder	13	2.8	2	0.1	5	1.8
Waste biomass	2	0.4	2	0.1	33	1.0
Waste from food industry	1	0.2	4	0.3	30	0.9
Out of date foodstuffs	0	0	0	0	29	0.9
Other	10	2.1	40	2.5	198	6.1
Total	469	100	1574	100	3224	100

Source: Own elaboration based on [18]

When analysing data presented in Table 2 one may conclude that with the continuous new appearances of biogas plants the mass of used substrates shifted (more than triple increase in the initial tested period, whilst in the second one – twofold) further to its percentage share. In 2011 slurry constituted more than half of the mass of used substrates, since out of 14 operating at the time biogas plants 8 belonged to the company Goodvalley Agro S.A. which owned large pig farms in Pomerania and West Pomerania Voivodeships. In the subsequent years the share of such substrates as fruit and vegetable leftovers, distillery grains and silage from corn escalated.

Between 2011 to 2016 the mass of organic waste used as substrates in domestic agricultural biogas plants increased almost 7 times (Table 2). The highest increase was observed in the case of fruit and vegetable residues (from 11,000 Mg to 665,000 Mg) and distillery waste (from 30,000 Mg to 476,000 Mg). Between 2011 and 2016, the amount of maize silage used for biogas production also increased from 109,0000 Mg to 439,000 Mg. This growth is at the expense of reducing the acreage of other crops and threatens to cause a shortage of forage as it happened in Germany [19].

The obtained information regarding agricultural biogas plants enabled the conduct of strategic analysis for the enterprise with the use of SWOT analysis *(Strength, Weakness, Opportunities, Treatment),* which has been presented in Table 3. It transpires that the strong sides of agricultural biogas plants include the possibility of using and utilizing waste produced by agricultural and food industry for production of biogas which may subsequently be applied for power supply purposes or as a fuel for powering vehicles. The digestate which is a by-product in production of biogas may be used as an organic fertilizer thus bringing financial benefits to owners of biogas plants and to the environment.

Table 3. SWOT analysis of agricultural biogas plants in Poland

Strong sides	Weak sides
▪ greater stability in electricity and thermal energy supplies than in the case of other RES, such as for instance: wind energy or solar energy, ▪ strongly developed agriculture and large volume of agricultural and food waste, ▪ utilization of animal faeces preventing the emission of methane to the atmosphere, ▪ decreased volumes of gathered waste of animal and plant origin, ▪ cogeneration as an eco-friendly manner of electricity and heat recovery from waste, ▪ digestate applied as high quality organic fertilizer, ▪ creating new work places for the local society.	▪ lack of spatial management plans in the local municipalities which would encompass the possibility of locating construction area for a biogas plant, ▪ high investment costs, ▪ high power production costs when compared to other RES, ▪ long-lasting process of arranging for permissions for biogas plant construction, ▪ non-stability of law concerning RES and the power market, ▪ lack of support on the side of the country, ▪ problem with managing heat in the period off the heating season, ▪ resistance of the local community, ▪ odour nuisance, ▪ methane explosion hazard, ▪ the possibility of contamination of surface and ground water in the event of a system breakdown, ▪ significant costs of connecting the biogas plant into the power grid.
Chances	**Threats**
▪ favourable price of “blue certificates”, ▪ EU energy policy focusing on obtaining energy from RES, ▪ high fees paid by the producers from agricultural and food sector for utilization of waste which might constitute biogas plant's substrate, ▪ existence/construction of large food processing plants in vicinity of a biogas plant, ▪ close vicinity of large animal farms such as cattle, pigs, poultry, ▪ expansion of the local power grid, ▪ possibility of selling heat and gas, ▪ constantly growing demand for electricity.	▪ drop in the prices of “blue certificates”, ▪ volatility of prices of substrates originating from power-targeted cultivations, ▪ drop in the prices for utilization of agricultural and food waste, ▪ drop in the prices of conventional fuels, ▪ increase of land tax and property tax, ▪ shutdown of large food processing plant that provided substrates for the biogas plant, ▪ animal epidemy causing entire herd culling, ▪ recurrent natural disasters (droughts, floods, hailstorms, frosts, hurricanes etc.).

Source: Own elaboration

The benefits stemming from biogas plants' operations can substantially overshadow the weaknesses of this type of investments. These include: high construction costs, long period of obtaining building permits, no local spatial development plans that would prevent the protests of local residents due to the unpleasant smell nuisance of this type of activity for residents.

The operation of a biogas plant can be associated with a methane explosion hazard that can cause human casualties and emissions of hydrogen sulfide, methane and carbon dioxide [20]. The unfavourable situation on the agricultural biogas plant market in Poland is also affected by the emerging threats resulting i.e. from the fall in prices of "blue certificates," utilization of waste and conventional fuels, the increase in taxes and the downturn of the agri-food industry. Fortunately, opportunities for improvement may appear, such as an increase in prices of "blue certificates" conducive to investment in the biogas market, EU energy policy geared to supporting this type of business, high costs and the obligation to dispose the waste in the agri-food industry.

The production of biogas used for electricity and heat production is not the only benefit of biogas plants. A by-product of anaerobic methane fermentation is digestate used as a natural fertilizer in agriculture and horticulture, which has a positive effect on soil quality and contributes to an increase in the number of crops. What is more, grown plants have greater health properties, due to the appropriate content of macroelements (nitrogen, phosphorus, potassium) and microelements. At the same time, the number of nitrates and nitrites in agricultural products is reduced and cereals contain more B vitamins, carbohydrates and high-quality protein. The digestate has better nutritional properties than traditional slurry or manure, because plants better absorb the ingredients contained in the slurry after its fermentation. The use of digestate reduces the risk of groundwater contamination by nitrogen and phosphorus compounds, as it can occur when raw organic fertilizers (manure and slurry) are used. By using digestate as a fertilizer, we also avoid the risk of introducing pathogens and weed seeds into the soil [1].
The use of digestate as a fertilizer has another important advantage, which is the reduction of unpleasant odours associated with natural fertilizer dumps. The digestate is much less odorous than fermented liquid slurry or manure. When fertilizer, which is digestate, is intended for sale, it becomes a source of additional income for a biogas plant [2].

The most important advantage from the point of view of environmental protection is the production of fuel, the combustion of which causes zero balance of carbon dioxide emissions to the air. Methane contained in biogas comes from carbon dioxide taken from the atmosphere by plants during vegetation. Producing 1 MWh of electricity from agricultural biogas also results in emissions of sulphur dioxide and nitrogen oxides into the air several times lower than in case of fossil fuels (mainly coal). Biogas plants, using organic matter for biogas production, limit its uncontrolled decomposition and thus reduce the emission of methane to the atmosphere [2].

Discussion
Biogas plants can be an important element of the national energy policy specified in the document, adopted on 10 November 2009 by the Council of Ministers, entitled "Polish energy policy until 2030" [12]. It assumes that in 2020 energy from renewable sources (RES) will have at least a 15% share in final energy consumption (electricity, heat and cold). It also anticipates "a further increase in this indicator in subsequent years." What is more, it assumes a 10% share of renewable energy on the transport fuel market [5].

The EU is facing ever greater challenges for member states to achieve climate neutrality. In November 2016, the European Commission published its 'Clean Energy for all Europeans' initiative. As part of this package, the Commission adopted a legislative proposal for a recast of the Renewable Energy Directive. In the context of the co-decision procedure, a final compromise text among the EU institutions was agreed in June 2018. In December 2018, the revised renewable energy directive 2018/2001/EU entered into force [21].

Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources, called RED II. "In RED II, the overall EU target for Renewable Energy Sources consumption by 2030 has been raised to 32%. Within the 14% transport sub-target, there is a dedicated target for advanced biofuels produced from feedstocks listed in Part A of Annex IX. The contribution of advanced biofuels and biogas produced from the feedstock listed in Part A of Annex IX as a share of final consumption of energy in the transport sector shall be at least 0.2 % in 2022, at least 1 % in 2025 and at least 3.5 % in 2030. Renewable electricity will count 4 times its energy content towards the 14% renewable energy in transport target

when used in road vehicles, and 1.5 times when used in rail transport. The Commission will also develop a framework to guarantee that the renewable electricity used in transport is in addition to the baseline of renewable electricity generation in each Member State [21].

In December 2019, at the EU leaders' summit, the European Commission presented the main assumptions of the European Green Deal, which envisage further tightening of climate goals, including a reduction of greenhouse gas emissions by at least 50% till 2030. (formerly it was 40%). To achieve this goal, the emissions trading system will be revised, as well as a new tax policy and climate law will be introduced. Investments in green innovation will increase. Supported by investments in green technologies, sustainable solutions and new businesses, the Green Deal can be a new EU growth strategy [22]. To achieve the presumed goals, EU countries must put more emphasis on renewable energy. Increasing biogas production (including agricultural biogas) in Poland may contribute to switching local power and heating plants to this energy source. This concept can be implemented mainly in rural areas, where agricultural production, culture (cultivation of crop plants, animal husbandry) and forest management are carried out. The estimated raw material potential in this type of areas in Poland was estimated in 2013 at the level of production of about 5 billion cubic metre of agricultural biogas annually with high-methane natural gas parameters [15].

Production of energy and heat in agricultural biogas plants would increase the country's energy security. Given the constantly increasing demand for energy, the construction of agricultural biogas plants in rural areas would be an antidote to the more frequent power outages caused by adverse weather conditions [7]. Situations of this type occur more often in Poland, even in the summer months, when the demand for electricity is often higher than in winter (related to the production of cold). In Polish conditions, agricultural biogas plants also have an advantage over wind or solar power plants due to the fact that energy derived from biomass and waste can be produced more evenly than from other RES. The only condition is to ensure the quality of the substrates. It is known that agriculture generates a very large amount of organic waste, which is a serious problem for farmers and communes. Waste that does not pose an epidemiological threat but has nutritional value can be processed into animal feed, fertilizer or used in other production processes. On the other hand, managing other waste poses many problems, as their disposal is often costly and time consuming. This applies especially to waste from gastronomy, agri-food production and slaughtering of animals. One of the possibilities of their management is using them as substrates in agricultural biogas plants. This is a particularly attractive perspective for producers who generate very large amounts of organic waste with high energy value. The use of this type of waste for the needs of biogas plants allows their utilization in an economically more advantageous way compared to traditional methods [23].

In Poland, according to the document adopted on 13 July 2010 by the Council of Ministers entitled "Directions for the development of agricultural biogas plants in Poland for the years 2010-2020" [5], it is possible to produce about 5 billion cubic metres of agricultural biogas. "The realistically available raw material potential for biogas production, contained in agricultural by-products and waste of the agri-food industry, is about 1.7 billion cubic metres per year" [9]. This would cover about 10% of the country's gas demand or 100% of the gas demand of rural consumers and produce additional amounts of electricity (estimated at around 125,000 MWhe per year) and heat (estimated at around 200,000) MWhe per year) [9].

According to the previously mentioned document, in 2020 one biogas plant is expected to operate on average in each commune [9]. Since there were 2,477 communes in Poland at the beginning of 2019, there should already be about 2,000 of them in the country (according to cautious estimates). Meanwhile, in 2018 biogas was produced only by 97 biogas plants, whose annual capacity was about 405 million cubic metres. The obtained biogas was burned in cogeneration aggregates producing electricity and heat, whose total installed electric power is about 102 MW [11].

The state of development of agricultural biogas plants in Poland is related to the functioning of the operating support system for renewable energy sources. Until 2016, it was the so-called a system of certificates of origin (green certificates), as well as support for the production of heat energy in cogeneration in the form of "yellow certificates." The factor supporting the improvement of the situation on the biogas market was supposed to be the investment support mechanism in the form of subsidies and low-interest loans in the EU financial perspective 2007-2013. The value of subsidies granted was to be 30-70% of eligible costs at an average unit investment cost of 10-16 million PLN/MW [13].

The effect of favourable subsidies were investments in agricultural biogas plants with a capacity of 0.5-1.5 MWe, which in 2015 accounted for 55% of all working installations. On the one hand, biogas plants of this size enable optimization of investment outlays, and on the other, maximization of revenues from green energy and certificates of origin. Larger biogas plants are built less often because of the complex logistics of raw material supply, as well as the potential impact on the environment and the associated risk of social protests [24].

The factor limiting the creation of agricultural biogas plants was the lack of prospects of stable conditions for the implementation of the investment, primarily in terms of the amount, length and form of financial support. The prices of renewable energy certificates of origin (so-called green certificates), listed on the Polish Power Exchange (TGE), also decreased. In the years 2011-2015, prices of certificates of origin dropped from PLN 280 to PLN 120. As a result, the biogas plant's revenues decreased from PLN 480 to PLN 300/MWh, which was the border price for profitability [24]. This, in turn, reduced the interest in investing in the biogas market, and those projects that had already begun to be implemented, were frozen at the initial stage. Commenced investments were suspended in order to be able to take advantage of the provisions in the new RES Act and clarification of the new auction system.

The Act of 29 December 2015 on renewable energy sources, called the Energy Law, introduced a distinction between energy certificates of origin, effective from 2016, depending on the source of its production. "Green certificates" are issued for energy generated from all renewable sources, except for agricultural biogas, for which the so-called "Blue certificates" have been introduced. They were more expensive than "Green certificates," as shown in Figure 2. This, combined with the modification of the auction system, increased the profitability of installations operating on the biogas market. This situation also encouraged potential investors who planned to build new biogas plants. If the adopted solutions are maintained, this is conducive to the development of the domestic energy sector. The introduction of a long-term solution, guaranteeing the maintenance of the purchase price of energy, produced from biogas (in Germany it is 20 years) should be considered [20].

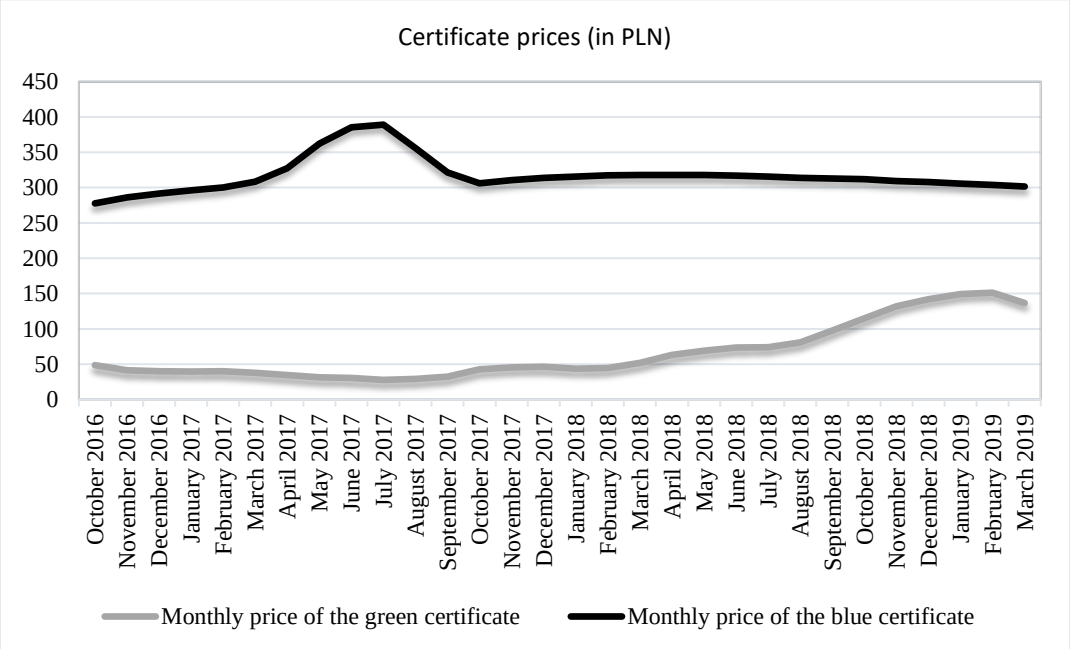

Figure 2. Price relations of green and blue certificates
Source: [25]

Despite the above-mentioned favourable conditions for the sector, there are further barriers to its development. According to investors, the creation of biogas plants is hindered by the issue of permits, arrangements, opinions and other acts in the field of spatial planning and development, environmental protection, nature protection or building law that precede the construction process. The legal regulations related to the construction of biogas plants are the same as for the construction of other industrial plants and it seems that they should remain so. The functioning of biogas plants causes increased traffic of heavy vehicles and risk of road accidents, destruction of the road surface, increased exhaust emissions and, in the case of incomplete containment of the process,

unpleasant smell. Pursuant to the Act of 22 June 2017 on access to information on the environment and its protection, public participation in environmental protection and environmental impact assessments, "biogas plants are investments that have the potential to significantly affect the environment." The introduction of more liberal regulations could cause even greater reluctance of rural residents, whose expected benefits, in the form of a market for their agricultural products or jobs, do not compensate for the inconvenience [7].

Therefore, it seems that a new approach to local spatial development plans in rural areas is needed. Communes should designate places for construction of biogas plants that are distant from areas designated for housing construction, which develops very quickly near cities. The observed process of urban population moving to the countryside means expanding of the areas excluded from food economy, which are associated with agricultural biogas plants, they cover up to 20 km of the area outside the borders of medium-sized cities and are much larger in the case of large agglomerations.

As for the use of digestate produced in biogas plants, placing it on the market as organic fertilizer is only possible after meeting the requirements set out in the Regulation of the Minister of Agriculture and Rural Development of 18 June 2008 on the implementation of certain provisions on fertilizers and fertilization (Journal of Law no. 119, item 765). This regulation imposes an obligation to test organic fertilizers or plant conditioners for their suitability for fertilizing soils and plants. The digestate to be considered as a soil quality improvement agent must be tested in physio-chemical, chemical and microbiological terms. In Poland, this type of research is performed by voivodeship and poviat sanitary and epidemiological stations [26].

Uncertainty and impact of research results on science, economy, environment and society

The construction of biogas plants in Poland is associated with a number of difficulties, resulting primarily from uncertainty arising from the external environment. Risk factors may be of a macro (general economic) and mesoeconomic (industry) nature. Enterprises receive signals from the monetary and budgetary policies of the country implemented at a given time to what extent they may be guided by their own interests in their activities. Monetary policy affects: the level of interest on bank loans; the possibility of obtaining soft loans; obtaining of loan repayment guarantee etc. In favourable conditions, entrepreneurs can count on cheaper loans, and therefore the economy is developing, creating new products, new jobs and filling the budget with direct and indirect taxes. In turn, budget policy: shapes the amount and types of taxes paid; determines the tax relief and the direction and amount of transfer payments, including to support specific activities or develop specific territories (e.g. subsidies, investment grants, etc.). In addition, it is the state that is responsible for regulatory risk, as there is uncertainty about the ever-changing legal provisions. The assumptions adopted in the Document of the Council of Ministers "Directions for the development of agricultural biogas plants in Poland in the years 2010-2020" [9] have no chance of being implemented. Faster development of agricultural biogas plants in Poland would be possible if the legislator and the government introduced legal and financial facilitations for investors. Communes that would like to facilitate the construction of agricultural biogas plants for potential investors should find places in their local spatial development plans for their location. Such information should be made public to avoid a situation of issuing permits for the construction of residential houses in a biogas plant protection zone. This is very important because spatial development plans are adopted by communes and building permits are issued by Poviat Starosties.

In addition to economic risk, the investor is exposed to the risk of lack of social acceptance because people are often afraid of: unpleasant smell; heavy vehicle traffic; reducing the value of plots and real estate in a location close to the biogas plant. This may result in protests from the authorities and the local community. On the other hand, the already constructed biogas agricultural waste processing plant is exposed to ecological risk in the event of a breakdown and, consequently, increased costs and social dissatisfaction.

Summary and conclusions

The construction of an agricultural biogas plant has become a profitable investment after the introduction of "Blue certificates" in 2016. This revived the industry and appeased biogas plant owners, who were often on the verge of bankruptcy before implementing these regulations. An agricultural biogas plant can also profit from the sale of digestate as an organic fertilizer, which is a good alternative to traditional fertilizers and can attract interest of local farmers. It is also beneficial for breeders of slaughter animals, slaughterhouses and the food industry, as they will incur lower costs of waste disposal. In many cases, they are limited only to the cost of transporting waste to the biogas plant.

Based on the analysis of the literature and interviews, a SWOT analysis of the construction of a biogas plant has been carried out.
Its results made it possible to indicate the following main reasons for low implementation of biogas policy in Poland:

- lack of a comprehensive government support program for the construction of agricultural biogas plants including a program of subsidies, low-interest loans and a long-term program of guaranteed electricity prices;
- existing subsidies, unfortunately, are granted only in the case of construction of small agricultural biogas plants (with a capacity of 0.5-1.5 MWe), which causes their large dispersion in the territory of the country;
- a large number of small biogas plants creates logistical problems related to the supply of substrates to many different places and additional costs (financial and environmental) on a national scale,
- a large number of small, low-power biogas plants are associated with an additional negative impact of their activities on society and the environment;
- the lack of long-term local spatial development plans in most communes means that the existing single-family houses turn out to be in the "impact zone", which causes social opposition to the construction of a biogas plant.

Despite many problems and barriers, there is a good chance for further development of this sector in Poland. Many potential investors see a number of benefits in building agricultural biogas plants. However, they are deterred by excessive bureaucracy, high construction costs and a long investment period. The data presented in the Bio Alians database shows that in 2016 there were 570 agricultural biogas plant projects, 95 of which were already existing installations. The database includes 475 agricultural biogas plants projects at various stages of completion with a total planned capacity of 570 MWe. A positive environmental decision was issued for 243 projects [27]. This means that the potential for building agricultural biogas plants in Poland is high and a change in legal regulations to more favourable and larger government subsidies would contribute to the development of the domestic biogas energy sector.

Conflict of interest
There are no conflicts to declare.

Acknowledgments
This research has not been supported by any external funding.

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ENVIRONMENTAL RISK MANAGEMENT IN THE CONTEXT OF ENVIRONMENTAL MANAGEMENT SYSTEMS FOR AGRICULTURE BASED ON THE ISO 14001:2015 STANDARD

Abstract
Agriculture is a risky industry because forces beyond human control influence the quality and profitability of their activities. Farmers' incomes reveal high volatility due to product and crop price as well as catastrophic risks such as natural disasters and diseases. The following paper discusses different methods, also those not specific to EMS, and their exemplary application. An attempt has been made to answer the question of what methods of risk analysis and management are appropriate for agriculture. The goal is to identify methods which can be used in EMS for agriculture, especially in the family farmsteads. The paper is based on the latest, third edition of ISO 14001.

Keywords
risk, risk management, agriculture, family farmsteads, EMS, ISO

Introduction

According to ISO 14001, risk can be defined as effect of uncertainty. An effect is a deviation from the expected — positive or negative behavior. Uncertainty is the state, even partial, of deficiency of information related to, understanding or knowledge of, an event, its consequence, or likelihood. Risk is often characterized by a reference to potential *"events"* and *"consequences"* (as defined in ISO Guide 73:2009, 3.6.1.3), or a combination of these. Risk is often expressed in terms of a combination of the consequences of an event (including changes in circumstances) and the associated *"likelihood"* (as defined in ISO Guide 73:2009, 3.6.1.1) of occurrence.

In terms of environment and safety management, the term 'risk' may be defined as the most likely consequence of a hazard situation, combined with the likelihood or probability of it occurring. Usually, health, safety, and the environment are linked despite being separate disciplines [1]. The reason for this is organizational management structures. Furthermore, there are strong links among these disciplines, for example, that a single risk event may have impacts on the all above areas, albeit over differing timescales. For example, the uncontrolled air pollution has an impact on the environment, which is the decrease of air quality, and the impact on human health, which may be an increase of lung diseases.
Risk management is a relatively recent corporate function. From the very beginning, risk management has been associated with pure economics: the use of market insurance to protect individuals and companies from various losses associated with accidents [2]. Over time, environmental risk analysis has developed, which is a field of study that attempts to explain events and activities that bring risk to the environment or human health [3].
Risk management is the taking of decisions and the implementation of actions aimed at achieving an acceptable level of risk by an entity. In practice, risk management is identified with risk diagnosis and control processes, the objective of which is to intentionally ensure stable financial results and to create conditions for further development [4].

From the agricultural point of view, risk is imperfect knowledge where the probabilities of the possible outcomes are known and uncertainty when these are not known. Thus, improving risk assessment and risk management methodologies will affect resilience in agriculture and, as a consequence, leverage finance and investments [5]. This observation can also be applied in few other areas with beneficial impacts for all stakeholders. Furthermore,

countries that have risk indexes such as low social vulnerability and adequate coping capacity under control, tend to have better economic performance [6].
Regarding the environment, there are two types of environmental risk. The first is the possibility of negative deviations from corporate aims by environmental effects [7]. It is the risk which is created by the environment and may have a negative impact on a company, for example a flood or heavy rain which may destroy the crops.

The other is the possibility of negative effects on the environment, caused by the presence and activities of a company, with following compensating reactions, burden or overload of the environment [8]. To illustrate this type of risk, the example of contamination of groundwater by pesticides may be used.
The aim of this paper is to review risk management methods and to indicate which of them can be used at different stages of the process in family farms that have implemented the ISO 14001 standard.

Materials and methods
In the following analysis, the focus is primarily on the ISO 14001 standard. The overall goal of ISO 14001 is the improvement of the environment. It is the added benefit of reduced business risk and increased operating efficiencies that have brought the acceptance of the standard to what it is today. It specifies requirements that enable an organization to achieve the intended outcomes it sets for its environmental management system.

The latest, third edition of the ISO 14001 standard has been released after a relatively long period of time. The previous version was reviewed and introduced with changes in 2004. The relatively long period of time between revisions was also influenced by the fact that the changes introduced in the standard are so significant that they cause an almost complete change in the content of the standard.

The reading of the standard clearly indicates the increase in the importance of environmental management in planning processes. Introduced new requirements in terms of understanding the organization's context and impact of interested parties in a radical way affect the perception of environmental threats from the organization as well as the environmental impact on the organization. Consideration of the interested parties at the planning point means taking the requirements of state authorities, administration or other influences that may pose a threat to the organization or provide opportunities into account.

Risk is an important part of the Environmental Management System (EMS), because it has strong impact not only on the environment, but also on a company's image and its financial performance. Standard risks and opportunities were mentioned twice in the ISO: first in the planning chapter as actions to address risks and opportunities and second in the operation chapter as emergency preparedness and response. According to ISO 14001, each risk management process consists of four successive stages: risk identification, risk assessment, risk management, monitoring and control of risks. An attempt was made to review not only environmentally specific methods of risk identification, but also risk assessment and risk management.

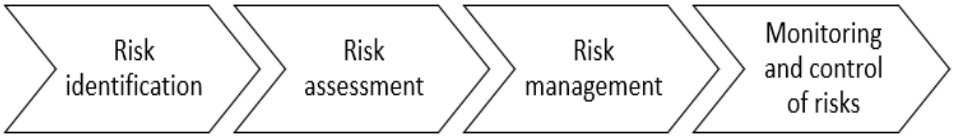

Figure 1. Risk management process
Source: Jajuga, 2007

Most of the reviewed risk assessment methods contain common elements, which include: the identification of hazards, the assessment of the likelihood of potential hazards and the losses they may cause. This applies to both the business and the environmental spheres. Regardless of which methods or strategy the company chooses, it is always necessary to collect information that will help to identify and develop an optimal methodology for risk management.

In order to achieve the objective of the study, the current literature on risk management has been reviewed. Resources available in the ScienceDirect - Elsevier database were used for the study. The search for literature on the subject was conducted according to the following keywords: risk management, ISO14001, agriculture. In the first stage of the research, risk management methods were assigned to particular stages of the risk management

process. After that they were reviewed and examined as to whether they are appropriate for EMS and finally whether they are appropriate for risk management in agriculture. Guidance on the implementation of these methods in an organization dealing with agricultural activity is also presented.

Results of the review of risk management methods

Agriculture is associated with the pursuit of certain economic activities by a specific entity. Usually, an investment is a part of a business which is supposed to achieve the assumed goals, mainly economic. A number of activities carried out are therefore connected with making many decisions. Every economic decision includes an element of risk, which is naturally an innate part of doing business [10]. The implementation of agricultural investments within the framework of the conducted business can therefore be described as exposed to high risk due to such characteristic features as: high complexity of problems, long execution and production cycle, capital intensity, high involvement of material resources, complicated system of cooperation, a wide range of stakeholders and natural factors which are not influenced by the participants [5].

The development of a working methodology for the entire project management team is of great importance in the project risk management process. The construction of the decision-making platform will constitute a constant point of reference for all project stakeholders during the implementation of subsequent stages of the risk management process. The roles and responsibilities of risk managers, risk management costs, deadlines for action (control, monitoring), risk categories and classifications should be defined. Risk identification, as the next stage of project risk management, contributes to determining which threats may appear during the project life cycle. The identification is carried out continuously and repeatedly as a detailed description of the data already processed or in response to new situations. Risk factor identification methods usually require the contact of many people in the form of meetings of the project manager, project management team, persons responsible for a given risk factor, internal and external experts, client, investor and other stakeholders of the project. The result of individual or group workshops is usually a list of identified risk factors, which will be assessed during a qualitative and quantitative analysis to determine how to react to the risk. The consequence of the risk management process is a continuous monitoring and control process. It is a planned supervision over the entire project and risk monitoring. Both the factors disclosed in the identification process and the new ones, which were not diagnosed earlier and were disclosed during the implementation, are subject to constant observation.

Monitoring is aimed at activating planned remedial actions by introducing established reactions to a given factor. The result of iteration, i.e. the re-examination of a given event, may be: a change in the risk factor's importance status, a change in the resource responsible for the monitored factor and a modified approach to the response to its occurrence [11]. Table 1 presents risk management methods indicating those which, in the opinion of the authors, are most useful for family farms, which can be used and those whose use is not recommended.

Table 1. Scope of using risk Management methods in the management process, XXX – Predominant use, X – Secondary use.

	Risk identification	Risk assessment	Risk management	Monitoring and control of risks
Analogy comparison	XXX	X	X	
Assumption analysis	XXX			
Avoidance of risk				XXX
Brainstorming	XXX		X	
Checklists			X	XXX
Crawford Slip Method (CSM)	XXX		X	
Decision analysis - Expected monetary value		XXX		
Decision Tree		XXX		
Delphi technique	XXX	X	X	
Documentation review	XXX		X	X
Estimating relationships		XXX	X	
Expert interviews	XXX	X	X	
Failure Mode and Effect Analysis FMEA	XXX	X		
Financial control of risk				XXX
Monte Carlo simulations		XXX		
Network analysis	X	XXX	X	
Performance tracking			X	XXX
Plan evaluation	XXX			
Planning meetings	X	X	XXX	
Program Evaluation and Review Technique (PERT)	X	XXX		
Project templates		X	XXX	X
Rating schemes		XXX	X	
Risk factors		XXX	X	
Risk practice methodology		X	XXX	
Risk response matrix			XXX	
Risk reviews and audits			X	XXX
Sensitivity analysis		XXX		
SWOT analysis	XXX		X	

Source: author's own study

Predominant use in risk identification

The method of analogy comparison shall use archived documentation previously implemented projects. Referring to such documentation, processes are being searched for solutions analogous to the current project and those applied in the past, the analyses and the results and results obtained. Despite the uniqueness of each project, it is possible to use previous experience in analogous or similar applications projects. This approach makes it possible to benefit from the valuable information retained on risks, problems, failures and successes of previous implementations in relation to the current project [12]. This method has the advantage of being applicable in a wide variety of situations, therefore it can also be used in EMS and agriculture. However, it should only be used as first step in identifying the risk, because every situation is still unique, and using only this method may result in the omission of important risk sources.

The assumption analysis consists of documentation that ensures a consistent interpretation of the design environment. Although the documentation can take many forms, the key is its consistent application. If all projects in the organization use the same structure of documentation to capture assumptions, it is much easier to interpret information in a consistent manner. The technique also includes the analysis of data collected in the documentation in order to determine the validity of each assumption. The most effective assumptions analysis will be done with multiple parties and with extensive documentation. This method may be used in EMS, when the organizations have many projects and there is the need to compare them or assume some outcomes. This is rather not useful for EMS in agriculture. However, it may be used to prepare assumptions based on previous agriculture seasons. In this way stakeholders may improve risk management with every season.

The brainstorming method is used to obtain information from the participants of the meeting on a risk problem clearly defined by the leader in the project. Each participant has the opportunity express their opinion, which is not evaluated in relation to the value of the information. No assumption is made a rigid framework for discussion. What is important is how the greatest flow of information without stereotyping thinking about a particular issue. This leads to significant openness of the participants and expression new opinions and solutions [13]. This technique has the advantage, that it's applicable in an exceedingly wide selection of areas, consequently in EMS and agriculture. It is very beneficial, because it does enable various point of view from different employers and different experience. Ideas should be verified by experts or more experienced employers to outplace the irrelevant ones or to give them various priorities.

The Crawford Method is a clearly formulated question or a specific risk problem in a project is posed to the participants in the study. In a tenfold repetition of the questioning process, participants answer or express their opinion anonymously and in writing. The multiple posing of the same question or problem make allows for a new look at the same question or problem to be obtained. This increases the chance of revealing new information about risks that could be missed with fewer repetitions. This is useful, when there is no time or ability to discuss ideas, and just the will to collect people's thoughts. [12]. This method can be compared to brainstorming, when there is the possibility of getting more answers from various people. However over 96% of the farmsteads in the EU are family farms [14], so questionnaires does not make much sense in this situation.

The Delphi technique is based on the knowledge of experts in a given field. The opinion of all survey participants is obtained (by correspondence) by filling out a developed risk questionnaire for a given project. The aim is to obtain a common, uniform expertise of all the respondents. Participants are anonymously acquainted with the opinions of other experts in order to express their opinions in this area or to verify their views. The process is repeated several times, as appropriate [15]. This technique has the advantage that it's applicable in a wide selection of areas, therefore, also in EMS and agriculture. Process of risk identification in agriculture requests the opinion of specialists, particularly in upcoming investments or vital changes of profile.

Documentation review consists in a detailed analysis and reading of the documentation used for the implementation of the project in terms of risk identification. An overview is carried out in order to avoid omitting relevant information that may permit the identification of risk factors. The documentation under review should originate from both the client and the project implementers. The method was implemented at the time of the development of the first project documents and in the course of the creation of new ones. Documents to be submitted for review: structure of the division of labor, project fiche, contract, scope of works, documentation concerning requirements, network diagrams [12]. This method has advantage in processes, during which a lot of documentation is produced and the information included in them may be useful for risk identification. It has a wide application in EMS, however it is not advantageous for agriculture.

Expert interviews are based on the selection of a suitable expert in a given field of the project and providing him/her with specially prepared questions, in the form of a questionnaire, concerning this field. They obtain information about the risks of the project and possible threats in the case of its occurrence. It gathers knowledge about the probability and consequences of unfavorable events. It gathers information about the possibilities of preventing critical situations. It predefines how to react to risk factors. It gives the possibility to identify areas in the project that are particularly susceptible to risk [12].The expert interview has the advantage that they are applicable in a wide variety of situations, therefore it can also be used in EMS. The identification of risk in agriculture requests the opinion of experts especially in uncommon situations, such as investments or significant changes of the profile. Therefore, this method may be very beneficial for agriculture, but not in ‘everyday use’.

The Failure Mode and Effect Analysis (FMEA) is based on dividing the process or product into the smallest possible units and to identify the risk which may take place there. The FMEA methodology should already be applied in the early phase of product development (planning and development) within the product life cycle, since cost/benefit optimization is most economical in the development phase (preventive error avoidance). The later an error is discovered, the more difficult and cost-intensive its correction will be [16]. This method is rather used in developing new methods, processes or services or looking for improvement. It has a wide application in EMS, but it is rather not useful in agriculture.

Plan evaluation is based on the fact that the implementation of the project is preceded by a detailed planning and documentation Planning. It defines what is to be done, how is it to be done, when and by which participant in the project. To avoid omitting details that are relevant to the project, it is important for the efficient implementation of the project, that the actions are carried out methodologically, carefully and repeatedly. A verification of the completeness and consistency of all materials should also take place. At the same time, this is also a way to assess the error-freeness and the timeliness of the relevant data [12]. This method is used in the

project planning process and may be used in EMS. Due to the specific nature of the agriculture industry, this approach does not have a wide application.
The SWOT analysis is a directional method of risk identification in a project and in a wider context at the level of an organization. During the analysis, information is collected as a result of the questions posed: what the advantages and weaknesses in the organization are, what possibilities the project opens and what threats the project implementation poses for the organization. Conducted in the initial stage of project planning, it leads to a description of the general risks or possibilities of project implementation [17]. The SWOT analysis may be used in fact in everyday decision-making processes; therefore, it is also applicable for risk management in EMS and agriculture. Table 2 presents all the discussed methods and their relevance for EMS in agriculture for family farms.

Table 2. Summary of methods

Method	Usefull for agriculture
SWOT analysis	Yes
Analogy comparison	Yes, with other method
Brainstorming	Yes, results should be reviewed
Delphi technique	Yes, for special situations, not in everyday use
Expert interviews	Yes, for special situations, not in everyday use
Crawford Slip Method (CSM)	May be used
Assumption analysis	No
Documentation review	No
Failure Mode and Effect Analysis FMES	No
Plan evaluation	No

Source: author's own study

Predominant use in risk assessment
In situations where good probability estimates can be developed for the states of nature, the expected monetary value (EMV) method is a popular technique for making decisions. In general, three steps are involved in formulating a decision theory problem using the EMV method: Define the problem, identify alternatives that the decision maker may consider and identify those relevant future events that might occur and are beyond the decision maker's control. In decision theory terminology, an outcome that results from a specific decision and the occurrence of a particular state of nature is referred to as the payoff [18]. This technique may be used with success in EMS and in agriculture. If there's a negative risk, for example flood with a 10 percent probability, the impact of not getting the insurance is estimated at EUR 400,000. For the same situation, there is big chance there will be no flood and there will be no need to pay EUR 40,000 insurance. After calculation:

$$10\% \cdot -EUR\ 400{,}000 = -EUR\ 40{,}000$$
$$90\% \cdot EUR\ 40{,}000 = EUR\ 36{,}000$$

It is visible, that the more beneficial solution is the second one. This method may be used in more complex situations with more outcomes. In this case it is worth drawing a decision tree to estimate all of the possibilities and their probabilities. It is applicable in EMS and consequently in agriculture.
The estimating relationship method enables the evaluation of a project, and the application of an equation to determine an appropriate contingency or risk funds budget. When using this method, the contingency funds represent the amount of funding required for work associated with unanticipated risks. The computed contingency funds requirement is usually expressed as a percentage of the baseline cost estimate. The technique is called an estimating relationship method because it uses some of the same techniques associated with cost estimating relationships (The CER method is based on the observation that costs of systems seem to correlate with design or performance variables.) used in parametric cost estimating [12]. This method is most appropriate in circumstances where a good description of a historic project and contingency fund requirements are available for several similar projects. If the required relationship for estimating risk financing is available, this method has the advantage of being quick and easy to apply. This method may be applicable in EMS, to estimate costs of various risks and to compare similar projects. It has no practical application in agriculture.

The Monte Carlo simulation uses simulation analysis to establish relative levels of risk. In many cases it is assumed that all project risks must be accounted for in the worst case. In contrary to this approach, this method takes a more holistic approach: it calculates various risks from random values from the highest and the lowest possible. This action is repeated many times to provide a frequency distribution of total costs, reflecting the aggregate of the cost risks associated with all individual elements. Therefore, a computer with appropriate software

is necessary to use this technique, as the method requires many repeated computations. This method can be used in EMS and in agriculture. With its holistic approach all possible risks may be assessed and included. By taking the flood or other natural risk as an example, it is unlikely that this will destroy 100% of the crops. Also, some risks do not occur simultaneously, or some are effects of various situations. This method may include it.
Network analysis is based on the methods of arrow and nodal diagrams (also known as sequence diagrams), which graphically illustrate the logical relationships between all tasks or groups of activities in a project. The basic idea describes the relationship between tasks as an end - beginning, saying that the next task (successor) cannot start unless the task immediately preceding it (predecessor) is completed. Other relationships are end - end, beginning – beginning, beginning - end. The risk analysis is carried out, determining the probability of the occurrence of negative factors. The analysis focuses on the relationship between all tasks in the network diagram and at risk, that may exist for these tasks [12]. This method may be used in EMS, because it holistically analyses all process. It may be consequently used in agriculture, however it is not very convenient, because the process itself is relatively simple and risks usually come from the outside. It does help, however, to predict where to expect them.

Program Evaluation and Review Technique (PERT) objectives included managing schedule risk by establishing the quickest development schedule, monitoring progress and funding or applying necessary resources to maintain the schedule. The PERT method is particularly useful in managing research and development projects, where deterministic determination of activity times is generally difficult, if not impossible [19]. This approach may be used in EMS but it is inefficient for small projects, therefore it is suitable for managing large, complex projects. Due to the specific nature of agriculture, this method is rather inefficient.
Rating schemes are standardized and applied either at the project or (ideally) at the organization level. They clarify the relative magnitude in terms of impact and probability for a given risk using terms such as "high", "medium" and "low". This method uses clear definitions and the means to verify the compliance of individual risks [12]. Rating schemes are appropriate any time a qualitative analysis is conducted, therefore they might be used in EMS. On the other hand they require an up-front investment of time and management energy to establish consistent measures for probability and impact, what makes them not that easy to apply in simple processes such as agriculture.
The risk factor method is considered simple and easy to implement. First the obtained project costs should be estimated, by breaking down process into the work package level. This should include enough information to answer any question or issue about their content. A risk factor shall be made after the identification of the work package. The level of additional cost risk shell be expressed as a percentage of the original estimation and should be added to the task costs to accommodate additional work resulting from risk. After the sum of the work packages risk may estimate new project costs [12]. This technique is applicable exclusively when single data-point assess in work package is available. The method's simplicity makes it applicable to all projects regardless of size, therefore it may be applicable in EMS in all kinds of industries.

Sensitivity analysis is a simple analytical tool which consists in examining the impact of changes in the formation of project benefits and costs, discount rate, life expectancy on its profitability level, both in financial and economic terms. This analysis is used to determine the sensitivity of profitability assessment results to changes in various variables is an important tool for reducing the risk of decisions taken in a market economy, and in particular, may concern the profitability of investment. The basis of this method is that the future cannot be predicted and with this the actual values of each variable taken into account in the investment account will deviate from these assumptions. The basic function of this analysis is to calculate the turning point, which means that the cost of the product sold equals the income [20]. This method is rather beneficial for financial end economic considerations of project; therefore, it does not find its application in EMS.
Table 3 presents all the discussed methods and their relevance for EMS in agriculture for family farms.

Table 3. Summary of methods

Method	**Useful for agriculture**
Risk factors	Yes, applicable for simple processes
Decision analysis - Expected monetary value	Yes
Decision Tree	Yes
Monte Carlo simulations	Yes, gives worst case scenario
Network analysis	May be used

Program Evaluation and Review Technique (PERT)	Mostly no
Estimating relationships	No
Rating schemes	No
Sensitivity analysis	No

Source: author's own study

Predominant use in risk management

Planning meetings are conducted to ensure the organization has a consistent vision in terms of the project's risk management. It does include risk methodology, roles and responsibilities, thresholds, timing, reporting formats, and approaches to tracking. These meetings focus on connecting key stakeholders on risk to conclude the risk practices to be pursued or the approach to be applied in pursuing them. [12]. This technique is recommended for all type of projects, but is the most effective in the initial risk planning stages. It can be widely used in EMS and in agriculture.

The technique of project templates involves the creation of various templates covering a specific scope that may pose a technical risk to the project or to specific processes. Each template considers the area that often poses a risk and then describes the methods (or gives examples) to avoid or control that risk. Many descriptions and solutions of risks have their roots in other projects. Project templates can be used for most projects, independently or in combination with other techniques. This method can be relevant for projects of any size at any stage of development. Since the technique sees project management as a complete process, the solutions presented reflect the interdependence of each part of the cycle [12]. This method may be used in EMS and for agriculture.

The risk practice methodology consists of several steps to be taken based on the structure and needs of the project in question. Most methodologies will outline clear steps in the process, form and practice. They will dictate (based on scale) the frequency with which these components are applied. They may be stored and made available in paper or electronic form, but they allow the organization of a common repository for both the forms and their filled-in equivalents. Since the risk practice methodology represents the accumulated practices of the project organization, it is usually used only in the most extreme circumstances. It applies as described for all projects where the methodology is already in use [12]. It may be used in EMS and risk management in agriculture, however it is time consuming and usually applicable in the most extreme circumstances.

A risk response matrix involves the initial and consistent performance of a number of specific tasks. The first step should be identification: all possible risks should be listed and defined. The next step is to assess the threat. Under this section, the previously selected probable problems are divided according to their threat to the company's design, life, health and finances. After that, possible actions that may be aimed at minimizing the damage should carefully be considered, therefore, this should be done in such a way that the problem does not occur at all. As an option, a scheme of reactions should be considered if the situation occurs. The last and longest stage is a performance check that includes the execution of actions that reduce risk and uncertainty. The results of such a matrix can be applied in the planning and decision-making process. As it presents a broad overview of the situation, it allows you to find out which decisions will be the right ones [12]. This method is also relatively inexpensive and applicable in small projects. It can be used widely in EMS and in agriculture. Table 4 presents all the discussed methods and their relevance for EMS in agriculture for family farms.

Table 4. Summary of methods

Method	Useful for agriculture
Project templates	Yes
Risk practice methodology	Yes, it requires team discussion
Risk response matrix	Yes, it requires team discussion
Planning meetings	May be used

Source: author's own study

Predominant use in monitoring and control of risks

Checklists are a simple tool to control the correctness and/or the degree of completion of a project. This tool consists of a series of questions or issues concerning the project or its environment. The effectiveness of a checklist depends on its complexity. The more precise and detailed the questions it contains, the more effective it is, however, the longer the time it takes to prepare it. In risk management, the use of checklists at various stage of project implementation allows for a quick assessment, locations and causes of any risk [21]. This method has the advantage that it is applicable in a wide variety of situations, therefore it can be used also in EMS and agriculture.

Financial risk control allows managing risks within the company (retention, risk retention) or transferring them to the outside world. The simplest solution - risk retention in a company - does not involve additional initial expenditure, so the temptation to use the method is very strong. However, the entrepreneur must be aware that in the event of a natural disaster, the size of potential losses may exceed the financial capabilities of the company and result in its bankruptcy. The question of whether the entrepreneur had previously been aware of the potential risk and kept it inside as a result of a conscious decision (active attitude) or had no knowledge about the existence of a potential threat (passive attitude) comes to the background [22]. It does not find its application in EMS.

The performance tracking technique requires the use of a periodically updated technical risk assessment report. This report is based on activity-specific data but aims to provide an overall assessment of current trends and project status. The technique uses a set of standard technical indicators, which proved to be effective measures of technical parameters. Additionally, the analysts also develop particular technical indicators for the project. Each of them has clearly described performance projections and an array of warning criteria. This technique is most efficient when measurable and objective criteria are created. The method is best used to manage short-term processes, but with minor adjustments, could be implemented on various types of projects [12]. It is applicable for EMS and for agriculture. It cannot be widely used in agriculture, because it is the best applicable to manage near-term projects.

Risk reviews and audits are an independent advisory and verification activity designed to improve the operational efficiency and added value of the organization, as well as risk management. An audit helps the organization to achieve its objectives through a systematic and methodical approach to assessing and improving the effectiveness of its risk management, control and management processes. Risk reviews and audits may take a variety of forms and formats, but they always contain enough common elements to be discussed together. The key to a robust risk review is to assume that it is a comprehensive risk review and not a review of a single isolated risk event. It is highly recommended for EMS and agriculture [23].

Table 5 presents all the discussed methods and their relevance for EMS in agriculture for family farms.

Table 5. Summary of methods

Methods	Useful for agriculture
Risk reviews and audits	Yes, requests second party
Checklists	May be used
Performance tracking	May be used, request developing indicators

Source: author's own study

Conclusion

Based on practical experience, small and medium-sized enterprises (SMEs) may implement an effective EMS and gain a variety of benefits. However, the implementation of EMS can present various challenges. One of the advantages of implementing ISO 14001 is that it can be done in an organization of any type or size, since the requirements of an EMS are the same for all. However, the manner of implementing one will vary according to the size and activity of the organization [24].

An important element of the standard is the implementation of risk management in certified companies. Therefore, this article presents a review of risk management methods useful in family farms in agriculture, indicating those that seem to be the most useful for particular stages of risk management, and those that can be used in this process, but their usefulness seems to be limited.

It is worth noting that the list prepared by the author may constitute a basis for further implementation and testing of the proposed risk management methods by farmers. However, this process requires a conscious and methodical approach and the improvement of actions taken on the basis of current experience.

In this case, it concerns both the identification of sources and risk factors and the usefulness of particular methods in the projects carried out. The key element of this process is to introduce changes in the adopted approach on the basis of previous experience and to introduce improvements and even more innovations. Moreover, it is also important that the farmer carefully identifies the type of risks influencing the project implemented by the farmer and the stage in which such risks may occur. In combination with the farmer's experience from previous projects and the knowledge accumulated in the literature in the identification of risk factors, these methods will give a chance to increase the probability of the end of the growing season without disturbing the balance.

The next step would be to conduct empirical studies on the actual level of implementation and use of risk management methods in family businesses that have implemented ISO14001. An important issue requiring further research is also the subjective assessment of users of these methods in terms of their usefulness in particular stages of the risk management process. An interesting direction would also be to conduct comparative research in EU countries on the most commonly used risk management methods in family farms.

Conflict of interest
There are no conflicts to declare.

Acknowledgments
This research has not been supported by any external funding.

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LEGAL ISSUES OF THE FORMATION AND FUNCTIONING OF THE NATIONAL INNOVATION SYSTEM IN UKRAINE

Abstract
Introduction - the purpose of the article is to determine the theoretical and legislative bases for the definition and construction of the national innovation system and its subsystems, to establish gaps in the regulatory legal regulation of the economic activity of individual elements - subjects of the NIS.
Methods of research - structural and functional methods of analysis are used to determine the existing competence of the participants of the national innovation system of Ukraine and the ability to perform the necessary functions for the system. Methods of analysis and synthesis were used in the study of theoretical models of innovative systems and their structure. The normativist method (formal and legal) was used in the study of the actual state of legislative securing of the NIS.
Results of the research - Based on the analyzed scientific sources and on the basis of regulatory acts of Ukraine, it is necessary to distinguish the following NIS subsystems, which require significant legislative regulation: subsystem of generation of knowledge and education, subsystem of production of products and services, subsystem of innovative infrastructure, subsystem «National network technology transfer», Territorial (regional) subsystems.
Discussion with the other scientists - most views on the essence of a NIS can be divided into the following groups: structural approach, subsystem approach, functional and structural. However, these models do not sufficiently address the role of the lowest level of the administrative system - the united territorial communities as the only one as close as possible to the governmental structure. In this direction, it is necessary to extend the limits of financial capacity of territorial communities on the principles of transparency, accessibility, sufficiency.
Summary and conclusions - for the harmonious and timely development of the National Innovation System it is necessary to comprehensively approach the legislative regulation of relations in the innovation system and its subsystems, as well as to formulate guidelines for the formation of the system of regulation of innovative activity in the laws.

Keywords
National innovation system, NIS subsystems, technology transfer system, regional NIS subsystems, innovation code.

Nomenclature, Abbreviations
NIS – national innovation system.
CMU - Cabinet of Ministers of Ukraine

Introduction

The building up of the innovation system is a key task and a strategic state priority for present-day Ukraine. It is the transition to innovative development on the basis of the economy's innovative platform that will enable Ukraine to pass from an economy of consumption to that of development. By way of solving this complicated problem, our state will have to achieve a number of goals which will stipulate the creation of necessary preconditions for building up an economy of an innovative type. These goals are:

- ensuring stable economic growth
- approving an innovative state development model
- social redirection of economic policies.

As the lower-order tasks, one should consider the implementation of such measures pointed out by scientists as the formation of a normative-legal base and economic mechanism for sustaining and stimulation of innovative activities; determining and support of priority directions in innovative activities; outlining and implementation of state, branch, regional, and local innovation programs; protection of rights and interests of innovative activities subjects; financial support of innovative projects' implementation; stimulation of commercial banks and other finance-crediting institutions that provide credits for accomplishing innovative projects; establishing

favorable taxation for innovative activities subjects; support for the development and functioning of modern innovative infrastructure.[1].

There were also different attempts made by scientists to illustrate the elements and connections that make up the innovations system, as well as the flows of information and resources within the system, and between the system and its environment. Thus, an analytic distinction between the "narrow" concept of NIS, which includes institutions and policies immediately involved in scientific and technological innovations, and the broad understanding of NIS, which takes into account the social, cultural and political environment, as well as the studied country was made. The narrow version is "an integrated system of economic and institutional agents that immediately enhance appearance the and application of innovations in the national economy", depending on one or several strategies discussed above. [2] Despite the fact that there are great differences between national economies and tremendous complexity within the system, it is possible to determine the characteristics of the key innovations subjects.

The OECD's specific approach to solving this theoretic issue, which in its documents and manuals applies doctrinal interpretations by leading scientists without giving preference to any of them, is noteworthy. In particular, as written in one of its documents, Freeman considers the NIS as a network of institutions in the public and private sectors, which in the course of their activities and interaction initiate, import, modify, and spread new technologies. Lundvall sees it as elements and relationships that interact in production, spreading, and the application of new economically useful knowledge… and are located or stay within the borders of a nation state. Nelson views it as a set of institutions, whose interaction determines innovative activities … of national companies. Patel and Pavitt define it as technological training (or an amount and content of activities that generate changes) in a country. Metcalf treats it as a set of various institutions that jointly and individually promote the development and spreading of new technologies and which sets the limits wherein governments form and implement their policies to influence innovation process. Thus, it's a system of mutually connected institutions for generating, storing, and passing the knowledge, skills, and artefacts that determine new technologies.[3]

Method of research

Structural and functional methods of analysis are applied to determine the existing competence of the participants of the national innovation system of Ukraine and the ability to perform the necessary functions for the system.

The national innovation system is not considered in the broad sense, but only one that consists of specialized actors, both private and public, also with the participation of authorized bodies.

Methods of analysis and synthesis were used in the study of theoretical models of innovative systems and their structure. Attention was paid to the institutional construction of innovative systems and the functional, according to the directions of economic competence of NIS participants or the economic and administrative competence of participants - authorized bodies.

The further application of the results of theoretical analysis has led to the need to compare theoretical models of NIS construction and operation with the actual state of the normative regulation of innovation relations.

The normativist method (formal and legal) was used in the study of the actual state of legislative consolidation of the concept, the structure of the national innovation system and the economic and legal competence of its participants.

Results of the research

Solving these tasks is inseparably based on understanding the concept of the national innovation systems (hereinafter the NIS). Here, the notion of "national" is to be interpreted as the "state" innovation system, while in some sources, the NIS is opposed to the globalized innovation system, although it is acknowledged as a necessary phenomenon for economic development in each country.

In her reviewing of the understanding of national innovation systems, G.P. Klimova notes the variety of innovation systems and, summarizing the existing in scientific literature points of view, points out that innovation systems that exist on macro-, meso-, micro-, and local levels should be singled out. On the macro-level, it is the world innovation system, international and transnational systems that constitute it, including the NIS. Regional innovation systems can be distinguished on the meso-level, branch (cluster) innovation systems on the micro-level, and innovation system of a specific enterprise on the local level. [4]

The national innovation systems of separate countries are considerably different form one another, which is manifested in the choice of priorities and tasks of innovative development, the mechanisms of interaction between the state and the private sectors, the significance of big and small business, the proportion between fundamental and applied research and development, the dynamics in development and branch structure

of innovative activities. According to this, several basic models of national innovation systems are distinguished in the world practice: the Euro-American, Japanese, South-east-Asian, and the alternative innovation systems. [4]

In A. A. Kayal's opinion, a NIS is composed of a totality of mutually connected elements, components, links, and attributes. Components, as the scientist sees them, are operational parts of the system and exist in the forms of both separate persons and organizations like: business companies, banks, universities, science-research institutes, and state power bodies. Apart from, A.A. Kayal relates to the components of the NIS structure in higher education institutions, techno-parks and techno-polices, as well as technologies transfer centers. [5]

Analyzing the structural elements of a big (in a broad sense) NIS, determined by W.F. Maloney, it is possible to conclude that the scientist relates to the NIS components in universities, analytical centers, technologies dissemination centers, as well as the government and the market. [6]

S. Feinson notes that the acquisition and implementation of technological possibilities presupposes heavy investments in technological and social infrastructure. For countries with limited resources that can be directed to the NIS development and operation, Ch. Edquist has presented the concept titled Systems of Innovations for Development (SID). The SID highlights some key differences from the NIS approach in developed economies. He claims that four main spheres in which SID differs from NIS exist:

- the innovation product is more important than innovation processes through influencing the product structure;
- gradual innovations are more important and attainable than radical ones;
- innovations' broadening is more important than the development of new innovations in the world;
- innovations in the branches with low and medium technologies are more attainable than those in high-technological systems. [7]
- In any event, developing countries can (through getting an assistance in educating or through agreements to avoid paying foreign companies) facilitate the national potential through various components of NIS necessary for long-term industrial and economic development. [8]
- S. Feinson, when analyzing the OESR documents, divided the NIS institutions into five categories:
- governments (local, regional, national, and international with different weight in different countries) that play the key role in determining the broad directions in policies;
- intermediary institutions like scientific councils and research associations that pose as mediators between governments and researchers;
- private enterprises and research institutes financed by governments;
- flows of knowledge, innovations, and education in the developing countries;
- universities and affiliated institutions that provide key knowledge and skills;
- other state and private organizations, which play a certain role in the national innovation systems (state laboratories, technology transfer organizations, joint science-research institutes, patent offices, training organizations, etc.). [7]

At the all-European level, one of the most wide-spread definitions of this legal category is the one supposed by Bengt-Ake Lundvall, who views it as a system of organizations and institutions, taking part in research, like R&D departments, technological institutes and universities. [9]

In Ukraine, a legally set NIS structure is nonexistent, which leads to the problem of the definition of the very notion of NIS, so there is currently no unified determination of the notion of a NIS neither in the national, nor in the international legislation.

Applying structural and functional methods it is possible to state that unlike the national normative approach, the European theoretical base stems from the two main understandings of the NIS: 1) as a system of institutions that create, realize, and apply innovations, or enhance such activities; 2) as a system of relationships, in the course of whose implementation the creation, execution, and application of innovations takes place.

Contrary to this, despite the use of activity terminology, the national legal system considers the NIS as wide network of state and non-public institutions that perform specific functions facilitating innovations development through a system of all-sided legal, material-economic, education, production, and other relations between each other.

Departing from what was previously stated, it is possible to conclude that the national approach to the understanding of the essence and the contents of the NIS, on the whole, corresponds to the international one. The advantage of the normative fixating in the legislation of Ukraine is a structured enumeration of the NIS components by the functional principle. Among the main functions of such components, the following functions can be singled out: the normative and the control functions, qualification improvement function, information-communicative, material-technical, production, and other functions. Thus, each of the NIS elements is involved

at a specific stage of the innovative process from the stage of the arising of an idea to the production and implementation of innovative goods, forming the necessary conditions for innovation development in Ukraine.
Ukraine's programming documents contain an extensive NIS structure. According to the Concept of development of the national innovation system, the NIS is a set of legislative, structural and functional components (institutions) involved in the process of creation and the application of scientific knowledge and technologies and defining the legal, economic, organizational and social conditions for ensuring the innovation process. According to this NIS regulatory act, it consists of an extensive network of subsystems, such as the subsystem of state regulation, education, knowledge generation, innovative infrastructure and production. [10]

NIS subsystems

To build a legal mechanism for regulating a NIS state, it is necessary to isolate its subsystems using the methods of analysis and synthesis of the elements and functions of these subsystems. A. A. Kayal subdivides the NIS into the following main subsystems:

- science and technical policies
- innovation strategy
- human support technical service
- technical support services
- mobilizing of financial resources
- international cooperation. [5]

The review documents recognized the NIS subsystems as follows: state regulation, knowledge generation, innovative infrastructure; production. [11] Some scientific and review sources also refer to the sectoral formation of NIS subsystems. We believe that this option requires more detailed research regarding the discussion of the practical application of the components of one logical system that are different in function.
On the grounds of scientific sources previously analyzed, and on the basis of normative-legal acts of Ukraine, we will distinguish the following NIS subsystems, which we will view in the following enumeration.

Knowledge generation and education subsystems

The knowledge generation subsystem is understood as a total sum of organizations that are engaged in fundamental research and development, as well as in applied research.
In this aspect, L.I. Fedulova notes that education, as one of the key subsystems of a NIS, becomes the nucleus of he innovative development territory. It is connected, among others, with creating numerous innovative structures on the basis of higher education institutions (HEI). This is to say, that the understanding of the role of higher education within the innovation process becomes broader: on the higher education basis not only science-research and research-and-design projects are created, but also other wholesome structures are formed, which enable an efficient innovation process to be performed. [12]
E. Viotti asserts that in the case of economic development “training can be determined as a process of technical changes achieved through diffusion (from the perspective of technologies assimilation) and gradual innovations. In other words, training is the consumption of existing methodologies, that is, the consumption of innovations developed elsewhere and generating improvements for obtained methodologies”. [13] For developing countries, as S. Feinson explains, it should be taken into account that training takes place on three analytical levels: 1) the main functions of a system; 2) broad strategies that can be used for efficient the creation and management of these functions; 3) subjects, institutions, and links within the system that mutually realize this strategy.[8] As S. Feinson observes, the countries with weak higher education systems lack quality human capital to train, for which a strong primary and secondary education is needed.[8]
It is correctly noted that in national innovation system of all countries generating innovations is made by industrial science, state research institutes, as well as research universities. As a specific form of scientific and education activity organization, a research university is intended to considerably intensify innovative activities in higher education. A distinctive sign of such a university is the ability to generate new scientific knowledge on the basis of a wide range of fundamental and applied research, the possibility of transferring technologies to the real sector of the economy and the availability of an efficient system of highly qualified personnel training. These characteristics determine a university’s innovative road of development, which is connected with the introduction of new technologies, ideas, and knowledge to the scientific-and-research process with the aim of their practical application. [14]
It is also necessary to agree that a mandatory attribute of universities’ innovation process should be the innovation climate, and a condition of its formation is a clear presence of three components in a university’s activity: education, science, and novelties generation. [15]

Production of goods and services subsystem

The subsystem of goods and services production includes, first and foremost, science-containing goods which are maintained by both large corporations and small and medium enterprises operating in the sphere of science-containing business.

It is correctly noted in previous research that a peculiarity of Ukrainian legislation is indirect regulation of highly technological produce export support. As components of highly technological branch development, the presence of management mode, education development, innovations development and that of the engineering-design-and-technology infrastructure have been determined, meaning that the industrial aspect starts with the development of separate NIS subsystems. [16]

It seems that in the course of the improvement of legal regulation of innovative activities in Ukraine, the experience of industrially developed countries should be considered, namely the practices of innovation activity support, like preferential taxation for enterprises that develop innovative products; granting zero-interest credits, compensations, donations, etc., partial or complete financing of innovative goods production. All the mentioned supporting measures indicate that legal regulation of innovative activities and innovation legal relations' development have to be built-up on the principle of creating and ensuring favorable conditions for innovative entrepreneurship. [17]

Innovation infrastructure subsystem

The Law "On Innovation Activity" [18] doesn't clearly specify the enumeration of the innovative infrastructure participants, but only provides the list of their functions. Contrary to that, a non-specific regulation in relation to innovative activities - Lawof Ukraine"On Development and State Support of Small and Medium Entrepreneurship (SME) in Ukraine" relates to the objects (or rather subjects) of SME support infrastructure business centers, business incubators, innovation business incubators, science-technology centers, technologies transfer centers, small entrepreneurship support funds, leasing companies, consultative centers, other enterprises, offices, and organizations. [19]

According to its functional aims, the innovative infrastructure contains the following elements: business-innovational, telecommunication networks and retail chains, techno-parks, business incubators, innovation-technological centers, consulting companies, financial structures, etc. It is possible to agree that the main purpose of innovation infrastructure is support, assistance, as well as resource and financial provision of the innovation process (finance-credit, material-and-technical, information, personnel support). [20]

To sum up, it is possible to note that innovative infrastructure institutions formation takes place under the influence of three groups of factors: legislative; organizational-managerial; economic ones. These factors should also account for the existing of the components of the "information infrastructure" subsystem: technologies, commodities, and services.

"The national network of technologies transfer" subsystem

The inter-regional technologies transfer network was established by the Ministry of Education and Science of Ukraine on the basis of the Ukrainian Institute of Science-Technical Expertise and Information (UkrINTEI) in the course of the "Inter-Regional Technologies Transfer Network Development" project realization.

V. Gurova singles out the main NIS determinants that, in our opinion, can be related to the functions of the subsystem of education and technologies transfer:

- establishing of research centers at the leading universities;
- development of links between higher education establishments and the corresponding branch of industry;
- development of cooperation on the basis of the network system between the national innovation system's elements on mutually profitable, coordinated, and parity conditions along with working out a common development strategy. [21]

Territorial (regional) subsystems

Access to innovation structures and participation in the national innovation system is possible with the proper ensuring of regional structures' activities and legal regulating the competencies of the NIS subjects on the regional level.

Intense attention to the issue of regions' innovative development attests to the importance of certain regional resources in the aspect of stimulating innovation possibilities and the competitiveness of corresponding economy subjects. In this connection, it is important to accentuate that the key goal in forming the regional innovation system is to enhance activation of the regional innovation activities and to increase a region's

competitiveness level. At the current conditions of innovative processes intensification, the raise in attention to regions' innovation development becomes even more urgent and calls for permanent monitoring. Consequently, the efficient formation and development of regional innovation systems should take place in conditions of increasing competitiveness and corresponding stimulation of the regional innovative activities. [22]

The information-communicative technologies subsystem

As this subsystem's component, one should also consider the totality of information infrastructure, which is also related to the "innovation infrastructure" subsystem.

One of key factors of such a subsystem's functioning is the Digital Agenda for Europe adopted in 2010 and intended till 2020. Most of the EU countries considered it as the mainframe and adopted corresponding National Programs of Digital Society Development for 1 – 3 years where they provisioned priority medium-term and short-term goals and indicators of attaining those goals. A draft law was developed in Ukraine in 2017 "On Digital Agenda in Ukraine", but it was never adopted a law. The Concept of Digital Economy and Society Development of Ukraine for 2018 – 2020 approved by the Decree of the Cabinet of Ministers of Ukraine of January 17, 2018 No. 67-p, is currently in force.

At present, the Ministry of Digital Transformation of Ukraine coordinates state power bodies' activities regarding digital transformations in Ukraine, including those connected with the EU Program "Common Digital Market". Thus, in accordance with the Regulation on the Ministry of Digital Transformation of Ukraine, adopted by the Cabinet of Ministers of Ukraine's Decree of September 18, 2019 No. 856, the mentioned Ministry ensures the formation and realization of state policies: in the spheres of digitalization, digitalized development, digital economy, digital innovations, electronic government and electronic democracy, information society development, informatics; in the sphere of citizens' digital skills development and digital rights; in the spheres of open data, development of national electronic information resources and interoperation, development of broadband access to the Internet and telecommunications infrastructure, electronic commerce and business; in the sphere of electronic and administrative services provision; in the spheres of electronic trust services and electronic identification; in the sphere of IT industry development. [23]

One of elements of the information-communicative technologies subsystem is Grid-technologies. Their popularity has just recently started growing, though their introduction began in Ukraine as early as in the mid-2000s with the Decree of the National Academy of Sciences of Ukraine's Council of 25.04.2006 No. 249 "On Approving the Concept of the Program on Grid-Technology Introduction and Formation of Clusters". They were promoted thanks to the implementation of the of the State Science-Technical Program of Grid-Technologies introduction and application for the period of 2009 – 2013 and the Target Complex Program of Scientific Research by the National Academy of Sciences (NASc) of Ukraine "Grid-Infrastructure and Grid-Technologies for Science and Science-Applied Uses" approved by the Decree of the NASc of Ukraine Council of December 11, 2013 No. 164-a for 2014 – 2018.

Nevertheless, the recognition of the efficacy and convenience of Grid-technologies application takes place episodically and non-systematically. Lately, the notion of grid-technologies appears ever more often in the national legislation. Thus, in the new Law of Ukraine "On Scientific and Science-Technical Activities" a "grid" is defined as a part of research infrastructure. In the Supreme Council of Ukraine's Resolution "On the Parliament Hearings Recommendations on the Issue of 'On the State and Legislative Support of the Country's Science and Science-Technical Base" there is recognition of the functional advantage of Grid-technologies application. In particular, it is noted that "in the middle of 2012, Ukraine entered the top-ten European countries in terms of the number of internet users; about 15 million of Ukrainians have access to the world web. The national Grid-infrastructure has been created, which is integrated with the European one and is actively working on solving super-complicated tasks of modern physics, chemistry, and biology". [24]

Using the normativistic (formal-legal) method, the author conducted a separate analysis of the NIS, its structure and elements on two issues, in which normative legal acts determine the entity as a subject of law, its organizational and legal form and whether the economic competence of NIS participants is present. As a result, the following conclusions were obtained.

1. The concept and structure of the NIS are not contained in the laws, only in the by-laws: Concepts of development of the national innovation system and the Regulations on the procedure for the creation and operation of technoparks and innovative structures of other types. [25] The NIS subsystem - the technology transfer system is not regulated at all by regulations.
2. As members of NIS, among private legal entities, the concept and status of scientific [26], technological [27] and industrial [28] parks, as well as innovative enterprise [18] are enshrined in the laws.
3. Other innovative structures (business centers, business incubators, science and technology centers, technology transfer centers, small business support funds, leasing companies, innovation and advisory

centers, technopolises, innovation clusters, venture funds) are only prescribed by law [19] [29] [30], without fixing their status as a legal entity or other entity.

4. The status of NIS participants in the National Council of Ukraine for the Development of Science and Technology and Higher Education Institutions is relatively clearly established among governing bodies and state institutions. At the same time, the competence of special bodies with powers in the field of NIS is enshrined only in their provisions (Ministry of Economic Development, Trade and Agriculture of Ukraine;[31] Ministry of Education and Science of Ukraine; [32] Ministry of Digital Transformation of Ukraine [23]).

Discussion the other scientists and papers

Thus, most views on the essence of NIS can be divided into the following groups: structural approach (A. Kayal, W. Maloney, S. Feinson, H. P. Klimova and others); subsystem approach (S. Feinson, C. Edquist, L. I Fedulova, E. Viotti); functional and structural (B-A Lundvall and others). However, these models do not sufficiently address the role of the lowest level of the administrative system - the united territorial communities as the only one as close as possible to the governmental structure.

In this direction, it is necessary to perform the broadening of the limits of territorial communities' financial capabilities on the principles of accessibility and sufficiency.

Within the reform of local self-governance, it is necessary to broaden the range of services, providing which can be passed on immediately to local authorities, to develop a number of programs on regions' innovation development that have to provide for beneficial investment conditions for this sector and to avoid the loss of existing assets. Such programs should be fixated at the state level, to get maximum development priority, in fact to become the state's course for a set period of time, because their introduction is resource-consuming and demands that resources be spent under strict control.

It is necessary to introduce special funds within local budgets, which be designated exclusively for accumulating funds to be used later on for financing strategic innovations within activities of communal enterprises and private business structures through mechanisms of regional and local innovation development programs. Such funds can be additionally subdivided by the industry branch principle and ensure the financing of innovation projects in different branches of industry.

To ensure the efficient formation and filling in of such funds, local authorities can involve investors within public-private partnerships. Not only are local authorities interested in innovations implementation at a certain territory, but also big business, for which the local innovation potential is one of key factors of further strategic development and maintaining market position, as well as a source of quality human capital.

The basic normative act on this issue is the Law of Ukraine "On State-Private Partnership". According to part 1 Art. 1 of this law, state-private partnership (SPP) is cooperation between the state of Ukraine, Autonomous Republic of Crimea, territorial communities represented by corresponding state bodies and local governing bodies (state partners) and juridical persons, except public and communal enterprises, or physical persons – entrepreneurs (private partners), which is accomplished on the basis of an agreement in the order established by this Law and other legislative acts. The aim of such a partnership is raising technical-and-economic rates of utilizing a public partner's property (that of the state, Autonomous Republic of Crimea (ARC), and / or local communities) on the basis of its transfer to a private partner for the long term and with bestowing financial-investment and social obligations on the private partner. As O. M. Vinnyk notes, for the efficient use of private business' resources, assisting in implementing investment-innovative projects is necessary. [33].

Nevertheless, the Law of Ukraine "On State-Private Partnerships" is unable to solve the problem issues of public-private partnership on the territorial communities' level, in particular due to: a) the absence of consolidated methodological approaches to regulating peculiarities of conducting public-private partnerships (methodologies and methods of undertaking an efficiency analysis of such partnerships, of conducting a selection of a private partner, etc.); b) the sequence of multilateral projects' implementation remains unregulated in which, apart from a private partner and a territorial community the state, or the ARC, or other territorial communities, etc. act as another partner. Unfortunately, as of today, not a single SPP project as meant by this Law has ever been completed in Ukraine.

In our opinion, in the present condition, an integral part of the interaction of local authorities with business, apart from public-private partnerships, is the creation of clusters to harness the potential of individual regions. It is necessary to agree with researchers that the basic directions of the definition of a cluster are shown in the development of separate forms of economic activity, participation of separate scientific institutions, formation of separate production chains and networks around big companies. These directions form the most effective eco-innovative systems. [34]

Uncertainty and impact of research results on science, economy, environment and society.

As a result of this study, no links between NIS elements were found in the regulatory acts of Ukraine. Also, most private sector NIS participants are not identified as entities and their legal forms. The elimination of these shortcomings will enable the NIS to function effectively and promote entrepreneurship in Ukraine.

Institutional transformations should focus primarily on the development of high-tech industries in the industries through:

- unification of highly specialized scientific and design organizations that carry out research and development in the interests of mainly one customer into a single scientific and industrial structure
- establishment of centers of science and high technology on the basis of large scientific institutions - leaders in the relevant fields of science and technology
- restructuring of part of sectoral research and design institutes into engineering firms with advanced financial, economic, marketing and commercial infrastructure
- formation business together with higher educational establishments of innovation-technological centers, innovation-industrial complexes, technological and scientific parks, oriented on production of high-tech products which will attract national and foreign investments and take advantage of national and foreign trade network
- creation of small business infrastructure for servicing high technology implementation programs, as well as the creation of basic regional and interregional innovation technology transfer centers to ensure the communication of small enterprises with large enterprises.

Summary and conclusions

The following steps in legislative regulation are proposed to eliminate the negative NIS factors identified in this article.

Considering the subjective structure of NIS and its current activity mechanism, it is possible to offer the following definition. The national innovation system is, on the one hand, the total sum of interconnected organizations (structures) involved in the production and commercial implementation of scientific knowledge and technologies within national borders: big, medium and small companies, universities, laboratories, techno-parks and incubators, while on the other hand, the complex of institutions of a legal, financial, and social nature that ensure innovation processes and rely on national habits traditions, cultural, and political peculiarities.

For the harmonious and timely development of the National innovation system, making a complex approach to legislation regulating the relationships in the innovation system and its subsystems is necessary. The adoption of the Innovation Code that exists in many EU countries, and the draft of which was developed and presented by Scientific and Research Institute of Providing Legal Framework for the Innovative Development of National Academy of Law Sciences of Ukraine in 2012 may serve as the foundation for this process.[35] The main goals generated in the draft of this Code was regulating the main and most important relations in the National Innovation System, which enhances its harmonious development.

Some of the main tasks should be noted as guidelines for the formation of a system of regulation of innovative activity:

1. Attaining terminological correspondence of the main terms in the sphere of technologies transfer in Ukraine with the EU legislation considering criteria put forward by the EU to the states that aspire to join it.
2. The introduction of an all-sided innovative activity support that includes: financial, credit, tax mechanism, infrastructure development, broadening cooperation between science institutions and the business sector of the EU countries in accomplishing innovation projects.
3. Creating an efficient all-state mechanism of adopting legislation, including the verification of acting normative-legal acts, draft laws of Ukraine, and other normative-legal acts on the issue of their correspondence to the main approaches established by the EU which are compliant with the “Europe – 2020” Strategy.
4. Abolition of any limitations of rights of scientific institutions and higher education establishments to spend finances obtained by them from enterprises, grants from international organizations, which may lead to a disruption of budget institutions’ activities on the introduction of innovations, or the refusal of enterprises and foreign organizations to conclude contracts with budget-financed institutions, or the impossibility for scientific institutions and higher education establishments to participate in the EU “Horizon 2020” scientific program.

For bringing the normative-legal base of innovation activity regulation to comply with the Strategy of Innovative Development of Ukraine with the maximum consideration to the regulations, main goals, and standards for the EU countries determined in the "Europe 2020" Strategy, to the following is necessary:

1. Develop a unified system of legislation determining and approving priority directions of science-technical and innovative activities in Ukraine and their implementation, to imbed these legal mechanisms in a comprehensive law, to develop a renovated State Program of prognosticating science-technological development of Ukraine.
2. Develop and legally instill the mechanism of stimulating investments into scientific research and developments, as well as the education sphere, similar to those applied in the EU (exempting the sums spent on scientific research and development, or on higher education establishments' support, faster depreciation of scientific appliances and experimental equipment of science-research institutions and innovative enterprises, etc., from enterprises' taxation base).

Conflict of interest

There are no conflicts to declare.

Acknowledgement

This research was financially supported by the fundamental themes of the research "Legal Support of the Functioning of the National Innovation System in Modern Conditions" (state registration number 0117 U 002507), 2017-2020.

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IDENTIFICATION OF EXTERNAL RISK FACTORS: ON THE EXAMPLE OF PRODUCTION OF FERTILISERS BASED ON DIGESTATE

Abstract
In the era of renewable energy development, one of the most important problems is the utilisation of residues of production of the so-called clean energy. In the case of biogas plants, the problem is the utilisation of waste after the anaerobic methane fermentation process of the organic substrate. One of the ways to use it is to produce organic and mineral fertilisers. However, the fertiliser plant may be exposed to a number of threats that may prevent its functioning. To avoid this, the factors that carry the risk need to be identified. The purpose of the article is to identify external risk factors for a fertiliser plant based on digestate. The following types of risk were identified as a result of the research: risk of supplying fertiliser components of inadequate quality; risk of non-compliance with deadlines for the delivery of raw materials or their total absence; risk of the presence of eggs of parasites and pathogenic bacteria in fertiliser; price risk; cyclical risk; risk of competition; currency, credit and interest rate risk.

Keywords
biogas plant, digestate, fertilisers, hazards, risk factors, types of risk.

Introduction

The escalating effects of climate change have forced governments of many countries to revise their energy policy. Many of them prioritised actions to support the production of energy from renewable and alternative energy sources (instead of using conventional sources). One of the popular ways of obtaining "clean energy" is to convert organic waste to gas in agricultural biogas plants. The product obtained in them - biogas (product of anaerobic methane fermentation, biomethane) - can then be used in many ways, for example as a source of electricity; fuel for driving cars; heat source for cooking, heating utility water and heating rooms (pumped into the local gas network). Unfortunately, the substrates used for biogas production are not completely decomposed, as another waste (called pulp, mass or post-fermentation sludge, in short - digestate) is created, which must be disposed of or utilised. Utilisation of digestate entails costs for biogas plant owners, and therefore a better solution for them is to use digestate for other economic purposes. "One of the promising proposals for the use of sludge is to use it for the production of heating pellets for fuel purposes" [1]. This is called thermal utilisation. The digestate (sludge) can also be used to fertilise soil, which contributes to improving its quality. Such a solution brings benefits for both the economy and the environment.

Post-fermentation mass as a source of minerals for plants

Post-fermentation waste used for soil fertilisation can be a valuable source of nutrients for plants and can also improve soil properties, especially in Poland, where acidic and strongly acidic soils are dominant. "Such soils are characterized by low sorption of nutrients and low water retention. As a result, they require an inflow of organic matter, which has a positive effect on many parameters determining the yield" [2].
The use of digestate for fertilising purposes is economically justified for at least two reasons. Firstly, the costs of utilisation of waste generated in agriculture and agri-food industry as well as in households are reduced (in the

light of the new method of waste segregation which separates the "Bio" fraction). Secondly, digestate pulp used as a natural fertiliser (which will ensure the supply of necessary biogens to the field) will bring measurable benefits to nature and farmers, and thus - to final consumers by providing more healthy food to the market. Thirdly, it will generate additional income for biogas plants for the substrates sold [3].
Fertilisers produced with the use of digestate[1] can be used by large-scale farmers, in forestry, horticulture, as well as in nurseries of plants, trees and shrubs. "Considering the digestate in the context of its chemical properties, it should be noted that it contains a large amount of nitrogen (N), especially in the form of ammonia, easily available to plants, as well as other macro- and microelements necessary for plant growth" [4]. In addition to nitrogen, digestate contains mineralised phosphorus and potassium, which has a positive effect on plant growth. Unfortunately, it can also contain heavy metals, which pose a threat to agricultural crops. Therefore, the legislator imposes certain requirements regarding the content of individual fertiliser components and impurities (Table 1).

Table 1. The minimum content of beneficial components for soil and plants and the maximum content of impurities in organic and organic-mineral fertilisers

Component	Solid organic fertiliser	Liquid organic fertiliser	Impurity	Maximum content [mg/kg]
Organic substance [% d.m.]	30	–	*Cadmium*	*5*
Nitrogen [%]	0.3	0.08	*Chrome*	*100*
Phosphorus [as % P_2O_5]	0.2	0.05	*Nickel*	*60*
Phosphorus [as % K_2O]	0.2	0.12	*Lead*	*140*
			Mercury	*2*

Source: [5]

In addition, fertilizers produced on the basis of digestate as well as digestate in pure form may be used in agriculture if they meet the requirements of the Regulation [6] of the Minister of the Environment on the R10 recovery process[2].

Method of research

However, the use of digestate pulp for the production of organic and mineral fertilisers used for agricultural production may raise a number of questions and doubts, including:

- Is their use safe for farmers?
- Is the obtained agricultural production and its products safe for consumers?
- If they are not safe, where can such fertilisers be used?
- What are the risks of using this type of fertilisers?
- What risks should be taken into account when establishing plants producing such fertilisers?
- What threats have to be considered when operating such a plant?

In this article we will try to find answers to at least some of the questions asked. Namely, we will focus on the risk analysis of a manufacturer of agricultural fertilisers produced on the basis of digestate pulp which is a waste of agricultural biogas plant.
The following methods were used in the research: review of legal acts; critical analysis of scientific literature; community interviews.

Results of the research

1. Selected external risks in relation to the organic-mineral fertiliser plant

Sources of risk can be both internal and external. However, this division is not entirely precise, because they can intertwine with each other and influence each other in a way that neutralises or intensifies the threat.

[1] Digestate pulp is liquid and solid residues after the methane fermentation process in a biogas plant.
[2] The R10 recovery process concerns the use of waste as fertilizing or soil improving substances.

Each business entity operates under specific market and non-market conditions, which can generally be called the external environment. Changes taking place in this environment may have a positive or negative impact on it. However, the entrepreneur should be worried by these changes that may threaten business continuity and even lead to bankruptcy.

1.1. Risks related to business partners

Under market conditions, the production company must cooperate with many entities, which may include: suppliers of raw materials, materials, machinery and equipment; companies providing services (e.g. transport); brokers purchasing manufactured goods for resale; end customers. Therefore, as the first group, we will discuss the risks associated with business partners.

Risk of supplying fertiliser components of inadequate quality. Because the composition of the substrates from which biogas is produced in a biogas plant is not fixed (e.g. it changes in relation to the season of the year or due to a different structure and quality of the input), the chemical composition of digestate can change significantly over time. Even if initially (at the beginning of cooperation between the digestate supplier and its recipient) it met the assumed requirements, there is no guarantee that it will always be identical. Therefore, in a situation when the delivered material is grossly different from the required quality of digestate, a problem arises which consists in quickly finding a replacement in another biogas plant, signing a new contract (short or long-term) for delivery, taking into account the possibility of increased transport costs. This risk increases significantly when the fertiliser manufacturer already has its obligations towards the fertiliser recipients, because failure to comply with them on time may generate additional costs related to the payment of penalty for delay. In an extreme case, the plant owner may not only lose the customer, but also his reputation as a reliable business partner. Unfortunately, this type of loss is difficult to estimate.

Risk of non-compliance with deadlines for the delivery of raw materials or their total absence. Similar consequences are associated with the risk of discontinuing or delaying the supply of raw materials. If the raw material inventory in the production plant is not large enough, the lack or delay of new digestate supply will result in downtime in the plant, and thus - lack of production and difficulties in paying employees' salaries and other obligations. As a consequence, the plant owner will not supply fertilisers to his customers (farmers), who in turn will suffer losses due to the inability to fertilise their fields in a timely manner, resulting in lower harvest in the future. Therefore, farmers will claim damages and the fertiliser plant will suffer severe losses as a result of paying penalties for delay, which can lead to the bankruptcy of the plant.

Risk of the presence of eggs of parasites and pathogenic bacteria in a fertiliser Because in biogas plants, in addition to plant-derived residues, also manure, liquid manure and liquid manure are used, it is likely that the parasite eggs contained in them will get into digestate, which will then be used as an ingredient in the produced organic-mineral fertilisers. A similar threat is caused by pathogenic bacteria from the food sector (including animal waste), as well as those that can develop in the anaerobic methane fermentation process in a biogas plant or during storage of digestate pulp. Then there is a high probability that the eggs of parasites and bacteria (with insufficiently high treatment temperature in the fertiliser production process) will get from fertilisers to the soil and then to the plants grown on it. This is a severe risk to the health of consumers, especially when consuming fruits and vegetables that do not undergo subsequent heat treatment but are consumed raw. That is why it is so important to test the raw material (digestate) before using it for the production of fertiliser, as well as test ready fertilisers in terms of their content of organic pollutants.

All the above types of risk can therefore be defined as the risk of incurring losses due to the inability to ensure continuity of the production process. To reduce their impact, digestate suppliers must be diversified, even at the expense of increased transport costs. Diversification of supply sources also applies to other components used in the production of fertiliser (e.g. ash from biomass combustion, a special type of fungus with beneficial effects on plant growth and yield, etc.).

1.2. Risks related to the macroeconomic and megaeconomic environment

The external environment also includes the country that has specific impact on individual sectors of the national economy. International organisations may also have such an impact. For example, for the member states of the European Union such organisations are the European Commission, the European Parliament and the European Central Bank. Market factors from both the domestic and global markets also have a certain impact. The above-mentioned factors can generally be described as macroeconomic and megaeconomic. We will discuss them in turn.

Price risk. It is known that the price of a product on the market is primarily determined by demand. Without buyers and demand, there would be no sales and hence no production. The higher the demand with constant supply, the higher the price is. However, in addition to demand, there are other factors, that the manufacturer must take into account, that may also affect the price. These include, above all, broadly understood production costs, including the value of materials, energy, labour, taxes paid and interest on loans. In addition, the price

https://doi.org/10.32933/ActaInnovations.33.8 • ISSN 2300-5599 •

is influenced by the general market situation (e.g. focused on greening in food production), the total supply of the product on the market, which in turn is closely related to the risk of competition. If a new (in this case ecological) product is being introduced to the market, its price may be higher than its artificial substitutes. Therefore, there will be a problem consisting in how to convince potential customers to change their preferences, i.e. persuade them to use a different fertiliser than the one used so far, which is at the same time more expensive. An active advertising campaign will be useful here, which should reach a wide target group, and this involves additional costs, especially in the initial period when the product enters the market. In other words, one should focus on marketing activities while developing their own brand. Other non-price factors of demand are: economic policy implemented in the home country and in the countries of business partners, geopolitical situation, prices on the world market, climate change and its consequences for agriculture around the world.

Risk of price increase for the components of the fertiliser produced. One of the types of price risk is the risk of price increase by suppliers of raw materials (digestate and other fertiliser components). First of all, it may result from increased demand for them, if, following the innovator (who used them for the first time), other similar production plants (followers) will be created. Second of all, supply reduction may contribute to this (e.g. the supplier has limited or suspended its activities for some reason). Then, there is a need to look for a new supplier that can be located so far that the cost of delivery may exceed the price of the finished product. Third of all, the reason may be the increased demand for raw materials as a result of a new alternative use - e.g. production of pellets for heating purposes, etc.

Risk of increasing motor fuel prices. Since road transport (trucks) is required to both import raw materials (including digestate) and deliver the finished product (fertilizer) to customers, the impact of fuel costs (diesel oil, gasoline, gas) on production costs, and consequently on the price of the finished product needs to be taken into account. In turn, fuel costs depend on how oil and gas prices change around the world. These prices are usually expressed in US dollars. Therefore, currency risk should also be taken into account in this case. Analysis of the literature on the subject showed that the most important factors affecting the prices of energy raw materials (including crude oil and natural gas) are: global demand, global supply, business cycle phases and the level of investment in a given industry. The risk of political change as well as conflicts and wars around the world are also equally important.

Cyclical risk is associated with the cyclical nature of economic development in all countries. The theory of economics indicates that the most vividly expressed are medium cycles (Juglar cycles), repeating on average every 8-10 years. Unfortunately, in the era of globalization of the world economy, few countries (mainly the ones "closed" to international cooperation) can avoid the impending crisis that covers many countries at once. It is even said that there is an “import” of crisis. Therefore, the question arises as to how the crisis can affect a particular enterprise. When economic circumstances are advantageous, there are many business entities and many new ones appear. This gives a "guarantee" of constant demand and stability of business partners. However, during periods of weak market, companies go bankrupt and people lose their jobs and income. As a consequence, our example plant will experience a drop in demand for fertilisers as well as shortages in raw material supplies and other disruptions in its operations. Unfortunately, all this together can lead to the collapse of the entire company. Therefore, when planning investments, it is necessary to take into account the phase of the business cycle, and in the current activity to make allowance for making plans, especially for long-term planning.

Competition risk. This type of risk is associated with many external factors, including the number of domestic manufacturers of a similar product, its price and production scale, the number of domestic manufacturers of a substitute product (e.g. fertiliser with a similar effect), the quantity and price of imported fertilisers with the same performance characteristics, the nature of the fertiliser market - free-competitive, monopolistic, oligopolistic, monopolistic competition etc. The last factor is the most important one because it determines the relations of manufacturers of the same or similar product on the market. Only in conditions of a free-competitive market, the plant has the best chance to survival and develop.

Currency risk. If equipment (technologies) for the production of fertiliser (or other - e.g. for product packaging) are bought abroad, then it is also worth considering currency risk in the risk management system. With an increase in the exchange rate of a foreign currency, e.g. EURO relative to the domestic currency PLN (so-called PLN depreciation), the manufacturer will pay more money for the imported equipment in terms of the national currency, as he will have to buy the European currency at a higher rate. On the other hand, if he makes contact with foreign recipients of his goods (e.g. in the USA), then, as an exporter, he has to take into account the potential risk of a decrease in the foreign currency exchange rate (so-called PLN appreciation), because he will get a smaller amount after exchanging US dollars for the PLN. It should be emphasized that the currency risk is the most dangerous in the periods of economic crises referred to above. However, the currency risk should not be underestimated also in other phases of the business cycle, as small fluctuations in the exchange rate, with large amounts of exchange, can pose a significant threat to the financial stability of the production plant.

https://doi.org/10.32933/ActaInnovations.33.8 • ISSN 2300-5599 •

Credit risk. In general, credit risk is associated with lending institutions (e.g. banks). It consists in the danger that the borrower will not fulfil his obligation to pay the loan instalments in a timely manner (e.g. he will repay them with some delay or unevenly). In a worse scenario, he will not repay part or all of the loan at all. As for the fertiliser plant, credit risk may arise when it sells finished products for the so-called merchant credit. This type of solution is often used for several reasons. The main of them include:

- establishing cooperation with a larger number of recipients who are not able to pay for the goods immediately (e.g. farmers often lack money for sowing and other field works, especially in the spring and summer, so they can only settle accounts after selling harvested crops);
- retaining regular customers who may experience a temporary shortage of cash;
- willingness to reduce expenses related to the storage of finished products that have not been sold due to the temporary reduction of the financial capacity of fertiliser recipients.

In addition, it is possible to increase one's own accounting liquidity if the production plant accepts drawn bills of exchange in settlements with customers (especially wholesalers). They can be used for further settlements between business entities in subsequent purchase and sale transactions. Another option is realisation of the promissory note by discounting it at a commercial bank, which can withdraw cash before the maturity date in the amount that takes into account the time value of money. However, one should remember that the promissory note should be additionally signed (guaranteed) by three people considered to be solvent and that the deadline for its expiry should not exceed 90 days. Only if such conditions are met, it can be accepted by the bank. Credit risk is associated with the risk of losing accounting liquidity and bankruptcy risk.

Interest rate risk. If an enterprise has financed its investment activities and/or finances current operations with bank loans (long and/or short-term) and bonds (e.g. it issues bonds - long-term debt securities or vouchers or commercial papers - short-term debt securities), it may expose itself to the risk of changes in market interest rates. In the event of an increase in the market interest rate, this is the issuer of the said securities (owner of the plant) that has to repay higher loan instalments, which will adversely affect his economic account. On the other hand, when issuing debt securities with a fixed interest rate, the risk entails a decrease in interest rates, as the issuer will pay interest to bondholders at a higher rate than that set up on the free market, and therefore its opportunity cost will increase, which will not increase the accounting cost, however, it will increase the economic cost. This risk is associated with the risk of losing accounting liquidity and bankruptcy risk.

Discussion with the other scientists and papers

Links between different types of risk

Each type of risk carries some threats to the business entity's operations. Therefore, it is important to include all possible risks in the risk management strategy, which should be understood as diversified risk (i.e. consisting of many types of risk and having many causes and manifestations). In addition, as has already been mentioned, different types of risk are often interrelated, and they can be compound or can mitigate each other. Table 2 shows the consequences of occurrence of individual types of risk and the types of risk they may increase.

Table 2. Types of risks, their consequences and links

Type of risk	Risks and links with other types of risks
Types of risks related to business partners	
Risk of supplying fertiliser components of inadequate quality	Risk related to the inability to produce fertilisers with predetermined characteristics. Legal (regulatory) risk. Risk of incurring penalties for not providing fertiliser to customers that may negatively impact the company's financial result. Risk of losing accounting liquidity. Risk of losing a client. Risk of losing good reputation. Bankruptcy risk.
Risk of non-compliance with deadlines for the delivery of raw materials or their total absence.	Risk connected with incurring penalties for not providing fertiliser to customers (e.g. compensation to farmers for losses suffered), that may negatively impact the company's financial result. Risk of losing accounting liquidity. Risk of losing a client. Risk of losing good reputation. Bankruptcy risk.
Risk of the presence of eggs of parasites and pathogenic bacteria in fertiliser	Risks to consumers' health and compensation payments for them (possible court costs) that can ruin the company. Risk of losing accounting liquidity. Risk of losing a client. Risk of losing good reputation. Bankruptcy risk.

Risks related to the macroeconomic and megaeconomic factors	
Price risk (relative to the price of the finished product - fertiliser)	A sharp drop in demand for the fertiliser produced causes a drop in its price (due to the market mechanism). In turn, the increase in demand for digestate from which the fertiliser is made (e.g. for the production of other goods, for example pellets for heating purposes) increases the costs of fertiliser production and increase its price. The increase in fertiliser production costs may also be caused by the increase in prices of: raw materials and materials, energy and labour, taxes and interest on loans, ecological fees. However, the increase in costs cannot always be passed on entirely to the customer (i.e. the price of the product), as the product may become uncompetitive and clients will not want to buy it. As a consequence - the lack of revenues and collapse of the company. Competition risk. Risk of losing accounting liquidity risk of bankruptcy.
Risk of increasing motor fuel prices	One of the components of the price of many products is the price of fuels. In the case of organic-mineral fertiliser plants, fuels are used to drive vehicles that supply raw materials for production and deliver finished products to brokers and sometimes also to customers. If we consider gasoline and diesel, their prices depend on world prices for the crude oil from which they are made. In turn, the price of this raw material is influenced by many other types of risk (mainly of global significance), for example: the risk of political changes; wars and conflicts; currency risk; phase of the business cycle.
Cyclical risk	The threat due to this type of risk is related to the general condition of development of the national economy, i.e. whether economic conditions are good or bad. When economic conditions are good, enterprises grow, they need more and more raw materials, materials and products. Then both demand and supply are stable. On the other hand, in times of economic downturn - companies go bankrupt, customer demand on most goods and services drops (due to reduced income and the impact of economic instability, and thus changes in the structure and size of consumption), which further increases bankruptcy processes among business entities with various business profiles.
Competition risk	A sharp increase in the supply of a similar fertiliser or substitution product may result in a decrease in demand for the fertiliser produced and/or a reduction in its price. One should also be afraid of domination on the market of one producer of similar fertiliser (monopolist) or an organized group (oligopolists). This risk may increase during the economic downturn, when the demand for most goods and services naturally drops.
Currency risk	Threats related to exchange rate fluctuations on the domestic and global market. These fluctuations may be a consequence of the impact of both national (e.g. balance of payments difficulties, economic and political instability) and global (economic crises, political tensions, wars and conflicts) factors. Entities conducting international exchange, including exports and imports, are most affected by this consequence. Exporters suffer losses in the event of appreciation of the national currency, while importers should be concerned about the depreciation of this currency in relation to foreign currencies, mainly the one that occurs in their business operations. Failure to take into account this type of risk may cause accounting liquidity problems or even lead to the collapse of the company.
Credit risk	In the case of selling fertilisers on merchant credit, there may be a risk that the customer will not pay it back on time or at all. Risk of losing accounting liquidity. Bankruptcy risk.
Interest rate risk	In a situation where an economic entity finances its activities with the participation of foreign capital (e.g. bank credit), it may be exposed to this type of risk. The threat increases with the extension of the maturity of the loan, especially with the use of a variable interest rate (and this is most often the case with long-term investment loans). This threat is associated with an increase in interest rates based on market interest rates, which usually go up in times of crisis and economic instability caused by different reasons. Then the loan instalments increase, and, as a consequence,

	there may be a problem with maintaining accounting liquidity and reducing the rate of return on investment. Bankruptcy risk.

Source: own elaboration

Uncertainty and impact of research results on science, economy, environment and society

Each type of human activity involves making decisions in conditions of uncertainty and risk. To sum up, the biggest reason for risk is volatility, which can bring both positive and negative effects. However, researchers and practitioners focus on the negative effects of risk, as they can lead to smaller or larger distortions in the stability of the economic entity or even to its bankruptcy. Hence, the attempts are made to identify potential threats (sources of risk) and forecast the consequences of their implementation. Risk identification is the first stage of the risk management process, which sets the foundation for further actions and determines their effectiveness. These activities may be geared to reducing or eliminating risk, depending on the probability of a threat occurring and the size exposed to risk (usually estimated in monetary units). However, the risk of economic activity is not only material losses, but also a threat to human health and life and a source of nuisance to the local community. And the consequence of this state of affairs may be the lack of social acceptance for a given economic activity. Also state organs and institutions may impose penalties in the event of environmental pollution.

Summary and conclusions

Generating energy from renewable sources is currently a priority in the economic policy of most countries, especially highly developed countries, which have the financial means to develop this part of energy, despite its lack of profitability. Hence, the attitude of the government of each country, which supports the idea of renewable energy sources, plays a huge role.

The second important task of current governments is to combat the growing amount of waste generated, mainly by high-standard societies. This waste harms not only the environment, but also people themselves through a negative impact on their health and comfort of life.

The "Biogas Plant - Digestate Fertilizer Plant" tandem at least partially solves both problems of modern societies. However, it is important that the activities of both participants of this tandem are stable and profitable. Business risk management, which starts from the stage of identifying risk factors, plays a significant role in providing them with appropriate operating conditions. Awareness of risk and taking appropriate actions to protect the company against its impact is a necessary condition for survival on the market, which is the main goal of every business entity (especially during periods of economic downturn when risk factors become active).

Conflict of interest

There are no conflicts to declare.

Acknowledgments

This research has not been supported by any external funding.

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USING ALTERNATIVE SOURCES OF METHANE FOR ENERGY AS A METHOD OF ENVIRONMENTAL PROTECTION AND IMPROVEMENT OF ECONOMY CONDITION, ON EXAMPLE OF POLAND

Abstract
The article analyses the types of waste generated in economy and the possibilities of their management, on the example of Poland. The main focus was on using selected types of waste for methane production. The impact of the decomposing mass of organic waste on the production of greenhouse gases was examined and various types of biogas plants operating in Poland were presented (biogas plants at landfills, biogas plants at sewage treatment plants, agricultural biogas plants). The article also presents the benefits for the economy from the use of methane from methane drainage. Unfortunately, in Poland, methane resources are used to a small extent. In the case of mines, landfills or sewage treatment plants it is related to high costs of constructing methane capture installations, which are not offset by revenues from sales of gas and green certificates. Although much more favourable blue certificates have been introduced for agricultural biogas plants, the obstacle standing in the way of their progress is the lack of local spatial development plans for the places designated for their construction.

Keywords
energy management, environmental protection, greenhouse gases, methane, municipal and agri-food waste, biogas

Nomenclature, Abbreviations
CSO - Central Statistical Office, EU - European Union, GHG - Greenhouse gas, CCS - Carbon Capture and Storage, GDP - Gross Domestic Product, TGE – Towarowa Giełda Energii (eng. Polish Power Exchange), UV - ultraviolet, TGCs - Tradable Green Certificates system, TREC - Tradable Renewable Energy Certificates, RES - renewable energy sources, PRM - Property Rights Market, Ƞ - efficiency

Introduction
Since the dawn of time, man has had an impact on the environment. However, recently this impact has become more and more noticeable due to the ever-growing human population, progress in its development and the desire to increase the quality of life. As a result, the demand for food and industrial products increases, the production of which is very material- and energy-consuming. There is also a growing demand for energy, which is still obtained mainly from fossil fuels in the process of combustion of which carbon dioxide (CO_2) and other gases responsible for global warming (so-called greenhouse gases) are emitted to the atmosphere. In order to decrease their emissions, efforts are made to reduce the energy consumption of products and processes, as well as to use renewable and alternative energy sources for energy purposes. In order to reduce carbon dioxide emissions, the European Union requires Member States to ensure that the share of energy obtained from renewable sources in 2020 is not less than 15% in the total energy consumption of these countries [1].

The EU's climate and energy policy for 2021-2030 introduces higher requirements regarding [2]:
- reduction of greenhouse emissions (by at least 40% compared to 1990),
- increasing the share of energy from renewable sources (up to 32%),

- increasing energy efficiency (by at least 32.5%).

Going even further in its plans (until 2050), the European Commission has agreed to reduce greenhouse gas emissions to net zero (introducing so-called climate neutrality) and started a discussion on changing to more ambitious emission reduction targets by 2030 [3].
„The European Commission's vision outlines seven main strategic building blocks:

- maximise the benefits of energy efficiency, including zero emission buildings;
- maximise the deployment of renewables and the use of electricity to fully decarbonise Europe's energy supply;
- embrace clean, safe and connected mobility;
- a competitive EU industry and the circular economy as a key enabler to reduce GHG emissions;
- develop an adequate smart network infrastructure and interconnections;
- reap the full benefits of bioeconomy and create essential carbon sinks;
- tackle remaining CO_2 emissions with Carbon Capture and Storage (CCS)" [4].

Still, the main focus of EU and international organizations dealing with the problem of global warming remains on reducing CO_2 emissions. While focusing on carbon dioxide, less attention is paid to emissions of another dangerous greenhouse gas into the atmosphere - methane, which is separated from fossil fuel deposits during their exploitation (e.g. hard coal and brown coal) or is formed during uncontrolled anaerobic digestion of an organic substance, which is classified as waste in agriculture and animal husbandry as well as agri-food processing. Methane is the basic component of natural gas (also known as high-methane gas) extracted from the Earth's interior, which is used for various economic purposes, mainly energy. It is also found in coal deposits, during exploitation of which it is released. Due to the explosive nature of its mixture with air, it poses a huge threat to the safety of miners. Methane is also produced as a result of anaerobic fermentation of organic matter, and if it occurs uncontrollably it escapes into the atmosphere, reinforcing the greenhouse effect, because its carbon equivalent is 25. Technical progress in recent decades, on the other hand, has resulted in the containment of the released methane in some cases and in using it (as an alternative source) for energy production. In order to obtain gas, the mines carry out degassing of deposits and recover them from air ventilating in mine workings. Methane is also a basic component of biogas (45-70%) obtained from municipal waste landfills, sewage treatment plants and agricultural biogas plants. Biogas is most often burned in cogeneration units producing energy and heat, efficiency of which can be up to 90%. A particular feature of methane is that it is considered the most ecological fossil source of primary energy. That is why its development is so important, especially when it goes hand in hand with a positive effect for environmental protection. The purpose of this article is: to examine the production potential of the Polish economy in terms of methane production of various origins; analysis of the current degree of its use in Poland; identification of factors affecting the use of methane for business purposes in this country.

Method of research

The following research methods were used in the research: review and analysis of scientific literature; analysis of data published by the Central Statistical Office of Poland, National Agricultural Support Centre of Poland; analysis of data obtained from the Energy Regulatory Office and the State Mining Authority of Poland; environmental interviews. As a result, it was possible to identify the causes of the current situation in renewable energy and to propose solutions that will allow better use of methane obtained from alternative sources for energy purposes

Results of the research and Discussion with the other scientists and papers

1. Greenhouse gas emissions in Poland

Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and industrial gases. Aggregated emissions of these gases are expressed as a CO_2 equivalent. Equivalent means one megagram (1 Mg) of carbon dioxide or an amount of other greenhouse gas equivalent to 1 Mg of carbon dioxide, calculated using the appropriate warming factor. The global warming rate is as follows: carbon dioxide - 1, methane - 25, nitrous oxide - 298 [5].
Greenhouse gas emissions are associated with traditional energy production, industrial processes, product operation, agriculture and municipal waste. The Kyoto Protocol imposes an obligation on individual countries to declare a reduction in greenhouse gas emissions compared to the base year. For Poland, it was 1988, when the emission amounted to 569.8 million Mg. Poland has committed to a 6% reduction in emissions of this type of gas in 2008-2012 compared to the base year. Already in 2005, national greenhouse gas emissions amounted to 397.7

million Mg and remained almost unchanged until 2016 (in which it amounted to 396 million Mg of carbon dioxide equivalent). This means that compared to the base year there was a decrease in emissions by more than 30%, and thus much larger than declared, despite the increase in Gross Domestic Product (GDP) in this period. The total amount of greenhouse gases emitted to the atmosphere in 2016 was: 321 million Mg of carbon dioxide, 1.8 million Mg of methane (46 million Mg of equivalent) and 65,000 Mg of nitrous oxide (19 million Mg of the equivalent). Emission of 1.8 million Mg of methane is about 2.5 billion Nm^3, which is about 1/6 of the current domestic consumption of high-methane natural gas. The majority of methane, which is 41% (1.02 billion m^3), is emitted to the atmosphere in connection with the extraction of fossil fuels (liquid and solid). Other sources include: agriculture with a 30% share (0.75 billion m^3) and waste 19% (0.475 billion m^3) [5].
Among greenhouse gases that have such a negative impact on the Earth's atmosphere and cause long-term climate changes, sometimes with catastrophic effects, only methane can be used for energy purposes and benefit the economy.

2. Firedamp as a source of energy

Most Polish mines extract hard coal from methane deposits. In Polska Grupa Górnicza Sp. z o.o., which took over 11 mines from Kompania Węglowa S.A. only KWK "Piast-Ziemowit" is a non-methane mine. Methane is the greatest natural threat for miners in hard coal mines. The parameters determining the magnitude of the methane hazard are: "methane content - the volumetric amount of methane of natural origin, contained in a weight unit deep in the coal cathode and absolute methane content, which determines the amount of methane released in relation to the unit of time" [6]. The authors learned from correspondence with the State Mining Authority that the absolute methane content of Polish hard coal mines in 2018 was estimated at 916.05 million m^3 of methane. Due to the spontaneous methane extraction in the years 2000-2013, 11 national methane hazards, and one methane and rock outburst occurred in domestic coal mines, resulting in death and injury of several dozen miners [7]. There would be many more events and casualties if the mines did not have methane drainage, "which on the one hand raises mining costs, but on the other hand allows obtaining high quality gas and significantly improves underground work safety" [6].
It should be mentioned that firedamp is not pure methane, but it is a mixture of it with air of varying proportions. It can be burned for the needs of mines (heating and technological), electricity and heat generation in cogeneration systems or sold to external customers. The correspondence of the authors of the article with an employee of the State Mining Authority shows that in 2018, 316.97 million m^3 of methane was obtained in the process of methane drainage of mines, which was utilized in 60%.
A good example is "Brzeszcze" coal mine in which methane removal has been carried out since 1976. In 2013, it managed to sell about 37 million m^3 of gas to Energetyka Dwory in Oświęcim and about 1.5 m^3 to Nadwiślańska Spółka Energetyczna [6]. In order to manage more gas, KWK "Brzeszcze" together with Tauron Group plans to launch two cogeneration installations with a power of 2.7 MWe each by 2021. Their construction will produce up to 160 MWh / day (588,400 MWh / year) of electricity and the same amount of heat. It will also be an environmental protection measure and will reduce fees related to methane emissions to the atmosphere. The project implementation is part of the postulates of the Tauron Group Strategic Research Agenda. The installation is carried out by MAGENTA Grupa Tauron [8].

3. Obtaining biogas from municipal waste landfills

According to CSO data [5], in 2017, 12 million Mg of municipal waste (9.5% of all waste) was generated in Poland, of which only 7% (848 thousand Mg) was intended for biological processing – composting or fermentation [9]. The rest was disposed of in municipal waste dumps or incinerated in thermal waste treatment plants.
As already mentioned, natural fermentation processes occur in landfills, causing the release of biogas, which is a product of the anaerobic breakdown of organic substances contained in the waste. The resulting biogas can be used for economic purposes. The Regulation of the Minister of the Environment of 30 April 2013 on waste landfills contains "detailed requirements regarding the location, construction and operation of waste landfills, which correspond to particular types of waste landfills". Paragraph 8.1 states that "a landfill where biodegradable waste is to be stored is equipped with an installation for discharging landfill gas" and the resulting gas "is cleaned and used for energy purposes, and if it is impossible – it burns in a flare" [10]. Biogas collection installations are mounted on specially sealed landfills, built as a well system, to which biogas consisting of 45-65% methane, 25-35% carbon dioxide, 7-10% nitrogen and up to 3% oxygen diffuses. From the well, it is sent through a pipe system for development. Biogas is subjected to mechanical treatment, desulphurization and drying [9]. The calorific value of biogas from landfills ranges from 16-24 MJ / m^3 of waste.
At large landfills, biogas is burned in cogeneration units generating electricity and heat, the total efficiency of which is up to 80% [11]. Smaller landfills only use it to generate heat or burn it in torches. Electricity is sold

to the energy network and heat is used to heat water and rooms related to the operation of the landfill. On the other hand, the possibilities of selling heat to external customers are very limited due to the location of storage sites. In 2017, 301 landfills were legally being operated in Poland, of which 267 had degassing installations [12]. An additional advantage of the latter (apart from the energetic use of methane) is the reduction of odours that are burdensome for the inhabitants of the surrounding towns. According to data from the Energy Regulatory Office [13], as of December 31, 2018, only 97 landfills in Poland produced electricity. Table 1 provides information on the number of installations for receiving landfill biogas in individual voivodships, installed generating power and quantities of electricity sold.

Table 1. Power and electricity production form installations at landfills in 2018 in voivodships in Poland

Voivodship	Installations at landfills			
	Number	Power in MW_e	Energy production in MWh_e	Power utilization %
Dolnośląskie	9	6.136	5,434.796	10.11
Kujawsko-pomorskie	7	3.254	8,782.551	30.81
Lubelskie	3	1.428	398.304	3.18
Lubuskie	2	0.940	4,654.656	56.53
Łódzkie	4	3.678	16,024.764	49.74
Małopolskie	6	4.260	8,071.171	21.63
Mazowieckie	18	9.286	26,712.509	32.84
Opolskie	3	1.394	1,334.049	10.92
Podkarpackie	2	1.191	4,394.879	42.12
Podlaskie	1	0.320	1,111.138	39.64
Pomorskie	6	5.359	9,083.892	19.35
Śląskie	15	12.055	25,938.864	24.56
Świętokrzyskie	1	2.040	2,398.770	13.42
Warmińsko-mazurskie	3	1.407	2,243.082	18.20
Wielkopolskie	10	7.380	7,912.977	12.24
Zachodniopomorskie	7	2.720	4,232.822	17.76
Total	97	62.348	128,729.224	23.57

Source: Elaboration based on [13]

Most of such installations were in the following voivodships: Mazowieckie (18), Śląskie (15), Wielkopolskie (10) and Dolnośląskie (9). Podlaskie and Świętokrzyskie voivodships had one installation each, Lubuskie – two, and Warmińsko-Mazurskie Voivodeship – three. The highest power installations were reported in Śląskie (12,055 MWe) and Mazowieckie (9,286 MWe) voivodships. In turn, the smallest power was installed in the Podlaskie Voivodeship (only 0.32 MWe).

These installations produced a total of about 129 GWh of electricity, including the most – in Mazowieckie and Śląskie voivodships, and the least – in Lubelskie. The low number of electricity producing storage sites may be due to the fact that with the current price of energy sold to the network and low rates of utilization of installed power, local governments do not decide to invest in power generators, as it is unprofitable. The low utilization of installed power does not, however, disqualify installations for the recovery of methane from landfills, because their most important goal is to reduce methane emissions to the atmosphere.

4. Biogas production in sewage treatment plants

Important tasks of local governments in Poland include water supply and sewage management. Municipal sewage is "domestic sewage or a mixture of domestic sewage with industrial wastewater, rainwater or snowmelt, discharged with devices used to carry out the commune's own tasks in the field of sewage and municipal wastewater treatment". Their treatment takes place in specially designated plants – municipal sewage treatment plants, the number of which in 2000-2017 increased from 2,417 to 3,258 (increase by 34.78%) [5].

The full cycle of municipal wastewater treatment includes: mechanical, chemical and biological treatment as well as removal of nutrients (nitrogen and phosphorus compounds). New and modernized municipal sewage treatment plants are in 75% equipped with installations for biological treatment and 25% for increased removal

of nutrients. The equipment of the sewage treatment plant with installations for biological treatment and removal of nutrients has significantly improved the purity of water in Polish rivers. In sewage treatment plants, however, sewage sludge management is a problem. The best way is to subject them to methane fermentation, resulting in biogas containing up to 70% methane [14]. The limitation of the methane fermentation process is the low level of degradation of the organic substance and the long residence time of the sludge in the reactor. Therefore, improving efficiency requires preliminary disintegration of the sludge and enriching it with organic matter contained, e.g. in waste from the food industry or kitchen waste, which would be crushed in grinders installed at the sinks. The effect of the latter would be the reduction in the content of organic substances in mixed municipal waste, directed to landfills.

Some municipal sewage treatment plants have biogas installations and devices for burning it in cogeneration aggregates producing electricity and heat. The former is sold to the network and the latter is intended to support the methane fermentation process in about 30%. The remaining part is used for the needs of the sewage treatment plant and possible selling. As of December 31, 2018, only 109 municipal sewage treatment plants from amongst 3,257 (mechanical - 8, biological – 2,439, with increased removal of nutrients - 810) produced electricity [15, 16]. This means that electricity from biogas is produced only by around 3% of municipal treatment plants, and while 75% of treatment plants could do that. For comparison: in Germany per 10,000 sewage treatment plants, 1,200 have already biogas plants. They produce totally so much electricity that it would be enough for 300,000 households [17]. Table 2 provides information on the number of biogas plants in Poland, installed capacity, amount of electricity sold, broken down by voivodships.

Table 2. Power and electricity production in installations at sewage treatment plants in 2018 in voivodships in Poland

Voivodship	Installations in sewage treatment plants			
	Number	Power in MW_e	Energy production in MWh_e	Power utilization in %
Dolnośląskie	9	3.702	19,272.72	59.43
Kujawsko-pomorskie	5	4.251	14,056.36	37.75
Lubelskie	4	2.642	17,590.33	76.00
Lubuskie	2	1.190	2,618.58	25.12
Łódzkie	5	4.204	3,932.84	10.68
Małopolskie	10	4.903	19,754.48	45.99
Mazowieckie	14	11.254	29,797.05	30.22
Opolskie	3	1.252	5,661.33	51.62
Podkarpackie	10	3.313	11,054.81	38.09
Podlaskie	5	4.112	20,065.26	55.70
Pomorskie	5	6.897	22,703.32	37.58
Śląskie	18	9.673	35,906.95	42.38
Świętokrzyskie	2	0.982	3,613.32	42.00
Warmińsko-mazurskie	6	3.791	12,671.09	38.16
Wielkopolskie	7	6.637	25,013.56	43.02
Zachodniopomorskie	4	1.478	5,731.00	44.26
Total	109	70.281	249,443.00	40.52

Source: Elaboration based on [13]

In 2018, all sewage treatment plants produced about 250 GWh of electricity in total. Most biogas plants producing electricity from wastewater were located in Śląskie (18) and Mazowieckie (15) voivodeships, which is associated with a large number of inhabitants and a high degree of urbanization. The least amount of them function in the following voivodships: Świętokrzyskie (2), Lubuskie (2) and Opolskie (3). In terms of energy generated, the leading voivodships: Śląskie, Mazowieckie and Wielkopolskie.
Analysis of the data contained in Tables 1 and 2 provides grounds to conclude that the utilization of installed power at sewage treatment plants is much higher than at waste landfills; on the other hand there is no data on the use of heat. Only by observing the location of the sewage treatment plant in Krakow it can be assumed that it is higher compared to waste landfills. The heat is used to heat the technical facilities of the treatment plant. The surrounding plants also receive heat generated in the wastewater treatment plant.

The conducted interviews show that the profitability of municipal sewage treatment plants is not impressive at present time. Perhaps the introduction of special certificates (similar to green certificates) for electricity obtained from biogas (from sewage treatment plants) would increase the interest of local governments in the installation of power generators.

It is worth to remind that the Tradable Green Certificates system (TGCs) or Tradable Renewable Energy Certificates (TREC) is a mechanism to support the production of energy from renewable sources, which was introduced on October 1, 2005, pursuant to the amended Act of April 10, 1997 Energy Law [18]. Green certificates are documents that confirm the production of electricity using geothermal energy, solar, wind, water (waves, currents and tides as well as rivers fall) or obtained from biomass. Certificate trading was organized on the Polish Power Exchange (TGE) on the Property Rights Market [19]. The essence of the TGCs system is imposed on energy companies dealing in the sale of electricity to end users, the obligation to have the number of green certificates specified by the President of the Energy Regulatory Office. The company can generate the applicable amount of energy from renewable energy sources (RES), it can also buy green certificates on the free market or pay so called "substitution fee".

5. Agricultural biogas as a source of energy

The Act on renewable energy sources (adopted by the Sejm of the Republic of Poland on February 20, 2015) defines agricultural biogas as "fuel obtained in the methane fermentation process from agricultural raw materials, agricultural by-products, liquid or solid animal excrements, by-products or residues from the processing of agricultural products or biomass forest, excluding gas derived from raw materials from sewage treatment plants and landfills. " It is produced in biogas plants consisting of a complex of buildings adapted to convert the above-mentioned raw materials (substrates) into biogas and digestate which is a valuable fertilizer [20].

Agricultural biogas contains 40-85% of methane, 16-48% of carbon dioxide, 0.6-7.5% of nitrogen [21]. After removal of hydrogen sulphide, carbon dioxide and water vapor, it is most often burned in cogenerators. The main advantage of combined electricity and heat generation is a much higher overall efficiency of this process compared to separate generation (Figure 1). When heat and energy is generating separately, 156 units of fuel are needed to produce 34 units of electricity and 56 units of heat. However, with cogeneration combustion, 100 fuel units are enough to get the same result. This means that the total efficiency of cogeneration aggregates is about 90%, and the efficiency of separate production of electricity and heat is only 58%. Obtaining such high efficiency is possible due to the use of heat recovery generated in the process of electricity production [22].

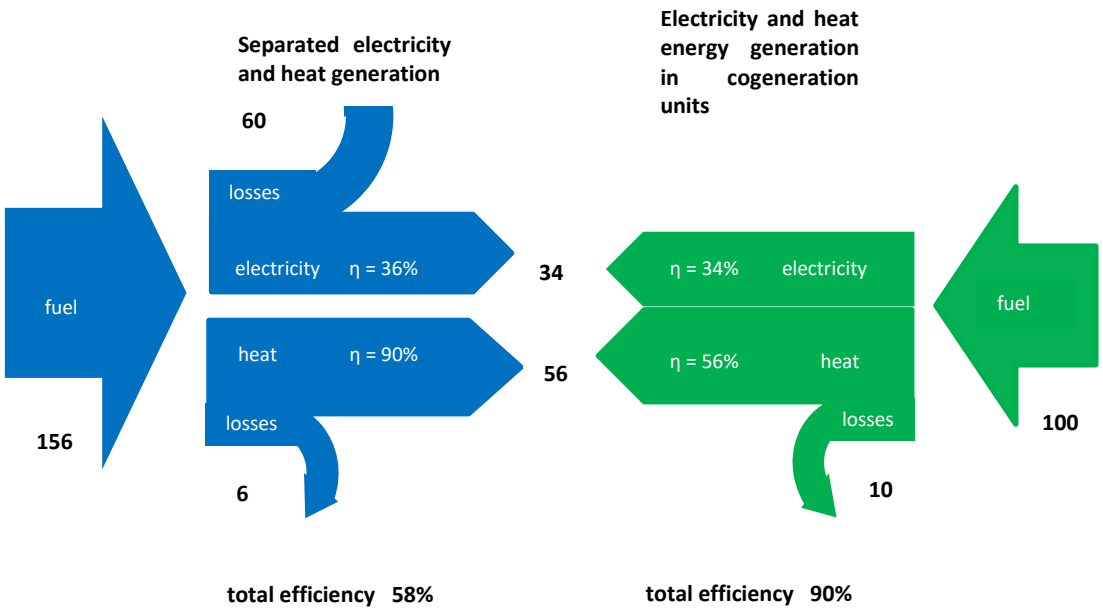

Figure 1. Comparison of efficiency of electricity and heat generation in a separated process and in cogeneration units, Source: [22]

Agricultural biogas plants can be an important element of the national energy policy implemented in rural areas where agricultural production and breeding (cultivation of crop plants, animal husbandry) and forest management are carried out. The estimated raw material potential in these areas allows for the production of about 5 billion m^3 / year of agricultural biogas with high-methane natural gas parameters [23]. Considering this potential, in 2010 the Council of Ministers adopted a document entitled "Directions of development for agricultural biogas plants in Poland for the years 2010-2020" [24], in which it was assumed that by 2020, on average, one biogas plant will operate in each commune. Meanwhile, only 95 of such biogas plants operated at the end of 2018. Table 3 summarizes data on their number in individual voivodships, installed power and amount of electricity produced.

Table 3. Power and electricity production of agricultural biogas plants in 2018 in voivodships in Poland

Voivodship	Agricultural biogas plants			
	Number	Power in MW_e	Energy production in MWh_e	Power utilization in %
Dolnośląskie	10	9.410	33,808.488	41.01
Kujawsko-pomorskie	6	7.991	49,974.044	71.39
Lubelskie	7	9.859	55,906.743	64.73
Lubuskie	4	2.792	18,366.557	75.09
Łódzkie	4	5.057	35,943.210	81.14
Małopolskie	2	1.150	9,555.870	94.86
Mazowieckie	6	6.819	24,181.135	40.48
Opolskie	1	2.000	7,604.988	43.41
Podkarpackie	3	2.498	11,067.572	50.58
Podlaskie	9	7.596	30,189.763	45.37
Pomorskie	9	10.159	79,996.491	89.89
Śląskie	2	1.596	11,638.826	83.25
Świętokrzyskie	1	0.800	3,403.420	48.56
Warmińsko-mazurskie	10	9.606	69,043.861	82.05
Wielkopolskie	11	10.678	54,105.624	57.84
Zachodniopomorskie	13	12.690	72,311.543	65.05
Total	95	102.688	567,099.135	63.04

Source: Elaboration based on [15]

The majority of biogas plants in 2018 operated in the following voivodeships: Zachodniopomorskie (13), Wielkopolskie (11), Dolnośląskie (10) and Zachodniopomorskie (10). One biogas plant operated in Opolskie and one in Świętokrzyskie voivodship, and two in either Małopolskie and Śląskie. The total installed power of all agricultural biogas plants in Poland amounted to 102.688 MW then. In total, biogas plants produced about 570 GWh of electricity, the majority – in the Pomeranian, Warmińsko-Mazurskie, Lublin and Wielkopolskie voivodships. Biogas plants from Małopolskie, Śląskie and Warmińsko-Mazurskie Voivodeships showed the highest factor of utilization of installed power. As for the use of power in agricultural biogas plants, it is much higher than in installations at landfills and municipal wastewater treatment plants.
Cogenerated biogas produces more heat than electricity. In the years 2011-2014 and until mid-2015, agricultural biogas producers were required to provide information on the amount of heat produced. According to the data of the National Agricultural Advisory Centre [25], the amount of heat produced at that time was as follows: 2011 - 82.628 GWh, 2012 - 160.128 GWh, 2013 - 246.557 GWh, 2014 - 373.906 GWh and in the first half of 2015 - 224.996 GWh.

There are several reasons why the agricultural biogas production potential is not being used. The most important reason is the lack of places in local spatial development plans of communes for the location of new biogas plants, therefore the time for obtaining a building permit is extended, mainly because of residents' protests. The reason for the protests is primarily that biogas plants are a potential source of odour emissions and should be located away from residential buildings [26].

The factor limiting the creation of new agricultural biogas plants is also the lack of prospects for stable conditions of implementing investments, primarily in terms of the amount, length and form of financial support. In addition, in recent years there has been a decline in the prices of certificates of origin for energy from renewable energy sources (the so-called green certificates) listed on the Polish Power Exchange (TGE – in Polish: Towarowa Giełda Energii). In the years 2011-2015, prices of certificates of origin dropped from PLN 280 to PLN 120. As a result, the biogas plant revenues decreased from PLN 480 to PLN 300 / MWh, which was the border price for profitability [27].

Blue certificates were introduced in Poland due to the Act on Renewable Energy Sources, which entered into force on 1 July 2016 [28], in order to support the development of biogas energy production in Poland. The support mechanism is based on the commitment of energy companies to buy parts of electricity produced in agricultural biogas plants. If the energy companies do not have such a possibility, they are obliged to purchase so-called "Blue certificates" directly from biogas plant owners or on the Polish Power Exchange (TGE).

Uncertainty and impact of research results on science, economy, environment and society
It is known that business activity involves many types of risk as a result of uncertainty arising from the external environment. Waste management allows reducing the impact of ecological risk primarily on human health and life. However, their rational use also allows for obtaining economic effects, e.g. in the form of obtained biogas, which can be used for the production of electricity and heat.
Waste management activities are part of the new economy model – the Circular Economy, which is implemented in the member states of the European Union. The model is focused on reproducibility and renewal, and the main effects of its implementation are the rationality of management and reduction of negative impact on the natural environment.

Increasing amounts of waste generated by individual countries pose a threat to the flora and fauna of our planet. In addition, a large part of the waste is unused raw materials that can return to the economy. For example, the substrates used as input in agricultural biogas plants are agricultural and food waste. Sewage treatment plants obtain biogas from waste waters. Biogas can also be a by-product of operations, such as mine gas escaping during coal mining, or gas generated in municipal waste landfills.

Technologies for capturing or obtaining methane in the process of anaerobic waste fermentation are a new direction of scientific research that will bring measurable benefits to humanity, such as the development of more efficient waste treatment methods that the Earth's inhabitants constantly produce.

Biogas is pure or purified methane. On the one hand, the use of methane for energy purposes benefits the economy, it is used for the production of electricity and heat, and as fuel for driving vehicles. On the other hand, methane is a greenhouse gas that contributes to climate change with all its negative effects, including extremely

low or high temperatures, drought, hurricanes, storms, floods, melting glaciers, rising temperature and ocean water levels, flooding low-lying territories, spreading infectious diseases, climate migrations, political tensions. Therefore, reducing methane emissions to the atmosphere through its management is a pressing challenge for science and the economy.

Summary and conclusions

As it results from the data cited in tables 1-3, in 2018, 945 GWh of electricity was generated from biogas in Poland. This result was 18% higher compared to 2014 (800 GWh). However, this increase is far from sufficient to meet the obligations regarding the share of renewable energy in the Polish energy mix. For example, in Germany already in 2014, 86,062 GWh of electricity was produced from biogas [29].

The construction of installations for the production of energy from biogas obtained at landfills and in municipal wastewater treatment plants requires high expenditures, the return of which is very slow, due to the low power utilization of installed cogeneration aggregates. An incentive to invest in these installations could be the granting of blue certificates for energy produced from any type of biogas.

In addition, the development of agricultural biogas plants is currently limited by the protests of residents who are afraid of emissions of substances harmful to health (hydrogen sulphide, ammonia, mercaptans, carbon monoxide). Limiting the odour nuisance of agricultural biogas plants means building them at a sufficiently large distance from human settlements, using substrates with less odour nuisance, encapsulation of lines and production rooms, purifying waste gases, using: biofilters, bioscrubbers, bioflushers, physical-chemical methods, ozonation, UV radiation exposure [23]. The fact that this is a problem that can be solved is demonstrated by the large number of such biogas plants in Germany, where the population density is much higher than in Poland.

Producers and distributors of electricity and heat should be more widely involved in the use of methane from unconventional sources for energy purposes. Currently only ENEA Wytwarzanie Sp. z o.o. operates two agricultural biogas plants. They are located in Liszków (Kujawsko-Pomorskie Voivodeship) and Gorzesław (Dolnośląskie Voivodeship). Their installed power is 2.126 MW and 1.698 MW, respectively [22]. However it is most important that the state's energy policy is aimed at supporting the energy use of methane from alternative sources, for the benefit of the economy and the environment.

Conflict of interest

There are no conflicts to declare.

Acknowledgments

This research has not been supported by any external funding.

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ANALYSIS OF INNOVATIVE ACTIVITIES OF SMALL AND MEDIUM-SIZED ENTERPRISES AS FUNDAMENTALS OF THEIR SUSTAINABLE ECONOMIC DEVELOPMENT

Abstract
This article seeks to address the pressing issue of developing the innovative activity of the domestic economy through the use of the potential of small and medium-sized enterprises, which has to do with the possibility of application of existing experience of the more developed foreign countries in order to achieve economic success. The purpose of this study is to examine the trends in the development of innovative activity of small and medium-sized enterprises in Ukraine, as well as to determine the distribution of the total amount of expenditures by areas of innovation. Analysis of the literature on this issue has shown that the economic development of a country depends on many factors, and the use of intellectual potential is quite a significant factor in modern society. The relevance of this issue is supported by the fact that the majority of developed countries that have high levels of national income and are distinguished by the quality of life of the population are introducing the latest innovative inventions and using them appropriately in: production, agriculture, trade and other fields of activity. The research of the development of innovation activity of small and medium-sized enterprises in the article is carried out in the following logical sequence: analysis of small and medium-sized enterprises in Ukraine, analysis of small and medium-sized enterprises of EU countries, evaluation and comparison of innovation activity of Ukraine and EU countries. The methodical tools of the study included methods of statistical analysis. The study period was 2010-2018. The object of analysis is the process of development of innovation activity of small and medium-sized enterprises, as they are the majority of enterprises in Ukraine. The article presents the results of the analysis of the state of innovation the activity of small and medium-sized enterprises, which showed that our country needs significant transformation in this direction. Studies show that increasing the turnover and the production of small and medium-sized enterprises depends on the level of innovative development. The results of the study may be useful for small and medium-sized enterprises.

Keywords
innovation, scientific and technical activity, technological readiness, innovation development, innovation activity, small and medium-sized enterprises.

Introduction

The development of innovation activity of the domestic economy through the use of the potential of small and medium-sized enterprises is a pressing issue, which has to do with the possibility of application of the existing experience of the more developed foreign countries in order to achieve economic success. The term and concept of “innovation” as a new economic category was introduced into scientific circulation by the Austrian (later American) scientist J. Schumpeter [0]. The economic development of a country depends on many factors, and the use of intellectual potential is quite a significant factor in modern society. The majority of developed countries, which have high levels of national income and are distinguished by the quality of life of the population, are introducing the latest innovative inventions and using them appropriately in production, agriculture, trade and other fields of activity. The increase in the turnover and the production of small and medium-sized enterprises directly depends on the level of innovative development. New and demanded goods and services are the main factor of the existence and competitiveness of these enterprises. The rapid changes in consumer needs, the updates of quality requirements, the small life cycles of goods or services and the increase in their diversity

are all due to the fact that the production of small and medium-sized enterprises has to be modernized in the shortest possible time. Innovation is a key condition for the development of any enterprise and the economy of the country.

Method of research

The author proposes to review the general condition of small and medium-sized enterprises in Ukraine — to evaluate the component of small and medium-sized enterprises in the economy of the country, to determine the volume of sales of small and medium-sized enterprises and to identify the main types of economic activity of small and medium-sized enterprises.

The next step in analyzing the statistical information on the innovative activity of small and medium-sized enterprises (SMEs) will be to analyze SMEs in the EU. First, the EU's SMEs are evaluated, and then the innovation performance of EU countries is evaluated — the proportion of EU enterprises that have had innovative products, the innovative SMEs of the EU, the distribution of innovative SMEs by major types of innovation, the Summary Innovation Index (SII) of EU countries, SMEs with innovative products or processes, marketing or organizational innovations and SMEs' innovations in their own businesses.

The last step is to conduct an assessment of Ukraine's innovative activity — the main indicators of Ukraine's innovation activity, the "Innovation" and "Technological Readiness" sub-indices of the GCI rating. After assessing the state of innovation, a consideration of the intensity of innovation spending of Ukraine with other countries and an analysis of the distribution of sources of financing the innovation activity of industrial enterprises are proposed.

Results

In 2017, the number of large enterprises in Ukraine amounted to 399 (0.02% of the total number of economic entities), the remaining 99.98%, including 15,524 medium-sized enterprises and business entities, 322,920 small enterprises (incl. micro-enterprises) and 1.4 million small and micro-sized business entities (0).

Consider the dynamics of changes in economic entities for 2010-2017. (Table 1). We see a downward trend in the number of working enterprises, so compared to 2010, the number of large enterprises decreased by 32% and in 2017 amounted to 399. The number of medium-sized business entities also decreased by 28% in 2017 compared to 2010. The number of small business entities decreased by 23%, micro entities by 17%.

Analyzing the volume of sold products (goods, services) we can say that the ratio for 2010-2017 remains almost unchanged (Fig. 1). In 2017, the share of large entities accounted for 35.2% of the total sales, the medium entities 39.9%, small and micro entities 12.2% and 12.7% respectively.

Table 1. Indicators of Structural Statistics by Economic Entities with Size Distribution

	Total	Large Entities	Change,%	Medium-sized Entities	Change,%	Small (excl. Micro Entities)	Change,%	Micro Entities	Change,%
Number of Economic Entities									
2010	2183928	586	N/A	21338	N/A	68316	N/A	2093688	N/A
2011	1701620	659	+12.46	21059	-1.31	71083	4.05	1608819	-23.16
2012	1600127	698	+5.92	20550	-2.42	68103	-4.19	1510776	-6.09
2013	1722070	659	-5.59	19210	-6.52	65021	-4.53	1637180	+8.37
2014	1932161	497	-24.58	16618	-13.49	55159	-15.17	1859887	+13.60
2015	1974318	423	-14.89	15510	-6.67	47555	-13.79	1910830	+2.74
2016	1865530	383	-9.46	15113	-2.56	49298	+3.67	1800736	-5.76
2017	1805059	399	+4.18	15254	+0.93	52324	+6.14	1737082	-3.53

Source: Author's based on [4]

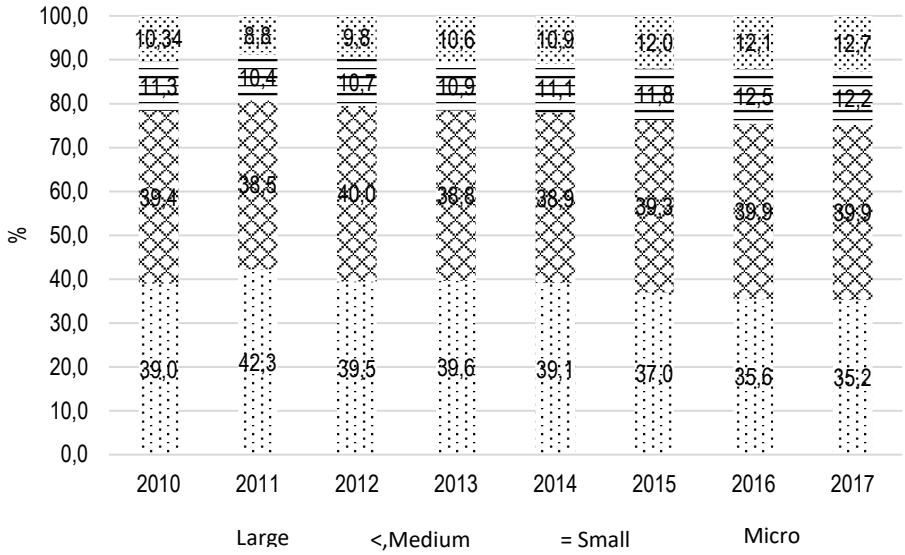

Figure 1. Distribution of Sales of Enterprises by Size in 2010-2017 % of Total Sales (Compiled by the Author) [2]

Thus the volume of sales of enterprises in modern conditions is the most important performance indicator of economic activity. The volume of sales of SMEs is 64% which is the majority. The value of this indicator is affected by fluctuations in structure and physical sales volume and changes in product prices. To increase sales volumes is the following are recommended for businesses:

- Produce competitive and quality products (services)
- Expand the range of goods or services
- Effectively use labor resources
- Carry out innovative activity.

Analyzing the 2018 Summary Innovation Index (SII) for each EU country, the highest rates are in: Sweden (0.71) Finland (0.70) and Denmark (0.68) against 2010 Sweden (0.68) Denmark (0.66) Finland (0.63). The lowest rates are in: Romania (0.16) Bulgaria (0.23) Poland (0.29) against Romania (0.22) Latvia (0.23) Bulgaria (0.24). According to this index, the leading countries have changed in 2018. Finland was in second place compared to third in 2010. Denmark is in 3rd place (against 2nd in 2010) and the Netherlands are in 4th place (+2 positions) [3] (Fig. 2).

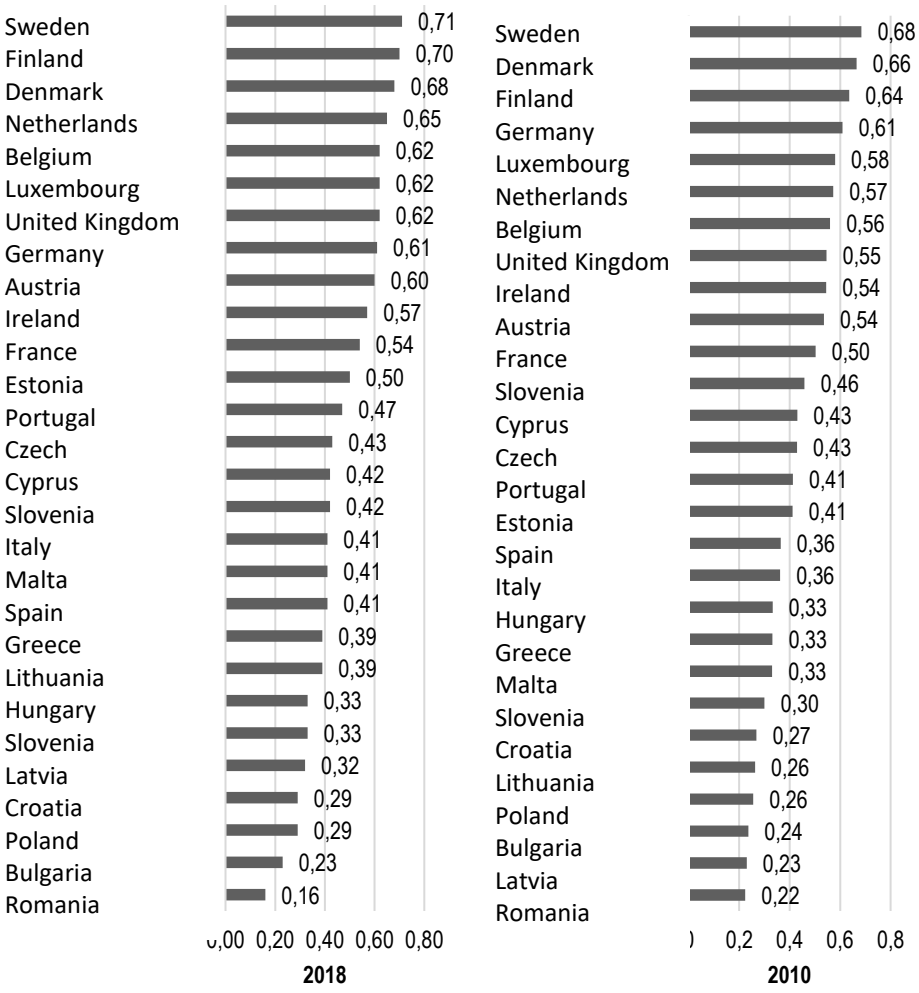

Figure 2. Summary Innovation Index (SII) of EU Countries in 2018 Compared to 2010 [3]

Comparing EU innovation performance in 2010 we can say that in 2018 they increased by an average of 5.8%. In the last 8 years, innovative activity has grown in 18 EU countries and decreased in ten.

The following are: Denmark — environment for human resources and innovation; Luxembourg — attractive research systems; France — finance and support; Ireland — innovation in SMEs and employment and sales impact; Belgium — innovative relations and cooperation [3].

Given the global trends of globalization, an international comparative analysis of innovative trends is of particular importance in order to answer the question of Ukraine's place in the global innovation process. Innovative capacity and technological readiness are integral components of the *competitiveness of the* national economy. According to the report of the World Economic Forum on Global Competitiveness, Ukraine's rating under the "Innovation" sub-index increased to 61st place in 2016-2018 compared to 93rd in 2013-2014 climbing 32 positions in the rating (Table 2). The growth in this rating (compared to 2013) was influenced by the improvement in almost all its components in particular: innovative capacity (+49 positions) quality of research institutes (+9 positions) companies' expenditures on research and development (+36 positions) university relations with industry (+4 positions) government procurement of the latest technology and products (+22 positions). The quality of these components depends first and foremost on the efforts of the state to finance the costs of research and development, the acquisition of external knowledge, as well as machinery equipment and software.

Table 2. Innovation and Technology Readiness Sub-indices of GCI Rating for Ukraine

Components of the Global Competitiveness Index	2013-2014		2014-2015		2015-2016		2016-2017		2017-2018		2013-2018
	Rating	Score (1-7)	Rating	Score (1-7)	Rating	Score (1-7)	Rating	Score (1-7)	Rating	Score (1-7)	Rating Deviation
Innovation sub-index and its components											
Innovation	93	3.0	81	3.2	54	3.4	52	3.4	61	3.4	+32
Innovative capacity	100	3.2	82	3.6	52	4.2	49	4.4	51	4.3	+49
Quality of research institutes	69	3.6	67	3.8	43	4.2	50	4.2	60	3.9	+9
Research and development (R&D) spending of companies	112	2.7	66	3.1	54	3.4	68	3.3	76	3.2	+36
Relationships between universities and industry in R&D	77	3.4	74	3.5	74	3.5	57	3.5	73	3.4	+4
Public procurement of the latest technologies and products	118	3.0	123	2.9	98	3.0	82	3.1	96	3.0	+22
Presence of scientists and engineers	46	4.5	48	4.3	29	4.7	29	4.7	25	4.7	+21
Number of patents received in the US (per million people)	52	2.9	52	3.2	50	3.6	49	3.9	52	3.6	0
Technological readiness sub-index and its components											
Availability of the latest technologies	106	4.3	113	4.1	96	4.3	93	4.3	107	4.1	-1
The level of technology development	100	4.3	100	4.2	100	4.2	74	4.4	84	4.3	+16
Foreign direct investment and technology transfer	131	3.6	127	3.7	117	3.8	115	3.7	118	3.5	+13
Internet users	93	33.7	82	41.8	80	43.4	80	49.3	81	52.5	+12
Broadband Internet access	71	8.1	68	8.8	72	8.4	64	11.8	63	12	+8
High-frequency Internet	84	14.3	50	52.9	64	40.7	68	45.7	54	79.9	+30
Broadband mobile coverage	94	5.5	107	5.4	121	7.5	130	8.1	115	22.6	-21

Note: *N/A – not available

Source: Author's based on [4]

Activities of the enterprises themselves also directly influences these components since the they prefer using foreign technology to a greater extent through licensing over their own development and research. The rating of the "number of patents received in the United States" remained unchanged. Particular attention should be paid to the technological readiness sub-index, the rating for which is constantly increasing and which is associated with the rise in place all its components (see Table 2) except for the position of the "Broadband Mobile Coverage" index (-21 positions compared to 2013-2018) and the "availability of the latest technologies" index (-position).
The main reasons for the increase in technological readiness in Ukraine can be attributed to the following: the Ukrainian economy mainly started utilizing new technological advances; innovative activity of enterprises (compared to EU countries) started to increase; improvement of legal instruments for the protection of property rights.

In terms of "Technological Readiness" (Fig. 3) in 2017-2018 Luxembourg, Switzerland, the Netherlands and the United Kingdom took the leading positions confirming the correlation between the level of innovation and the overall development of the country. These countries have not only maintained their position but also improved their results.

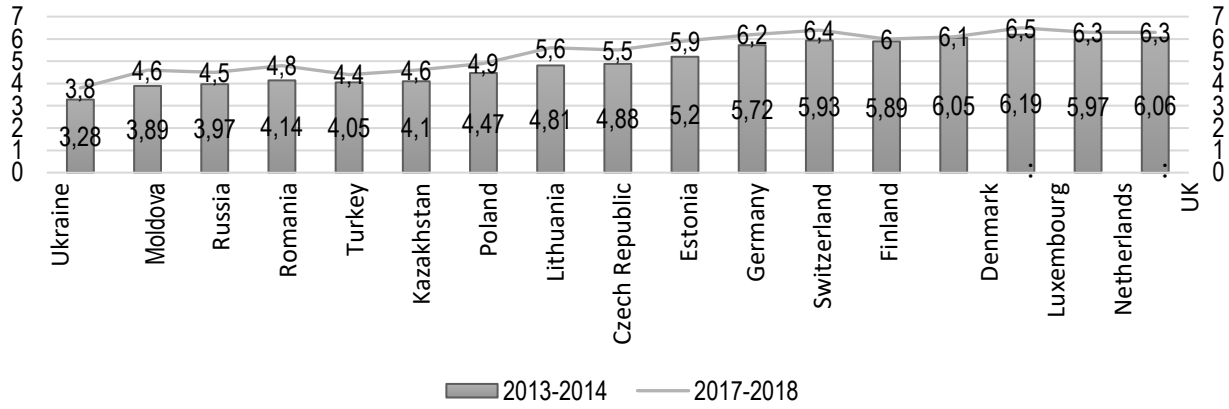

Figure 3. Ratings of Ukraine and Other Countries under the "Technological Readiness" Index
Compiled from [4]

Ukraine had a positive trend and climbed 13 places in the ranking (94th place in 2013 81st place in 2018). This is due to the fact that the pace of technological growth in Ukraine is rising significantly. Countries of the former Soviet Union have also increased the value of their indices which indicates a certain development in the fields of information mobilization, Internet distribution and more. The development of innovation activity in the regions of Ukraine is extremely uneven which is largely related to the level of development of the innovation infrastructure. The analysis of the existing infrastructure of innovative activity in Ukraine firstly testifies to its underdevelopment, functional incompleteness and inability to reach all links of the innovation process. Switzerland, the United States, Israel and Finland which in the period from 2013 to 2018 have improved their positions (Fig. 4) also take the top places in the rating of innovation countries (sub-index "Innovation").

https://doi.org/10.32933/ActaInnovations.33.10 • ISSN 2300-5599 •

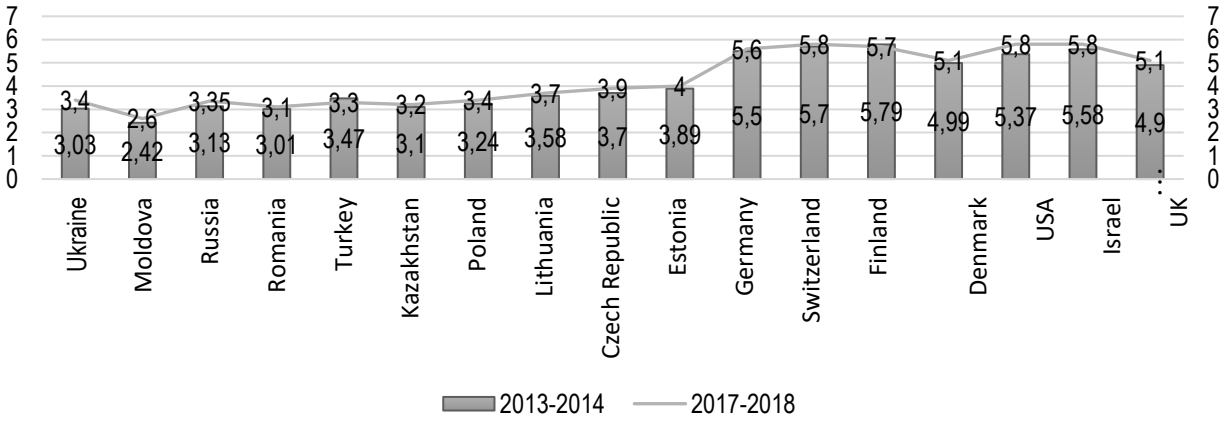

Figure 4. Ratings of Ukraine and Other Countries under the "Innovation" Index Compiled from [4]

The general trends of global development together with a real assessment of the level of scientific technical and innovative activity in our country testify to the threat of danger of being left out of the global processes of formation of a powerful innovation system. The lack of a comprehensive system for managing innovation processes in the country and the state-imposed repression of innovators initiated in 2005 have led to the following negative consequences:

1. The share of innovative products sold in total industrial production declined to 0.8% in 2018 (one of the lowest values in the last ten years) (Fig. 5) which is due to a decrease in consumer demand and the demand for industrial products caused by the financial and economic crisis.

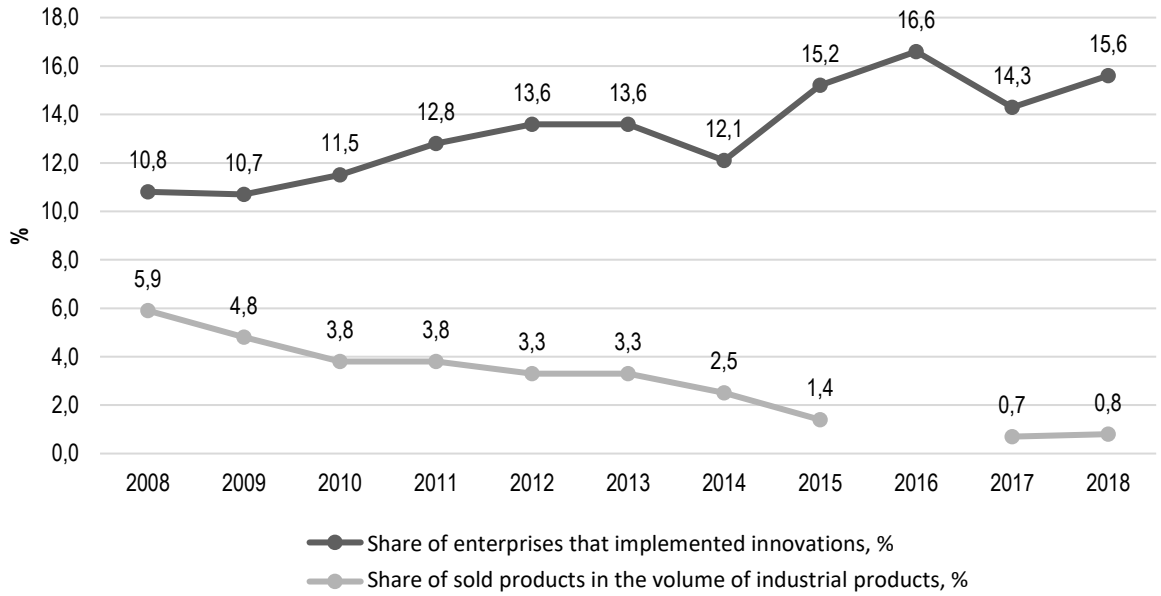

Figure 5. Main Indicators of Innovation Activity of Ukraine Compiled from [2]

Despite the growth of the share of innovative enterprises (by 4.8% in 2018 compared to 2008) in this indicator, our country is significantly behind the European countries where the share of innovators is from 30% (Croatia, Czech Republic) to 65% (US, Germany, Japan). In Ukraine the innovative activity of industrial enterprises is at a level that does not reach even the minimum value among European countries, and if compared to the leading countries in terms of innovative development, the gap is about 5 times. The consequence of the formation and consolidation of a model of economy in Ukraine built mainly on low-tech industries and paradigms was the deepening in the industrial complex of the tendency of dominance of industries with low scientific intensity. Of the total number of innovatively active enterprises almost 95% were in the processing industry, which corresponds to the global trends in the development of processing enterprises due to the need to maintain the competitiveness of their products compared to foreign counterparts by actively participating in the implementation of innovative developments.

The effectiveness of the innovation spending structure is the topical issue. In 2010-2018 innovative enterprises spent a significant portion of their costs on the purchase of machinery equipment and software (Fig. 6) which is the highest indicator among other types of costs (62.79% in 2010 versus 68.07% in 2018 year). Much less funds were used to fulfill external R&D and acquire external R&D and other external knowledge. These figures range from 1.7% to 6.93%. The level of costs for the acquisition of new technologies — the lowest of the directions of expenses — shows that the domestic business does not accept the latest achievements of science and technology. Sweden's R&D expenditure accounts for 63.2%, the Netherlands - 62.5%, Luxembourg - 53.8%, Belgium - 42%, Turkey - 28.9%, Poland - 8.3%, Romania - 13.4 %, the Czech Republic - 23.2% Russia - 15% of the total costs of innovation. Research and development costs exceed investment in equipment in Belgium, Iceland and Luxembourg by 1.5-2 times. In Eastern Europe investment is more focused on upgrading fixed assets. Cost relations for research and equipment purchase are: in Bulgaria 1:19, Estonia 1:8, Poland and Slovakia 1:7, Russia 1:6.

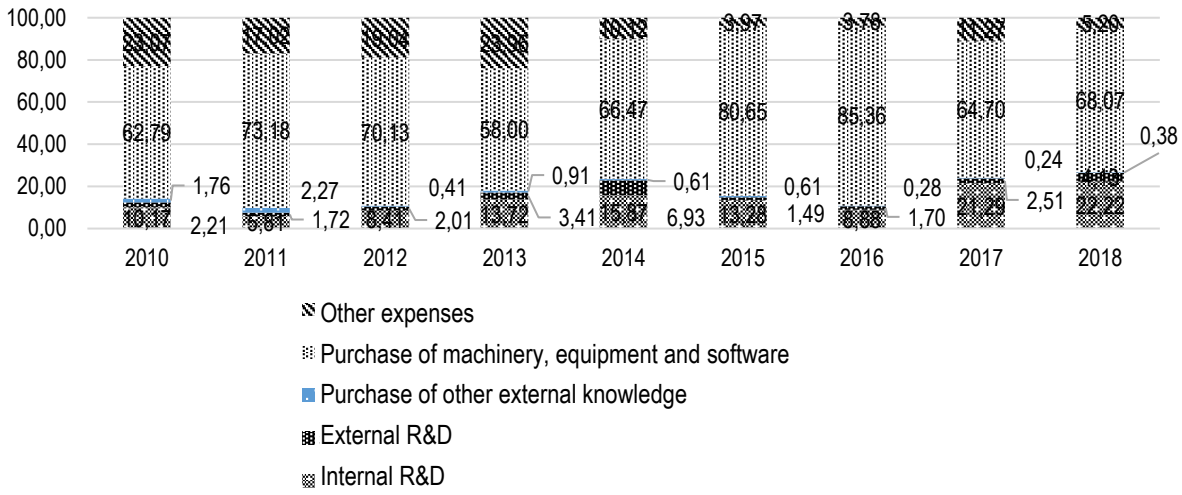

Figure 6. Allocation of Total Expenditures by Areas of Innovation in 2010-2018% of Total Expenditures (Compiled from [2])

Considering the distribution of sources of financing of innovative activity for 2010-2018 (Fig. 7) it may be noted that the own funds are spent the most. In 2010-2014 there was a significant proportion of foreign investors (in the range of 1.8-29.97%) but since 2015, this financing has stopped which is explained by the instability in the economic situation of the country.

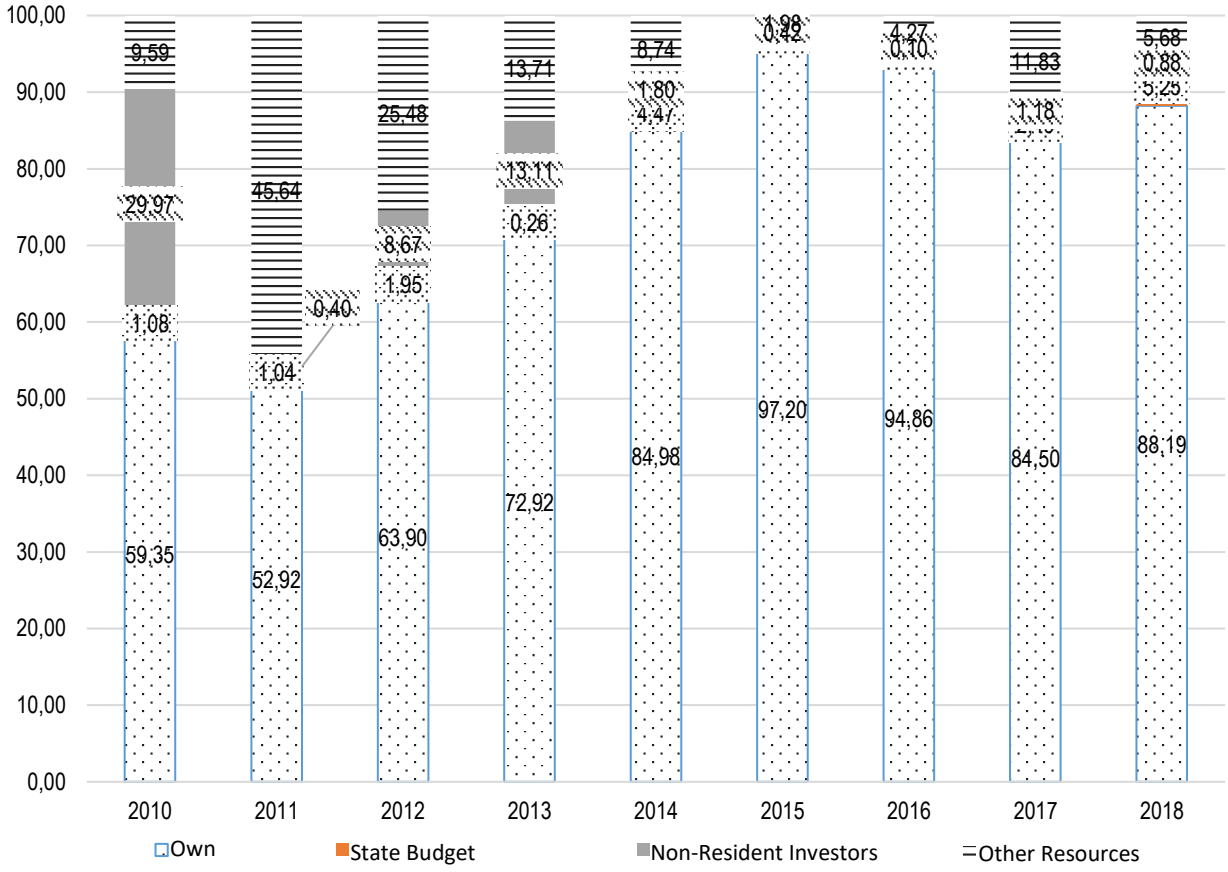

Figure 7. Distribution of Sources of Financing of Innovative Activity of Industrial Enterprises in 2010-2018 % of Total Financing [2]

Discussion the other scientists and papers

The economic content features problems of innovative development are actively discussed in the writings of economists. Studies of innovative development of the national economy have been reflected in the works of foreign and domestic scientists. While examining models of economic growth, the Nobel Prize winner in Economics D. Hicks [5] came to the conclusion that it is innovation that creates the stability of a market economy. Also the study of the role of innovative processes in the economy was discussed in their works by such prominent foreign scientists as M. Kondratyev [6] M. Porter [7] Yu. Iakovets [0] et al. Considering the works of domestic authors, we should highlight the works of V. Heits [0] et al. The state and development of the financial and economic component of the innovative infrastructure of the region are discussed in the works of P. Bubenko [0] O. Amoshi [0] et al.

Uncertainty and impact of research results on science, economy, the environment and society according

Analyzing the state of development of innovation activity of SMEs we can say that Ukraine is significantly inferior to the world countries in terms of innovative development. Creating preconditions for stimulating innovative growth requires a comprehensive approach from the state and enterprises (Fig. 8). It is the creation of interaction between the state and the SME sector that will promote the existence of healthy competition and stimulate SMEs to innovate. With the introduction of the innovative activity, businesses will be able to increase their profitability and not lose their competitive advantage in the market. The state should also be guided by a long-term strategy for innovative development.

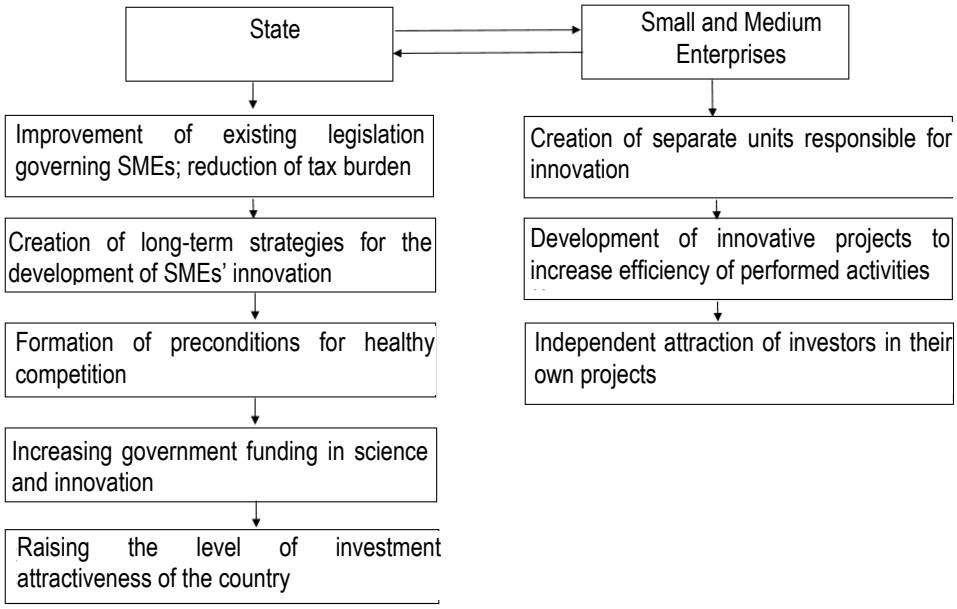

Figure 8. Set of Measures for Improving the State of Innovation of SMEs (Compiled by the Author)

The results of the study show that there is a significant lag behind the more developed countries of the world in Ukraine. An important factor in the growth of economic well-being at the moment is the introduction of innovative activity in enterprises. The SME sector, which is the largest layer among all enterprises, is flexible enough to adapt to new conditions. It is SMEs that can be a catalyst for a country's development.
The results of the study can be used by future researchers to study the role of innovation in small and medium-sized enterprises in the development of the economy.

Summary and conclusions
To summarize, the conducted analysis shows that the state of innovative activity in Ukraine requires significant changes. A comparison of innovative indicators allowed for an estimation of the level of innovative activity and placed it at the critical level. This is due to the lack of comprehensive support from the state. Particular attention in the development of innovative activity is paid to the SME sector which constitutes the majority (99.98%). This is because SMEs are focused on innovation while large companies are engaged in the introduction of production and the promotion of goods.
SMEs are the most important actors of innovation because they are the basic condition for the functioning of the innovation economy as well as the main source of innovation and the generator of new ideas. There are a number of constraints on the development of SMEs in Ukraine including the lack of funding sources. In the current conditions, the provision of financial support from the state is insufficient therefore attracting funds from foreign investors is recommended The state needs to create a favorable investment climate for this purpose. The main indicators of the investment climate are the level of inflation, unemployment, lending, tax burden, stability of the national currency, the level of competition etc.
A set of measures is proposed to improve the state of innovation of SMEs which involves the interaction of the state with the latter.
Enterprises should set up separate units for innovative activities which will be responsible for developing innovative projects to increase the efficiency of their performed activities. Funding is an integral component. Therefore, the independent attraction of investment funds into their business will contribute to the growth of innovative activity.
In conclusion it can be noted that improving the innovation activity of SMEs is a necessary direction for the effective development of the domestic economy.

Conflict of interest
There are no conflicts to declare.

Acknowledgment
All studies were conducted by the authors themselves (without joining any scientific topic).

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SPATIAL FORMS OF ORGANIZING INNOVATIVE INFRASTRUCTURE OF UKRAINE IN TERMS OF SUSTAINABLE DEVELOPMENT

Abstract
The article is devoted to the study of spatial forms of organizing innovative infrastructure of Ukraine in terms of sustainable development. In the course of the study, modern trends of innovative development of the regions in Ukraine are highlighted. The peculiarities of implementing innovative policy in the context of smart specialization strategy are analyzed. Diagnostics of processes of formation and development of innovative infrastructure in regions of Ukraine is carried out. A conceptual approach to assessing the level of innovation infrastructure development is proposed.

Keywords
innovative infrastructure, clusters, smart specialization.

Nomenclature, abbreviations
CERN – Conseil Européen pour la Recherche Nucléaire; EEN – Europe Enterprise Network; EGI – European Grid Infrastructure; EU – European Union; KET – key enabling technologies; RIS3 – Research and Innovation Strategies for Smart Specialization; SME – small and medium-sized enterprise; IT – Information Technology.

Introduction

At the present stage of development, the implementation of innovative activities and the choice of their optimal spatial forms is the main factor in the competitiveness of the regional economies. The situation is so because it contributes to the localization of business activity, the formation of “growth points”, ensuring the development of interregional and intraregional cooperation and activation of local entrepreneurial initiative. Spatial forms of innovative infrastructure development (horizontal and vertical)such as: network structures, production and innovation clusters, science parks, industrial parks, fab labs, training centers, business incubators, and technology transfer centers, from the simplest to the most complex integrated forms, stimulate innovative development of regions thus forming their competitiveness. Ultimately, this allows to reduce territorial disparities and intraregional asymmetry of socio-economic development, primarily by strengthening the economic potential of the territory, including the smallest territorial units.

Spatial forms of innovative infrastructure development are the centers of coordination and accumulation of economic and social relationships between individual regions or countries. The development of new forms of implementation of innovative activities contributes to the formation of competitive advantages of individual territories and their territorial capital due to the localization of transnational corporations and, accordingly, international production networks with the advantages of the introduction and concentration of innovations; development of innovation clusters on the basis of internationalization of economic relations and inclusion

in global innovation systems with high mobility; institutional, market and structural transformations as factors of territorial attractiveness.

The topicality of the study is supported by the project "Concept of the state target economic program for the development of innovative infrastructure for 2017-2021" which was approved by the Cabinet of Ministers of Ukraine in November 2015 in order to provide appropriate conditions for the development of innovative institutions and assistance to scientists, innovators and enterprises. In addition, in June 2015, with the support of the International Fund for investment assistance in Ukraine, a National Scientific and Technological Association was established. This association aims at promoting structural reforms in the national economy and forming a knowledge economy in Ukraine, which will solve existing environmental and economic problems, and significantly improve the standard of living of Ukrainians [13]. In July 2016, the Cabinet of Ministers of Ukraine adopted a Strategy for the development of high-tech industries until 2025 [20], the implementation of which is aimed at creating a new model of economic development – an innovative economy, by increasing technological efficiency and competitiveness as well as improving the efficiency of existing production.
At the same time, modern practice of innovation management poses a list of issues to the scientific community that require additional research in the organization of spatial forms of innovative infrastructure development.

Method of the research
The authors used general scientific and special methods of cognition: structural-logical method – to build the general structure of the research; content analysis and bibliographic search – to study contemporary trends in the implementation of strategies for smart specialization and generalization of spatial forms of innovative activity development in the region; a logical-historical approach – to study the evolution of spatial forms of innovative activity development; cluster analysis – to compare the regions of Ukraine in terms of innovative development; economic and statistical method – to form a conceptual approach for assessing the level of development of innovative infrastructure in the spatial plane; the graphical method – to visualize the results of the study; scientific generalization – to justify the conclusions.

Results of the research
1. Current state of innovative development of regions in Ukraine
In the conditions of tough international competition and growing globalization processes, national policy only creates a platform for innovation, while the source of innovation activity is the regions where representatives of the business environment, higher education institutions and local authorities interact directly. According to David White, the President of the European Commission for innovation policy, it is the regional level which is the place where innovation appears, where research is transformed into economic results [38]. Centralized innovation systems are replaced by local innovation ecosystems, which retain their global orientation, but their development is based on endogenous factors.
Assessment of the level of innovative development (LID) of regions in Ukraine based on the indicators of 2017 is conducted using the SPSS Statistics program. As a result we obtained a dendrogram showing the similarity of regions (Fig. 1). According to the results of the cluster analysis, four groups were obtained: the first included regions with the highest LID, the second group consisted of regions with high LID, the third group –with medium LID, the fourth group – with low LID.
Thus, Kyiv, which belongs to the first cluster, takes first place in almost all indicators. Dnipro and Kharkiv regions belong to the second group. The first region is in second place in the number of industrial enterprises engaged in innovative activities of Ukraine (484 units). Upon all other indicators, the Kharkiv region occupies the leading position in the cluster.
The group of regions of the third cluster, which is represented by Donetsk, Zaporizhzhiia, Kyiv, Lviv, Poltava and Sumy regions, is characterized by an average level of innovative development. For example, the number of innovative active enterprises in the industry in 2017 ranges from 22 units in the Donetsk region to 48 units in the Lviv region. Among them, the Donetsk and Poltava regions are characterized by relatively low levels of investment support for innovative development, which is the reason for the decline of their positions in the rating compared to the previous periods.

The group of regions with a low level of innovative development is represented by Vinnytsia, Volyn, Zhytomyr, Zakarpattia, Ivano-Frankivsk, Kirovohrad, Luhansk, Mykolaiv, Odesa, Rivne, Ternopil, Kherson, Khmelnytsky, Cherkasy, Chernivtsi, Chernihiv regions. The characteristic features of this group are different levels of scientific and technical, educational and investment support for innovative development.

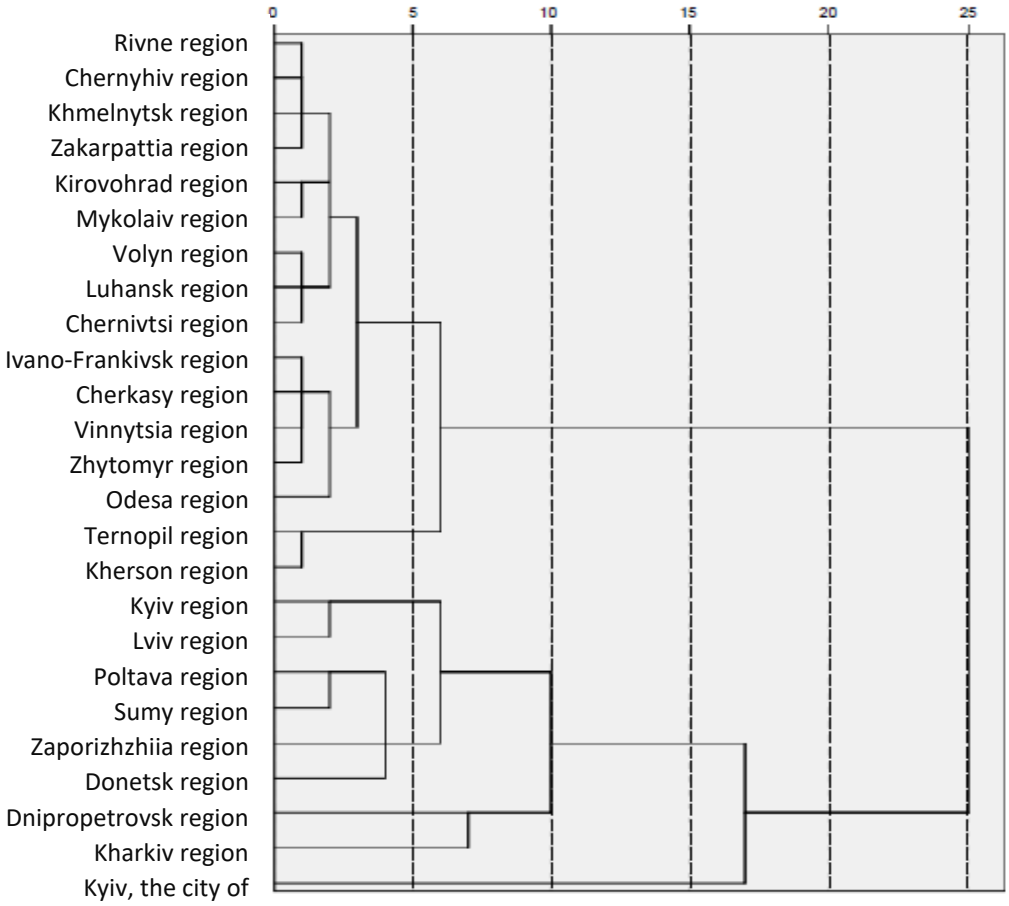


Figure 1. Dendrogram of similarity of regions in Ukraine on the level of innovative development in 2017
Source: Authors'

The greatest differences in the levels of innovative development of regions in Ukraine in 2017 are observed upon indicators which characterize the number of organizations that perform scientific and technical work; the number of innovative enterprises in industry in areas of innovation; the volume of sold innovative products that are new to the market; share in the total volume of realized innovative products outside Ukraine; introduction of innovative technological processes in industry and innovative products in the industry; the number of created enterprises and advanced technologies.

The uneven distribution of innovations in the regions of Ukraine, the reasons for which is the slowdown in the transition to new technologies of the V-VI technological paradigm, the complexity of implementing new formats of interaction between regional authorities and economic agents of the "science-education-production" system, the inability to overcome the "fragmented" nature of the institutional environment and infrastructure support of innovative development, make it necessary to fulfil the transition to a model of regional development management based on smart specialization. This approach [2] to development management is aimed at orienting the basic branches of specialization of the region to the introduction of intelligent technologies in the production and management processes, as well as the creation and development of new areas of activity at the regional level, and the use of new technological and market opportunities to strengthen regional competitive advantages.

2. Peculiarities of implementing regional innovation policy in the context of smart specialization strategy

According to D. Foray, P. David and B. Hall, the founders of the concept of regional development based on RIS3, smart specialization of the territory is determined at the intersection of existing capacities, competencies and relevant technologies by analyzing experience, resources, competencies and technologies in other regions in order to intensify interregional cooperation. The latter includes buying / selling technologies, expanding the activities of local businesses and including them in global networks and value chains [30].

V. Deffa, Director General of the Department for Regional and Urban Policy of the European Commission, is convinced that an effective strategy of "smart specialization" should be based on an in-depth analysis of the economic, social and innovative structure of the region. It should also carry out an assessment of all existing assets as well as the potential for future development. The general principle is a broad understanding of innovation that extends to economic activity and includes many sectors of civil society. The analysis should take into account such regional assets as: technological infrastructure; relations with other countries and regions; the place of the region in the national, regional and global economy; the dynamics of the business environment [49].

On November 14, 2018, the Cabinet of Ministers of Ukraine adopted a resolution according to which the strategic planning of regional development should be based on the RIS3 principles, which provide for the construction of local knowledge and innovation economies with subsequent competition between them [15].

A. Markus, the head of the "German-Ukrainian Chamber of Commerce", is convinced that the time of specialization is coming to the world economy. On the one hand, Ukraine has an old industry and on the other hand, it has a well-developed IT sector. However, there is a gap between these two sectors of economy. Industrial parks are just a platform but at this particular time they have to be created on the basis of new technologies and for such productions which benefit the world. [3] Otherwise, Ukraine will remain only a platform for small-scale production in other countries. This is a strategy for ten years, it is a variant of a strategy used in Poland. Ukraine will not bridge the gap by calling on investors, so it must create industrial parks with smart specialization.

An effective strategy of "smart specialization" should be localized and based on specific regional and national assets and resources, taking into account also the peculiarities of their socio-economic situation. Priorities should not be artificially imposed from above. They should be determined through a multi-stakeholder process focused on "unlocking entrepreneurial potential". It is an interactive process in which market participants and the private sector uncover and provide information on new areas of activity, and authorities assess the outcomes and encourage those participants who can best unlock the potential of the region [37].

Considering the abovementioned, we can claim that at the present stage of development of Ukraine, smart specialization of its regions is determined at the junction of indicators of business structures, development of innovative infrastructure and the quality of human capital.

A key principle that underpins smart specialization is economic differentiation with an emphasis on conjugate variability, which assumes that a regional economy can realize its competitive advantages by diversifying its unique, localized know-how through new combinations and innovations that are close to or adjacent to these know-hows. It is crucial that the implementation of these new combinations is possible and affordable, taking into account existing assets and the experience gained by regional stakeholders [5].

In such conditions, the key to achieving important multiplicative effects for the development of the region's economy through an interdisciplinary, intersectoral nature is the development of innovative infrastructure that provides assistance to scientists, innovators and enterprises throughout the innovation process: from turning an idea into an innovation to its implementation in business structures.

3. Formation and development of innovative infrastructure in the regions of Ukraine

The Law of Ukraine "On innovative activity" [16] defines innovative infrastructure as a set of enterprises, organizations, institutions, their unions and associations of any form of ownership which provide services to ensure innovation (financial, consulting, marketing, information and communication, legal, educational, etc.). In fact, we talk about a set of economic entities that ensure the implementation of innovative activities, in particular by ensuring the implementation of innovative projects, i.e. innovative structures.

The scientific literature develops approaches to the classification of innovative structures, according to which innovative structures are distinguished by their specialization, types of scientific and industrial products, types of activities, the nature of the sector of economy, the level of coverage of the innovation cycle, and the facility to improve the principles of creation, etc. [12, 23, 25]. Having studied the existing developments on the subject of the study, the authors developed their approach to the classification of spatial forms of development of innovative infrastructure of the region in accordance with the peculiarities of the organization of innovative activity (Fig. 2).

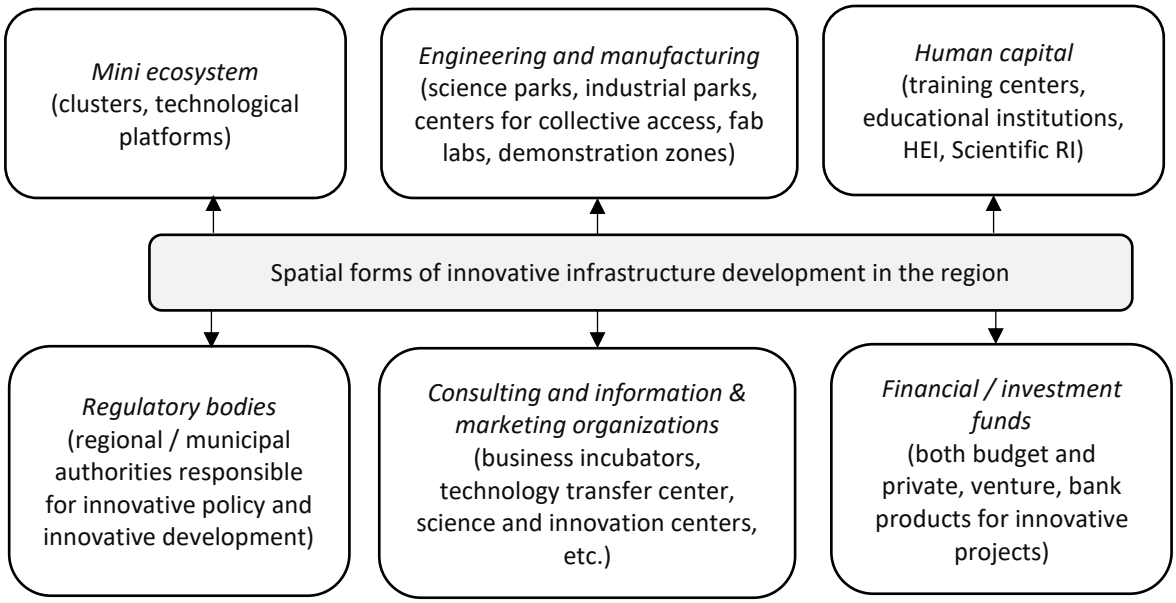


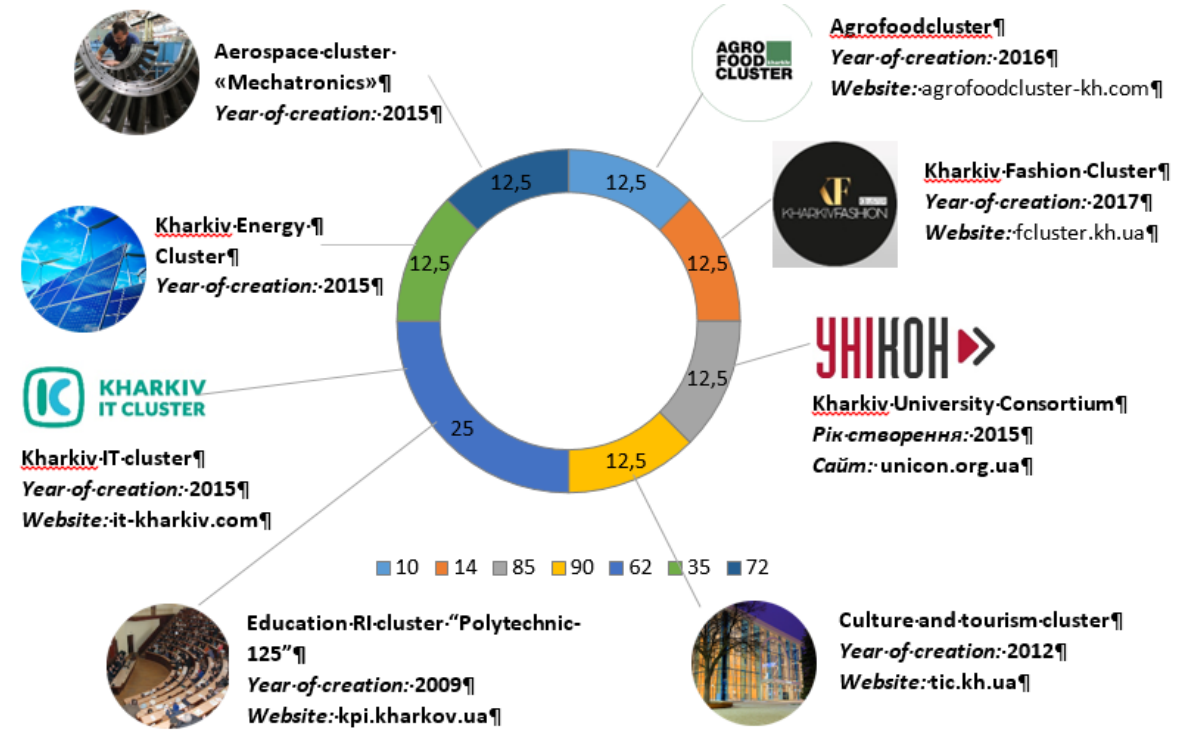
Figure 2. Spatial forms innovative infrastructure development in the region
Source: Authors

According to the Ministry for Development of Economy, Trade and Agriculture, nominally in Ukraine, there are almost all spatial forms of innovative infrastructure development. In particular, as of January 1, 2014, there were 79 business incubators, 480 business centers, 538 leasing centers, 4148 non-bank financial and credit institutions, 226 business support funds, 3034 investment and innovation funds and companies, 4238 information and advisory institutions in the territory of Ukraine [22]. However, their activities do not provide the expected result and do not meet the requirements of the time. A significant part of the spatial forms of innovative infrastructure development exist only formally, they are narrowly localized, for example, in the Kyiv, Donetsk and Kharkiv regions, while in other regions they are poorly developed. In particular, in 13 of the 27 regions of Ukraine there were no science parks, but today the system of science parks of Ukraine is expanding. As of April 1, 2019, 40 economic entities are included in the Register of industrial parks of Ukraine (Fig. 3).

Figure 3. The number of industrial parks in the regions included in the Register of industrial parks of Ukraine (as of 01.10.2019)
Source: [10]

One of the most common forms of innovative infrastructure development in Ukraine's regions is clusters.
M. Porter and his colleagues conducted empirical studies in the United States in 2011. They revealed that the presence of strong clusters encourages the development of the regional economy (growth of employment, an average salary, the number of new companies, entrepreneurial activity), enhances its diversification and accelerates the growth of all other local industries [26]. The synergy effect was also confirmed: the dynamism of the cluster and the companies that are part of it increases with the consolidation of related clusters in this region, as well as similar clusters in the nearest regions [26]. It stands to reason that there is a positive correlation between the level of cluster development and the country's innovation index: according to the Global Ranking of Innovation Ecosystems, it is equal to an average of 0.77 in the European economy and 0.67 in the world economy.
Other sources [36] provide evidence that clusters contribute to the emergence of new, customized markets, as well as fundamentally expanding the possibility of creating new firms and startups while reducing the level of risk in case of project failures. In addition, the territories where clusters are formed can quickly equip economically undeveloped areas, relying on the synergy of collective actions of regional development subjects. Moreover, the involvement of local authorities in cluster projects allows planning the development of the regional economy from the bottom, taking into account the specifics of local realities, which is more effective than the implementation of instructions from the top, which are given by the authorities in the framework of their regional policy.
According to the investment portal of Kharkiv region, this region provides for the formation and development of clusters in the following areas: production and processing of agricultural products and food production; energy and engineering; pharmaceuticals and healthcare; information technology and education; high-tech production [9]. The possibility of cluster initiatives on the basis of newly created united territorial communities is considered. In some of these areas, 8 cluster initiatives are developing dynamically (Fig. 4), however, their activities are concentrated in the territory of the city of Kharkiv.
Unfortunately, information about the activities of clusters in Kharkiv region is fragmentary and insufficient. Only the Kharkiv IT cluster in November 2019 published the results of a large-scale study Kharkiv IT-Research, conducted by PricewaterhouseCoopers and the IRS-Group. According to the study, about 25 thousand specialists in the field of information technology are employed in 445 IT companies that are actively developing. The number of IT specialists in Kharkiv significantly exceeds the number of representatives of other major IT locations in Ukraine, second only to the Kyiv hub. 15% of the country's IT sector representatives work in Kharkiv, which is twice as much as in Dnipro, and three times as much as in Odessa [31].
In 2017, the IT industry of Kharkiv transferred about 5 billion UAH to the state budget of Ukraine, of which 43% was transferred to the local budget of the region. 95% of sales of Kharkiv IT companies are realized for foreign customers, 65% of which – for the USA and 25% – for Europe. Given the current growth rate, it is expected that tax payments to the Kharkiv IT industry will increase to 14.6 billion UAH by 2025. The average income of an IT specialist in Kharkiv is $1800, which is six times as much as the average income of a Kharkiv citizen ($265) and five times as much as the average income in Ukraine ($313).
Given the fact that the Kharkiv IT industry demonstrates stable growth, provides jobs to 25 thousand residents of the region, forms a significant share of tax deductions to the state and local budgets, one of the potential priorities for the reasonable development of Kharkiv region can be Smart IT Solutions.

The experience of leading countries shows that one of the key conditions for the harmonious development of clusters is the availability of a developed research infrastructure of the appropriate level.
Ukraine inherited about 20% of the experimental centers of the Soviet Union, including nuclear reactors, astronomical observatories and ships for marine research, but much of this infrastructure was lost during the times of independence. Today, research infrastructure centers in Ukraine need to be updated due to constant underfunding. According to Yegorov I. Yu. [5], the problem has existed for many years and has so far reached such proportions that neither fast nor inexpensive solutions are acceptable. At the same time, Ukraine, as before, has at its disposal several functioning infrastructure facilities of the R&D sphere, which have received international recognition, despite their insufficient funding. Most of them are in various institutes of the Academy of Sciences of Ukraine. 15 research organizations in Ukraine are included in the List of European Research Infrastructures [8].



10¤	Food·production¤	**62¤**	Computer· programming,· consulting· and· related· activities¤ ¤
14¤	Clothing·production¤	**35¤**	Energy,·gas,·vapor,·conditioned·air·supply¤ ¤
85¤	Education¤	**72¤**	Scientific·research·and·developments¤ ¤
90¤	Creativity,·art·and·entertainment¤	¤	¤ ¤

¶

Figure 4. Sector specialization of clusters of Kharkiv region (developed by the authors in accordance with [9])

Today Ukraine participates in two out of eight European Intergovernmental Research Organizations (EIRO), which are part of the European Association EIROForum. Thus, on October 5, 2016, the Agreement on granting Ukraine the status of an associate member in CERN (European Organization for Nuclear Research) was notified, and on January 1, 2017, Ukraine became a member of EUROFusion [4].

Of the entire range of European Research Infrastructures, which now amount to 50, Ukraine takes part in three: DANUBIUS-RI (operational start in 2022), EISCAT_3D (operational start in 2021) and CTA (preoperative start in2019, full operational start in 2023) [4].

Of the five most common E-Infrastructures in Europe, Ukraine cooperates with two. At the political level it is GEANT, the pan-European data network for the research and education community (they signed an agreement with Ukrainian scientific and educational telecommunications network URAN), and EGI, the European Grid Infrastructure (they signed a Memorandum of mutual understanding at the technological level with the Ukrainian national Grid in 2012) [4].

As we can see, the national innovation infrastructure does not meet the necessary level of technological readiness to provide high-tech services. Instead, EU member states can improve the state of technological readiness with the help of EU Structural funds, to which Ukraine does not have access. There is no similar mechanism in the country, so it is difficult for Ukraine to bridge the technological gap in research and effectively use their results at the final stage of the value chain in the economy or new values in the social sphere.

The improvement of the state and quality of research infrastructure led to the fact that Ukraine joined the European Union framework program for research and innovation "Horizon 2020" (total funding of 80 billion euros) [19], which is focused on achieving three main objectives: to make Europe a more attractive place for first-class scientists, to promote the development of innovation and competitiveness of European industry and business, and to solve the most pressing issues of modern European society with the help of science.

During 2014-2019, the Horizon 2020 program financed 133 projects, which were implemented with the participation of 184 Ukrainian institutions for the amount of 21.57 million euros [19]. At the same time, the number of projects with the participation of Ukraine is 0.61% of the total number of projects supported by the European Commission for financing, and the budget of these projects is 0.05% of the total amount of project financing by the program.
Funding for the projects is distributed as follows: 11 million euros were received by private business organizations, 6 million euros went to research institutions and 4 million euros went to higher education establishments [19].
Table 1 gives the results of how the countries from Eastern Partnership participated in "Horizon 2020" program.
The COSME (Competitiveness of Small and Medium Enterprises) program, which Ukraine joined in May 2016, is aimed at supporting the development of cluster initiatives in Ukraine. The program is designed for 2014-2020, and its total budget is 2.3 billion euros, 900 million euros of which are available for Ukraine [17].

Table 1. The results of how the countries from Eastern Partnership participated in "Horizon 2020" program (developed by the authors in accordance with [19])

Country	Number of projects	Number of "participations"	Funding, million euros
Azerbaijan	9	10	0,49
Belarus	40	44	2,26
Armenia	23	29	1,24
Georgia	26	31	2,69
Moldova	44	57	5,13
Ukraine	*133*	*184*	*21,57*

COSME program for Ukrainian SMEs consists of 25 subprograms. They can be systematized in three directions: improvement of access to foreign markets; improvement of conditions for an increase of competitiveness and stability of subjects being managed; assistance for the development of business and business culture. Among the sub-programs, there are such important initiatives as Erasmus for Young Entrepreneurs, European Strategic Cluster Partnerships, European Destinations of Excellence and others.
The financial instrument of the program is not yet available for domestic SMEs, since its use is a rather complex process that requires a high level of development of the Ukrainian SME support infrastructure and an appropriate level of knowledge. However, similar financial instruments work under other international programs (EU4Business, HORIZON-2020, etc.).

Today, within the framework of the COSME program, the European enterprise network (EEN) is already actively working in Ukraine, which is a virtual trading platform for stimulating international cooperation and innovative development of SMEs, as well as for stimulating technology transfer from scientific organizations to business. EEN-Ukraine should search for new customers, suppliers, partners, investors, manufacturers or distributors for SMEs, provide advice on participation in EU-funded programs, hold information days and trainings, international fairs and exhibitions [28].
Another initiative of the European Union for establishing partnerships in the field of research and innovation through the cooperation of clusters and cluster organizations of the EU and Eastern partnership countries is the EaP PLUS project [34]. Within the framework of this project, two Ukrainian clusters received €20,000 in the field of eco-energy and industrial automation: the Carpathian Eco-Energetic Cluster and the Association of Industrial Automation Enterprises of Ukraine [27].
In addition, at the initiative of the European Union, a platform for cluster cooperation (European Cluster Collaboration Platform) was created, where 21 Ukrainian clusters are registered today, among which are 3 clusters of Kharkiv region – Kharkiv Fashion Cluster, Kharkiv IT Cluster, Agrofoodcluster [36].

In Ukraine, there are examples of the formation of national cluster networks. Thus, in May 2018, the project "Tourism clusters 300+" was launched, which provides for the creation of more than 300 clusters with developed infrastructure in 3 years, which will bring in the region of 800 million to 1.5 billion dollars of investments. According to the authors of the project, more and more actors in the tourism business understand the potential for the development of domestic tourism and join the project to create tourism clusters [21].

4. Conceptual approach to assessing the level of innovative infrastructure development

Today, the issue of assessing the innovative infrastructure of the territories is limited by the regional context, and this issue has become an object of study recently. For example, S. Rakitskaia [18] proposes a method of assessing the level of development of innovative infrastructure of the region based on the transformation of the main provisions for assessing the level of infrastructure development proposed by D. Bil [1].

T. V. Kharitonova, and M. T. Krivosheieva [24] propose selecting the necessary indicators from among the indicators of developing an innovative potential of the region that would meet the performance criteria in order to estimate the efficiency of innovative infrastructure of the region. The authors propose seven stages of the methodology and a scoring system (from 1 to 5). The indicators are given in fragments, and the introduction of a weighting factor is proposed. Depending on the number of points, the effectiveness of the innovative infrastructure model and its type are evaluated.

The work by T. Kashizina [11] also deserves attention. She proposes evaluating the innovative infrastructure of the region for quantitative indicators, which are grouped by subsystems of the innovative infrastructure of the region based on the calculation of the integral index taking into account weighting values of each component and determining the area of the polyhedron. It should be noted that there are no statistical data or observations to assess the partial indicators proposed by the author, which prevents the application of this technique.

O. Zhikhor's monograph [7] describes an attempt to assess the infrastructure component of the innovative potential of the region, but only half of the 10 indicators proposed by the author concern the objects of innovative infrastructure.

At the same time, the works of leading researchers increasingly raise the question of assessing the concentration of innovative infrastructure in a space and the prerequisites for its integration, both in the economic systems of countries and global value chains. Thus, Nobel laureate in Economics P. Krugman is convinced that today there is an urgent need to take into account spatial factors in the placement of innovative objects, since they can act as points of growth of individual territories [33]. According to Dutch researchers, K. Kourtit and P. Nijkamp, the key prerequisite for effective collaboration of economic entities from different countries or regions is precisely the innovative infrastructure, as it contributes to the establishment of links between producers and consumers of innovations, government agencies, business and academia [32]. In addition, the need to take into account the spatial factor in the development of innovative sectors of the economy sharess the theme of the World Bank Report, which emphasizes that spatial transformations significantly affect the efficiency of the functioning of the national economy and are a prerequisite for its qualitatively new structural transformations based on innovation [39].

The problem of spatial distribution of innovative infrastructure, as a rule, was determined by the principle of belonging to economic centers. On the contrary, the experience of developing the most economically powerful regions of the world proves the effectiveness of network structures that ensure that the objects of innovative infrastructure come closer to the centers of innovation consumption. This proves the relevance of assessing spatial concentration of innovative infrastructure for the regions of Ukraine, as one of the key prerequisites for achieving the trend of exponential growth. It is the objects of innovative infrastructure that can act as one of the key drivers of overcoming imbalances and ensuring balanced development of territories, which is one of the priorities of the decentralization of power reform, which is now actively implemented in Ukraine.

The formation of a conceptual approach to assessing the level of development of innovative infrastructure in the spatial area should take into account a wide range of indicators of innovation. These indicators include: the number of institutions of innovative infrastructure by type (clusters, science parks, higher education establishments, business incubators, etc.); the number of scientific research agents and researchers; the volume of financing for innovative projects; the number of industrial enterprises that have introduced innovations; the number of innovations introduced in industrial enterprises; the volume of innovative products sold; the number of patents for inventions, utility models, industrial designs; the number of publications in journals indexed in scientometrics databases (Scopus, Web of Science) and the like.

Relative values characterizing the level of concentration of innovative infrastructure objects in the area can be used as evaluation indicators:

$$I_k = \frac{Q_n}{S}; \quad (1.1)$$

where I_k is the index of spatial concentration of innovative infrastructure objects;
Q_n – the number of n-type innovative infrastructure objects;
S – the space of the territory where a set of objects of innovative infrastructure of n-type is located.

The integral index of spatial concentration of objects of innovative infrastructure can be defined as a set of the following indices. For each type of objects, it is appropriate to carry out their rationing according to the indicators of the reference regions. Reference regions can be determined by the structural stability index calculated according to the methodology of the joint research Centre of the European Commission. This indicator characterizes the degree of divergence of the structure of the innovation system of the territories. Detailed calculations of the structural stability index for the Kharkiv region are given [34]. That means that the rationing of indexes of spatial concentration of objects of innovative infrastructure is appropriate to carry out according to the formula:

$$I^{nor} = \frac{I_k}{I_k'}; \quad (1.2)$$

where I^{nor} – the normalized value of the spatial concentration index of innovative infrastructure objects;
I_k – the index of spatial concentration of objects of innovative infrastructure of the region which are under research;
I_k' – the index of spatial concentration of objects of innovative infrastructure of the standard region.

The integral two-level (at NUTS-1 and NUTS-2) index of spatial concentration of objects of innovative infrastructure can be calculated by the formula:

$$\overline{I_k} = \sum_{m=1}^{n} {I_m}^{nor} \times w_m; \quad (1.3)$$

where I_k – the integral index of spatial concentration of innovative infrastructure objects;
${I_m}^{nor}$ – the normalized value of the spatial concentration index of innovative infrastructure objects of *m*-type;
w_m – the weight coefficient of the normalized index value of the spatial concentration of innovative infrastructure objects of *m*-type.

The weighting indexes of spatial concentration of innovative infrastructure in a particular area are determined by expert, taking into account the population, the results of economic activities of economic entities, their level of inclusion in the global markets, assessment of the potential economic growth areas, maintaining the principle of $\sum w_m = 1$. The proposed approach can be used to assess the uniformity of placement of innovation infrastructure across the country or region.

Discussion with other scientists

The multidimensional nature of the research directions, the search for approaches to the activation of innovative development of regions, received its coverage in the scientific works of foreign and domestic scientists: O. Amoshi, I. Buzko, V. Geits, H. Barnet, G. Dobrov, E. Mansfield, E. Toffler, D. Chervaniov and others. The problems of regional innovation management are the subject of scientific research of such scientists as V. Onishchenko, R. Mann, D. Solokha, O. Finagina. Various aspects of the study of spatial forms of business organization as a catalyst for the development of innovative activity are studied in the works of I. Bobukh, Yu. Marchuk, M. Melnik, T. Pisarenko, A. Stoyanovsky, S. Tkach. Research of theoretical and practical developments of these authors makes it possible to assert that they formed the theoretical foundations and practical tools of innovative development of regions, but require further solutions to the formation of spatial forms of development of innovative infrastructure in the regions, which led to the choice of research topics.

Uncertainty and impact of research results on science, economy, environment and society

The article provides justification of spatial factors of innovative infrastructure development in Ukraine, which in the conditions of the fourth industrial revolution becomes a key driver of economic growth and social well-

being. Innovation is the circuit that drives all components of the knowledge economy and ultimately leads to economic growth and changes the quality of life. One the most obvious changes is the introduction of technological innovations to all areas of human life – from the workplace to social life and leisure.
Innovation and the practical use of new ideas become the most essential condition: the preservation and development of new jobs that require highly qualified well-trained personnel; the efficiency and success of businesses that create new and improved products and services; the use of new technologies that reduce the anthropogenic effects of the previous technological base of the industrial economy.
Some results of the article are used in the framework of the policy of innovative development of territories: the policy documents on the development of the united territorial community and structural units of Kharkiv Regional State Administration that are responsible for the coordination and implementation of policies of local development based on innovation.

Acknowledgment
We thank our colleagues from Karazin Business School who provided insight and expertise that greatly assisted the research, although they may not agree with all of the interpretations/conclusions of this paper.

Summary and conclusions
Nowadays the key task of the authorities and management of most countries is the transition to a post-industrial type of organization of territorial socio-economic systems. Such qualitative changes are aimed primarily at the transition from the mobilization (resource) type of development to the innovative one. The solution to this issue is possible only in the conditions of a steadily growing demand for innovative goods and services; and only clusters are able to provide them.
The strategy of smart specialization is an advanced tool in the field of cluster policy, in particular it concerns estimating the territories where clusters can be placed. This strategy also involves establishing the priorities aimed at obtaining competitive advantages by developing the scientific and innovative potential in accordance with the needs of business, in order to fully use existing opportunities and market trends, but avoid duplication and fragmentation of efforts. Identifying potential poles of regional development based on the analysis of international experience and the potential of regions is a key condition for a national and regional progress.
Creating the system of cluster formation which is based on the concept of reasonable specialization will improve the quality of the regions' value proposition for foreign investors by focusing on the unique areas of each region. Registration of Ukrainian regions on the Smart Specialization Platform will allow to position regions of Ukraine and Europe on an equal footing, which will provide an impetus for the formation of international brands with the participation of our country. The development of interregional and interethnic relations will significantly increase the investment attractiveness of the regions of Ukraine.

Implementation of the smart specialization in Ukrainian economy can make positive changes in the process of innovative regional development in such areas as:

- ensuring the transition from the traditional sector to the sector of interaction and cooperation of R&D, engineering and production, which form a knowledge base aimed at the development of a new business activity;
- modernization of existing sectors through technological re-equipment (foresight of the region) through the use of key enabling technologies (KET): photonics, nanotechnology, semiconductors, new materials, etc.;
- achieving synergies between different business areas and regions through their diversification.

However, the development of clusters in the domestic economy within the framework of the smart specialization strategy is associated with a number of problems that are typical for the regions of Ukraine. The solution to these problems involves finding a balance in the interaction of public authorities, business environment, scientific institutions and civil society, involving all participants in the process of entrepreneurial discovery, creating comfortable conditions for innovative development on the part of the state. These aspects require further research, since the strategy of smart specialization is a promising direction for the development of the domestic economy when adapted to the challenges of the market in order to obtain the most effective results from existing assets.

Conflict of interest
There are no conflicts to declare.

Acknowledgments
This research has not been supported by any external funding.

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