Using Decision-Making Tools to Analyse the Renewables in the Industrial Energetics Sector

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Abstract: As part of sustainable development is important to propagate and practice renewables. Therefore, the aim of the work was to proposed a tool to analyze the renewables in the context of their production volume and effectiveness in improving the natural environment. This tool was the AHP method (Analytic Hierarchy Process) which was integrated with numeral data about the production volume of electricity from renewables. It was shown that a proposed tool is useful to analyze the renewables and allows decided, which from renewables has the most influence on improving the natural environment. Therefore, the practice of the proposed tool supports the analysis, and undertaking adequate actions within the framework of sustainable development, in which enterprises producing and managing renewables.

Keywords: renewables, quality, industrial energy, industry, production engineering

Introduction

As part of actions the enterprises compatible with sustainable development, resulting from the industrial revolution (Industry 4.0) and actions providing well-being of society (Society 5.0), it is important entrepreneurship and innovation of enterprises (Piwowar, Dzikuc 2019: 1). However, this practice, despite economic progress and also energy-saving progress is still difficult, in view of the need for continuous electricity supply (Energetyka, raport końcowy z przeprowadzonych badań 2013: 15). Therefore, under sustainable development, the key is propagated and practiced renewables (Marks-Bielska et al. 2019: 2), which are contributed to reducing pollutants and greenhouse gases (Marks-Bielska et al. 2019: 2; Ochrona środowiska 2019: 101), in this the anthropological climate changes which arise from greenhouse gases (Bukosa et al. 2019: 7055; Wu, Mu 2019: 2; Zwoliński 2011: 6). This propagation and exploitation the renewables is accordance with Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 by Member States. Under Directive, the aim of Poland was to achieving a 15% share of electricity in final consumption (brutto) in Community (to the 2020 year), wherein Poland with 10,9% in 2017 was in the 21st position (Energia ze źródeł odnawialnych w 2018r. 2019: 13). In turn, comparing the volume of energy obtained by the European Union countries, in the 2005-2017 ratio, the largest increase was recorded on Cyprus (from 0,01 % to 9%), Estonia (from 1% to 17%), Belgium (from 2% to 17%) and United Kingdom (from 4% to 29%), wherein in Poland the increase was estimated from 2,7% to 13,1% (Energia ze źródeł odnawialnych w 2018r. 2019: 102). Despite this, Poland and also Malta, Hungary, Luksemburg, Cyprus are countries in which the share of electricity from renewable sources is relatively small. This aspect is important, in view of, that the country's primary energy demand is forecast to increase by 2030 up to 27% compared to 2010, with the share of renewable energy in total energy consumption increasing by 12% this year (i.e. 2020), and by 12.4% in 2030 (Marks-

Bielska et al. 2019: 2). Besides that, the significance of the issue of renewables is confirmed by numerous scientific publications. For example, authors of work (Piwowar, Dzikuc 2019: 1) were analyzed the possibility of using the biogas, wind farms and solar farms, in order to reduce greenhouse gases and increase energy efficiency. In turn, in work (Hassan, Kalam 2013: 39) was analyzed the biofuel based on rules and norms about biofuel and techniques in its processing, after which, it was concluded that there is still a need for their development, e.g. in the context of biofuel engines. Next, in work (Mudassar et al. 2020: 1, 8) it was analyzed the municipal wastes in context their production, progress and physical/chemical composition and assess their potential as renewables. In was shown, that burning 2000 tone of municipal wastes/day will allow on the recovery of the 48 MW energy, and in turn of contributes to improving the natural environment. By contrast, authors of work (Perkovic et al. 2016: 249), the flow of energy in complex energy systems, parallel to supply fresh water and electrical energy were modeled. It was shown, that under the proposed model, the increase of optimal range from 1 to 24 hours allows to reduce the surplus of electricity production by 80%, and increase of more than 5% renewables (in this case water).

After a review of the selected positions of subject literature, it was concluded that the issue of using renewables is the current research problem. It was analyzed the using renewables among others to restrictions emission of greenhouse gases or used to biofuel engines (Hassan, Kalam 2013: 39; Piwowar, Dzikuc 2019: 1). Also, it was analyzed among others to what extent using renewables sources will contribute to improving the environment (Mudassar et al. 2020: 1, 8; Perkovic et al. 2016: 249). However, it was considered, that one technique was not developed, which would be allowed to analyze the renewables in the context of production volume and effectiveness in improving the environment, what is a gap in making effective analysis of these aspects, and making right actions under sustainable development.

Therefore, the aim of the work was to proposed a tool to analyze the renewables in the context of their production volume and effectiveness in improving the environment. This tool was the AHP method (Analytic Hierarchy Process) which was integrated with numeral data about the production volume of electricity from renewables. In order to practice the possibilities of using the proposed tool, it was analyzed the current data (form 2018) about production volume electricity in main activity producer plans and autoproducer plants, which was obtained from a reliable source of statistical data, i.e. the Central Statistical Office (GUS).

Subject of the study

The subject of the study was a sector of main activity producer plants, in which produce and rotation of electricity is the main activity of the plants, and the sector of autoproducer plants, in which electricity is producing for needs the plants and is so-called side effect under production process (Energetyka, raport końcowy z przeprowadzonych badań, 2013:13). Selection of the subject of the study was resulted from context of the proposed technique, about including production volume of electricity from renewable energy sources.

Method

The proposed tool was the AHP method (Analytic Hierarchy Process) integrated with data about the production volume of electricity from renewables. Purpose of testing the proposed tool, figures on the volume of production in Poland for 2018 were obtained from a reliable source, i.e. the Central Statistical Office (GUS). Choice the AHP method (multi-criteria method of hierarchical analysis of decision problems) was resulted from their proven effectiveness in analyzed the qualitative and quantitative data (Horvathova et al. 2019: 2599; Saaty 2007: 860; Stoltmann 2016: 144). It was important in view of necessary the simultaneously analyze the qualitative data (production volume of electricity from renewables) and quantitative data (effectiveness in improving natural environment). In addition, AHP results are numerical values that are sometimes more favorable compared to attribute terms (Siwiec et al. 2019: 1594). In turn of choice of the data from GUS was conditioned by fact, that it is reliable and one of the main sources of data in Poland. The method of using the proposed tool was shown in 9 steps.

First step

The first step is to choose the goal. In this case, the aim was to indicate which of renewables in Poland in 2018 had the greatest impact on improving the state of the environment.

Second step

The second step is to choose the subject of the work. As part of the testing of the proposed tool, it were sectors: the main activity of the plants and autoproducer plants, which was characterized in part of the subject of study in this work. Due to the test nature of the analysis, these sectors were marked in random and conventionally from E1 to E2.

Third step

The third step is to choose renewables. As part of the testing of the proposed tool, it were:

- hydro,
- wind,
- solid biofuels ,
- municipal waste,
- biogas of landfill gas,
- biogas of sludge gas,
- other biogas,
- biopłyny,
- photovoltaics.

The renewables were selected based on the sets of production volumes of electricity from renewables in Poland in the 2018 year for main activity producers and autoproducers (Energia ze źródeł odnawialnych w 2018 r. Analizy statystyczne 2019: 84). Due to the fact that in 2018 in autoproducers was only recorded the hydro-1 MW, so the sum of production volumes this type of renewable was analyzed. Due to the test nature of the analysis, these renewables were marked in random and conventionally from R1-R9.

Fourth step

The fourth step is to make an assessment of production volumes of electricity from renewables. The assessment should be done separately for the main activity of the plants and for the autoproducer plants. The assessment is made by Saaty scale (adequate in AHP method), i.e.

1-9 (Stoltmann 2016: 144), where in the context of the proposed tool, grade 1 – smallest production volume, grade 9 – the biggest production volume. Rating are awarded by the entity using the tool, based on data about the production volume of electricity from renewables. In this case, it was data from GUS. In this case, the rating was awarded by the two people, i.e. the authors of work, which results from the test character of the proposed method.

Fifth step

The fifth step is to make an assessment of the effectiveness of renewables in improving the natural environment. Ratings are awarded by the entity using the tool in using the Saaty scale (1-9), where in this case: grade 1 – influence not very effective, and grade 9 – influence absolutely effective. In order for the grade would be reliable, it is important to be made by an expert, who will be based on knowledge and experience. However, under testing the proposed tool, the assessment was made in a subjective way by authors of the work.

Sixth step

The sixth step is to make a matrix of pairwise comparisons for a rating of production volumes and effectiveness. The matrix are so-called Saaty matrix, where on the diagonal there is always a rating equal to 1, which means that the given elements are equivalent, and above the diagonal, there are pairwise comparisons, in turn, under the diagonal are rating opposite (Horvathova et al. 2019: 2598).

Seventh step

The seventh step is to make a calculation and achieve the weight of production volumes and effectiveness of renewables, according to the AHP method whose detailed course is presented in works (for example Ammaarapala et al. 2018; Horvathova et al. 2019; Pacana, Siwiec 2018, Stoltmann 2016). After calculated it is necessary to check if the results do not violate the principle of constancy of preferences. In this aim it is necessary to calculate coherence factor λ_{max} (1), Consistency Index CI (2) and Consistency Ratio CR (3) (Horvathova et al. 2019: 2; Stoltmann 2016: 145):

$$\lambda_{max} = \frac{1}{w_i}\sum_{j=1}^{k} w_{ij}w_j \tag{1}$$

$$CI = \frac{\lambda_{max} - n}{r(n-1)} \tag{2}$$

$$CR = \frac{CI}{r} \tag{3}$$

where: n – number of renewables,

r – average random index value for n according to Saaty.

Full compliance of results is obtained when λmax = n, CI = 0, CR = 0. But, compliance is acceptable for λmax is close to n, for CI < 0,1 and CR < 0,1 (Ammaarapala et al. 2018: 33).

If there is a lack of full or acceptable compliance, the process should be repeated from step four until the results match.

Eighth step

The eighth step is to take into account the volume of production and the efficiency of renewable in order to indicate which renewable had the greatest impact on improving the state of the natural environment in Poland in 2018. Therefore, the weights of the production volume of two sectors (main activity of the plants and autoproducer plants) were multiplied by the weights of the efficiency of renewable. Next, the values obtained for a given renewable sector were added together.

Nine step

The ninth step is to point one renewable electricity, which had the greatest impact on improving the natural environment in Poland in the 2018 year. According to the proposed tool, it was an energy renewable with a maximum sum of weights.

The calculations of the AHP method can be performed using the applications supporting the AHP method, for example Matlab or Program R (Bartłomowicz 2016: 11; Zhang 2019: 10).

Results

The aim of testing the proposed tool was to indicate which of renewables in Poland in 2018 had the greatest impact on improving the state of the natural environment. The analyze was based on current data from the Central Statistical Office (Table 1).

Table 1. The set of production volumes of electricity from renewables in Poland in the 2018 year.

<table>
<tr><th colspan="2" rowspan="2">Specification</th><th>main activity producer plants</th><th>autoproducer plants</th></tr>
<tr><th colspan="2">GWh</th></tr>
<tr><td colspan="2">Hydro</td><td>1 966,7</td><td>3,3</td></tr>
<tr><td colspan="2">Wind</td><td>12 798,8</td><td>-</td></tr>
<tr><td colspan="2">Solid biofuels</td><td>3 617,0</td><td>1 716,2</td></tr>
<tr><td colspan="2">Municipal waste</td><td>-</td><td>85,0</td></tr>
<tr><td rowspan="3">Biogas</td><td>Biogas of landfill gas</td><td>128,1</td><td>41,5</td></tr>
<tr><td>Biogas of sludge gas</td><td>30,4</td><td>306,1</td></tr>
<tr><td>Other biogas</td><td>462,8</td><td>158,8</td></tr>
<tr><td colspan="2">Bioliquids</td><td>-</td><td>2,0</td></tr>
<tr><td colspan="2">Photovoltaics</td><td>6,9</td><td>300,5</td></tr>
</table>

Source: Own study based on: Energia ze źródeł odnawialnych w 2018 r. Analizy statystyczne 2019: 84.

The assessment of the production volume of electricity from renewables was made based on Table 1, and then the calculation according to the AHP method was made (Table 2 and Table 3). Next, the assessment of the effectiveness of renewables in improving the natural environment was made, after it, the calculation according to the AHP method was made (Table 4). The Rx marks used in Tables 2-4 were used randomly based on Table 1, it was resulting from the test character of analysis and also from individual assessments of authors of work, who aimed only shown the effectiveness and usefulness of proposed a tool to analyze the renewables in the context of their production volume and effectiveness in improving the natural environment. So, after calculation, the full compliance of results was obtained, i.e. $\lambda max = n = 9$ (where n – number of renewables), CI = 0, CR = 0, and average random index value for n = 9 was 1, 45 (Ammaarapala et al. 2018: 33). In part of proposed tool, the values were unified by multiplied the weights for production volume and effectiveness of renewables (Table 5), after it, it was possible to indicated which of renewables in Poland in 2018 had the greatest impact on improving the state of the natural environment. It was renewable electricity with the conventional designation R9.

It is necessary to remember that result from the analysis is objective, but the assessment of each criterion which was made by authors of the work were subjective, so the results of the analysis may vary.

Table 2. The result of the analysis for the sector designated E1.

E1	R1	R2	R3	R4	R5	R6	R7	R8	R9	E1	R1	R2	R3	R4	R5	R6	R7	R8	R9
R1	1,00	9,00	1,50	2,25	1,80	4,50	3,00	9,00	1,29	**R1**	0,23	0,24	0,24	0,24	0,24	0,24	0,24	0,23	0,11
R2	0,11	1,00	0,17	0,25	0,20	0,50	0,33	1,00	0,14	**R2**	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,01
R3	0,67	6,00	1,00	1,50	1,20	3,00	2,00	6,00	0,86	**R3**	0,15	0,16	0,16	0,16	0,16	0,16	0,16	0,15	0,08
R4	0,44	4,00	0,67	1,00	0,80	2,00	1,33	4,00	0,57	**R4**	0,10	0,11	0,11	0,11	0,11	0,11	0,11	0,10	0,05
R5	0,56	5,00	0,83	1,25	1,00	2,50	1,67	5,00	0,71	**R5**	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,06
R6	0,22	2,00	0,33	0,50	0,40	1,00	0,67	3,00	0,29	**R6**	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,08	0,03
R7	0,44	3,00	0,50	0,75	0,60	1,50	1,00	3,00	0,43	**R7**	0,10	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,04
R8	0,11	1,00	0,17	0,25	0,20	0,50	0,33	1,00	0,14	**R8**	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,01
R9	0,78	7,00	1,17	1,75	1,40	3,50	2,33	7,00	7,00	**R9**	0,18	0,18	0,18	0,18	0,18	0,18	0,18	0,18	0,61
Sum	**4,33**	**38,00**	**6,33**	**9,50**	**7,60**	**19,00**	**12,67**	**39,00**	**11,43**	**Sum**	**2,00**	**0,22**	**1,33**	**0,89**	**1,11**	**0,47**	**0,69**	**0,22**	**2,08**
										Weight	**0,22**	**0,02**	**0,15**	**0,10**	**0,12**	**0,05**	**0,08**	**0,02**	**0,23**
λ_{max} = n = 9					CI = 0								CR = 0						

Source: Own study.

Table 3. The result of the analysis for the sector designated E2.

E2	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**E2**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**
R1	1,00	0,25	0,50	0,33	0,20	0,17	0,14	0,50	0,11	**R1**	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03	0,03
R2	4,00	1,00	2,00	1,33	0,80	0,67	0,57	2,00	0,44	**R2**	0,10	0,11	0,10	0,10	0,10	0,10	0,10	0,10	0,10
R3	2,00	0,50	1,00	0,67	0,40	0,33	0,29	1,00	0,22	**R3**	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05
R4	3,00	0,75	1,50	1,00	0,60	0,50	0,43	1,50	0,33	**R4**	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08	0,08
R5	5,00	1,25	2,50	1,67	1,00	0,83	0,71	2,50	0,56	**R5**	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13
R6	6,00	1,50	3,00	2,00	1,20	1,00	0,86	3,00	0,67	**R6**	0,15	0,16	0,15	0,15	0,15	0,15	0,15	0,15	0,15
R7	7,00	1,50	3,50	2,33	1,40	1,17	1,00	3,50	0,78	**R7**	0,18	0,16	0,18	0,18	0,18	0,18	0,18	0,18	0,18
R8	2,00	0,50	1,00	0,67	0,40	0,33	0,29	1,00	0,22	**R8**	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05
R9	9,00	2,25	4,50	3,00	1,80	1,50	1,29	4,50	1,00	**R9**	0,23	0,24	0,23	0,23	0,23	0,23	0,23	0,23	0,23
Sum	**39,00**	**9,50**	**19,50**	**13,00**	**7,80**	**6,50**	**5,57**	**19,50**	**4,33**	**Sum**	**0,23**	**0,93**	**0,46**	**0,69**	**1,16**	**1,39**	**1,59**	**0,46**	**2,08**
										Weight	**0,03**	**0,10**	**0,05**	**0,08**	**0,13**	**0,15**	**0,18**	**0,05**	**0,23**
λ_{max} = n = 9					CI = 0							CR = 0							

Source: Own study.

Table 4. The result of the analysis for renewables.

R	R1	R2	R3	R4	R5	R6	R7	R8	R9	R	R1	R2	R3	R4	R5	R6	R7	R8	R9
R1	1,00	1,00	1,17	0,67	1,75	0,88	1,40	1,75	0,88	**R1**	0,12	0,12	0,13	0,11	0,12	0,12	0,12	0,12	0,11
R2	1,17	1,00	1,17	0,78	1,75	0,88	1,40	1,75	0,88	**R2**	0,14	0,12	0,13	0,12	0,12	0,12	0,12	0,12	0,11
R3	0,86	0,86	1,00	0,67	1,50	0,75	1,20	1,50	0,75	**R3**	0,10	0,10	0,11	0,11	0,10	0,10	0,10	0,10	0,09
R4	1,29	1,29	0,78	1,00	2,25	1,13	1,80	2,25	1,13	**R4**	0,15	0,16	0,09	0,16	0,16	0,16	0,16	0,16	0,14
R5	0,57	0,57	0,67	0,44	1,00	0,50	0,80	1,00	0,50	**R5**	0,07	0,07	0,07	0,07	0,07	0,07	0,07	0,07	0,06
R6	1,14	1,14	1,33	0,89	2,00	1,00	1,60	2,00	1,00	**R6**	0,14	0,14	0,15	0,14	0,14	0,14	0,14	0,14	0,12
R7	0,71	0,71	0,83	0,56	1,25	0,63	1,00	1,25	0,63	**R7**	0,08	0,09	0,09	0,09	0,09	0,09	0,09	0,09	0,08
R8	0,57	0,57	0,67	0,44	1,00	0,50	0,80	1,00	0,50	**R8**	0,07	0,07	0,07	0,07	0,07	0,07	0,07	0,07	0,06
R9	1,14	1,14	1,33	0,89	2,00	1,00	1,60	2,00	2,00	**R9**	0,14	0,14	0,15	0,14	0,14	0,14	0,14	0,14	0,24
Sum	**8,45**	**8,29**	**8,94**	**6,33**	**15**	**7,25**	**11,60**	**14,50**	**8,25**	**Sum**	**1,06**	**1,10**	**0,93**	**1,31**	**0,62**	**1,24**	**0,77**	**0,62**	**1,36**
										Weight	**0,12**	**0,12**	**0,10**	**0,15**	**0,07**	**0,14**	**0,09**	**0,07**	**0,15**
λ_{max} = n = 9					CI = 0								CR = 0						

Source: Own study.

Table 5. Results of integrated production volume and effectiveness of renewables.

Symbol of renewables	Weight			Production volume and efficiency			Maxiumum weight (the greatest impact on improving the state of the natural environment)
	Production volume		Efficiency				
	E1	E2		Weight		Sum of weight	
R1	0,22	0,03	0,12	0,03	0,00	0,03	
R2	0,02	0,10	0,12	0,00	0,01	0,02	
R3	0,15	0,05	0,10	0,02	0,01	0,02	
R4	0,10	0,08	0,15	0,01	0,01	0,03	
R5	0,12	0,13	0,07	0,01	0,01	0,02	R9 = 0,07
R6	0,05	0,15	0,14	0,01	0,02	0,03	
R7	0,08	0,18	0,09	0,01	0,02	0,02	
R8	0,02	0,05	0,07	0,00	0,00	0,01	
R9	0,23	0,23	0,15	0,03	0,03	0,07	

Source: Own study.

Conclusions

The aim of the work was to proposed a tool to analyze the renewables in the context of their production volume and effectiveness in improving the environment. This tool was the AHP method (Analytic Hierarchy Process) which was integrated with numeral data about the production volume of electricity from renewables. In order to practice the possibilities of using the proposed tool, it was analyzed the current data (form 2018) about production volume electricity in main activity producer plans and autoproducer plants, which was obtained from a reliable source of statistical data, i.e. the Central Statistical Office (GUS). The analysis was indicated electricity renewable, which in the context of the proposed tool had the greatest impact on improving the state of the natural environment (in the case of Poland on the 2018 year). It was renewable electricity with the conventional designation R9. Despite the results may vary, what is resulting from the assessment of the entity who is using the tool (i.e. authors of work), it was shown that this tool is effective in case the analysis of production volume and effectiveness of electricity renewable. Therefore, the practice of the proposed tool supports the analysis, and undertaking adequate actions within the framework of sustainable development, in which enterprises producing and managing renewable energy sources.

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