The Triple Helix Concept in the Aspect of Counteracting Barriers in Science, Industry and the Public Sector

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Abstract. The aim of this article is to present a set of barriers activities occurring in collaboration between scientists, business and infrastructure at the public sector level. The current capacity for the current strengthening of the knowledge networking and collaboration foundations in line with the concept of Triple-Helix (Academia - Business – Public sector) was highlighted. It is essential to transfer knowledge and technology from academia to industrial and social ground, highlighting and adapting solutions to some of the major problems related to industrial and societal challenges. The main goal is to create added value for the real economy. It is a particular challenge for companies with complex production technology (foundry, plastic processing, meld plastic working). In this respect, a special role lies in the good communication of the public sector, industry as well as modern universities focused on the willingness to cooperate. The examples of research results provide the financial commitment of particular triple-helix partners, which turned out to be successful in research and science.

Keywords: Triple helix · Innovation brokers · Counteracting barriers

1 Introduction

At the end of the 20th century, new opportunities appeared for a significantly accelerated development of production companies. This is due to the possibility of obtaining investment funds from the EU budget, which can be used in whole or in part to cover the costs of specific investments in fixed assets (machines and stationary devices), mobile measuring equipment or even commissioning research and development [1–5].

Many enterprises decided to introduce changes in the field of technology and work organization, which could make them more competitive in relation to other companies operating on the market. As you know, the competitiveness of enterprises is determined primarily by the possibility of satisfying customer needs in the best possible way. This means providing specific customers with the products or services that best meet their

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requirements for timeliness, quality and price. Free market economy and hence – the dominant role of the client cause that these requirements are more and more diverse and individualized [6–8]. Recently, it has been especially noticeable in non-waste processes such as foundry, plastic processing, meld plastic working with assistive technologies such as laser technology or technology modeling [9].

The emergence of new business models based on innovation, collaboration networks and the expansion of endogenous resources is expected to make a strong contribution to the development of competitive European economies and regions. The triple helix [10, 11], following the logic of Smart Entrepreneurial Ecosystems [12] is not only based on a purely academic dimension, but also technological and entrepreneurial, in the most diverse sectors of activity.

Modern economics has reformulated conventional economic theory so that knowledge, technology, entrepreneurship and innovation are at the center of **the new model of economic growth,** rather than being seen as independent forces that are also largely independent of state policy [13]. The above is based on the fundamental assumption that the main objective of the state policy is to stimulate higher productivity and economic efficiency by stimulating innovation manifested in implemented projects. Consequently, it will also stimulate economic development. Nowadays, cooperation in complex innovative projects requires active cooperation and network connections with other entities and institutions.

Optimal cooperation between individual participants in projects can be ensured by **the triple helix (TH) model,** which is an innovation model that covers the mutual complex relationships occurring in the process of creating knowledge between three types of entities: research centers (universities, research centers, institutions supporting), industry (enterprises) and government (excluding local government institutions). The mutual relations between these three entities, undisturbed by barriers, determine the potential of cooperation. The lack of these connections significantly impedes the flow of knowledge [14]. Triple Helix describing the crossing of three worlds is presented in Fig. 1.

According to such a vision of an innovative economy, business is of key importance for all other activities, because both the networks of mutual connections in TH, the services provided and capital are focused mainly on entrepreneurs. Innovation intermediaries (brokers) are an important element in the network of mutual connections. They constitute a wide group of participants in innovation processes, knowledge exchange and technology transfer. Although they are not a party to these processes, they can perform many functions, such as foresight (discussion on the future among representatives of decision-makers – public authorities, scientific circles, industry, media, non-governmental organizations) or diagnosis of the demand for technologies, information and knowledge processing, gatekeeping (information dissemination) and brokering (technology flow control and brokerage), testing, building a framework for legal protection of commercialized knowledge, commercialization of knowledge and technology and many others [16, 17].

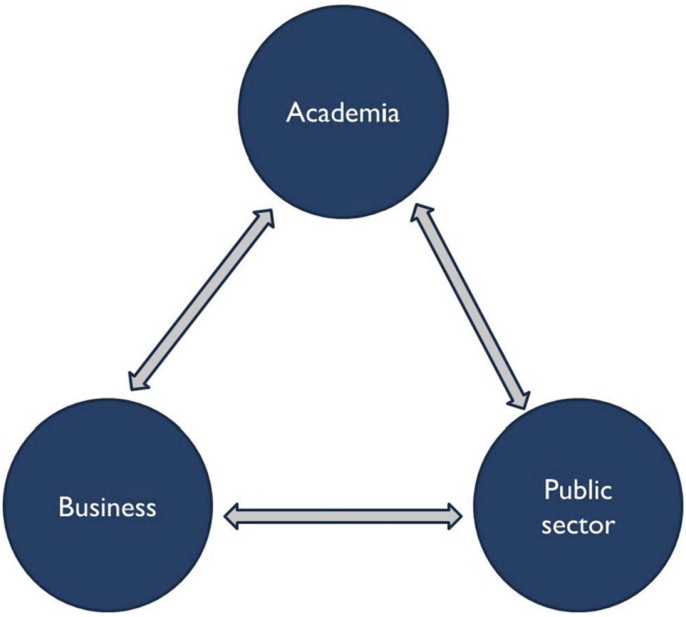

Fig. 1. The structure of mutual connections according to the Triple Helix assumptions [15].

For this, first of all, conscious, qualified staff – both on the side of government support institutions and on the side of BEI (a new model of compre-hensive service for the needs of innovative enterprises, so called INNO-BROKER), universities and entrepreneurs are need. Their goal is to provide specialist knowledge in the field of cooperation network management. Moreover, such a person is to be both an animator of relations between business and science, and a competence center in the area of e.g. intellectual property protection. The diagram of the relationship between the broker and other network participants within the TH is shown in Fig. 2.

Nowadays, science and technology play a very important role in technological progress and are one of the key driving forces behind the growth of modern economies. In order to effectively transfer knowledge from the science and research sector to the economy, appropriate tools and system solutions are necessary with participation. The most important of them, apart from legislative changes, include [18]:

- the existence in scientific and research centers of **units with appropriate human resources responsible for developing a network of contacts** between the world of science and business, and constant communication in order to exchange information taking into account the current demand for innovative solutions from industry or scientific achievements created in the units research,
- **intensification of cooperation** between university technology transfer centers (TTC) and business environment institutions, i.e. technology and industrial parks, business incubators, regional development agencies, scientific foundations or chambers of industry and commerce,

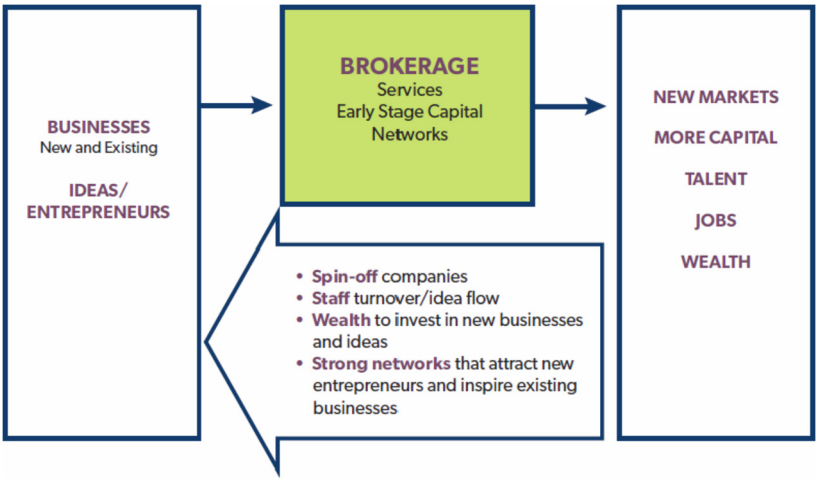

Fig. 2. The Innovation Broker in aspect of connects businesses and entrepreneurs to community resources [11].

- **creation of university platforms for the exchange of information** that would be used to disseminate the results of scientific works created at the university as well as provide the opportunity for the business sector to formulate inquiries and generate ideas directing the conduct of research works directly related to the needs of the industry,
- commitment of more funds to help researchers obtain funding from external sources for early stages of research, i.e. **proof-of-principle** and/or **proof-of-concept,** administered, for example, by government agencies, regional public funds or private funds characterized by high risk tolerance,
- **increasing the low awareness of the scientific** staff in the field of commercialization of knowledge and technology transfer, resulting from the unfavorable position of commercialization of scientific research results in the parametric evaluation system of both the university and the scientist,
- **support for activities in the field of technological brokerage** by assigning selected employees by universities and business environment institutions or by employing external experts specialized in specific areas of knowledge who, using effective mechanisms of verification and assessment of the market potential of conducted research works, are able to assess on an ongoing basis market suitability of the solutions being developed.
- Technology brokering may be performed by natural persons acting as a broker, technology broker, innovation broker or other entities. It is important that they can be both legal persons and organizational units that carry out similar activities and have appropriate competences. Technological brokerage carried out by scientific units primarily focuses on acquiring and analyzing information on the research and development work carried out at the university, while at the same time verifying the size of their

commercialization potential. In the event of a positive opinion on the commercialization potential of the created solution, the phase of presenting the obtained results among potential recipients of the developed technology takes place. The last step is to establish cooperation between the university and the business partner.

- The process of initiating the transfer of knowledge from universities to business carried out in this way, with the participation of specialists in the field of commercialization, is possible provided that **various barriers that arise between intersectoral partners are overcome.**

2 Tools and System Solutions Supporting Triple Helix

Nowadays, science and technology play a very important role in technological progress and are one of the key driving forces behind the growth of modern economies. In order to effectively transfer knowledge from the science and research sector to the economy, appropriate tools and system solutions are necessary with participation. The most important of them, apart from legislative changes, include [18]:

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3 Barriers in the Commercialization of Knowledge

3.1 Barriers on the Side of Scientists

In addition to the broadly understood system and organizational barriers related to the state and university policy, there are barriers related to the commercialization awareness and competences to carry it out, occurring in all entities involved in the commercialization process, i.e. the world of science, the economy sector and the business environment. On the side of the scientific community, the main barriers include [17, 19]:

- reluctance and low openness of scientists to commercialization activities and cooperation with the economy sector,
- lack or a small number of appropriate models for successful commercialization projects,
- no reaction of scientists to the emerging cooperation offers from industry,
- poor communication skills of scientists,
- reluctance to bear the risks associated with the commercialization of research,
- little knowledge of research workers about technology transfer mechanisms,
- imprecise and constantly changing provisions in the field of intellectual property law,
- too much bureaucracy in cooperation,
- lack of ongoing cooperation with the industry sector, which is mainly due to the limited flow of information about the specificity and details of activities and problems of entrepreneurs,
- concerns about understating the valuation of intellectual property,
- low supply of projects for commercialization.

3.2 Barriers on the Side of the University

The most important barriers identified on the side of universities include the reluctance of the scientific community to commercialization, which directly translates into reluctance to cooperate with Technology Transfer Centers responsible for knowledge transfer. Moreover, TTCs, which should be mainly responsible for the commercialization of technologies, often have too small and untrained staff to effectively carry out research commercialization processes, e.g. the lack of direct support from a patent attorney or lawyer on the part of the university during difficult talks with entrepreneurs [19, 20]. These difficulties result from the insufficient number of trained employees in relation to the demand. These difficulties are not only badly received by scientists, but also by entrepreneurs. In addition, the lack of developed mechanisms and basic knowledge about the available tools for the protection of intellectual property, often the lack of regulations and templates of agreements regarding intellectual property rights and broadly understood commercialization, licensing, conducting business activities by scientists in the form of spin-off companies or sharing profits from commercialization, result in the creation of barriers between science and business. Another barrier to commercialization is in many cases the low budget that universities have for basic commercialization activities, such as testing patent purity or technology valuation. Other barriers encountered in the process of commercialization of knowledge faced by universities include:

- no market demand for the developed technologies, which most often results from the mismatch between the offer of the obtained research results and the needs of the industry,
- lack of friendly formal and legal conditions,
- too few projects submitted for commercialization,
- complicated legal procedures related to technology transfer,
- low awareness among entrepreneurs about the possibility of establishing cooperation with the university.

3.3 Barriers of Entrepreneurs and Business Environment Institutions

The above-mentioned barriers were applied directly to scientists and universities, but it is not only scientists who are the main cause of weak links between universities and industry.

On the part of entrepreneurs, there are also identified limitations that adversely affect mutual relations, the most important of which are [17, 20]:

- lack of interest on the part of entrepreneurs in the implementation of research works by universities,
- low level of business confidence in the world of science,
- lack of wider interest of entrepreneurs in innovations,
- low legal awareness of enterprises,
- financial restrictions, especially for beginning SMEs,
- poor development of commercialization awareness,
- little experience in the field of cooperation with the world of science,

- uncertain return on investment in innovation or too long payback period,
- lack of a sufficiently effective legislative policy (unclear and non-transparent provisions, constant changes to them).

3.4 Barriers from Government Institutions

The most important institutional barriers to public administration include:

- legislative changes. Legislative changes include: amending the complex VAT Act, which causes difficulties not only for private entrepreneurs, but also for universities and other public institutions. It does not contain indications on how to introduce the invention to the market [19]. Consequently, the situation of the unit implementing the invention usually depends on many factors. In such a situation, it is necessary to apply for an individual interpretation of the provisions to the Tax Office, which makes it difficult to make many decisions, not only for accountants, because it is also associated with many months of waiting [20],
- regional policy not adjusted to the needs of entrepreneurs and scientists,
- public procurement law (PPL) not adjusted to the realities of universities. Polish public procurement law is not adapted to the realities of today's science [17]. The thresholds set out in the Act make it very difficult to conduct research, and the purchase of research equipment takes months and is not always successful. It is related to many formal and legal reasons that will not be discussed in this article,
- lack of a coherent model of introducing innovations to the market by universities. Many studies show that universities are not willing to establish cooperation with business [17]. There is still a sense of distance between the two worlds. The improvement of the situation requires the improvement of communication between the university or research and development unit and entrepreneurs,
- financing changes. In Poland, the path "from idea to market success" is very tedious and complicated. There is no need to convince anyone that, apart from a good idea, the key to the success of an innovative enterprise is finding an effective way to finance it in the initial phase.

It seems that in order to eliminate the above-mentioned barriers, profound institutional changes should be introduced, i.e.:

- legal order in the sphere of intellectual property protection,
- pro-innovative legal regulations in the science sector,
- improvement of the legal environment for the functioning of the economy in the field of innovation and technology transfer,
- creation of coherent regional innovation support systems,
- effective management of pro-innovative services.

4 Examples of Partnership Cooperation Implemented with Triple Helix

Below, this chapter describes in detail practical examples of cooperation carried out within the framework of ongoing projects, taking into account the triple helix formula [21, 22]:

- ISM project (see Table 1) [23],
- TPPA project (see Table 2) [24],
- KWB project (see Table 3) [25].

4.1 The ISM Project

The first of the ISM projects was entitled "The increase in the efficiency of the public transport as a result of implementing the concept of LCC and RAMS compatible to IRIS based on an integrated IT system" (see Table 1).

The final effects of the project were mainly used in the railway industry. As part of the project, an IT monitoring system was developed to collect, process and analyze data (see Table 1) on the damage to the fleet of rail vehicles (trams) according to the LCC (Life Cycle Costing) and RAMS (Reliability, Availability, Maintainability and Safety) concepts in accordance with the standard IRIS. The developed IT system was used by the manufacturer for quality management in the railway industry.

As part of the project, apart from the development of an IT system for the needs of Solaris Bus & Coach S.A., several master's theses were defended at the Poznan University of Technology, one habilitation thesis and many scientific publications.

The project consisted of a consortium, with an entrepreneur being the leader of the consortium, and the university acting as a consortium member.

Table 1. Data from the ISM project.

Design data				Name of the entity, role in the project and financial resources [PLN]		
Type of partnership	Acronym	Project duration [months]	Project budget [PLN]	Government	Education	Business
				National Research Center and Development	Poznan University of Technology	Solaris Bus & Coach S.A.
				Executive Founding Agency	Consortium member	Leader
Triple	ISM	26	3 080 000	1 780 000	–	1 300 000

4.2 TPPA Project

As part of the second, with the acronym TPPA (see Table 2), an innovative method of reducing the moisture content of loose materials in alternative fuels production technologies was developed.

On this basis, a prototype installation for reducing the humidity of an alternative fuel obtained from combustible waste in the form of a mixture of paper and plastic packaging was designed, built and tested, according to the patent registered in the Polish Patent Office under the number 397062. As part of the project, one invention was created, which received the claim Patent In addition, as part of the project, several engineers and master's degrees were created, which were defended at the Poznan University of Technology, as well as many scientific publications.

The second project, similarly to the first, consisted of a consortium, with an entrepreneur being the consortium leader, and the university acting as a consortium.

Table 2. Data of the TPPA project.

Design data				Name of the entity, role in the project and financial resources [PLN]		
Type of partnership	Acronym	Project duration [months]	Project budget [PLN]	Government	Education	Business
				National Research Center and Development	Poznan University of Technology	Ltd. Ekopoz
				Executive Founding Agency	Consortium member	Leader
Triple	TPPA	24	4 113 000	3 290 400	–	822 600

4.3 The KWB Project

As part of the KWB project (see Table 3), a prototype technological line was developed to obtain humic acids or potassium humate from lignite on an industrial scale and to obtain an innovative product in the form of humic acid with established parameterization values for the product ensuring its high quality.

Process innovation: an innovative technology for the production of humic acids from lignite on an industrial scale. As part of the project, one invention was created and several engineering and master's theses, one doctoral thesis and many scientific publications were created. Moreover, there were trainings and demonstrations of new technology for students.

In this project, the main contractor of the project was selected, which was business, while the universities acted as subcontractors. Summarizing the above-described examples of partnership cooperation implemented as part of the triple helix, the successor of its positive effects, expressed by project indicators, can be mentioned:

- joint patents, publications and conferences published in popular scientific journals with high impact factors,
- completed engineering, master's, doctoral and habilitation theses with very good final grades,
- joint technology development as part of basic and industrial research and development works,
- employing research workers in enterprises, which took place in the third of the discussed projects,
- special training, demonstrations and demonstration seminars for a specific technology.

However, the most important of the effects is jointly developed technologies that will contribute to the increase in the competitiveness of many enterprises and the overall dimension to technological progress and increase in the innovativeness of the economy.

Table 3. Data of the KWB project.

Design data				Name of the entity, role in the project and financial resources [PLN]		
Type of partnership	Acronym	Project duration [months]	Project budget [PLN]	Government	Education	Business
				National Research Center and Development	Poznan University of Technology, University of Technology and Life Sciences in Bydgoszcz	Brown Coal Mine Ltd. "Sieniawa"
				Executive Founding Agency	Subcontractor	General contractor
Triple	KWB	26	23 818 884	14 915 078	–	8 903 806

5 Conclusions

As indicated above, universities often do not have separate or well-specialized units for cooperation with industry with sufficient human resources. Therefore, in order to improve the efficiency of the process of commercialization of knowledge or greater

integration of science with industry, the barriers that have arisen should be eliminated. The aforementioned technology brokerage, involved not only in the industry, but also in leading research centers, can help.

The key factor deciding on overcoming some barriers is the broker or broker using both formal and informal contacts through a network of connections and personal acquaintances, as well as reaching the sources of information about research projects and the results obtained. This may be a strong support for CTT in the process of commercialization of knowledge, as the information obtained often concerns projects which managers have not submitted for commercialization for many reasons. In addition, the form of personal contact with the scientist allows you to quickly assess the commercial potential of the works carried out by the scientist, as well as translates into their later more understandable presentation to the interested entrepreneur. As shown in the given examples, the government is able to provide a large share of the required funds with an appropriate consultations between the university and industry, taking into account the industry's own financial contribution.

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References

1. Mousavi, S., Bossink, B., Vliet, M.: Microfoundations of companies' dynamic capabilities for environmentally sustainable innovation: case study insights from high-tech innovation in science-based companies. Bus. Strategy Environ. **28**, 366–387 (2019)
2. Sika, R., et al.: Decision support system in the field of defects assessment in the metal matrix composites castings. Materials **13**(14), 3552-1-3552–27 (2020)
3. Ludmyla, Z., Petro, M.M., Chepurda, G., Lyzunowa, O., Shmygol, N.: Strategy of innovative development as an element to activate innovative activities of companies. Acad. Strateg. Manage. J. **18**(4), 1–6 (2019)
4. Zdobytskyi, A., Mykhailo, L., Panchak, R., Sika, R., Kalinowski, K.: Increasing the strength of materials by topological optimization methods. In: IEEE 16th International Conference on the Experience of Designing and Application of CAD Systems (CADSM), vol. 21, ISBN 978-1-6654-3894-0 (2021)
5. Popov, G., Legutko, S., Kliemntov, K., Kostov, B.: Applying criteria equations in studying the energy efficiency of pump systems. Energies **14**(17), 5256-1-5256–13 (2021)
6. Srinivasan, P.L., Kadu, K.: Organizational change with respect to technology and workforce for creating an optimized organization. Int. J. Adv. Res. Manage. **3**(9), 181–186 (2018)
7. Bartkowski, D., Bartkowska, A., Piasecki, A., Jurci, P.: Influence of laser cladding parameters on microstructure, microhardness, chemical composition, wear and corrosion resistance of Fe–B composite coatings reinforced with B4C and Si particles. Coating **10**(9), 809-1-809–18 (2020)
8. Matysiak, M., Duspara, M., Cumin, J., Smardzik, I.: Conventional shaping the edges of thick steel plates after welding process. Techn. Gaz. **28**(2), 663–667 (2021)
9. Sika, R., Hajkowski, J.: Synergy of modeling processes in the area of soft and hard modelling. In: 8th International Proceedings on Manufacturing Science and Education – MSE, MATEC Web of Conferences, Sibiu, 050071–050078 (2017)

10. Galvao, A., Mascarenhas, C., Marques, C., Ferreira, J., Ratten, V.: Triple helix and its evolution: a systematic literature review. JST **10**(3), 812–833 (2019)
11. Scalia, M., Barile, S., Saviano, M., Farioli, F.: Governance for sustainability: a triple-helix model. Sustain. Sci. **13**(5), 1235–1244 (2018). https://doi.org/10.1007/s11625-018-0567-0
12. Gorelova, I., Dmitrieva, D., Dedova, M., Savastano, M.: Antecedents and consequences of digital entrepreneurial ecosystems in the interaction process with smart city development. Adm. Sci. **11**(3), 94, 1–14 (2021)
13. Oettinger, J., Henton,, D.: The role of innovation brokers in a knowledge economy: the fourth strand to triple helix. In: Collaborative Economics, paper submitted to the Triple Helix XI International Conference, London (2013)
14. Bojar, M., Machnik-Słomka, J.: Model of a triple and quadruple helix in building network cooperation for the development of innovative regional projects, science notebooks in Silesian University of Technology. Organ. Manage.. **76**(1923), 99–111 (2014)
15. Beyond "Triple Helix" – towards "Quad Helix." The Bearing Wave, Bearing Consulting Ltd. March (2022)
16. Abbas, A., Avdic, A., Xiaobao, P., Hassan, M.M., Ming, W.: University-government collaboration for the generation and commercialization of new knowledge for use in industry. J. Innov. Knowl. **4**(1), 23–31 (2019)
17. Leydesdorff,, L., Etzkowitz, H.: The transformation of university-industry-government relations. Electron. J. Sociol. http://arizona.openrepository.com/arizona/handle/10150/106531. Accessed 06 Feb 2018
18. Cai, Y., Etzkowitz, H.: Theorizing the Triple Helix model: past, present, and future. Triple Helix **7**, 189–226 (2020)
19. Champenois, C., Etzkowits, H.: From boundary line to boundary space: the creation of hybrid organizations as a Triple Helix micro-foundation. Technovation **76–77**, 28–39 (2018)
20. Leydesdorff, L.: Synergy in knowledge-based innovation systems at national and regional levels: the Triple-Helix model and the fourth industrial revolution. J. Open Innov. Technol. Mark. Complex **4**(2), 16, 1–13 (2018)
21. Zhang, Y., Chen, K.: Scientific effects of Triple Helix interactions among research institutes, industries and universities. Technovation **86–87**, 33–47 (2019)
22. Anttonen, M., Lammi, M., Mykkanen, J., Repo, P.: Circular economy in the Triple Helix of innovation systems. Sustainability **10**(8), 2646 (2018)
23. Research project "The increase in the efficiency of the public transport as a result of implementing the concept of LCC and RAMS compatible to IRIS based on an integrated IT system", PBS3/B6/30/2015. https://www.solarisbus.com/pl/firma/dotacje. Accessed 27 Oct 2021
24. Research project "Development of Innovative methods of lowering of moisture content granular materials in alternative fuels production technology", GEKON-213086, 2015–2016, https://ekopoz.eu/projekty.html. Accessed 27 Oct 2021
25. Research project "Investigating the property of lignite and assessment of its suitability in production of humic acid", POIR.01.01.01-00-0799/16-04, 2017–2020. http://www.sieniawa.com/dofinansowanie. Accessed 28 Oct 2021