How different are Polish regions with regard to the utilisation of biogas plant technology application potential?

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Abstract

Environmental and economic issues make the widespread of the application of renewable and environmentally friendly energy resources tends to be more and more aware necessity amongst societal, selfgovernmental, and governmental circles. Biogas plants are one of the most promising renewable energy resources in Poland. This is because their widespread may result in considerable environmental and economic benefits. Despite, official efforts to support the investments in biogas plants, the widespread of them seems to be rather scarce across the country. There also seem to be considerable differences between Polish regions with this regard. This is why an effort to examine utilisation of actual potential of biogas technology is discussed in the paper. AHP methodology is applied in this regard. A vital AHP methodology enhancement is also proposed to adjust merits of the methodology to declared intangibility awareness.

Keywords: renewable energy, biogas technology, potential, utilisation, AHP/ANP, intangibility

1. Introduction

Quality of life of distinct people and whole society depends on different factors. Environmental factor belongs to the most influential factors. This is because it influences actual basic living conditions e.g. the availability of fresh air to breath, natural healthy food etc.

Actual possibility for the development of world's economy depends on energy availability. The majority of energy is spent by the society of highly developed countries of the world. Traditional means for mass energy production, which use fossil fuels, are often applied to produce energy with this regard. For example, nearly 50% of mass energy production results from the application of coal, crude oil, and natural gas, in EU countries (Ruszel 2017). Especially, the application of coal and crude oil results in a lot of environmental pollution.

Perspective environmental and population health-related consequences of using dirty energy sources, as well as, rising demand for energy and the resignation from using controversial nuclear power plants lead to the initiatives for energy production from renewable resources. Solar energy, wind energy, geothermal energy, hydropower etc. are considered as energy resources which may allow to cover future energy demand, in a considerable part, at least. The application of the resources results in some drawbacks, however. For example, wind energy use efficiency is susceptible to fluctuations of actual wind velocity which could change a lot, even during a single day. Solar energy requires daylight. The availability of hydropower depends on, often capricious, weather. A comprehensive exploitation of geothermal energy seems to require a lot of effort.

Note that there is another vital factor worth considering while applying alternative energy source. The factor deals with the possibility of the realisation of additional vital aims. Especially, the reduction, or even the elimination, of adverse effects of man's activities would be welcome. It seems that the application of biogas plants makes it possible, especially. This is because one can use them to get rid of wastes which result from both living (wasted food and sewage, general residental garbage), as well as, agricultural, manufacturing, service activities etc. in a environmentally-friendly way.

Perspective role of biogas plants as effective means for the severe reduction (or even elimination) of a need for waste landfills and environmental pollution in general is also acknowledged in Poland. This is why several governmental investment and financial programmes have been introduced here to foster the development of biogas plants in both municipal and rural regions. The nevertheless seem not to give expected results so far. Thus, further activities are welcome to make support further development of biogas plants more effective. Moreover, a need for such a development seems even more urgent as the EU council imposes more and more obligations with regard to the reduction in the share of fossil fuels in energy production.

Actual unsatisfactory results of Polish biogas plant sector development make preparation of adequate conditions for its further successful development necessary. A reliable assessment of biogas potential utilisation may help in this regard. Note that the actual results of the development are influenced by multiple factors, including intangibles. This is why the application of Analytic Hierarchy Process methodology application is proposed in the paper to support the assessment of biogas plant development potential utilisation.

2. Literature review

Biogas-related research deals with different issues. The issues range from particular technical analyses (Dubovskis, & Plume 2016) to strategical analyses (Dyiah, & Shriharti 2019). The majority of the research about biogas technology potential deals with regional affairs (Sliz-Szkliniarz, & Vogt 2012) and there are only a few works avaialble which appy a comprehensive influence of diverse factors into account (Chasnyk et al. 2015). Unfortunately, none of available research deals with modeling biogas technology application development while including the influence of intangible factors. This fact justifies the efforts made in the paper to propose an approach which would make reliable intangibility-aware modeling and the assessment of biogas technology application potential utilisation possible.

3. Hypothesis/Objectives

Intangibility awareness is one of fundamental AHP/ANP methodology strengths. The awareness also results in a lack of a need for the enhancement of the methodology by means of the application of other tools e.g. fuzzy numbers (Saaty 2006). One should be nevertheless aware that the AHP/ANP application provides strict numerical results. And they are considered as such during their analysis. Such instrumental treatment of the results seems to be incompatible with the idea of intangibility awareness demonstrated by the methodology. Therefore, some changes to the analysis of results provided by AHP/ANP methodology application are proposed in the paper. They are intended to make the analysis better adjusted to overall flexible nature of the methodology. The reliability of biogas technology application potential would also benefit from the utilisation of the proposed changes, as well.

4. Research design/methodology

The approach for enhancing the analysis of results, provided by AHP/ANP use, is based on checking if difference in scores obtained for two or more alternatives, which occupy adjacent ranks in a final or partial ranking, justifies the acknowledgment of the superiority of one or more of them.

The approach thus provides means for dividing considered alternatives into groups of the alternatives of similar scores. It is alternative score similarity, therefore, that comprises actual means for inherent AHP/ANP intangibility conservation while processing the results.

The implementation of the approach is based on original VIKOR methodology (Opricović 1980). A kind of acceptance threshold is applied in this regard to decide whether the difference in scores between two or more alternatives justifies declaring any of them as better than other ones. The threshold is applied in a step-wise manner:
1. A group (consisting of a single or more) top alternatives is identified in the first step.
2. Lower-level groups of similar alternatives are identified using a gradually updated threshold until all alternatives are processed.

5. Data/Model Analysis

Information about biogas technology application potential and actual performance of 16 Polish regions – voivodships was gathered. The regions included: dolnośląskie voivodship (D) with capital in Wrocław, kujawsko-pomorskie voivodship (C) with capital in Bydgoszcz and Toruń, lubelskie voivodship (L) with capital in Lublin, lubuskie voivodship (F) with capital in Zielona Góra and Gorzów Wielkopolski, łódzkie voivodship (E) with capital in Łódź, małopolskie voivodship (K) with capital in Kraków (Cracow), mazowieckie voivodship (W) with capital in Warszawa (Warsaw), opolskie voivodship (O) with capital in Opole, podkarpackie voivodship (R) with capital in Rzeszów, podlaskie voivodship (B) with capital in Białystok, pomorskie voivodship (G) with capital in Gdańsk, śląskie voivodship (S) with capital in Katowice, świętokrzyskie voivodship (T) with capital in Kielce, warmińsko-mazurskie (N) with capital in Olsztyn, wielkopolskie (P) with capital in Poznań, zachodniopomorskie (Z) with capital in Szczecin.
Diverse information sources were utilised in this regard. Several atributes for formal description of biogas technology application development process were selected and their levels were defined, based on collected information.

To make AHP analysis feasible, number of alternatives was reduced to 9. Initial clustering approach was applied in this regard. Actual cluster analysis was based upon detailed analysis of actual performance of distinct regions. Actual calculations were divided into two parts. The first part dealt with the identification of biogas technology application potential while the second pertained to actual voivodship performance.

The influence of three principal factors was assumed while assessing biogas technology. The factors included:
1. Agriculture-related potential (local availability of argicultural waste).
2. Population-related potential (local availability of domestic and landfill waste).
3. Population density—related potential (the odds inhibiting actual development of biogas plants).
Assumed set of the factors resulted from initial auxiliary analysis. The analysis was based on the application of a well established methodology of Fontela's and Gabus' DEcision MAking Trial and Evaluation (DEMATEL).

Note that all data for any necessary pair-wise comparisons while applying both DEMATEL as well as AHP, were provided by the authors of the paper. They resulted from careful analysis of about the performance of Polish regions back in 2016. The results for partial analysis of biogas technology potential are illustrated in Fig.1.

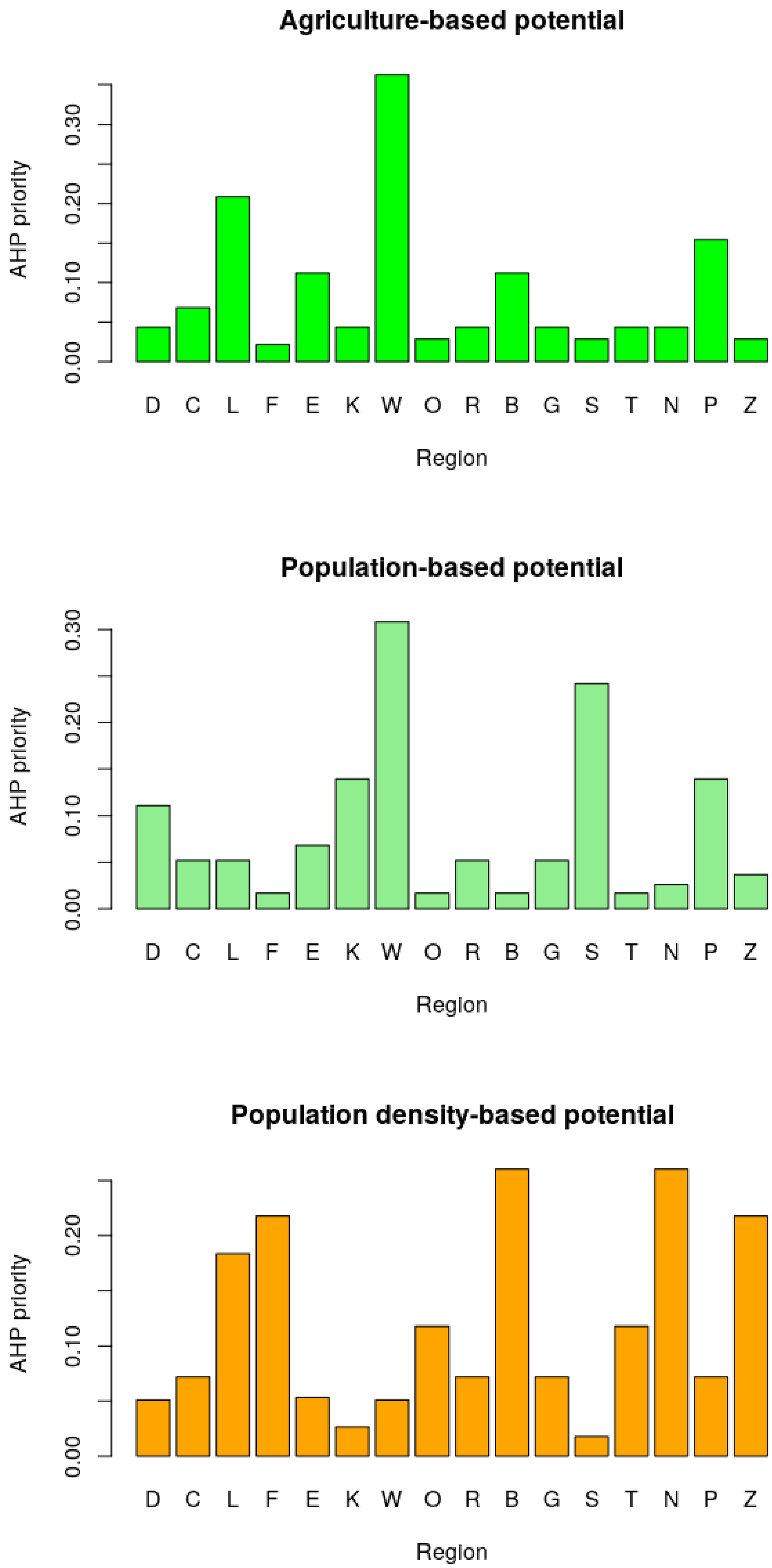

Figure 1. Illustration of partial AHP results

The obtained partial results were then aggregated to assess overall biogas technology potential. The aggregation of partial results was conducted thanks to the application of the results of an auxiliary AHP analysis. The analysis resulted in a set of priorities for considered biogas technology potential dimensions. Necessary data were provided by a careful analysis of actual conditions in Poland. It finally proved that despite considerable influence of agricultural and general population factors, actual biogas technology potential is influenced mostly by population density. Poland belongs to highly populated countries and biogas plants belong to noxious objects. This is why actual population density in Poland results in considerable problems with siting biogas plants. Final share of factors which influence biogas technology potential in Poland is presented in Fig.2.

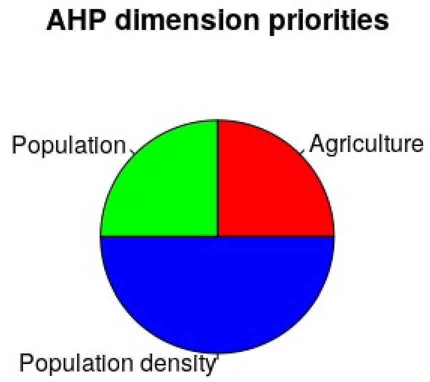

Figure 2. Assumed share of biogas technology potential factors

The results of overall biogas technology potential assessment are presented in Fig.3. The boxes which illustrate the potential for distinct regions results from actual application of the proposed, VIKOR-related technique of classification. The classification consisted of seven distinct stages. Necessary data for the classification were provided by means of biogas technology potential assessment's results. Raw data (columns 1-2) and results of initial four classification stages (the remaining columns) are presented in Tab.1. One should be aware that currently emerging class results from top regions whose difference in terms of actual ideal AHP priority is not greater than current threshold. The current threshold is reciprocal of current number (of not yet classified) regions decreased by one. Note that colors applied in the table denote the emerging classes of regions. The colors correspond with information presented in Fig.3. Thus, Fig.3 may be consulted for full classification results. It is evident, threrefore, that the regions are finally divided into seven classes (BN, WL, ZF, P, TO, ECSRGD, K). Note that both current threshold and regions comprising currently emerging class appear in Tab.1. in boldface.

Finally, the division of voivodshps according to biogas technology application potential was compared with the division of Polish regions based on their actual performance. Actual number of active biogas plants was used to express the performance in distinct regions in 2016. See: Tab.2 for details) about number of active biogas plants and results of four initial classification steps. Full information about overall classification according to actual performance of regions is presented in Fig.4. Class membership is expressed by diverse colors.

It is evident that the regions may be finally divided according actual performance into eight classes (W, S, D, ZP, GNC, KRLB, EF, OT). The classes consist of a one or more regions. The comparison with the division of regions according to biogas technology potential shows that there are the regions which are capable of exploiting the potential more than other regions e.g. mazowieckie voivoship (W). Some of such regions perform even extremally well despite rather unfavorable conditions for biogas potential exploitation e.g. śląskie voivodship (S) and dolnośląskie voivodship

(D). All in all, only 7 out of 16 regions seem to be currently capable of exploiting their potential, at least. However, the majority of the regions must still improve to exploit existing possibilities of biogas potential.

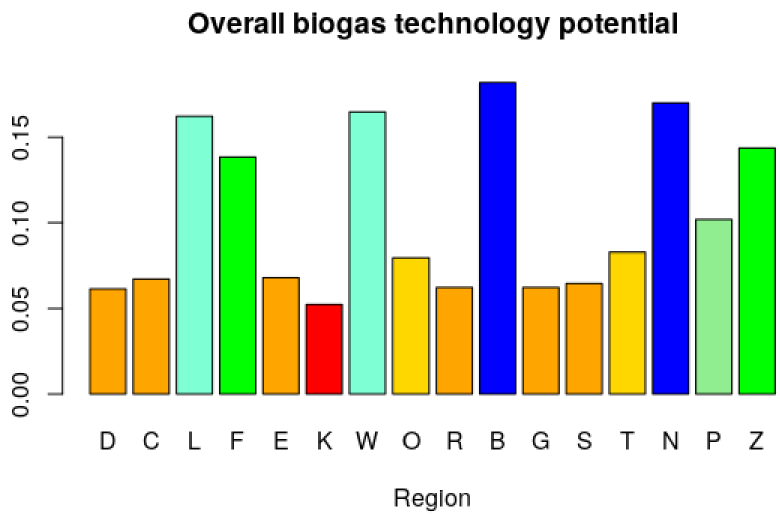

Figure 3. Overall classification of Polish regions according to biogas technology potential

Table 1. Classification of regions according biogas technology potential – data and results

Region	AHP priority	Region (sorted)	AHP ideal	Region (sorted)	AHP ideal	Region (sorted)	AHP ideal	Region (sorted)	AHP ideal
D	0.0615	**B**	**1**						
C	0.0673	**N**	**0.9346**						
L	0.1623	**1/(16-1)=**	**0.0667**	**W**	**1**				
F	0.1384	W	0.9054	**L**	**0.9848**				
E	0.0681	L	0.8917	**1/(14-1)=**	**0.0769**	**Z**	**1**		
K	0.0524	Z	0.7895	Z	0.8719	**F**	**0.9631**		
W	0.1648	F	0.7604	F	0.8398	**1/(12-1)=**	**0,0909**	**P**	**0.7091**
O	0.0797	P	0.5598	P	0.6183	P	0.7091	**1/(10-1)=**	**0,1111**
R	0.0624	T	0.4549	T	0.5024	T	0.5762	T	0.8125
B	0.1820	O	0.4379	O	0.4836	O	0.5546	O	0.7821
G	0.0624	E	0.3741	E	0.4132	E	0.4739	E	0.6683
S	0.0647	C	0.3697	C	0.4083	C	0.4683	C	0.6604
T	0.0828	S	0.3554	S	0.3925	S	0.4502	S	0.6349
N	0.1701	R	0.3428	R	0.3786	R	0.4342	R	0.6123
P	0.1019	G	0.3428	G	0.3786	G	0.4342	G	0.6123
Z	0.1437	D	0.3379	D	0.3731	D	0.4279	D	0.6035
		K	0.2879	K	0.3179	K	0.3646	K	0.5142

Table 2. Number of active biogas plants and the results of initial four steps of classification

Region	Number	Region (sorted)	AHP ideal	Region (sorted)	AHP ideal	Region (sorted)	AHP ideal	Region (sorted)	AHP ideal
D	29	**W**	**1**						
C	18	**1/(16-1)=**	**0.0667**	**S**	**1**				
L	15	S	0.9210	**1/(15-1)=**	**0.0714**	**D**	**1**		
F	8	D	0.7631	D	0.8285	**1/(14-1)=**	**0.0769**	**Z**	**1**
E	11	Z	0.6842	Z	0.7428	Z	0.8965	**P**	**0.9615**
K	17	P	0.6578	P	0.7142	P	0.8620	**1/(13-1)=**	**0.0833**
W	38	G	0.5000	G	0.5428	G	0.6551	G	0.7307
O	7	N	0.5000	N	0.5428	N	0.6551	N	0.7307
R	17	C	0.4736	C	0.5142	C	0.6206	C	0.6923
B	15	K	0.4473	K	0.4857	K	0.5862	K	0.6538
G	19	R	0.4473	R	0.4857	R	0.5862	R	0.6538
S	35	L	0.3947	L	0.4285	L	0.5172	L	0.5769
T	4	B	0.3947	B	0.4285	B	0.5172	B	0.5769
N	19	E	0.2894	E	0.3142	E	0.3793	E	0.4230
P	25	F	0.2105	F	0.2285	F	0.2758	F	0.3076
Z	26	O	0.1842	O	0.2000	O	0.2413	O	0.2692
		T	0.1052	T	0.1142	T	0.1379	T	0.1538

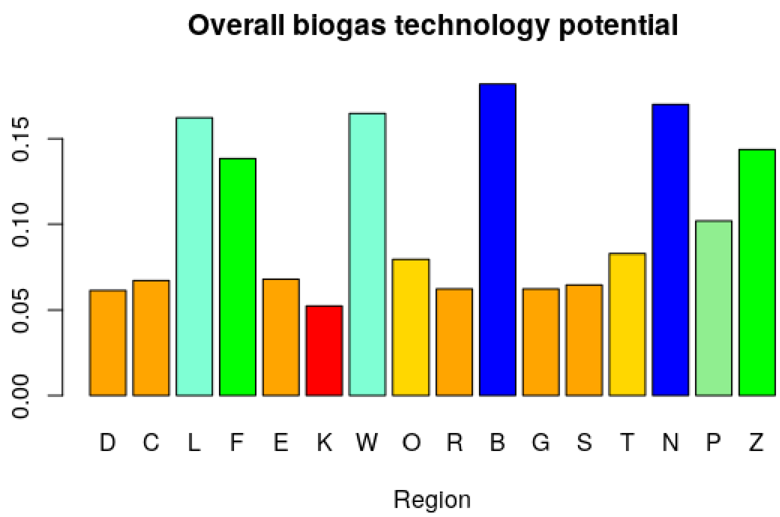

Figure 4. Overall classification of Polish regions according to biogas technology potential

The inconsistencies between both divisions allowed to indicate the differences between the voivodships according to the utilisation of actual potential. The voivodships which need more attention and spending more resources to balance the diffusion and the utilisation level of biogas technology application across the whole country are identified.

6. Limitations

The presented approach is based on a rather subjective choice of measure of alternative score similarity. It seems that the application of other alternative score similarity measures and/or alternative clustering methodologies would possibly help to improve of the merits of the approach.

7. Conclusions

Presented approach to the analysis of biogas technology potential utilisation has universal character. It may prove to be generally useful, therefore, in cases where the actual potential utilisation has to be assessed while including intangible factors. Inherent strength of the approach results from provided enhancement in the interpretation of AHP/ANP application results. This is because the enhancement allows to adjust analysis of the results to overall intangibility-aware nature of AHP/ANP methodology. The feature may become a vital means for improving the reliability of any analysis of results provided by the methodology. Note that universal nature of the approach makes it applicable to the analysis of both final and partial rankings of alternatives. Moreover, AHP/ANP methodology provides necessary means for ranking other entities e.g. alternative evaluation criteria, stakeholders etc., which are included in AHP/ANP models of problems. The approach becomes applicable in their case, too.

8. Key references

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