



Article

Model of Introducing Biogas Plants Depending on Expected Financial Results Important for the Business of Agriculture and the Economy in Republic of Serbia

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Abstract: The purpose of the research is to highlight the importance of choosing the size of future biogas plants in the leading country of the Western Balkans, namely the Republic of Serbia. The aim of the research was to discover the optimal size of future biogas plants based on a representative survey of two categories of respondents: top management of industrial enterprises and heads of state bodies. The main conclusion we came to would be that the mentioned managers gave greater confidence to the construction of smaller biogas plants (up to 250 kW) for almost all analyzed factors compared to the construction of larger biogas plants (up to 1 MW). The connection of the final opinions of managers with the analyzed factors in both models "A" and "B" is strong and highly significant ($p < 0.001$). All factors, except for the system documentation factor, have a very significant impact on the expressed final scores for both models ($p < 0.001$). Thus, the authors provided evidence in favor of the construction of smaller plants, which should be the basis for providing incentive measures by state authorities to reduce dependence on imports through renewable sources, i.e. biogas production.

Keywords: *Management enterprises; state bodies; plants; bio gas.*

1. Introduction

The idea of respecting institutional factors in countries that have decided to achieve the goal of sustainable energy is becoming more and more present within the functioning of governing bodies in international organizations. This is particularly present in the EU countries, especially during the events related to the events in Ukraine, as pointed out by numerous authors [1-3].

In addition to emphasizing the importance of an institutional approach, there are numerous authors who also emphasize the importance of individual efforts to improve the general energy efficiency of individual legal entities, as well as the situation at the state level as a whole [4-7].

However, in the world in recent years, the question of the realistic use of carbon fuels has been increasingly raised, and therefore indirectly the question of the substitution of such energy sources with real renewable energy sources [8-11].

The production of alternative energy sources is fundamentally harmonized with the adopted energy policy of state bodies, as indicated by numerous authors from several countries where they conducted their research and where the specifics of the application of the mentioned energy sources in the practical functioning of the economy are emphasized [12-16].

The application of alternative energy sources, and especially the production of biogas, is based on the premise of a multi-dimensional observation, such as, for example, opinions: whether the introduction of biogas production can improve the position of the population in a country, analyzes related to the overall potential, the introduction of slaughterhouse waste into the production of biogas, introducing cattle manure into biogas production, as well as other energy sources and [17].

The processes of decentralization that arise within the real functioning of the EU mean that at the level of national economies it is necessary to introduce a comprehensive observation of management functions by specific activities [18,19].

The essence of management observed in this way refers to the observation of a broad framework of the economy, from the public sector of the economy, to the real sector of the economy, where there is a particular need to establish internal control mechanisms in the management functions of legal entities [20].

The mentioned management processes should be observed and that most of the management decisions of the management of legal entities are made on the basis of realistically completed and maintained documentation.

Economic activities are essentially of great importance for the establishment of new approaches in economic organization, but also within the financial observation of overall economic. Such an approach often has the framework of finding possible economic activities within the primary economic sector, i.e. within the framework of observing agricultural production, which can be seen as one of the most important raw materials for biogas production. in newly built facilities.

Based on that, when the mechanism of framework treatment of energy problems and finding solutions for optimizing the use of energy resources at the level of the national economy is established from the macro-economic level of decision-making, it is necessary to make a thorough acquaintance with the legal frameworks that follow this issue

In addition, these practical issues related to the real functioning of the real post-communist largest country of the former Yugoslavia and today's Republic of Serbia are of great importance due to the assessment of the future size of the plant that will contribute to import substitution, but viewed through the entire focus of integrative procedures, which is in accordance and with already published works like [21].

2. Materials and Methods

2.1. Sample

The research in this study included 242 legal entities in the Republic of Serbia. The research itself was conducted in January 2025. It analyzed five factors, namely: costs, regulations, incentives, system documents and possible potentials in terms of impact on the construction of two sizes of biogas plants. The first plant size is shown as model "A" and the production from such a plant could be obtained up to 250 kW, and the second plant size is shown as model "B" with possible biogas production up to 1 MW.

The entire observation was carried out on the basis of 121 questionnaires received and completed by two groups of somewhat different decision-makers. The first group of respondents consisted of senior managers of industrial companies, and the second group of heads of state bodies of various decision-making levels, from local governments to republican bodies involved in monitoring energy policy in the Republic of Serbia.

The goal of such activities was to demonstrate the possible substitution of natural gas imports. The official energy policy of the Republic of Serbia, whose platform emphasizes that the natural

potential for biogas production in the Republic of Serbia is such that it can satisfy about 50% of the current needs for this energy source, which was the essence of the basis and this research of the authors aimed at discovering an innovative approach to this problem, namely the problem of optimal biogas production in the economy.

2.2. Methodology

The work was carried out by completing 121 surveys of managers of industrial enterprises in the Republic of Serbia and the same number of surveys completed by managers of state bodies. The research period was from 01.01.2025. to 30.01.2025.

The survey participants were given the opportunity to express their opinion on the assessment of five factors of influence on the construction of bio-plants, namely the following factors: costs, regulations, incentives, system documents and possible potentials. All this was done in order to reveal the gradation of the influence factors that were analyzed in relation to two models of different biogas production plants.

The survey participants could rate each of the listed factors on a scale of 1-10, with the highest level of trust being rated 10 and the lowest level of trust being rated 1. In this way, a basis was created for a comparative study of the two possible forms of biogas plant construction in the Republic of Serbia.

Based on the above, it follows that there are several possible bases for perceiving the value of this research.

The first focus of the author was directed at collecting individually given ratings by top managers of companies in relation to the two mentioned models of biogas plant construction in relation to the five mentioned factors of possible influence, namely: costs, regulations, incentives, system documents and possible potentials.

The second focus of the author was directed at collecting individually given ratings by the management of state bodies and discovering possible differences according to the previously given setting. This was done with the aim of finding out how this category of decision makers sees the same set of problems related to the introduction of possible biogas production.

The third focus of the authors was aimed at revealing the deviations of the overall ratings received by the top management regarding the optimal size of future biogas production plants.

The fourth focus of the authors was aimed at revealing the deviations of the overall ratings received by the management of state bodies regarding the optimal size of future biogas production plants.

The fifth focus of the authors was aimed at revealing the overall differences in the assessment of top managers of companies and management of state bodies regarding the possible construction of a smaller biogas production plant, with a capacity of up to 250 kW.

The sixth focus of the authors was aimed at revealing the overall differences in the assessment of top managers of companies and management of state bodies in relation to the possible construction of a larger biogas production plant, with a capacity of up to 1 MW.

The final (overall) observation of the problem systematized in this way regarding the possible construction of a biogas production plant in the Republic of Serbia aimed to reveal the real differences based on the assessments obtained both from top managers of companies and from the ocean of managers in the structure of state bodies. In essence, the goal was to reach a relevant conclusion about which possible model of future biogas production plants has a greater chance of being practically implemented in the Republic of Serbia.

The survey data were the basis for the classical statistical processing of the obtained data. After that, the authors presented the obtained results of descriptive statistical analysis. In addition, a presentation of the results based on the testing performed was given. The goal of the aforementioned activities of the authors was to obtain the most reliable and relevant evidence regarding the possible practical application of the introduction of biogas production in the Republic of Serbia.

2.3. Hypotheses used in the paper

The authors made the following hypotheses in order to get answers to the key question, which size of the future biogas production plant is more steel-based.

H: 1 There is no difference in the obtained individual ratings of the top management of industrial companies regarding the size of the projected biogas plants in relation to the analyzed influencing factors.

H: 2 There is no difference in the obtained individual evaluations of the management of state bodies regarding the size of the projected biogas plants in relation to the analyzed influence factors.

H: 3 There is no difference in the level of overall ratings obtained by the top management of industrial companies in relation to the possible built plants for the production of biogas.

H: 4 There is no difference in the level of the total received ratings of the management of state bodies in relation to the possible built plants for the production of biogas.

H: 5 There is no overall difference in the level of ratings obtained by the top management of industrial companies and the management of state bodies for the five analyzed factors regarding the planned plants for the production of biogas with a power of up to 250 kW.

H: 6 There is no overall difference in the level of the obtained ratings of the top management of industrial companies and the management of state bodies for the five analyzed factors regarding the designed plants for the production of biogas with a capacity of up to 1 MW.

2.4. Statistical analysis

Statistical data processing and analysis were done using the software IBM SPSS (Statistical Package of Social Science) version 25. The T-test of independent samples was applied in the paper to examine the differences between the ratings obtained from the top managers of industrial companies and the management of state bodies in relation to the projected size designed installations for the production of bio gas.

A Multiple Regression Analysis was performed and it was used to examine the effects of the five analyzed factors regarding the planned plants for the production of biogas in relation to the level of the final rating of the top management of industrial companies and the management of state authorities. The paper used a threshold significance level of 0.05.

3. Results

The adoption of an acceptable theoretical and practically functional business model is of great importance for a post-communist country like the Republic of Serbia.

Namely, in the former Yugoslavia, the largest republic, Serbia, often did not take into account savings when building production plants.

Such a legacy needs to be fundamentally changed, and the authors have tried in this study to point out the importance of optimization when making decisions by state bodies regarding the implementation of a production plant, in this case for biogas production.

A general schematic representation of the obtained research results is given in Figure 1.

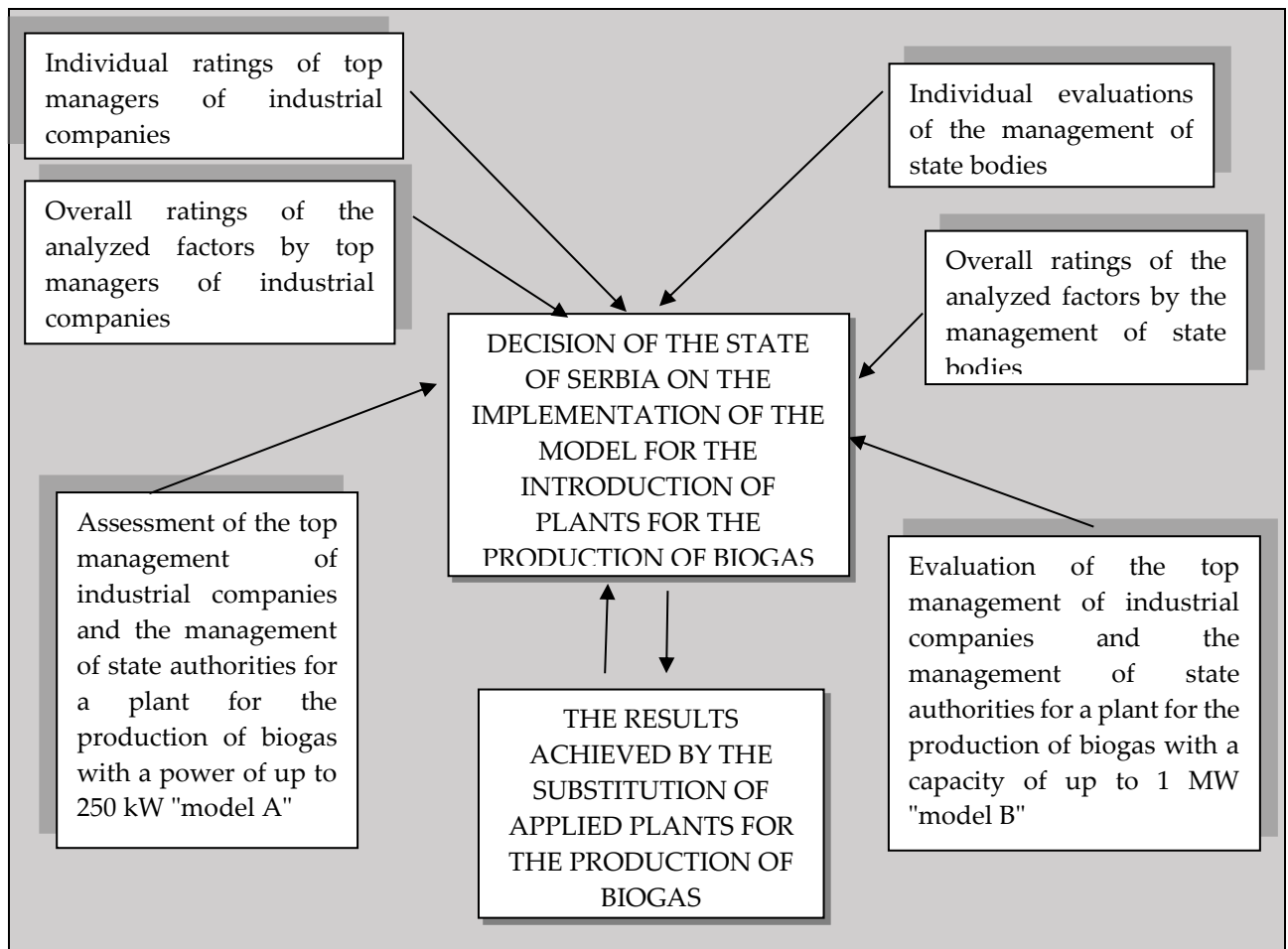


Figure 1. Presentation of the application of the model for the construction of a plant for the production of biogas for power.

3.1. Evaluation of top managers of industrial companies in relation to the size of the designed biogas production plants

The first level of the obtained results shows the evaluation of top managers of industrial companies in relation to the size of the designed biogas production plants and for the analyzed factors: costs, regulations, incentives, system documentation and the potential of renewable energy sources. To determine the differences in the size of possible biogas plants, an independent samples T-test was used.

A systematized presentation of the obtained results is shown in Table 1.

Table 1. Presentation of the resulting differences in the rating of the analyzed factors that can influence the construction of two types of biogas production plant according to the rating of the top managers of industrial companies.

Factors affecting the development of biogas plants	Model of the projected size of the bio-gas plant	Mean	Standard deviation	T-value	p
Costs (N=121)	A	9.75	0.43	150.432	<0.0005*
	B	2.14	0.34		
Regulations (N=121)	A	9.17	0.38	49.318	<0.0005*
	B	6.85	0.34		
Incentives (N=121)	A	5.17	0.38	6.693	<0.0005*
	B	4.85	0.34		
System documents (N=121)	A	4.17	0.38	-14.619	<0.0005*
	B	4.85	0.34		
Potentials of renewable energy sources (N=121)	A	9.82	0.38	120.009	<0.0005*
	B	3.08	0.40		

Note: (Model A refers to the construction of biogas plants up to 250 kW, and model B refers to the construction of biogas plants up to 1 MW).

3.2. Evaluation based on individual ratings received from the management of state bodies in relation to the size of the projected biogas production facilities

The second level of the obtained results included the presentation of the value of the evaluations of the management of the state authorities in relation to the size of the projected plants for the production of biogas and in relation to all five analyzed factors that can affect the construction of plants for the production of biogas.

T-test of independent samples was used to examine the differences in relation to the size of the projected biogas plants, and the presentation of the obtained results is given in Table 2.

Table 2. Presentation of the resulting differences in ratings for the analyzed factors that can influence the construction of two sizes of biogas production plant according to the assessment of the management of state bodies.

Factors affecting the development of biogas plants	Model of the projected size of the bio-gas plant	Mean	Standard deviation	T-value	p
Costs (N=121)	A	5.83	0.37	40.543	<0.0005*
	B	3.78	0.41		
Regulations (N=121)	A	6.83	0.37	0.824	0.411
	B	6.79	0.40		
Incentives (N=121)	A	9.83	0.37	0.981	0.328
	B	9.78	0.41		
System documents (N=121)	A	9.83	0.37	0.981	0.328
	B	9.78	0.41		
Potentials of renewable energy sources (N=121)	A	7.66	0.47	15.512	<0.0005*
	B	6.78	0.41		

Note: (Model A refers to the construction of biogas plants up to 250 kW, and model B refers to the construction of biogas plants up to 1 MW).

3.3. Overall ratings of the top managers of industrial companies in relation to the size of the projected plant for the production of biogas

In the third part, the results of the overall assessment of the top managers of industrial companies are presented in relation to the size of the projected biogas plants, i.e. for smaller plants up to 250 kW as well as for larger plants, i.e. for projected plants for the production of biogas up to 1 MW.

In addition to the above, a T-test of independent samples was performed in relation to the size of the projected plants for the production of biogas, which is systematized in the presentation of Table 3.

Table 3. Presentation of realized differences in the rating of the overall rating of the top managers of industrial companies in relation to the projected construction of two sizes of biogas production facilities.

	Model of the projected size of the bio-gas plant	Mean	Standard deviation	T-value	p
Total score (N=121)	A	7.61	0.28	93.278	<0.0005*
	B	4.50	0.23		

Note: (Model A refers to the construction of biogas plants up to 250 kW, and model B refers to the construction of biogas plants up to 1 MW).

3.4. Overall ratings of the management of state bodies in relation to the size of the projected plant for the production of biogas

In the fourth part, the results are given that show the existence of significant differences based on the obtained values of the evaluations pronounced by the management of the state authorities, for the analyzed five factors in relation to the two sizes of the projected plants for the production of biogas in the Republic of Serbia.

A systematized overview of the obtained results is presented in Table 4

Table 4. Presentation of the realized differences in the rating of the overall ratings obtained by the management of the state authorities, namely on the development of the construction of two sizes of biogas production facilities in Republic of Serbia.

	Model of the projected size of the bio-gas plant	Mean	Standard deviation	T-value	p
Total score (N=121)	A	8.00	0.36	13.958	<0.0005*
	B	7.38	0.31		

Note: (Model A refers to the construction of biogas plants up to 250 kW, and model B refers to the construction of biogas plants up to 1 MW).

3.5. Total ratings of the top management of industrial companies and the management of state bodies for the five analyzed factors regarding the planned plants for the production of biogas up to 250 kW

The results presented in the fifth part indicate that there are significant differences in the ratings given by top managers and the leadership of state authorities in relation to the analyzed factors in the projected plants for the production of biogas up to 250 kW.

A systematized overview of the obtained results is presented in Table 5.

Table 5. Presentation of differences in the rating of influential factors on the construction of plants up to 250 kW in relation to the ratings of top managers of industrial companies and the management of state bodies.

Factors affecting the development of biogas plants	Model of the projected size of the bio-gas plant	Mean	Standard deviation	T-value	p
Costs (N=121)	A	9.75	0.43	75.339	<0.0005*
	A	5.83	0.37		
Regulations (N=121)	A	9.17	0.38	48.298	<0.0005*
	A	6.83	0.37		
Incentives (N=121)	A	5.17	0.38	-96.255	<0.0005*
	A	9.83	0.37		
System documents (N=121)	A	4.17	0.38	-116.905	<0.0005*
	A	9.83	0.37		
Potentials (N=121)	A	9.82	0.38	39.126	<0.0005*
	A	7.66	0.47		
Total score (N=121)	A	7.61	0.28	-9.095	<0.0005*
	A	8.00	0.36		

Note: (Model A refers to the construction of biogas plants up to 250 kW).

3.6. Total ratings of the top management of industrial companies and the management of state authorities for the five analyzed factors regarding the planned plants for the production of biogas up to 1 MW

In the sixth part, the results presented indicate that there are significant differences in the ratings given by top managers and the management of state bodies in relation to the analyzed factors in the projected plants for the production of biogas up to 1 MW in size.

An overview of the obtained results is presented in Table 6.

Table 6. Presentation of the difference in the rating of influential factors on the construction of plants up to 1MW in relation to the ratings of the top managers of industrial companies and the management of state bodies.

Factors affecting the development of biogas plants	Model of the projected size of the bio-gas plant	Mean	Standard deviation	T-value	p
Costs (N=121)	B	2.14	0.34	-33.486	<0.0005*
	B	3.78	0.41		
Regulations (N=121)	B	6.85	0.34	1.357	0.176
	B	6.79	0.40		
Incentives (N=121)	B	4.85	0.34	-100.290	<0.0005*
	B	9.78	0.41		
System documents (N=121)	B	4.85	0.34	-100.290	<0.0005*
	B	9.78	0.41		
Potentials (N=121)	B	3.80	0.40	-57.091	<0.0005*
	B	6.78	0.41		
Total score (N=121)	B	4.50	0.23	-80.140	<0.0005*
	B	7.38	0.31		

Note: (model B refers to the construction of biogas plants up to 1 MW in size).

3.7. The influence of the analyzed factors on the final assessment of the top management of industrial companies and the management of state authorities for model "A" and "B" of the future built plants for the production of biogas

In the seventh part, the connection of the final grades with the analyzed factors in both models "A" and "B" was determined, all with the aim of determining the real significance. An overview of the systematized results is presented in Table 7.

Table 7. Overview of the management's final evaluations and analyzed factors in order to determine the suitability of the model to be applied.

Model	Factors	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B			Correlations	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part
A	Potential	0.196	0.000	0.221	400.83	0.000	0.195	0.197	0.988	0.999	0.011
	Incentives	0.424	0.000	0.427	2512.28	0.000	0.424	0.425	0.962	1.000	0.069
	Regulations	0.196	0.001	0.202	311.44	0.000	0.195	0.198	0.963	0.999	0.009
	Costs	0.173	0.001	0.179	198.9	0.000	0.171	0.175	0.986	0.997	0.005
B	Potential	0.200	0.000	0.180	7382395.9	0.000	0.200	0.200	0.998	1.000	0.011
	Incentives	0.200	0.000	0.223	40051391.8	0.000	0.200	0.200	0.969	1.000	0.061
	Regulations	0.400	0.000	0.505	25236940.1	0.000	0.400	0.400	0.996	1.000	0.038
	Costs	0.200	0.000	0.101	6111309.6	0.000	0.200	0.200	0.995	1.000	0.009

4. Discussion

Based on the obtained results, the existence of the following important characteristics can be observed in relation to the comparison of the size of future plants for the production of biogas in the Republic of Serbia, based on the received evaluations of the top management of industrial companies and the management of state bodies.

First, that there are significant differences in the scores obtained from the top managers of industrial companies in relation to the size of the projected plants for the production of biogas, because the results of the significance level of the T-test are lower than the threshold significance level for all analyzed factors. However, slightly higher ratings were given for the construction of smaller plants for the production of biogas, up to 250 kW (except for the factor of using system documentation). Based on the obtained results, hypothesis 1 can be safely rejected. The obtained results essentially coincide with already published works [22,23] especially in those that emphasize the importance of real management accounting in the economy.

Second, that there are significant individual differences in the assessments given by the heads of state bodies in relation to the size of the projected plants for the production of biogas, because the results of the significance level of the T-test are lower than the threshold significance level for the costs and potentials of renewable energy sources. Nevertheless, the existence of higher ratings of the management of state authorities for smaller plants (up to 250 kW) is observed. The level of significance of the T-test is higher than the threshold level of significance for: regulations, incentives and system documentation, on the basis of which it can be seen that there are no significant differences in the ratings of the management of state authorities according to the size of the projected biogas plant. Based on the obtained results, hypothesis 2 can be partially rejected. The results are compatible with the already published results of the authors who emphasize the importance of practical application of biogas production [24].

The third is that there are overall significant differences in the ratings given by the top managers of industrial companies in relation to the size of the projected plants for the production of

bio gas, because the level of significance of the T-test is lower than the threshold level of significance for the total score. However, smaller plants designed for the production of biogas up to 250 kW received a slightly higher overall rating compared to larger, i.e. designed plants up to 1 MW. Based on the obtained results, hypothesis 3 can be rejected. The results from the field of biogas plant design are of great importance for the successful achievement of the planned business results of the company, which has already been pointed out in their works by authors such as [25,26].

Fourthly, that there are overall significant differences in the ratings given by the managers of state bodies in relation to the size of the projected plants for the production of biogas, because the level of significance of the T-test is lower than the threshold level of significance for the total score. However, it can be seen that smaller plants designed for the production of biogas up to 250 kW received higher marks compared to larger plants for the production of biogas, i.e. up to 1 MW. Based on the obtained results, hypothesis 4 can be rejected. The obtained results, among other things, indicated the importance of the public sector in the design of biogas production facilities and are consistent with the already published data of the authors, which also indicated the importance of the overall management decisions of the management [27].

Fifth, that there are significant differences in the obtained ratings given by the top managers of industrial companies and the management of state bodies, for smaller, i.e., projected plants for the production of biogas up to 250 kW, because the level of significance of the T-test is lower than the threshold level of significance for all analyzed factors as well as for the total score. Top managers of industrial plants gave higher marks: for costs, regulations and potential of renewable energy sources and lower marks for incentives, system documentation and overall score. Based on the obtained results, hypothesis 5 can be rejected.

Sixth, that there are significant differences in the obtained ratings given by the top managers of industrial companies and the management of state bodies, and that is for larger, i.e. projected plants for the production of biogas up to 1MW. The level of significance of the T-test is lower than the threshold level of significance for costs, incentives, system documentation and the potential of renewable energy sources, as well as for the total score, on the basis of which it can be concluded that there are significant differences in the scores obtained between top managers and the leadership of state bodies. The top managers of industrial plants have lower scores for all the mentioned factors as well as for the total score. The level of significance of the T-test is higher than the threshold level of significance for regulations, on the basis of which we conclude that there are no significant differences in the ratings between top managers and the leadership of state bodies. Based on the obtained results, hypothesis 6 can be partially rejected. The presented results match the already published views of the authors, especially those who emphasized in their works the importance of respecting the standardization process as part of making management decisions [28].

Seventh, that there is a connection between the final grades and the factors in both models "A" and "B". It is strong and highly significant ($R_A, B=R_{2A}, B=1.000, p<0.001$). All factors, except system documents, have a very significant influence on the final grades for both models ($p<0.001$). According to t-values and correlations partial, the following factors influence the final rating of model "A" in order: incentives, potential, regulations and costs. The following factors influence the final rating of Model B in order: incentives, regulations, potential and costs. The obtained results are essentially very similar to the already stated positions in the framework of management decision-making by the author [29] and in their own special way highlight the importance of the adopted positions in relation to deciding which model should be chosen by the decision-makers in the Republic of Serbia.

The study confirmed the importance of researching one of the extremely important segments of state decision-making, namely the optimization of the construction of future biogas production plants in a post-communist economy, such as today's transition-type economy on the path to EU integration. The authors believe that the issue of the optimal choice of energy facilities in today's context of the struggle for resources is taking place in the field of state decision-making by two segments of decision-makers, both industrial enterprises and state authorities, which have a significant advantage in providing subsidies to the best option for the construction of a plant in terms of scale with economies of scale that make sense for the future of the economy. Similar research in

other post-communist economies, especially from the Western Balkans, is possible and useful through this example of optimization, but also through other forms of organization of production economies, especially if it concerns subsidizing state authorities for the purpose of optimizing production.

5. Conclusions

The general conclusion arising from the research carried out in this study would be that top managers of industrial companies, as well as heads of state bodies, gave higher ratings, i.e. the significance of the construction of biogas production facilities ($p < 0.0005^*$) is higher in smaller plants for production of bio gas (up to 250 kW), for almost all analyzed factors, in relation to the significance of the construction of larger plants for the production of bio gas (up to 1 MW).

The association of final grades with factors in both models is strong and highly significant (RA, B=R2A, B=1.000, $p < 0.001$). All factors, except system documents, have a very significant influence on the final grades for both models ($p < 0.001$).

According to t-values and correlations partial, the following factors influence the final rating of model "A" in order: incentives, potential, regulations and costs.

The following factors influence the final rating of model "B" in order: incentives, regulations, potential and costs.

This implies the conclusion that in the Republic of Serbia, greater attention in the future regarding the construction of biogas production plants should be given to the construction of smaller biogas production plants. These plants should be in the strong focus of incentive measures of state authorities in the future.

All these activities should be undertaken with the aim of replacing up to 50% of imported natural gas from Russia with domestic renewable sources, that is, in this way, the substitution of imported natural gas in the Republic of Serbia could be carried out to a large extent.

Conflicts of Interest: The authors declare no conflict of interest.

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