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The Evaluation of Factors Affecting Bioeconomy Development Using Transdisciplinary Approach

Zane INDZERE[1]*, Maira MELVERE[2], Indra MUIZNIECE[3], Dagnija BLUMBERGA[4]

[1–4]*Institute of Energy Systems and Environment, Riga Technical University, Azenes iela 12/1, Riga, LV-1048, Latvia*

Abstract **– Bioeconomy is a target that European Union has set to be achieved; however, despite the planning documents, strategies and the financial support already given to promote it, the development of bioeconomy is slow and has not shown any significant development in the recent years. In this research bioeconomy system that consists of seven factors: production, technology, climate change, infrastructure, bioresources, and pollution, is being evaluated. The selection of factors is based on literature review and opinions of the expert group. The main aim of the research is to understand which are the most influential factors within the bioeconomy system, particularly, which factors the highest attention should be paid to in the policy and strategy documents implementation on a national level. To evaluate the chosen bioeconomy system, a multi-criteria decision-making method TOPSIS was used. The TOPSIS method was performed by using transdisciplinary approach components, which emphasise the complexity of bioeconomy. The results have shown that the main three factors within bioeconomy system are bioresources, climate change and production. The least important factors are technologies and infrastructure.**

Keywords **– Analysis; bioeconomy; development; evaluation; factors; multi-criteria decision-making analysis; strategy; TOPSIS; transdisciplinary approach**

Nomenclature	
a	Alternatives
i	Criteria
r	Normalised value
w	Weight
V	Weighted value
d_a^+	Distance to ideal solution
d_a^-	Distance to nadir solution
c_a	Relative proximity for ideal solution

1. INTRODUCTION

Humankind is currently facing many great problems, such as running out of fossil fuels (some of these resources could be exhausted even sooner than expected), climate change, food and fresh water availability restrictions, ecosystem degradation etc. These problems are

* Corresponding author.
E-mail address: zane.indzere@rtu.lv

becoming even more relevant as they are turning into a bigger threat to humans' life quality by negatively affecting health and available resources needed for survival, such as food and water. World Economic Forum announced that in 2019 three biggest threats that are likely to happen in economics are related to environment: extreme weather, failure to adapt and mitigate climate change, and natural disasters [1].

These problems are being caused by many factors, one of them is CO_2 emissions. The study [2] shows the forecast of produced CO_2 emissions for several countries. The conclusion of the study is that there is the need for better environmental policies in order to avoid significant costs because of inactive and incompetent response to the current problems, both in economic and human terms. Also, despite the improved efficiency measures and warnings of the negative causes of climate change and measures already implemented to reduce CO_2 emissions, it is forecasted that CO_2 emissions will continue to rise in the coming years. What is more, the countries that are currently producing a high volume of CO_2 emissions already, will continue to produce and even increase the produced volume of CO_2 emissions, for example, CO_2 emissions produced in China in 2020 will grow by 9 %, Russia Federation by 12 %, South Africa by 16 % compared to 2015 [3]. This means that the environmental problems humans are facing now are not at their peak; in the future they can become even more dangerous, causing bigger and more complex problems.

Additionally, problems can be caused by rapidly growing population, for example, overpopulation and food shortage. That will cause a new problem to solve: how to feed all people. The total population growth rate is predicted to be positive till the end of the century, meaning that the total number of people will keep growing in the nearest decades [4].

These challenges each on its own, as well as a combination of them, set a major task for humanity – to take immediate action. More attention must be paid to the following questions: how to manage natural resources and production in a sustainable way, how to improve public health, how to mitigate climate change, and how to integrate and balance social development. It is clear that in order to deal with the existing environmental problems and to eliminate them in the future, the greatest challenge is to improve and innovate ways to produce and use food, products and resources in order to move towards a sustainable and more environmentally friendly lifestyle [5], [6].

Considering all the threats humankind is facing now and the potential disasters in the nearest future, the topics regarding the implementation of sustainability, bioeconomy, circular economy and similar concepts have become even more topical. All before mentioned concepts suggest solutions on how to solve and avoid problems and threats by reducing negative impact on environment as much as possible. Within the ideas of the concepts, some of the improvements are already being developed, for example, improvements in energy efficiency within the district heating network [7], production of materials by using environmentally friendly resources, i.e., microorganisms in the pulping, bioremediation and bio-ethanol production [8], treatment of the increasing volume of waste, i.e., glass [9], and using bioresources such as vegetable oil for fuel in the engines [10].

Despite the changes in the way products are being treated already, one of the main ways on how to accelerate the change is policy measures implementation based on facts. Currently the European Union (EU) has recognised the need to change the management of resources, more precisely, bioresources. The most important step was taken in 2012 [11] when the Bioeconomy Strategy was published; and in 2018 updated version of Bioeconomy Strategy was launched [6]. Additionally, legislation documents and researches about bioeconomy and bioeconomy related topics (for example, bioresources, biotechnologies, bioenergy, bio-production, etc.) are being implemented. The definition of bioeconomy can be viewed differently as seen in different development strategies and related documents [12]–[15], however most of these definitions share common things: sustainable use of renewable biological resources (bioresources) to produce food, feed, energy, and goods. Bioeconomy provides and maintains more efficient and environmentally friendly use of bioresources, which results in a cleaner environmental (including improved production processes, and energy efficiency) and independency from fossil fuels.

Bioeconomy has been recognised as the strategy that can solve the most essential environmental problems. In addition, it provides a sustainable future, in which all the most essential things to humans are provided in environmentally friendly way, using only renewable biological resources from forestry, fishery, agriculture, and even from waste sectors [11], [16]. Currently, the statistics shows that bioeconomy is an important part of human lives already. It is stated that the turnover value of the bioeconomy within the European Union (EU) is only 2.3 trillion euro in a year. Bioeconomy sector alone is responsible for 8.2 % of the EU's workforce with a potential to create new jobs, mostly in coastal and rural areas. The calculated number of new workplaces are approximately one million people by 2030. Also, bioeconomy stimulates creation of new jobs instead of protecting the old ones, which means that lifelong learning is being encouraged in communities. It proves that bioeconomy is already an important element in the EU economy and beyond, and it is very likely to become even more important in the future as the demand for natural resources and their management will increase [6], [16].

However, in spite of some measures and legislation documents that have been implemented to develop bioeconomy, recent studies show that the current development of bioeconomy is too slow and not efficient enough to achieve the goals that have been set by the EU [17]. Therefore, to understand how bioeconomy development can be increased and developed in a sustainable way, it is necessary to understand and evaluate the factors that affect bioeconomy. The previous study [18] has evaluated factors that influence bioeconomy. These factors are: land, waste, welfare, climate change, bioresources, fossil resource, human resources/population, research and innovation, energy, education/knowledge, policy, health, behaviour, technologies, water, natural environment, consumption, financial resources, economic growth, food, production and pollution.

It is essential to understand the inner relationships between factors in the system because factors within the system can affect each other; therefore, if one factor is affected, the whole system can change. This is very important because in most cases the intertwined relationships are not considered when important measures are being made, which could mean that improvements in one field (within a factor) could cause a serious damage in another field. As one of the examples of this problem is management of food and production of fuels from crops and any other edible plant. It leads to a competition between the fields, both of which are important in society [19]. From this it can be concluded that intertwined relationships are essential and need to be considered when the measures affecting bioeconomy are being taken.

The EU Bioeconomy strategy states that bioeconomy can be achieved by using multidisciplinary approach [11]; however, other studies have stated that transdisciplinary approach is needed [20], [21]. The approaches have some similarities, for example, the use of knowledge from different discipline fields and this particular knowledge is then exchanged between experts in order to find a solution for a complex problem. The main difference is that the transdisciplinary approach adds additional knowledge resource, which is society. The transdisciplinary definition states that a society has real-life knowledge obtained in the processes of dealing with complex problems in real life. It provides a comprehensive and realistic view on the problem; therefore, the society has a major importance in the transdisciplinary approach. Without this knowledge, the multidisciplinary or other approach has a theoretical solution for the problem.

Transdisciplinary approach is the latest disciplinary type that appeared in 1970s. The concept of transdisciplinary has been created taking into consideration all the previous disciplinarily types – interdisciplinarity and multidisciplinary, keeping and improving their advantages and avoiding their shortcomings. The fact that only academic disciplines are involved in previously mentioned approaches of disciplinaries has been recognised as a shortcoming. Therefore, engaging non-academic experts in the research is the reason why society has a high importance within the transdisciplinary approach. The knowledge that non-academic people have of the area they live in, and dealing with particular problem or being influenced by this problem one way or another, makes them "specialists of everyday life". It is stated that the sum of the knowledge of all the participants involved will give a higher impact than each individually would do. Also, while working on solving the specific problem, each participant's personal interest will be minimised. This diversity of experts plays an important role as they positively reframe and refocus on how nexus-related challenges are addressed. They can also help to avoid narrow disciplinary or institutional blinkers. Therefore, a transdisciplinary approach could be defined as a new research and solution-based approach by considering science and society as equals. As a result of a transdisciplinary research, a new methodology or a theory can be formed to solve complex problems [22]–[25].

Transdisciplinary approach is used to solve complex, also so called "wicked" problems. "Wicked" problems do not have obvious solutions; most of the time they include nexus type relationship between involved factors and social systems. These parties create new challenges for society and policy makers in order to find solutions [26]. This leads to the conclusion that complex problems need complex approaches, therefore, transdisciplinary approach is used to solve real life world problems for the common good in the fields of [8], [24], [27]–[29]:

- Development of social, technical and economic fields and their interactions with other factors (for example, health care, energy, waste management);
- Interaction between human and nature (for example, agriculture, forestry, industry);
- Development of technologies (for example, nuclear technology and biotechnology).

Transdisciplinary solves problems in both ways – horizontally and vertically. This approach is considered to be horizontal because it ensures cooperation between disciplines at the same level; it is vertical because disciplines are combined: NGOs, government agencies cooperate, interaction of local communities and local people [22].

2. Methodology

The methodology consists of several parts, including evaluation of factors affecting bioeconomy, selection of transdisciplinary components and the Technique for Order Preferences by Similarity to Ideal Solutions (TOPSIS) method to evaluate the bioeconomy factors (see Fig. 1).

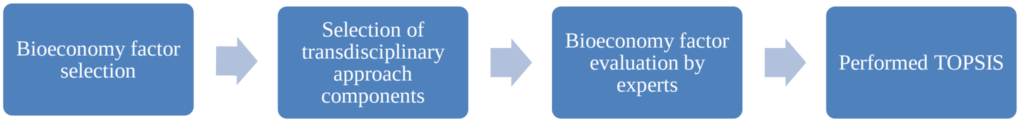

Fig. 1. Performed steps of the study.

Multi-criteria decision-making analysis has various methods and approaches that evaluate various alternatives in order to choose the most suitable one (and rank them by conformity) for certain cases, considering factors that influence them. Multi-criteria decision-making analysis methods are widely used, mostly to evaluate environmental and water management systems, as well as to choose the best alternatives for business and finance planning, logistics and transportation, human resources and engineering systems [15].

In this research, a method called Technique for Order Preferences by Similarity to Ideal Solutions (TOPSIS) is used to evaluate several factors, which is also a method of the multi-criteria decision making analysis. This specific method was chosen over other methods because it allows to simultaneously evaluate various alternatives, as well as to compare factors with each other even in the cases when the factors do not even share similar measuring units.

Even though TOPSIS is not the most commonly used method among other multi-criteria decision-making analysis methods, the research shows that the results obtained from TOPSIS and then compared with other multi-criteria decision-making analysis methods' results are very similar [15]. The main result that can be obtained from the performing method TOPSIS is that it is possible to calculate the score for each alternative, therefore, they can be ranked by their importance. This allows to identify the most and the least suitable alternatives and to later on make decisions on the basis of these results.

To perform TOPSIS, overall nine main steps need to be implemented in order to achieve rational and useful results [16]:

1) Select alternatives (factors) and criteria that are the most important for the evaluation of the specific system. The TOPSIS method has advantages in the selection process, because the number of alternatives and criteria does not affect the process of TOPSIS significantly;
2) Compile a decision-making matrix (see Table 1). This matrix includes the evaluation between the criteria and alternatives which is mostly conducted by literature analysis, statistical data or expert opinion;
3) All the values obtained from the decision-making matrix (Step 2) need to normalised. To conduct this step, Eq. (1) is used:

$$r_{ai} = \frac{x_{ai}}{\sqrt{\sum_{a=1}^{n} x_{ai}^2}} \; ; \tag{1}$$

4) Evaluate and allocate weight for each criterion (for example, mathematical analysis, literature analysis, expert opinion etc.), the sum of all the criteria should be 1. The weight allocated for each criterion shows how important each criterion is within the specific system – the higher the weight is, the more important the criterion is;
5) Obtained in Step 3 and normalized matrix values are multiplied by the weight calculated in Step 3 (see Eq. (2)):

$$v_{ai} = w_i \cdot r_{ia} \; ; \tag{2}$$

6) The most ideal alternative is determined by finding the value with the highest score within all the factors calculated in Step 5; the lowest value (also called nadir) is found;

7) Develop a distance measure for each criterion result that is calculated in Step 5 to ideal (see Eq. (3)) and nadir solutions (by using similar regularity as shown in Eq. (4)):

$$d_a^+ = \sqrt{\Sigma(v_i^+ - v_{ai})^2}\ , \tag{3}$$

$$d_a^- = \sqrt{\Sigma(v_i^- - v_{ai})^2}\ ; \tag{4}$$

8) For each alternative, determine a ratio c_a that shows the distance to the nadir value which is then divided by the sum of the distance to the nadir and the distance to the ideal alternative as shown in Eq. (5):

$$c_a = \frac{d_a^-}{d_a^+ + d_a^-}\ ; \tag{5}$$

9) Rank the alternatives by the results obtained in Step 8; therefore identifying, which of the alternatives is the most suitable for the chosen system. The results show the score for each criterion where all of them are the closest to the ideal possible solution, but farthest from the negative ideal solution.

2.1. Bioeconomy System

2.1.1. Bioeconomy Factors

In earlier research, the same factors had been evaluated to identify the most important ones within the particular system of factors. However, no external criterion was used for evaluation, therefore, the results has only shown the intertwined relationships between them. [17]. In the previous study it is possible to find a full description of each factor.

For this research, where the TOPSIS method and external criteria are used for the evaluation, seven most important factors in the bioeconomy system have been chosen. These factors are: bioresources, production, climate change, technology, pollution, infrastructure and natural environment. These factors have been chosen as the most relevant in bioeconomy context, which is based on literature review/analysis and expert opinions. To evaluate these factors within transdisciplinary approach, the criteria have been chosen on the basis of the most important influencing components. Economy was not included as an important factor in the bioeconomy system within this particular study; however, in the future research, this and other factors can be added for a comprehensive study of a wider list of factors.

2.1.2. Transdisciplinary Components

As mentioned before in the text, transdisciplinary approach is a complex method that evaluates specific and complex problems in order to solve them. This method not only includes the knowledge from various and related discipline fields, but also considers social knowledge as an important source to be used to evaluate and solve a certain problem. Within this bioeconomy system, in which seven bioeconomy influencing factors are being evaluated, transdisciplinary approach includes five most important components:

- Applied sciences;
- Social sciences;

– Natural sciences;
– Society;
– Innovation and research.

Additionally to previously mentioned disciplines and the knowledge and contribution from the side of society, one more component is added to the system, which is innovation and research. This component is evaluated separately from other components, because innovation and research has proved to be an important and valuable component in the systems that needs to be developed. Therefore, innovation and research has been considered within this study as an additional component, added to the regular list of transdisciplinary components.

3. RESULTS

In order to prepare the TOPSIS matrix, five experts were interviewed to receive their evaluation of each factor and how the transdisciplinary components affect each factor (each expert filled in the matrix individually). The evaluation was done taking into account the importance of the components within each individual factor, for example, the participants were offered to evaluate the importance of applied sciences for the technologies on a scale from 0 (non-important) to 10 (crucial). It is important to note that experts who participated in the interviews evaluated factors considering all five transdisciplinary components, therefore, even though the society itself was not directly involved in the evaluation (which means that none of the experts was a society representative), their opinion was included in the answers of the experts; the same applies for other transdisciplinary factors.

After the filled in matrix were collected, the average values were calculated and used for the further calculations by using the TOPSIS method. The weight of each transdisciplinary component was determined by assuming that each of them should have an equal importance within the system, therefore the same weight was allocated to each criterion – 0.2.

TABLE 1. DECISION MAKING MATRIX FOR BIOECONOMY SYSTEM

	Technology	Production	Climate change	Bioresources	Pollution	Natural environment	Infrastructure
Applied sciences	10	8	6	10	5	8	7
Social sciences	2	7	7	7	6	5	6
Natural sciences	5	5	7	10	8	10	3
Society	8	9	9	9	8	8	6
Innovation and research	10	7	7	8	8	6	8

Further steps to perform TOPSIS (as seen in Methodology part) were used to calculate the value of each bioeconomy system influencing factor. The results have shown the score for each factor and its importance within the bioeconomy system that consists of seven important factors within the chosen system. The results for all seven factors within bioeconomy system can be seen in Fig. 2.

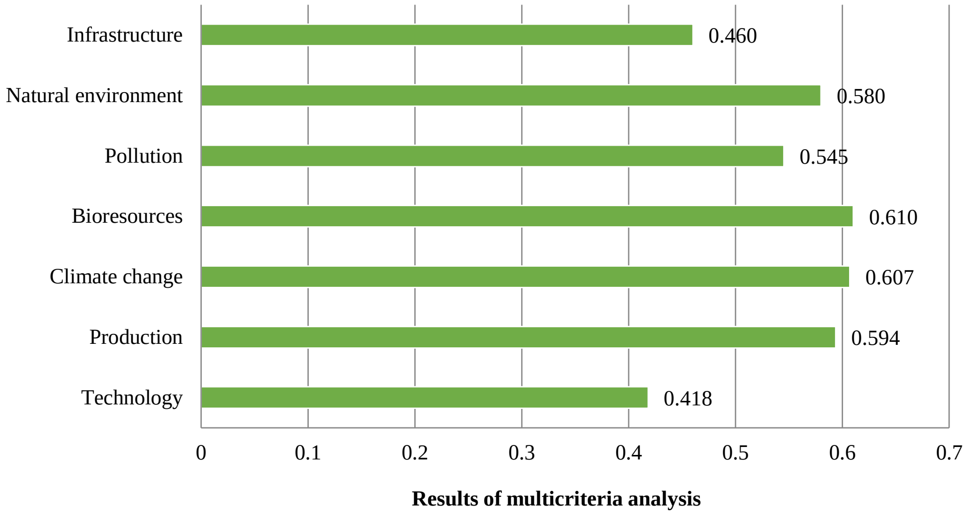

Fig. 2. Bioeconomy system influencing factors' evaluation by using TOPSIS.

The performed method has shown the results of all the factors included within the bioeconomy system that use transdisciplinary approach within its development. The ranking of bioeconomy influencing factors are: (1) bioresources; (2) climate change; (3) production; (4) natural environment; (5) pollution; (6) infrastructure; (7) technology.

4. Discussion and Conclusions

In the performed analysis of the bioeconomy affecting factors bioresources has shown a significant importance within other factors starting with the first evaluation steps. These results come from expert evaluation. The results given by experts do not show marks lower than 7 within the interlinkages with other factors; the highest mark is 10. This alone shows the importance of bioresources with other factors, therefore, it also shows the importance of bioresources in the bioeconomy as a whole.

Notable conclusions were drawn about other factors, taking into account interactions with transdisciplinary components within the performed TOPSIS method:

– Society has a great importance within most of the factors; the strongest links are shown between society and production, climate change and bioresources, but the link between society and infrastructure is weak;
– Applied sciences have a major impact on technologies and bioresources, but its impact on pollution is not significant;
– Natural sciences have diverse interlinkages with other factors: bioresources and natural environment are fully affected by it; however, it has a weak impact on infrastructure, as well as technology and production factors;
– The lowest value is given to technology factor by social sciences with the mark 2; the next smallest given value is 3 to the infrastructure by natural sciences.

The transdisciplinary components' weight is an important factor to consider. Even though they should have equal importance (as stated in transdisciplinary definition), in practice (real life) they have varying weight, which also depends on the system they are in. This is especially seen in the evaluation where the society factor is considered to have a low compared to other factors. However, in real life society has a strong importance on other factors and related decisions.

The obtained results have shown that the most important factors within the bioeconomy system are bioresources and climate change that is closely followed by production and environment factors; the least important factors are pollution, infrastructure and technology. However, Fig. 1 shows clear results in which the amplitude between the most important and least important factors within this bioeconomy system is quite small – 0.192; this leads to a conclusion that bioeconomy's development rate is affected by more than one or two factors. This conclusion is important as it needs to be considered when policy documents related to any of these factors are being implemented.

A notable fact is seen between bioresources and climate change as they both achieve almost identical results performed by the TOPSIS method. It describes the driving power of bioresources as the main source for bioeconomy in general; bioresources are the key aspect of bioeconomy as the resources needed for it come from the bioresources factor. Climate change is not the main source in bioeconomy; however, climate change and its increasingly negative impact on the environment is one of the main reasons why the current management system and bioeconomy themselves require changes. This leads to a conclusion that, considering the transdisciplinary approach, two main driving powers within the bioeconomy system are a solution tool and the main problem.

The results obtained from this study can be further used for policy planning documents that are directly or indirectly related to bioeconomy, especially for bioeconomy strategy documents on a national level. Also, the current policies that are in any way related to any of bioeconomy system's factors could be improved considering the interlinkages between factors and how the changes in one factor can affect the other. The policy, strategy and measures regarding bioeconomy should include factors with the highest score achieved, that way increasing bioeconomy's development rate.

For further studies it is suggested to increase the number of factors in the bioeconomy system, for example, to add economy, water, food etc., in order to have a wider view on the links and interlinkages between factors and their relationships.

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