IMPROVEMENT OF METRIC FOR QUANTIFICATION AND ASSESSMENT OF THE ENERGY JUSTICE

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This paper provide a qualitative analysis of existing metrics that directly or indirectly quantify energy justice. The main objective of the paper was to determine shortcomings and to suggest improvements in order to enhane existing metrics and create conditions for defining of new energy indicators. The emphasis was placed on the analysis of the readiness of the system for the energy transition. Therefore, elements of the energy trilemma of the observed countries were defined using known parameters related to the transition processes. The use of known economic, political, energy, environmental and other indicators provided the universality of the suggested metric and reduced the impact of subjectivity.

Proposed improvements for the metric of energy justice and the defining of new energy indicators served as a help tool for decision-makers in the energy sector. Political solutions should strive to a balancing of the energy trilemma, which was the main precondition for achieving the goals of sustainable development and a just transition.

The main results of this paper are the possibility of universal application of metric for the quantification of energy justice and a new composite indicator that indicated the level of energy transition fairness.

Key words*: energy justice, energy trilemma, sustainable development, just energy transition*

1. Introduction

Energy justice (EJ) is not a directly measurable physical unit. It represents a conceptual framework used for determining when and where injustices occur and the best way in which law and policy can respond [1]. Hence, the quantification of energy justice was conducred indirectly, through the determination of the level of balance of the energy trilemma. Firstly, the paper explained the connection between energy trilemma and energy justice and the way in which these two concepts are interconnected. It is important to include this as an introductory consideration in order to fully understand elements of the metric for quantification of energy justice as well as indicators that can be constructed based on a mentioned metric.

In philosophy, the term trilemma describe the choice among three unfavourable options. In economics, there is a similar term known as "impossible trinity". This term described the exchange between three different goals, two of which are harder to be developed according to the third goal. The energy trilemma is mostly described as a balance between energy safety, social impact, and environmental responsibility. These three terms are represented as opposite aspects for energy production.

The international institution - World Energy Council (WEC), accredited by the UN was one of the first institutions which started to use the phrase energy trilemma[1]. It was initially consisted of energy safety, social equality, and mitigation of impacts on the environment. This institution started to rank countries according to a value of the World Energy Trilemma Index - an energy indicator defined by this institution, since 2010[2].

Countries which tended to become the best in the balancing of energy trilemma were considered to be successful in balancing between adequate use of existing energy resources, political stability, social wealth, and the use of affordable environmentally friendly energy. Regarding long-term estimation of the value of the World Energy Trilemma Index, countries which conducted diversification of their energy resources and actively participated in the management of energy demand through well established programs of energy efficiency are considered as the most successful.

The real challenge of the energy trilemma is balancing of three following competitive objectives in energetics: energy safety, environmental sustainability, and energy capital (availability and affordability) [3]. On the other hand, according to Hefron et al. (2015), it was necessary to consider the energy trilemma in a different way and to place energy legislation and politics in the center. Three ends of the triangle should be supplied with politics (for example, energy security), economics (financing of energy projects), and the environment (climate changes) [4]. In this situation which, it is shown that balancing is provided through energy legislation and politics. The reason for that is the tendency that the economy, politics, and the environment (tops of the triangle) act in each of their directions.

Therefore, the modeling and schematic representation of the energy trilemma was best done over a zoned equilateral triangle. The three zones of the equilateral triangle cover political, economic and environmental issues. In this way, a universal representation of the energy trilemma was obtained, which is shown in Figure 1.

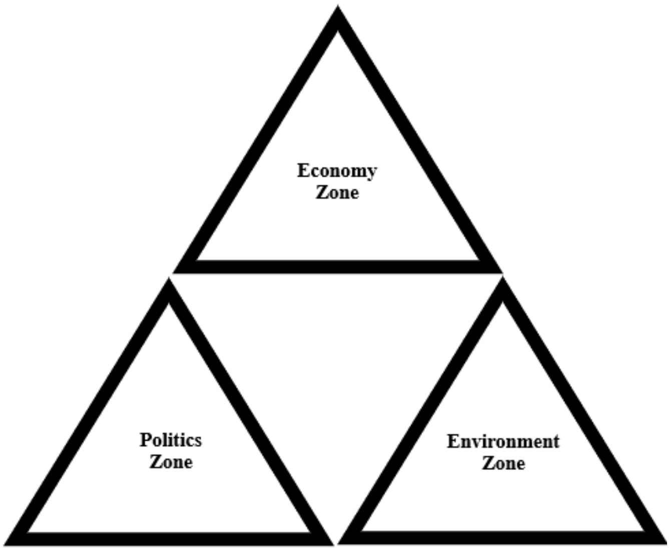

Figure 1. Schematic representation of the energy trilemma

The concept of energy justice was established in a similar period as the concept of the energy trilemma. During the last ten years, numerous works related to this area were developed. According to one of the definitions, energy justice is aimed to provide safe, affordable and sustainable energy to all individuals [5]. Heffron et al. (2018) stated in their work [6] that energy justice is a constitutive part of a "just transition" with predominantly short-term effects of a local character that affect environmental justice and climate justice [6].

Energy justice is mostly presented through two basic definitions (Heffron et al., 2017) [3]:

- The triumvirate of the following principles was presented through the EJ - distributive justice, procedural justice, and recognition justice all applied to the entire energy system.
- The EJ consists of the following main principles: accessibility, affordability, fair treatment, transparency and reliability, sustainability, intragenerational and intergenerational equity, accountability.

Jenkins et al. (2016) stated in their work [7] that distributive justice analyze the territorial distribution of energy infrastructure, benefits, and harms that the community has from it including an effort to distribute them evenly through the entire society while considering the fact that the nature of energy sources is such that they are not equally distributed over territory. Also, distributive justice is reffered to the possibility of individuals to access the existing energy infrastructure. The justice of recognition defined that citizens must be fairly represented, free from physical threats, and they must be offered full and equal political rights throughout the life cycle of energy projects. Procedural justice is related to the approach to decision-making processes and its manifestation is referred to the access to decision-making processes. Also, itself is manifested as a call to establish fair procedures that involve all stakeholders without any discrimination. In addition to energy legislation, procedural justice considered non-regulatory impacts such as practices, norms, values, and behaviours.

The concept of energetic justice is associated with both anthropocentric (human being in the spotlight) and ecocentric (ecosystem in the spotlight) values. In their article [8], Pellegrini and colleagues (Pellegrini-Masinia et al., 2020) argued that two points of view should not be opposite to each other in a case when human wealth should be considered in a sustainable way. However, it was obvious that the limitation of energy policy only in term of anthropocentric view would include different implications unlike those which would be considered in a case in which the energy policy is based only on ecocentric view. It implied the conclusion that energy justice is a suitable tool for balancing between these two views.

In his paper, Heffron et al., 2015, introduced the thesis that the best way of balancing energy trilemma can be obtained through the concept of energy justice. Hence, fair and equal balance among three opposing dimensions can be achieved [4][9]. As it was mentioned, it would provide the development of the appropriate tool for balancing of energy trilemma in order to help decision-makers in the energetics sector.

McCauley and Heffron stated that energy justice is a constitutive part of the "just transition" including predominantly short-term effects of local character which affected environmental justice and climate justice [6]. While keeping this in mind, a metric for quantification of energy justice could be used for the construction of composite indicators which could be used for the description of fairness of energy transition. As it was mentioned earlier, it is necessary to quantify energy justice to obtain a tool for decision-makers in the energy sector. Hefron et al. (2015) in their paper [4] defined the Energy Justice Metric (EJM) and stated that the main goal is to provide quantitative measurement for energy justice to enable comparison between different countries and to compare the performance of different energy technologies in terms of energy justice. These authors mentioned in their works [4], [9] that the calculation of EJM can provide three metric results. First - the quantification of the energy justice of the existing energy system for each country. Second - quantification of energy justice for each type of energy infrastructure (eg. coal, gas, RES, etc.). Third - the price of energy justice which can be weighted and included within economic models.

A similar approach was taken by the World Energy Council (WEC), which defined the World Energy Trilemma Index. Essentially, this index quantified energy trilemma and ranked 125 countries in terms of their ability to provide a secure, affordable and environmentally sustainable energy system [4]. Hence, in term of the economy, the focus is placed on affordability which keept the "status quo" for the energy sector while economic energetic solutions based on fossil fuels were encouraged [3].

Principally, both metrics are based on the energy triangle which includes two very similarly defined areas (environment and politics). The third area (economy) is different. The third area (energy capital) is based on the following indicators by the World Energy Trilemma Index [10]: accessibility of electricity grid, availability of clean cooking, quality of electricity supply, quality of supply in rural areas relating to urban areas, price of electricity, oil and gas, etc. On the other hand, the economy is the third area that defined EJM and it is based on indicators: cost-benefit analysis for new energy infrastructure, costs of subsidies for the energy sector (development, operation, and exploitation), the ratio of energy costs and disposable income, benefits from the creation of new jobs in energy infrastructure development projects (short-term and long-term) [10].

This was an example which showed that similarly defined metrics can be essentially different. According to indicators, it could be said that the metric established by WEC include more elements of energy justice than the Energy Justice Metric itself, despite the fact that the former was inspired by an energy trilemma based on the concept of energy sustainability, while the EJM is based on an energy trilemma based on energy justice[10].

Quantification of energy justice and its translation into policy tools provided an easier understanding of this concept partially for policy-makers and other stakeholders. Also, as it is mentioned in previous examples, there are space and need for the creation of such metrics according to subjective criteria selected by relatively narrowed groups of researchers and practitioners [10].

Within their works [4], [9], Heffron and associates defined and developed EJM as a tool for the quantification of energy justice. The authors themselves mentioned the lack of needed input data as the main shortcoming of their metric, which is especially expressed for less developed countries.

Further analysis of the EJM revealed other shortcomings. First of all, there was a great subjectivity in determining the parameters based on which values of indicators of the elements of energy trilemma were further calculated. Also, the reference point according to which energy justice is quantified is determined arbitrarily, i.e. authors themselves determined it according to their subjective feeling. Finally, the method of calculating the value of energy justice is not determined by an exact mathematical formula but is done descriptively.

Based on all of the above, it can be said that the main system problem of EJM is that there is no universality of methodology, so the results obtained for different countries can hardly be compared. This was a particularly big problem for developing countries where these deviations are significantly pronounced.

The main scientific contribution that this paper has given is the improvement of the model of the existing metric for the quantification of energy justice. It allows the implementation of an improved model in developing countries, which is not possible with EJM. So, a further breakthrough in the concept of energy justice helps in both scientific and practical terms.

2. Metric for quantification of energy justice - analysis, corrections, development of new tools

Eliminating observed shortcomings of the EJM and using additional parameters for the description of readiness of the system for transition into a model of energy trilemma for observed countries provided redefined and completed metric for quantification of energy justice. Based on redefined metric, the new composite index for quantification of the level of justice of energy transition could be constructed. In this way, a new tool is obtained that serves to help decision makers to direct the transition processes in the direction of a just energy transition.

2.1. Graphical modeling of metric for quantification of energy justice

Given that the energy trilemma consider the interaction among three different and often opposing issues (politics, economics and environment), the most suitable model for calculating and visual representation of energy justice present ternary plot, which is graphically represented on the ternary phase diagram [4]. The ternary plot is common in physical chemistry when describing the interaction among three different forms of matter (gas, liquid, and solid), but is also used in economics for analysis of Gross domestic product - GDP components for different countries as well as in Games theory. The ternary phase diagram is an equilateral triangle on which the interaction among three elements is plotted. Regarding metric for calculation of energy justice, it means that ternary plot serves as a place for plotting of interaction of parameters of the energy trilemma. In a graphical sense, it provide comparation among different countries. Software packages such as *SigmaPlot*, *Grapher* or some other programs for statistical data processing can be used for the generation of ternary diagrams

2.2. Defining mathematical formulas for calculating energy trilemma parameters

Modeling and visualization of the energy trilemma are based on a ternary diagram which includes values of economic, policy and environmental indicators for the observed countries. Using a diagram, parameters for quantification of energy justice are calculated. Elements of the energy trilemma represent the average values of a set of parameters that describ essential elements and processes. This method of calculation is from the models primarily defined by the authors of Energy Justice Metric [1],[4]. Parameters are grouped into sets in order to provide an indicator with a more realistic presentation of modeling of an important process (eg. the economic development of a country).

2.2.1 Modeling the economy

The impact of the economy on the energy trilemma of a country is determined by calculating the following economic indicators:

$$E_1 = \sum_{i=1}^{7} e_{1i}/7 \quad (1)$$

E_1 is an indicator of economic development based on the set of parameters e_{1i} whose elements are described in Table 1.

$$E_2 = \sum_{i=1}^{4} e_{2i}/4 \quad (2)$$

E_2 is an indicator of the investment climate based on the set of parameters e_{2i} whose elements are described in Table 1.

$$E_3 = \sum_{i=1}^{4} e_{3i}/4 \quad (3)$$

E_3 is an indicator of infrastructural development and innovative business environment based on the set of parameters e_{3i} whose elements are described in Table 1.

$$E_4 = \sum_{i=1}^{2} e_{4i}/2 \quad (4)$$

E_4 is a human resources indicator based on the set of parameters e_{4i} whose elements are described in Table 1.

The integrated indicator of the economy within the energy trilemma is calculated as:

$$E = \sum_{i=1}^{4} E_i/4 \quad (5)$$

2.2.2 Policy modeling

The impact of policy on the energy trilemma of a country is determined by calculating the following indicators p_{11}:

$$P_1 = \sum_{i=1}^{6} p_{1i}/6 \quad (6)$$

P_1 is the energy security indicator based on the set of parameters p_{1i} whose elements are described in Table 1.

$$P_2 = \sum_{i=1}^{5} p_{2i}/5 \quad (7)$$

P_2 is an indicator of the structure of the energy system based on the set of parameters p_{2i} whose elements are described in Table 1.

$$P_3 = \sum_{i=1}^{5} p_{3i}/5 \quad (8)$$

P_3 is an indicator of regulation and political stability based on the set of parameters p_{3i} whose elements are described in Table 1.

$$P_4 = \sum_{i=1}^{3} p_{4i}/3 \quad (9)$$

P_4 is an indicator of the strength of institutions based on the set of parameters p_{4i} whose elements are described in Table 1.

The integrated policy indicator within the energy trilemma is calculated as:

$$P = \sum_{i=1}^{4} P_i/4 \quad (10)$$

2.2.3 Environmental modeling

The impact of the environment on the energy trilemma of a country is determined by calculating the following indicators

$$E_{n1} = \sum_{i=1}^{4} en_{1i}/4 \quad (11)$$

E_{n1} is an indicator of environmental sustainability based on the set of parameters en_{1i} whose elements are described in Table 1.

Indicator of environmental performance (En2) would be calculated according to Environmental Performance Index (EPI) [11], which represent method of quantification of environmental performances of state policies. Considering the fact that it is complex index with calculated various environmental parameters of observed country, this indicator is taken as a reliable measure of overall environmental performances.

Indicator of the sustainable development level (En3) which is based on the rank of the country according to the overall result of the SDG Index[12]. This index measure the overall progress of the country in achieving all 17 sustainable development goals defined by the UN. Since it is a complex index in which various parameters of sustainable development of the observed country are already included, this indicator is taken as a reliable measure of the overall level of sustainable development.

The integrated environmental indicator within the energy trilemma is calculated as:

$$E_n = \sum_{i=1}^{4} En_i / 4 \quad (12)$$

2.3. Data collection and processing

The improved metric for calculating energy justice is based on parameters that were defined and measured by relevant institutions (domestic and international). A similar approach was used by developers of the Energy Transition Index (ETI) [11]. Within the ETI, parameters were also selected from the set of known economic, energy, political and environmental indicators. In this way, uniformity in the calculation was enabled for the largest number of countries. Also, this approach reduced the subjectivity in calculations.

In Table 1. the parameters are selected according to the following criteria: indicative of some segment of the energy trilemma; commonly used in practice; available for most countries in the world. Some parameters are such that they are determined by analyzing several different indicators and sources because there is no clear indicator (energy subsidies, for example). The list of parameters is not final. It is possible to add others that meet the above criteria. Several input parameters improve the quality of the output results because they enable better modeling of the energy trilemma.

Table 1. Parameters of the metric for calculating energy justice

Parameter	Data sources
e_{11} – household electricity price*	GlobalPetrolprices [14]
e_{12} – business users electricity price*	GlobalPetrolprices
e_{13} – gas price*	GlobalPetrolprices
e_{14} – energy subsidies**	International Monetary Fund[15]
e_{15} – energy excise costs (externalities)**	International Monetary Fund
e_{16} – fuel exports**	International Energy Agency[16]
e_{17} – fuel imports**	International Energy Agency
e_{21} – investment freedom	The Heritage Foundation[17]
e_{22} – access to credit	World Bank- Doing Business indicators[18]

e_{23} – RES capacities (trends)**	International Renewable Energy Agency[19]
e_{24} – investments in energy efficiency (trends)**	International Renewable Energy Agency
e_{31} – logistics performance	World Bank - Logistics Performance Index[20]
e_{32} – transportation infrastructure***	World Economic Forum Global Competitiveness Index[21]; Global Economy[22]
e_{33} – technology availability	World Economic Forum - Global Competitiveness Index
e_{34} – innovative business environment	World Economic Forum -Global Competitiveness Index
e_{41} – employees in the RES sector and other low-carbon energy sectors (trends)**	International Renewable Energy Agency
e_{42} – education quality	UN - Education Index[23]
p_{11} – electrification rate	World Bank- World Development Indicators[24]
p_{12} – solid fuels use	World Bank- World Development Indicators
p_{13} – net energy imports**	International Energy Agency
p_{14} – diversity of TPES**	International Energy Agency
p_{15} – diversity of energy imports**	Global Energy Security Index[25]
p_{16} – quality of electricity supply*	World Bank -Doing Business indicators
p_{21} – energy supply per capita*	International Energy Agency
p_{22} – share of electricity from renewables*	International Energy Agency
p_{23} – share of electricity from coal*	International Energy Agency
p_{24} – electricity system flexibility*	International Energy Agency
p_{25} – share of global fossil fuel reserves***	BP Statistical Review of World Energy[26]; US Energy Information Administration[27]
p_{31} – NDC commitment***	United Nations Framework Convention on Climate Change[28]; Climate Change Performance Index (CCPI) [29]
p_{32} – policy stability	World Bank - Political stability index[30]
p_{33} – energy efficiency regulations	World Bank - Regulatory Indicators for Sustainable Energy[31]
p_{34} – renewable energy regulations	World Bank - Regulatory Indicators for Sustainable Energy
p_{35} - energy access regulations	World Bank - Regulatory Indicators for Sustainable Energy
p_{41} – corruption	Transparency International - Corruption Perceptions Index[32]
p_{42} – rule of law	World Justice Project[33]
p_{43} – credit rating	Moody’s, S&P and Fitch[34]
en_{11} - PM2.5 level	IQAir’s - The 2020 World Air Quality Report[35]
en_{12} - energy intensity*	International Energy Agency
en_{13} - CO_2 per capita*	International Energy Agency
en_{14} - CO_2 intensity*	International Energy Agency

Meaning of labels on parameters:

* there are several relevant data sources (e.g. the price of electricity is available on several different platforms with the possibility of equally use);

** there is no exact indicator, but several sources are used for the final value by analysis conducted by the author (there is a dose of subjectivity);

*** complex indicators composed of several components.

The parameters given in Table 1 were measured and calculated or indexed in different units and therefore it is necessary to perform their unification. It would be done using linear the scale with values from 1 to 10. In equations (1) - (12), scaled parameter values are used.

Table 2. Parameters of scaling the metric for calculation of energy justice

Scaled values	1	2	3	4	5	6	7	8	9	10
Scaling zones	Zone of weakness		Zone of average			Quality zone			High-performance zone	

The linear scale is divided into four zones:

- Zone of weakness in which parameters values are scaled by grades 1 and 2. This zone includes parameters with low and inadequate values related to their purpose (eg. high pollution values). Grade 1 is the lower extreme and it is assigned to those parameters with the lowest values in the entire group of observed countries.
- Zone of average in which values of parameters are scaled with grades 3,4 and 5. The range of values for which a certain parameter belongs to this zone is determined based on analyses of values of the observed parameter for a large number of countries.
- Quality zone in which the parameter values are scaled with grades 6.7 and 8. This zone is determined in the same way as the previous one.
- High-performance zone in which the parameter values are scaled with grades 9 and 10. Grade 10 is the upper extreme and it is assigned to those parameters that have the highest values in the entire group of observed countries. Proper determination of the lower and upper extremes in absolute values of each parameter is very important for the entire scaling to be adequately performed.

The main challenge in scaling parameter values was to avoid subjective estimates. Subjectivity is reduced by simultaneously analyzing the values of the observed parameters for a larger number of countries. In this way, the boundaries of the parametric zones can be more clearly defined. Also, a big challenge is the lack of certain data, which can be partially corrected by determining the scaled values of this parameter based on the rating of the country for which it is calculated and other known parameters (eg. if some data on pollution is missing for a developing country, and it is known that that country predominantly uses coal for electricity production, it is realistic to expect that the scaled value of this parameter will be in the zone of weakness or lower values in the average zone).

Finally, to form a ternary diagram, it was necessary to normalize and convert into percentages the values of economic, political and environmental indicators within the energy trilemma:

$$EN = \frac{E}{E+P+E_n} \times 100 \quad (13)$$

$$PN = \frac{P}{E+P+En} \times 100 \quad (14)$$

$$E_nN = \frac{E_n}{E+P+En} \times 100 \quad (15)$$

2.4. Determining formula for calculating the degree of balance of the energy trilemma

Drawing the normalized values of the indicators on the ternary diagram enabled a visual representation of the balance of the energy trilemma. When calculating the energy trilemma indicators, parameters showing the readiness of the transition were also included.

The level of fairness of the energy transition is higher if the balance of the energy trilemma of the observed state is better. To quantify the balance, first was necessary to define the point of the Ideally balanced energy trilemma- IBET (ENI, PNI, EnNI), where ENI, PNI, and EnNI are coordinates of a three-dimensional point from a ternary phase diagram. We define IBET according to one of the two adopted criteria:

- "Rigid ideal" in which ENI, PNI and EnNI are 33,33,34 respectively. The point IBET (33,33,34) represent the physical center of the ternary diagram. This approach provide uniformity because all countries in the world are treated in the same way. In this way, it is possible to rank countries more easily. But the peculiarities between different groups of countries in the world are not taken into account (eg. the most developed and poorest, or differences between developing countries in Europe and Asia, etc.).
- "Floating ideal" in which ENI, PNI and EnNI are determined so that IBET is defined for each group of countries in the world. States are classified according to criteria determined by the World Economic Forum or some other relevant international organization. In this way, the peculiarities of countries are respected, so a more realistic picture of ranking is obtained, with the precondition to correctly choose the point of the ideal balance of energy trilemma, which is also the main drawback because the choice must rely on the subjective feeling of the author.

The indicator showing the fairness of the energy transition can therefore be determined considering the distance of the values of the energy trilemma parameters of the observed state from the point of Ideally balanced energy trilemma (IBET).

This new energy indicator is a complex index that could be calculated by the following formula:

$$JETI = \frac{JE+JP+JEn}{3} \quad (16)$$

JE, JP, and JEn represent measures of the distance of individual parameters of the energy trilemma concerning the point of the defined ideal (e.g. JE is a distance measure of the EN parameter for the analyzed country concerning the value of the ENI parameter) calculated as:

$$JE = 100 - \frac{|ENI - EN|}{ENI} \times 100 \quad (17)$$

$$JP = 100 - \frac{|PNI - PN|}{PNI} \times 100 \tag{18}$$

$$JE_n = 100 - \frac{|EnNI - EnN|}{EnNI} \times 100 \tag{19}$$

Just Energy Transition Index (JETI) is defined following the methodology given in the Handbook on Constructing Composite Indicators, Methodology and User Guide[36].

3. Validation of improved metric for quantification of energy justice

To confirm the improved metrics for quantifying energy justice, we performed a numerical experiment. For the Analysis of the parameters of the energy trilemma of Serbia and Denmark, we applied the methodology explained in detail in this paper. We selected these countries for the experiment for the following reasons: similar size; similar structure of energy dependence; Denmark is one of the most developed countries, while Serbia is a developing country.

3.1. Results

The results of a numerical experiment based on an improved methodology for energy justice quantification are in Figure 2. For the ternary phase diagram, we used the Grapher software package. Also, Figure 2 shows a separate part of the ternary phase diagram near the points that represent the current state of energy trilemma for Serbia and Denmark.

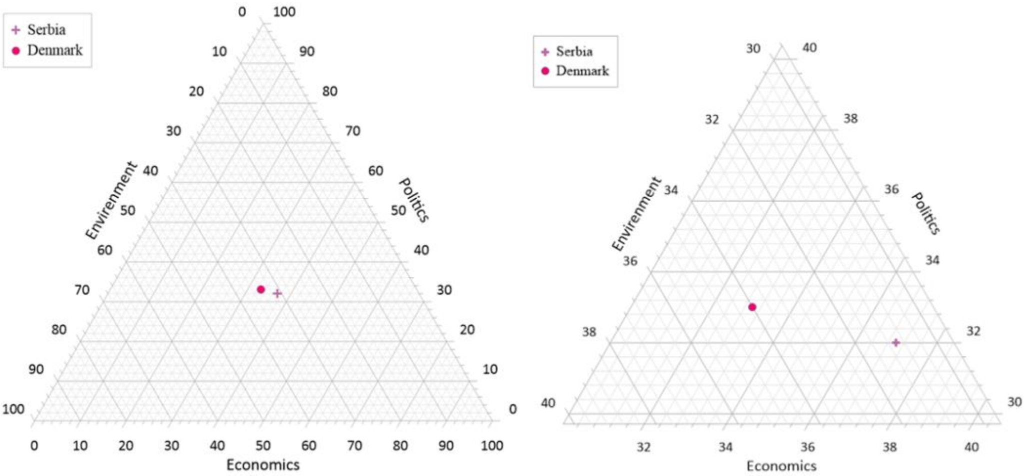

Figure 2. Current state of energy trilemma for Serbia and Denmark

The ternary diagram shows the results of the parameters EN, PN, and EnN. For Serbia, they are 37, 32, and 31, respectively, while for Denmark they are 33, 33, and 34. The concept of the “rigid ideal” was adopted, in which the point of the Ideally balanced energy trilemma is IBET(33,33,34), i.e. the parameters ENI, PNI and EnNI are 33,33, and 34, respectively. By applying formulas (17), (18), and (19), the values of the parameters JE, JP, and JEn are obtained. For Serbia, the values are 88, 97, and 91, respectively, while for Denmark they are 100,100, and 100. By formula (16), the JETI index value was for Serbia 92 and Denmark 100.

3.2. Discussion

To validate the improved metrics for the quantification of energy justice, we compared values of JETI with the already existing indicators that numerically describe the energy trilemma of an analyzed country. For this purpose, we used the parameters World Energy Trilemma Index parameters and the Energy Transition Index. For 2020, the values of these parameters were for Serbia 65 (60th in the world) and 44.3% (100th in the world). That same year for Denmark 84 (3rd in the world) and 72.2% (4th in the world).

The ternary diagram represented in Figure 2 and the calculated values of the JETI indicator show that Denmark has a very well-balanced energy trilemma. We may say that Denmark reached the just energy transition. On the contrary, Serbia does not, and there are many reasons for that. One of the most important is the low price of energy (primarily electricity), and because of that, there are no significant investments in the environment. An analysis of the parameters of the World Energy Trilemma Index and the Energy Transition Index for Serbia and Denmark leads to similar conclusions.

4. Applicability assessemnt of improved metric for quantification of energy justice

Metric for quantification of energy justice is an appropriate and useful tool for energy policy decision-makers. Based on this metric, it is possible to make a visual presentation of the current state of energy justice for the observed countries by using ternary diagrams. In this way, it is possible to detect which element of the energy trilemma needs impact in order to improve the overall balance. Also, the proposed metric can be useful for performing scenario analyzes of the energy transition of the observed countries in a way that the values of the metric parameters are determined in accordance with the setting of the scenario for which the analysis is performed.

When developing EJM, the authors had in mind the need for applicability with existing economic models that are commonly used in the analysis of labor costs and the development of energy systems. Hefron et al. state that the aim of the EJM is to feed directly into economists' models and deliver a concept which has a value that can be calculated and costed so as the consequence of its application can be more easily understood by the public[4]. The proposed indicator, the Just Energy Transition Index (JETI), is constructed based on the metric that represents the improvement of the EJM. In this way, applicability with existing economic models is retained and JETI can be used in analyses and plans to express the price needed to achieve a certain level of justice in the energy transition. The stated applicability of the JETI indicator with the increased universality brought by the improved metric in this paper enabled a wide practical application.

5. Conslusion

Research is pointed out the tendency that the authors have in the direction of developing methodologies for the quantification of energy justice. Special emphasis was placed on the analysis of the Energy Justice Metric. It was noticed that the methodological logic on which the EJM is based on is suitable for further development and creation of new tools for the quantification of energy justice. The impossibility of universal application was detected as a major systemic defect. The reason for that was great subjectivity in determining the input parameters and the reference point with which the degree of balance of the energy trilemma was measured.

The proposed improvement of the metric for the quantification of energy justice implied that the elements of the energy trilemma are determined based on known and generally accepted indicators. In that sense, a tabular overview of all input parameters, data sources, and the way of scaling values were provided. That solved part of the problem and ensured the application of metric for the largest number of countries in the world. By systematizing mathematical formulas for calculating the elements of energy trilemma, defining two ways of determining the reference point concerning which energy justice is determined (measured) ("rigid ideal" and "floating ideal"), the solution to the problem of universality of methodology is completed.

The set of input parameters based on which the elements of energy trilemma are calculated also included indicators of readiness for the energy transition. In this way, the metric for the quantification of energy justice has been further improved. From this improved metric, a new energy indicator, the Just Energy Transition Index (JETI), was created and mathematically defined. This composite index is considered as a new tool that can be used by decision-makers to steer processes in the direction of a just energy transition. Also, we validated the improved metric for the quantification of energy justice.

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