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Use of Indicator Methods for the Purposes of Monitoring Sustainable Energy in the Region

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Abstract

Implementation of the conception of sustainable energy requires a progress evaluation, which calls for an indicator system for monitoring sustainable energy. In this paper it is proposed to use simultaneously two systems, one based on a set of specific indicators and the other on a synthetic indicator. The usefulness of proposed indicator methods was checked on the example of rural areas of the Śląskie Voivodship by monitoring sustainable energy in given counties in 2004 and 2014.

Keywords: sustainable energy, indicators of specific consumption of heat, electricity and gas, biomass

Introduction

The concept of sustainable energy stems from the conception of sustainable development. Sustainable energy can be defined as conversion of primary energy into electricity and heat, and delivery to the final client in a way that meets the needs of present and future generations, taking into consideration economic, social and environmental aspects of human development (Prandecki 2014). Sustainable energy applies to both energy provision and its consumption. Energy provision includes in particular ways the least harmful methods for the environment, preferably from renewable sources and improvement of energy efficiency, while ensuring energy security. Apart from the term sustainable energy, the concepts of sustainable energy system, sustainable energy economy, etc. are used but in spite of differences in meaning are mostly treated interchangeably. One of the basic goals of European Union sustainable energy policy is sustainable energy development which, according to the European Commission, shall ensure until 2030 a 27% share of renewable energy in the general record of energy carriers in the EU and decreasing economy energy consumption by 20%.[1]

In Poland local authorities are responsible for energy economics, and their responsibilities are defined by the Energy Law.[2] They comprise energy planning and energy management. The system of energy planning and management currently existing in Poland does not fulfil the objectives for which it was designed and requires changes, implementing, according to the EU guidelines, the system of sustainable energy management on local, regional and national levels.[3] To make it possible, it is necessary to amend existing provisions of the Energy Law and prepare relevant implementing regulations. Implementation of the sustainable energy conception requires evaluation of progress and differences in this field, which calls for an indicator system for monitoring sustainable energy development. It can be a system based on specific indicators or synthetic measurements. In this

1. See: Note of Subject: European Council (23 and 24 October 2014). Conclusions on 2030 Climate and Energy Policy Framework. Brussels, 23 October 2014, (OR. en) SN 79/14, [@:] http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/145356.pdf.

2. See: Ustawa z dnia 10 kwietnia 1997 r. — Prawo energetyczne. DzU z 1997 r. nr 54 poz. 348 as amended.

3. See: Koncepcja krajowego systemu zrównoważonego gospodarowania energią. Report by Arkadiusz Węglarz and Marek Zaborowski. Krajowa Agencja Poszanowania Energii S.A. przy współpracy Instytutu Ekonomii Środowiska, [@:] http://docplayer.pl/6568457-Koncepcja-krajowego-systemu-zrownowazonego-gospodarowania-energia.html.

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paper both system types are proposed, having been used for monitoring sustainable energy on the example of the rural region of the Śląskie Voivodship. As the main energy users on the rural areas are households, the survey was restricted to this specific group.

1 Examination procedure

In order to evaluate sustainable energy, one needs indicators that explicitly reflect the problem, are measurable and based on accessible data. As sustainable energy should be a part of a sustainable development conception, it is important that descriptive indicators are compatible with the indicators describing sustainable development. Many research organizations are involved in creating indicator systems for monitoring sustainable energy, among others the Central Statistical Office in Katowice. It has elaborated a set of specific indicators describing sustainable development in terms of social, economic, environmental and institutional-political cohesion, whose values are systematically updated. Among these indicators, one may find those applying to energy economics, in particular electricity consumption in households per person, classified as consumption patterns describing social order and share of renewable energy in final energy consumption classified as a variable describing environmental governance.

As such indicators are also used in analysis of sustainable development by other authors (Bal-Domańska and Wilk 2011; Korol 2008; Roszkowska and Karwowska 2014), they were considered universal and joined into the indicator system for monitoring sustainable energy. Given the fact that sustainable energy shall ensure permanent and environmentally sound access to electricity and heat, a further measuring instrument implemented within the monitoring system was specific heat consumption. The set was completed with specific natural gas consumption which is not treated as a sustainable source, however it is included in all energy strategies.

In order to designate the values of given indicators, data available in studies of the Local Data Bank of Central Statistical Office of Poland was used, and additionally using the works of Trojanowska and Szul (2006), Trojanowska (2009), Kowalczyk-Juśko (2010), Ludwicka and Grzybek (2010) as well as Hałuzo and Musiał[4]. While calculating sustainable energy resources, taken into consideration were only agricultural (straw) and wooden biomass (biomass from forests, wood industry and orchards) which is the greatest source of renewable energy in the Śląskie Voivodship, easy and quickly supplied. The calculations were made for 2004 and 2014. Indicators designated in such a way were evaluated in terms of usefulness to monitor sustainable energy. The ranging method was used in regards to the set of specific indicators to rank counties of the Śląskie Voivodship in respect of sustainable energy development. For the purpose of regional general evaluation in terms of sustainable energy development, a synthetic measurement was designated for each country, for a previously determined set of indicators. The most frequently used measure was chosen, that is the synthetic measure of development (SMD). The calculation procedure comprised the following activities:

1. Normalization of diagnostic features
   Using recommendations of other authors (Jarocka 2015; Walesiak 2014) the formula of zero unitarization was applied

$$z_{ij} = \frac{x_{ij} - \min\limits_{i} x_{ij}}{\max\limits_{i} x_{ij} - \min\limits_{i} x_{ij}}, \tag{1}$$

   where:
   z_{ij} — value after unitarization of j-th diagnostic feature (indicator), $j = 1, 2, 3, 4$, in i-th object (county), $i = 1, 2,..., 17$,
   x_{ij} ($\min x_{ij}$, $\max x_{ij}$) — execution of j-th diagnostic feature in i-th object (the lowest value, the highest value).

4. See: Ocena zasobów i potencjalnych możliwości pozyskania surowców dla energetyki odnawialnej w województwie pomorskim by Mirosława Hałuzo, Ryszard Musiał. Biuro Planowania Przestrzennego w Słupsku, 2004, [@:] http://pbpr.pomorskie.eu/documents/294485/453192/Ocena+zasob%C3%B3w+i+potencjalnych+mo%C5%BCliwo%C5%9Bci+pozyskania+surowc%C3%B3w+dla+energetyki+odnawialnej...2005.pdf/ea6e7e64–1541–4991-a831–54aa1b8f4d4b.

2. Change of destimulants into stimulants
   Indicators were treated as stimulants z^S or destimulants z^D. In order to harmonize the character of features, destimulants were changed into stimulants with the use of the formula

$$z_{ij}^S = 1 - z_{ij}^D. \tag{2}$$

3. Determination of coordinates of the object-model z_{oj}.
   An upper model of development was adopted, where maximal total values for 2004 and 2014 were accepted for stimulants.
4. Determination of distance between counties and the object-model.
   The distance between the j-th country was designated with the use of the Euclidean metric

$$d_{i0} = \sqrt{\sum_{j=1}^{n}(z_{ij} - z_{oj})^2}. \tag{3}$$

5. Designation of the synthetic measure of development.
   Synthetic development indicators were calculated according to the relation

$$\text{SMD} = 1 - \frac{d_{i0}}{d_0}, \tag{4}$$

   where d_0 is the distance between the model and antimodel.
   SMD indicators were used to evaluate the sustainable energy of the counties in terms of territorial differentiation and changes in time.

2 Evaluation of sustainable energy on the basis of specific indicators

In this paper the following specific factors were designated: yearly heat consumption relating to the number of residents (aggregated and for heating buildings), electricity and gas as well as the share of energy from the renewable sources in final energy consumption. An important feature of the indicators which characterizes their utility to monitor sustainable energy is, along with comparability, the ability to discriminate objects which is designated by the variation coefficient higher than 10%. It turned out that this condition is not met in the case of indicators of specific heat demand, whereas the discriminatory ability of the indicator relating to heat consumption for heating buildings is significantly higher than the aggravated indicator and increases with years. As the heat demand cannot be omitted in energy analysis, a measure describing heat consumption for heating buildings was incorporated into the system for monitoring sustainable energy. Heating buildings in rural areas takes overs 75% of total heat demand and provides possibilities to improve heat efficiency. Table 1 shows a summary of specific indicators recommended for characterizing sustainable energy in the region, whereas the value of descriptive statistics is shown in table 2.

The greatest differences between the counties were observed in the scope of specific gas consumption, which is proven by high variability of the indicator. Lubliniec country is clearly different from the others, where the gas consumption is very low, on average 6 kWh per person in 2004 and 23 kWh per person in 2014. To compare, in Bielsko county, the leader in gas consumption, indicators of specific demand for the fuel are respectively 2,2 and 2,7 MWh per person.[5] This stems mostly from various degrees of gasification of counties, and therefore different structures of using energy carriers to meet basic needs of residents. In Lubliniec county under 1% of households are connected to the gas network, whereas in Bielsko county 70%, of which 60% use gas for building heating. High territorial variability is also characterized by the share of renewable sources of energy in the final energy consumption. Its value in 2004 was changing in the Śląskie Voivodship from 3% to 21%, and over the last 10 years decreased to the values from 1,5% to 16%. This situation is a result of a significant, by over 20%, decrease in the possibility to obtain energy from straw. The only county in which the resources of biomass increased in 2004–2014 is Gliwice county.

5. [In the journal European practice of number notation is followed—for example, 36 333,33 (European style) = 36 333.33 (Canadian style) = 36,333.33 (US and British style).—Ed.]

Tab. 1. Indicators characterizing sustainable energy

Indicator	Character	Unit	Design.
Yearly consumption of heat for building heating/number of residents	destimulant	MWh/resid.	W_1
Yearly consumption of electricity/number of residents	destimulant	MWh/resid.	W_2
Yearly consumption of natural gas/number of residents	stimulant	MWh/resid.	W_3
Share of renewable sources in final energy consumption	stimulant	%	W_4

Tab. 2. Basic descriptive characteristics of indicators characterizing sustainable energy

Indicator	Year	Minimum	Maximum	Average	Median	Stand. deviation	Coeff. of variation
W_1	2004	5,68	6,62	6,33	6,39	0,2765	0,0437
	2014	5,22	7,07	6,27	6,20	0,5557	0,0886
W_2	2004	0,64	1,01	0,88	0,93	0,1221	0,1382
	2014	0,62	1,03	0,88	0,93	0,1282	0,1454
W_3	2004	0,01	2,20	0,57	0,44	0,6033	1,0511
	2014	0,02	2,70	0,87	0,69	0,7787	0,8938
W_4	2004	2,95	20,84	8,13	7,56	4,9281	0,6065
	2014	1,54	16,27	6,65	4,81	4,4822	0,6740

Tab. 3. Rankings of counties in terms of indicators describing sustainable energy

	W_1		W_2		W_3		W_4		Sum of ranks	
County	2004	2014	2004	2014	2004	2014	2004	2014	2004	2014
Będzin	3	5	4	4	2	3	12	16	21	28
Bielsko-Biała	1	1	1	1	1	1	14	15	17	18
Bieruń	14	4	7	7	9	9	15	13	45	33
Cieszyn	10	3	3	3	3	2	6	10	22	18
Częstochowa	12	13	9	10	7	8	7	7	35	38
Gliwice	7	6	15	13	14	14	2	1	38	34
Kłobuck	8	14	16	17	16	16	3	4	43	51
Lubliniec	17	17	17	16	17	17	4	5	55	55
Mikołów	16	11	5	6	5	6	17	14	43	37
Myszków	11	16	10	11	8	7	8	8	37	42
Pszczyna	2	2	2	2	4	4	11	11	19	19
Racibórz	6	10	12	12	15	15	5	6	38	43
Rybnik	9	9	11	9	10	10	16	17	46	45
Tarnowskie Góry	15	8	6	5	6	5	9	3	36	21
Wodzisław	4	7	8	8	12	11	13	12	37	38
Zawiercie	5	12	14	15	11	13	1	2	31	42
Żywiec	13	15	13	14	13	12	10	9	49	50

Evaluation of the sustainable energy concept on the basis of the designated indicators is very hard. It requires a previous determination of optimal values of measure, which is nowadays practically impossible. Pursuant to the main rules of sustainable energy — energy saving, including improvement of energy efficiency and using as much as possible renewable energy to cover energy demand, lower values of specific heat and electricity consumption as well as possibly high share of energy from biomass were adapted as more favorable. Treating specific electricity consumption as a destimulant can be somehow doubtful. The systematic growth of electricity consumption in rural households in our country is mainly caused by a visible improvement in the number of electric receivers, and the demand for electricity per resident is more or less half the value in Western countries. However,

we still need to use it rationally. As far as natural gas is concerned, higher indicators are treated as better, as gas replaces fossil fuels and contributes to lowering environmental pollution; the European Union promotes its growing share in the strategy of sustainable energy development.

Table 3 shows a ranking of counties according to such defined optimization of indicators describing sustainable energy in 2004 and 2014. Bielsko-Biała, Cieszyn, Pszczyna and Będzin counties can come first in terms of completing the rule of sustainable energy, both in 2004 and in 2014. These counties are characterized by the lowest specific demand for heat and electricity per resident. Tarnowskie Góry county joined this group in 2014, which stemmed from natural gas consumption that increased by almost 2,5 times. Calculation results shown in table 3 picture high variability of county rankings within given indicators of sustainable energy, which can be even 14th positions for the Bielsko-Biała county. This stems from the fact that counties with favorable indicators of sustainable energy have low potential of biomass for energy. And the other way round, regions described with high values of W_4 indicator, such as Lubliniec or Kłobuck counties, have relatively high heat and electricity consumption at low use of natural gas.

3 Evaluation of sustainable energy on the basis of a synthetic measure

A synthetic measure of development SMD was designated for each county. On the basis of calculated SMD values, similar county rankings were obtained as for the ranking method (fig. 1 and 2). However, calculating the synthetic measure of development allows for a county ranking, but also for a situation interpretation in the region in terms of sustainable energy economics. In this paper, the situation in given regions was interpreted as (Bal-Domańska and Wilk 2011):

- very negative, where SMD $\in$ [0,0; 0,2],
- negative, where SMD $\in$ (0,2; 0,4],
- moderate, where SMD $\in$ (0,4; 0,6],
- positive, where SMD $\in$ (0,6; 0,8],
- very positive, where SMD $\in$ (0,8; 1,0].

As can be observed in the results, the situation of sustainable energy implementation is negative in most counties in the Śląskie Voivodship, and very negative in every third county.

Institutions responsible for sustainable energy in the region are interested not only by its condition and territorial diversity, but also changes taking place in time. In order to evaluate these changes, one might need values of increments in the synthetic measure of development. It was adopted in the paper after Bal-Domańska and Wilk (2011) that SMD increment of at least 0,1 means a visible improvement in sustainable energy management, and decrease of SMD by more than 0.1 means deterioration (danger). Calculation results of SMD changes for given counties from the Śląskie Voivodship in years 2004–2014 are shown in figure 3.

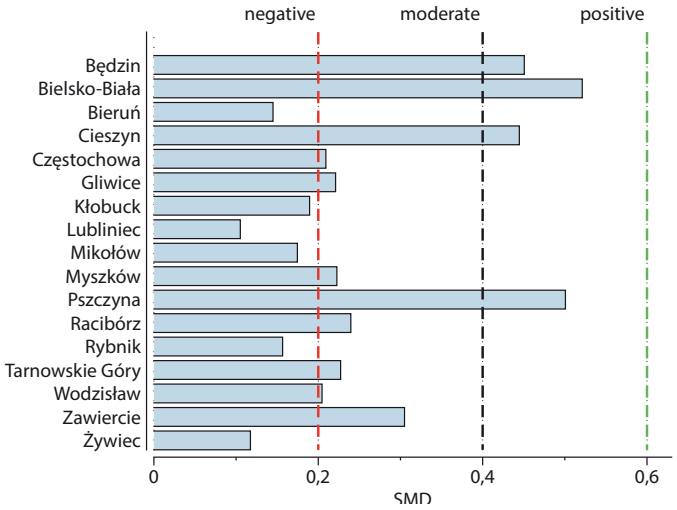

Fig. 1. Evaluation of counties in terms of sustainable energy in 2004

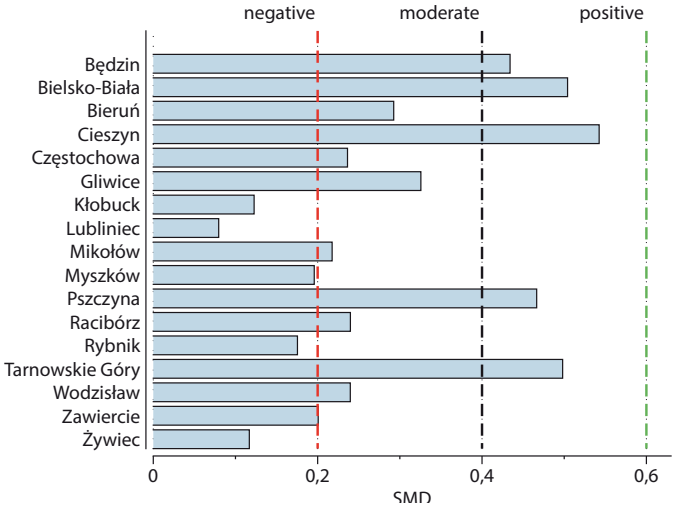

Fig. 2. Evaluation of counties in terms of sustainable energy in 2014

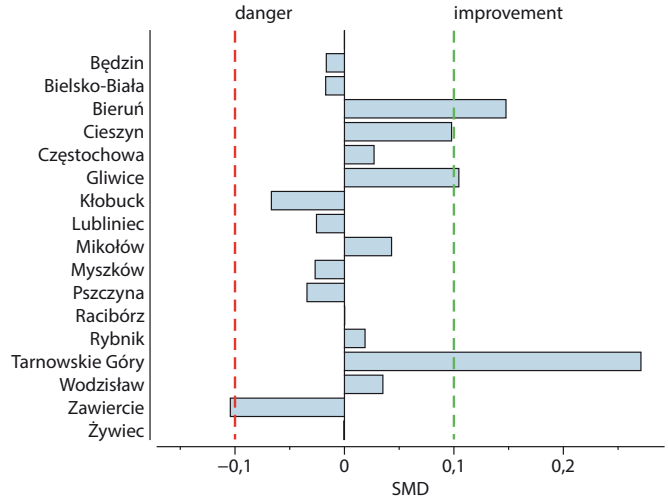

Fig. 3. Evaluation of changes in the field of sustainable energy in 2004–2014

Monitoring sustainable energy in the rural region of the Śląskie Voivodship showed that in 2004–2014 the value of synthetic measure of development for half of the counties dropped because of growing specific heat and electricity consumption and significant drop in energetic potential of straw. The greatest decrease of SMD was observed in Zawiercie county, where one can state a significantly deteriorated situation of sustainable energy. A visible improvement in the field of energy management was observed in Tarnowskie Góry county and Bieruń county, where the increment of synthetic measure of development was respectively 0,26 and 0,17.

Conclusions

In this paper it was proposed to use simultaneously a set of specific indicators taking into consideration yearly heat, electricity and gas consumption per inhabitant as well as the share of energy possible to obtain from biomass in final energy consumption and a synthetic measure. This comprehensively evaluates the phenomenon by means of diverse attitudes to the analyzed problem. The use of proposed indicator methods to monitor sustainable energy in the rural region of the Śląskie Voivodship showed that the situation in one third of counties is very negative, which is caused by relatively high specific heat and electricity consumption and decreasing resources of biomass that could be used for energy generation purposes.

References

Bal-Domańska, B., and J. Wilk. 2011. "Gospodarcze aspekty zrównoważonego rozwoju województw. Wielowymiarowa analiza porównawcza." *Przegląd Statystyczny* no. 58 (3/4):300–322.

Jarocka, M. 2015. "Wybór formuły normalizacyjnej w analizie porównawczej obiektów wielocechowych." *Ekonomia i Zarządzanie* no. 7 (1):113–126.

Korol, J. 2008. "Ocena zrównoważonego rozwoju regionalnego w Polsce w latach 1998–2005." *Gospodarka Narodowa* no. 19 (7/8):81–98.

Kowalczyk-Juśko, A. 2010. "Metodyka szacowania regionalnych zasobów biomasy na cele energetyczne." *Zeszyty Naukowe Szkoły Głównej Gospodarstwa Wiejskiego w Warszawie. Ekonomika i Organizacja Gospodarki żywnościowej* (85):103–116.

Ludwicka, A., and A. Grzybek. 2010. "Bilans biomasy rolnej (słomy) na potrzeby energetyki." *Problemy Inżynierii Rolniczej* no. 18 (2):101–111.

Prandecki, K. 2014. "Teoretyczne podstawy zrównoważonej energetyki." In *Polityka gospodarcza w okresie transformacji i kryzysu*, edited by A. Barteczek and A. Rączaszek. Katowice: UE w Katowicach.

Roszkowska, E., and R. Karwowska. 2014. "Wielowymiarowa analiza poziomu zrównoważonego rozwoju województw Polski w 2010 roku." *Ekonomia i Zarządzanie* no. 6 (1):9–37.

Trojanowska, M. 2009. "Analiza potencjału energetycznego biomasy dla potrzeb planowania energetycznego w regionie." In *Konwersja odnawialnych źródeł energii*, edited by A. Lisowski, 79–87. Warszawa: Wydawnictwo Wieś Jutra.

Trojanowska, M., and T. Szul. 2006. "Modelling of Energy Demand for Heating Buildings, Heating Tap Water and Cooking in Rural Households" *TEKA Komisji Motoryzacji i Energetyki Rolnictwa* (6A):184–190.

Walesiak, M. 2014. "Przegląd formuł normalizacji wartości zmiennych oraz ich własności w statystycznej analizie wielowymiarowej." *Przegląd Statystyczny* no. 61 (4):363–372.