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Risks Analysis of the Implementation of Sustainable Solution for the Oil and Fat Industry Waste Recycling

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Abstract. This article expands on the problem of oil and fat industry waste recycling via biogas plants. Authors assess the risk level of the proposed solution implementation, taking into account externalities of the industry in the Rostov Region of the Russian Federation submitted by the stability of centralized power supply, local personnel qualification, climatic peculiarities, and industry state finance support of the region. To achieve the study objective, the following methods were used: qualitative PESTEL-analysis (identified the external factors) and quantitative Fuzzy logic (assessed risk level. The result of this study shows that the risk level is predominantly below average, reflecting the preparedness of the external environment in the region. The uniqueness of the study is represented by a proposed model to assess the external environment risk level via fuzzy logic that also contributes to more qualitative subsequent studies.

Keywords: Biogas plant; Fuzzy logic; Oil and fat industry; Risk assessment; Waste recycling

1. Introduction

For the Russian Federation (RF), the problem of waste recycling in the oil and fat industry is extremely acute as it is a world giant sunflower producer. According to the United States Department of Agriculture (2022) in the 2021-2022 season, the share of Russian sunflower oil exports in global supplies amounted to 29% (3.2 million tons) (United States Department of Agriculture, 2022). Nevertheless, while the volume of crop processing is increasing yearly, the amount of waste rises proportionally. So, in today's world of scientific progress and the global focus on waste recycling technologies development it provokes the sustainable solutions implementation. This is especially relevant in oil and fat industry as its residual products of production are valuable resources conscious processing of which can provide circular economy realization, sustainable development goals achievement, and ecological damage reduction. The main direction of waste processing in the fat and oil industry is the process of obtaining biogas. Biogas is produced during the fermentation of biomass. To achieve this, the waste is introduced into the reactor of a biogas plant under optimal conditions. The process results in two products: the gas itself and biofertilizers. However, crude biogas contains impurities, with the methane content ranging from 45 to 70%. To use it as an alternative energy source, the gas needs to be cleaned. This final stage is also carried out at biogas plants, as they are equipped

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with a purification system. The implementation of biogas technologies is at the stage of its development in conditions of availability of traditional energy sources and high risks when working with methane. However, the development of technology is stimulated by the state as part of the implementation of environmental protection measures, the development of alternatives to energy supply in remote regions of the country and the implementation of sustainable development strategies at enterprises.

Due to the valuable energy and biochemical features of the industry's waste, it is used as an input resource for upcoming green technologies like green fuel production using anaerobic digestion, chemical production, and other compelling biotechnological directions (Sinha and Tripathi 2021). Biogas is being accepted as the most promising gaseous fuel. At the same time, risk assessment of methene-containing solutions is a priority because it helps to determine measures to prevent undesirable outcomes in economic, technological, ecological and other nature.

2. Literature Review

According to SCOPUS data, the publication activity on the topic of biogas plants has been showing a steady annual increase since 2005 (Figure 1). For the entire period reflected on the line chart, the maximum was reached in 2022 – 11089 publications (Scopus, 2022).

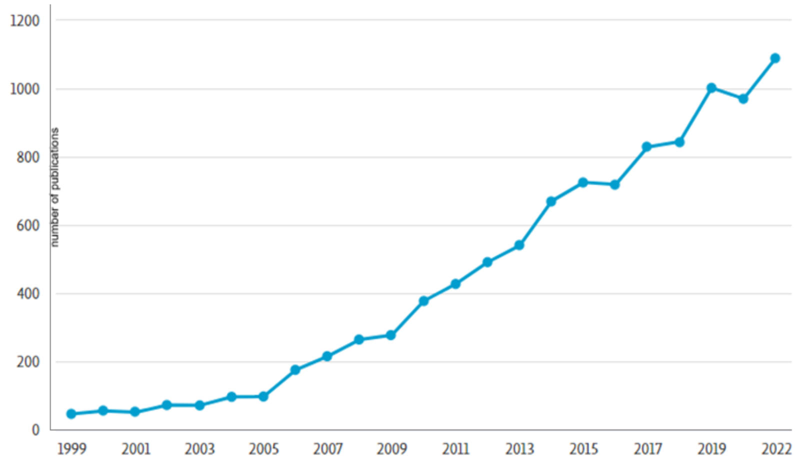

Figure 1 The analysis of SCOPUS results for "biogas plant" by number of publications, 1999–2022 (Scopus, 2022)

The leading regions with the highest interest in biogas plants in Agricultural and Biotechnological Sciences are Germany, China, Italy, Poland, and the United States of America (Figure 2). The industry specifics of the countries, the level of their technological development, and the need for environmental impact reduction stimulated at the state level explain this trend. In addition, the results are due to the shortage of fossil fuels in European countries and the demand for alternative energy generation.

The Russian Federation is not represented in this top; however, the development of carbon-free projects and biotechnologies is spurred at the legislative level. Strategic documents defining the biotechnological sector policy are aimed at sustainable practices implementation (Ministry of Agriculture of the Russian Federation, 2020; Strategy, 2018). All of this defines the relevance of the study.

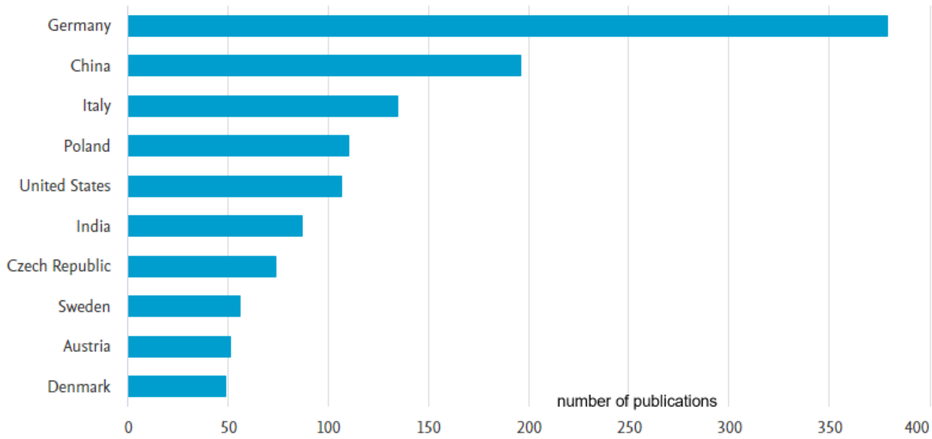

Figure 2 The analysis of publication activity according to the results of SCOPUS on the topic "biogas plant" by country, 1999-2022 (Scopus, 2022)

A literature search using keywords relevant to the study unveiled the primary areas covered within the topic. By examining various works on the subject (Severi *et al.*, 2022; Theuerl *et al.*, 2019) that delve into issues like "Biogas plant," "Biotechnology risk assessment," and "Waste recycling," it becomes evident that research interest is generally bifurcated into two main directions: investigating technological risks and exploring non-technological barriers that influence externalities, creating impediments to their global adoption, proper functioning, and widespread dissemination. While the predominant research interest is in the technological field caused by inherent upcoming biotechnology itself, non-technological issues are also relevant and include the study of biogas plant economic effectiveness (Salerno *et al.*, 2017; Gebrezgabher *et al.*, 2009), cover government policy points (Berhe *et al.*, 2016) as well as proposing management practices for proper biogas plant work organization (Slingov and Pridachin, 2014). Moreover, the local infrastructure of the implementing biotechnologies plays a significant role as it defines the possibility of such projects' integration in the environment: even if the technology is developed, the unreadiness of external conditions will not let it work.

Risk assessment in the field of biogas plant operation is popular with both Russian (Koshelev and Nurgaliev, 2016) and foreign researchers (Scarponi *et al.*, 2015; Trávníček and Kotek, 2015). Methods used in studies are diverse both in their fields of application and in the tools employed for calculations. For instance, biogas release is observed via Event Tree Analysis (Stolecka-Antczak and Rusin, 2021), and functional failure risk is measured with the help of fuzzy logic (Wang *et al.*, 2020).

A literature review has shown that nowadays, authors predominantly problematize waste disposal and recycling in the agricultural sector not only in terms of investment effectivity but also by biotechnology development and its risk assessment. Researchers look into the reasons for biogas plant failure, propose various methods of damage prevention, pose potential hazards, and calculate consequences. The main lessons learned are the need to develop and adopt specific safety standards and to improve the safety culture and risk awareness in the biogas production sector (Burova *et al.*, 2021; Moreno *et al.*, 2016). Rapid development in biotechnology causes new opportunities that are followed by new biotechnology risks (Lomakin *et al.*, 2022; Robaey, 2018).

A literature review has shown there is a high research interest in biogas technologies and waste recycling. However, there are no found papers with quantitative methods used to evaluate the external environment riskiness level. The study is novel in that it proposes a fuzzy logic model and its' linguistic description that provides external environment risk level assessment procedure conduction. The concept of "external environment" used in this article means the conditions and events outside a company that affect the way it operates. So, if the territory readiness for the project implementation is not assessed, it may lead not only to a decrease in its effectiveness but also to various harmful consequences.

Hence, the relevance of the problem and its theoretical and practical significance determined the objective of the study, which is to assess the external environment riskiness level of a biogas plant implementation in an oil and fat industry company on the example of the chosen region.

3. Methods

Qualitative and quantitative methods were chosen as methods used to achieve the goal of the study. The qualitative method is represented by strategic analysis methods such as PESTEL-analysis. PESTEL analysis was conducted based on a literature review compiled by SWOT analysis, as well as an Ishikawa diagram. To identify the most significant environmental factors, a quantitative PESTEL analysis was conducted, based on interviews with experts in the fields of biotechnology, environmental science, and economics. Authors choose the method of structured interviewing with an individual conversation: each respondent evaluates a fixed set of factors, that is, assigns them weight. Each block of factors included the 4 most relevant for quantitative analysis and significant from the point of view of experts. Quantitative methods include methods for collecting and processing statistical information and fuzzy logic. The most significant factors from PESTEL analysis will be included in the factors for conducting an analysis based on the fuzzy logic method to determine the level of risk. The conceptual framework of the research is presented in Figure 3.

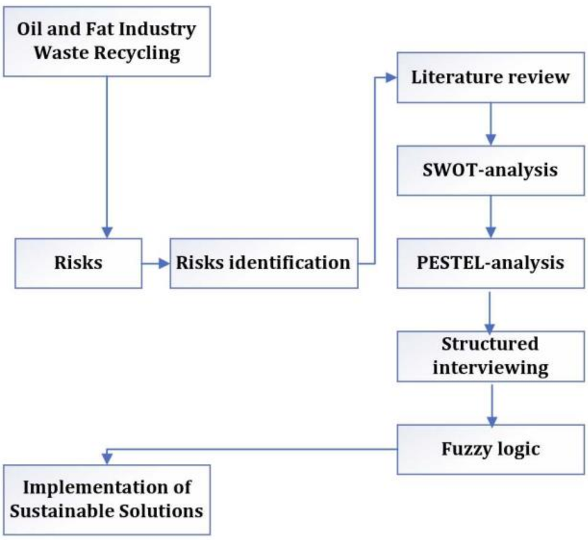

Figure 3 Research conceptual framework (complied by authors)

The analytical approach to statistical data and mathematical apparatus of fuzzy logic modeling (FLM) relies on the study introduced by L.A. Zadeh in the work "The Concept of a Linguistic Variable and its Application to Approximate Reasoning" (Zadeh, 1975). The step sequence of the research is as follows:

1. Introduction of a linguistic variable and formation of a scale to assess the risk level of biogas plant introduction in an oil and fat company in the chosen region.
2. Formation of indicators and a matrix of factors' values.
3. Calculation of the risk level aggregate indicator.

4. Characterization of the risk level of biogas plant introduction in an oil and fat company in the chosen region in the Russian Federation based on the formed scale.

To determine the risk level, we introduce the linguistic variable «external environment riskiness level of biogas plant implementation in an oil and fat company in the RF» describing it with a set of indicators (formula 1):

$$Y = [x;\ T;\ D], \qquad (1)$$

where x – is the name of the variable; T – the set of values: «Low level», «Below average», «Average level», «Above average», «High level»; D – is the domain at the segment [0;1].

When developing an innovative project, the most relevant approach to assessing risks affecting the environment and human life is based on the use of fuzzy logic, which allows making forecasts in conditions of uncertainty or the presence of poorly documented data (Doskočil, 2016).

The proposed initiative is supposed to be implemented in the company on the territory of the Rostov Region, which is located in the southern part of the East European Plain and partly in the Pre-Caucasus. The region is characterized as moderately continental and insufficiently humid with warm summers and moderately humid winters. Half of the regional sown areas are occupied for grain farming, while sunflower is the leading technical crop. In 2021, the Rostov Region became the leader in the RF in sunflower production, with a gross of over 1.92 million tons (Federal State Statistics Service, 2020).

4. Results and Discussion

Factors of external influence play a significant role when innovations are proposed due to the specifics of the industry and reflect the circumstances in which companies operate. Table 1 presents the PESTEL analysis' key factors.

Table 1 Results of PESTEL-analysis

Political factors	Economic factors
1. Instability of the geopolitical situation. 2. Military actions on the border territory. 3. Imposed sanctions on export and import transactions. 4. Dependence on foreign high-tech equipment suppliers. 5. Complication of international logistics. 6. RF import substitution policy.	1. Upcoming economic crisis caused by the COVID-19 pandemic and geopolitical problems: The projected decline in real incomes of Russians by 6.8% in 2022 (Ministry of Finance of the Russian Federation, 2022). 2. Seasonality and dependence of harvest efficiency on weather conditions. 3. Rising inflation rate: 8.4% in 2021 vs forecasted 15% in 2022 (Central Bank of the Russian Federation, 2022). 4. Anti-crisis measures of state support of the agro-industrial complex companies.
Social factors	**Technological factors**
1. Mass media influence on the stakeholders. 2. Reputation of a company. 3. Image of a proposed technology. 4. Percentage of people with higher education: in the first half of 2022, 34.9% of employees in the Russian labor market had higher education (Audit and consulting network FinExpertiza (2022)). 5. Predictable human capital flight	1. Lack of experience in implementing biogas plants in the country. 2. Problems with spare parts and equipment supplement. 3. Deterioration of infrastructure equipment of centralized power supply of the region: the average age of the equipment in Russia is 34 years (Nanosoft Development LLC, 2022).
Ecological factors	**Legal factors**
1. Legal regulation of industry. 2. Authorities' requirement strengthening to the conditions of wastes disposal. 3. Industry preferential subsidies (Ministry of Agriculture of the Russian Federation, 2022).	1. Socio-economic development strategy of the region (Strategy, 2018). 2. Quotas for greenhouse gas emissions. 3. Environmental legislation policy.

Presented negative and positive issues create an industry environment. In today's world situation, geopolitical problems influence the sector to a greater extent. Economic issues are directly dependent on it. Technological factors are complicated by insufficient technical equipment of domestic production facilities as well as yield and weather conditions. However, the state and the regions of presence in Russia encourage the introduction of sustainable and environmentally friendly biotechnological solutions. The Strategy of socio-economic development of the Rostov Region defines increasing the share of energy from renewable energy sources as one of its critical goals (Strategy, 2018).

Thus, along with the strengths ensuring waste-free production at the enterprise and the possibility of obtaining electricity, heat, and high-quality fertilizers, the introduction of a biogas plant is complicated by a number of technological features to which the project is highly sensitive and non-compliance with which can completely disrupt the biotechnological process. In addition, the implementation of such installations in the territory of the RF is complicated by the supply of foreign equipment. It may take more than one year to implement the import substitution strategy in this area and organize local production of components that significantly reduce the attractiveness of this technology for the Russian market.

The choice of factors for the fuzzy multiple approaches is based on their significance, which was evaluated within the framework of PESTEL analysis, the possibility of quantitative representation, and the availability of data in the public domain. To evaluate the level of external environmental risk associated with the introduction of a biogas plant in an oil and fat industry enterprise in the Rostov Region, the key factors with the most significant impact on the technology were identified.

Table 2 Factors of fuzzy-set approach

Factor	Factor's description
X1 – Harvesting capacity	Sunflower harvest volume, thousand tons
X2 – Staff	Share of people with higher education in the region, %
X3 – Financing	Amount of state support for the industry, thousand rubles
X4 – Planned capacity inactivation	The volume of losses in the power network, million kWh

The initial data for the riskiness level calculation is presented in Table 3 (Federal State Statistics Service, 2020; Ministry of Agriculture of the Russian Federation, 2020).

Table 3 Values of risk factors

Region	Sunflower harvest volume, thousand tons	Share of people with higher education in the region, %	Amount of state support for the industry, thousand rubles	Volume of losses in the power network, million kWh
Rostov Region	1 583.87	37.6	2 834 932	2255.8
Average over the RF	803.19	35.4	1 827 913	3069.22

Sunflower harvest indicator reflects the level of production waste generated, representing the volume of potential input raw material for a biogas plant. Data on higher education represent the amount of highly qualified personnel and potential resources of the region. Industry state support indicated government interest for the industry, implying its attractiveness for the country. The factors presented create a favorable environment for the implementation of the solution. An increase in the indicators reduces the risk, indicating a negative direction of influence.

Power outages from the planned capacity are calculated as the volume of losses in the power grids. This reflects the threat of a power outage that can lead to a shutdown of the bioreactor and ongoing internal processes. Indicator's influence direction is positive – an increase in power outages increases the risk. The value of the Y function will characterize the risk level of the external environment in the case of biogas plant implementation in the oil and fat company in the Russian Federation, depending on a number of selected factors. To assess the riskiness level a scale of fuzzy values for variable Y was developed (Table 4).

Table 4 Scale for assessing the risk level of external environment in case biogas plant implementation in an oil and fat company in the Russian Federation (complied by authors)

Set of values	Linguistic evaluation	General explanation of the evaluation
0–0.333	Low level	The amount of state support accounts a significant share in the structure of government expenditures to increase the efficiency of renewable energy sources and the introduction of sustainable waste management methods in the agro-industrial sector. The region is country's leader in sunflower harvesting. There is an agricultural cluster located in the area. The enterprises are provided with highly qualified, experienced personnel and high-tech equipment that minimize failures in the electricity transmission.
0.167–0.5	Below average	The state moderately finances the industry and encourages environmental protection measures. The climatic features of the region are favorable for growing crops. Sunflower harvesting plays one of the leading roles in the agro-industrial complex of the region. Global power plant failures occur no more than a few times a year or even less often. The equipment of the industry enterprises is in optimal condition. There is no shortage in qualified personnel in the region.
0.333–0.667	Average level	The industry receives limited funding from the state. The climatic features of the region impose restrictions on the cultivation of crops due to the peculiarities of temperature regimes and soil fertility. The share of people with higher education prevails in the region. Failures in the local power plant operation occur on average once a quarter.
0.5–0.833	Above average	The state finances the industry poorly. The volume of sunflower harvesting is low due to the specifics of the country's economic system and unsuitable climatic conditions. The Institute of Education is poorly developed. There are both population migration and brain drain. The share of the population with higher education is low. Intermittent failures occur at power generation stations due to the long service life of the equipment.
0.667–1	High level	There is nearly no state support for the industry. The country is located in the northern region, unsuitable for sunflower cultivation. Education of the population is at a low level, dominated by personnel with secondary vocational education. There are power outages in the regions due to both climatic conditions and poor technical equipment of production. At the state level, sustainable projects and solutions are either not encouraged or in their infancy.

After mathematical transformations: normalization of Xi indicators, distribution of factors by subsets of the scale "low" (0-0.333), "below average" (0.167-0.5), "average" (0.333-0.667), "above average" (0.5-0.833), "high" (0.833-1) and calculation of the levels of significance of factors, sub-indicators for each of the factor were calculated and the aggregate indicator Y was calculated.

So, the value of the aggregate indicator Y = 0.34. Thus, the external environment of the Rostov Region in Russia is auspicious for the proposed technology implementation in an oil and fat company as the risk level is 96% below average and 4% average. This result correlates with the idea of the socio-economic development strategy of the Rostov Region that stimulates sustainable project realization. The obtained value of the indicator also points out the investment attractiveness of the region. The significance of the study is in the revealed external environment readiness level of the Rostov region for the introduction of innovative technologies in agriculture.

Like any innovation, the introduction of biotechnology causes risks. The higher the expectations, the greater the risks. So, it is necessary to identify them and to see how to evaluate them. The best management alternatives for the recovery and food waste valuable components recycling are to be proposed in order to reduce the environmental impacts, minimize human health risks, and decrease the pressure on natural resources (Hatmoko, Astuti, and Farania, 2021; Ungureanu-Comanita *et al.*, 2020). The data can serve the top management of companies as the basis for making decisions on investing in projects. The results obtained will help industry specialists in data analysis, in reviewing possible methods for assessing risks, and in assessing the readiness of regions to implement innovative solutions. The results are useful for the state in terms of region development and growth point identification.

For the further development of the study, it seems necessary to analyze the selected indicators in dynamics in order to consider how the state of the external environment has changed for the technology being implemented. This will also allow us to identify key trends in changes in external factors and predict future events taking into account current regional problems. Moreover, it is possible to analyze all country's regions and consider the possibility of implementing similar projects in them in order to select the most attractive location that will help the government in making decisions. Besides, the study can serve as a basis for analyzing waste disposal alternatives and choosing the most appropriate one. For this reason, it would be appropriate to draw up a decision-making matrix for choosing the most affordable technology for the secondary use of by-products of the fat-and-oil industry (sorbents, nanocellulose, etc.) in this territory.

5. Conclusions

Bioenergy sustainable solutions in agriculture are stimulated at the international level. The proposed model can be beneficial for the oil and fat companies all over the world under conditions of the demand for carbon-free energy initiatives realization and the need for annual industry generated hazardous waste minimization. As a result of the study, we obtained a lower-than-average risk level for the introduction of a biogas plant, which indicates favorable external conditions for the introduction of biogas technologies in the Rostov region in accordance with the stability of the centralized power grid, the qualifications of local personnel, climatic features and state financial support of the region. The proposed solution is recommended to be implemented but taking into account current fluctuations in the geopolitical situation.

Future studies on the topic are to cover other regions, retrospective analysis, and decision-making matrix development for the oil and fat industry residual products of production recycling via analyzing different alternatives of waste utilization and value-added product creation. The target audience of the study the government, industry specialists, the company's top management departments responsible for decision-making in waste management, and firm's activity diversification. Enterprises taking into account all the specifics of their activities and climatic features of the regions of presence can use the results. The proposed solution will contribute to the sustainable development concept, providing both high ecological and economic effects and increasing in companies' reputation in the eyes of key stakeholders.

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