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A comparative approach toward renewable energy technologies, more effective in performance level of countries in clean energy development

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ABSTRACT
The aim of the current study is to compare the impacts of renewable technologies, effective in the performance of countries in the field of clean energy. This study is applied in terms of purpose and descriptive-survey method regarding its nature. To determine how each country examined in the statistical population has performed in the field of the development of wind and solar technologies, and consequently, to find out which of their technology has a better economic justification, and finally, to identify the method of policy making about energy and better technical development power between the two key technologies of wind and solar existing in each country, the data envelopment analysis model was applied and the efficient and inefficient units of each country were obtained distinctly for wind and solar technology, which provides a relative criterion for judgment. Efficient units are rated equal to one and the rest of the units are rated less than one. To answer the research question, each country was divided into two decision units based on both wind and solar technologies and data related to each technology. By introducing three inputs and two outputs to the data envelopment analysis model with returns to the fixed scale and output-oriented approach, the results of the evaluation of wind and solar technologies in each country were achieved by separating into efficient and inefficient units. Problem solving was performed using DEA Solver LV 8.0 software.
Keywords: Renewable technologies, performance of countries, Clean energy

Introduction

In recent decades, dynamics between economic, social, ethical, and environmental issues have created important challenges in policy planning and implementation. Therefore, a multi-criteria approach has been offered to analyze and implement useful policies to achieve long-term sustainability. In the current pluralistic society, where there is widespread decentralization and diversity of concentrations of power, the government should balance the multiple interests of stakeholders that can affect on the outcome of policy selections. Particularly, policies to promote renewable, low-carbon resources require a combination of science-backed strategies, stakeholder presence, and financial incentives to decrease initial investment costs. Through studying review articles, it can be perceived that the number of publications related to the evaluation of renewable energy investments has tripled in the last decade. Increasing the use of renewable energy has had a positive effect on skills development and the improvement of the performance of researchers seeking to progress decision-making knowledge.

It is noteworthy that choosing between all the existing methods is in fact a multidimensional problem. Each of these methods has its own pros andcond, and therefore it can not be declared that one method is necessarily more appropriate than the other methods. Choosing a method only depends on the preferences and priorities of the decision maker and the analyst. Considering the appropriateness of the method, its approval and validity are significant points that should be considered in choosing a method [1]. In reviewing the recent literature, mainly four main criteria, which were directly related to the goal of sustainability, were chosen for analysis: technical, economic, environmental and socio-political. A set of sub-criteria that explain each of the main criteria can be observed in scientific works related to decision making about sustainable energy (Wang et al., 2009 and Mateo, 2012) [2]. In a study done by Santos et al. (2015), a multi-criteria analysis of electricity scenarios is presented for a case study in Portugal that considers various perspectives on potential stakeholder preferences: economic, technical, social, environmental, and equivalent weights of these four dimensions are calculated. But the problem still remains, and that is to find a scenario that best fits the desired goals in a multidimensional context, considering that these dimensions do not have the same weight on different goals [3]. La Rovere et al. (2010) chose environmental, social, economic, and technological indicators to evaluate power generation options and used a data envelopment analysis (DEA) to identify the relative efficiencies of production units and their hierarchy [4]. Nerini et al. (2014) concentrated on a specific geographic area (Amazon) and used a multi-criteria approach to compare five power supply options based on interviews with specialists and the results displayed a clear orientation of priority towards renewables. The study was intended to advance the scope of the analysis and cover the entire country, as the MCDA has been used to compare scenarios designed for the entire Brazilian electricity sector, which included a set of technologies and not only did it reflect the lowest cost options, but it also reflected the opinions of experts on environmental, economic, technical and social criteria [5]. The results of the fuzzy target programming model, studied in the paper by Jayaraman et al. (2015), it has been clearly stated that carbon-focused energy sources may cause disease and premature death, which in turn will lead to deterioration of public health with very high cost. The model presented in this article can be extended to include more sustainability criteria in the following areas: (1) effective water resources management to study the water-energy relationship, (2) solid waste management and its impact on energy savings and GHG emissions, (3) energy savings related to recycling measures to analyze related challenges and opportunities in the field of sustainable, social and economic development [6]. As a result, the aim of this study is to compare the effects of renewable technologies, effective in the performance of countries in the field of clean energy.

Research Methodology

The goal of the current study is applied and regarding the nature of the method, it is of descriptive-survey type. Data envelopment analysis method was made used of to achieve the research goal. In general, Data Envelopment Analysis uses a linear programming technique to measure the relative efficiencies of options. This technique measures the efficiencies of options against each other so that the most efficient option scores 1 and the rest of the options will be a fraction of 1. This has benefits. This technique is able to use several inputs and outputs. Returns can be analyzed and quantified. It can also disclose relationships that remain hidden in other methods. An important downside is that it cannot work with inaccurate data and assumes that all input and output data are exactly accurate. But in reality, this assumption may not always be true. Results can be sensitive depending on inputs and outputs. DEA is used where returns need to be compared. It is usually used in economics, medicine, public industry, road safety, agriculture, retail and business problems. These categories are especially useful because they contain accurate data that can be used as input, leaving out one of the major downsides of this method.

Due to the need to determine the efficiency and effectiveness and the use of multiple inputs and outputs, the data envelopment analysis technique DEA (CRS-Output Oriented) was simultaneously applied because both the fixed-scale return model introduces efficient units more rigorous than the variable-scale or the same VRS and gives a better benchmark, and by presuming limited and almost constant inputs of each country and the current wealth of countries in the development of renewable technologies, the output-driven model was chosen which by keeping the input values constant, maximizes the output values.

To answer this question, each country was divided into two decision units according to both wind and solar technologies and data related to each technology. By introducing three inputs and two outputs to the data envelopment analysis model with fixed returns to scale and output-oriented approach, the results of the evaluation of wind and solar technologies in each country were obtained by separating into efficient and inefficient units. Problem solving was done using DEA Solver LV 8.0 software.

Table 1: Features of the DEA solution method

Inputs: Total installation cost - employment rate - technology
Outputs: Electricity generation - Reduction of greenhouse gas emissions
Number of decision units: Thirty-four
Data Envelopment Analysis Model: Return to Fixed Scale and Output-Oriented

Although in reputable and reliable global sources, most developing countries had limited and incoherent data, efforts were made to better compare the results with the best composition to be listed in the statistical population selected from developed and developing countries with reliable data.

Table 2: Selected countries in the statistical population

Australia	Brazil	China
Egypt, Arab Rep	France	Germany
Greece	India	Italy
Japan	Mexico	South Africa
South Korea	Spain	Turkey
United Kingdom	United States	

Findings

The cumulative values of each input and output data up until 2016 taken from the previously introduced global sources have been introduced in Table (3) where the following features can be found.

Inputs include: installation cost 2) number of employees 3) the amount of patents registered for each renewable technology, in which the patent actually contributes as a technology proxy in the production function.

Outputs include: Cumulative amounts of electricity generation up to 2016 by wind and solar technology. 2) The cumulative rate of reduction of greenhouse gas emissions from the replacement of solar or wind technology with fossil fuels.

The order of the countries in the table below is similar to the order of Table (3), which includes seventeen countries, which have been abbreviated, and the data of both wind and solar technologies of each country have been indicated with Wind and Sol, respectively. Therefore, each country has two DMUs that make up a total of thirty-four decision units.

Table 3: DEA model data

Sample	(I)Cost	(I)Empl	(I)Tech	(O)ElecGen	(O)Avoided
AusWind	4564.252	2.2	3157	11467	9.567
AusSol	2663.96	12.9	4296	5968	4.776
BraWind	9406.628	32.4	1701	21626	18.047
BraSol	14.00412	0.4	822	78.93	0.0667
ChinWind	139749.8	509	29925	180665	150.37
ChinSol	24284.81	1973	49210	52700	31.17
EgyWind	808.5	0.4	38	1444	1.2043
EgySol	27.495	3.2	54	66.26	0.0506
FranWind	11013.93	22	1134	21249	17.72
FranSol	4127.305	16.2	2135	7259	5.805
GerWind	48154.26	142.9	7388	79206	66.07
GerSol	24310.47	32.3	9441	38726	30.99
GreecWind	2254.098	2	176	4621	3.855
GreecSol	1591.044	1.9	146	3900	3.121
IndWind	27044.86	60.5	407	37361	31.16
IndSol	3359.889	120.9	328	8263	6.408
ItaWind	9849.686	26	593	14844	12.38
ItaSol	11546.68	12.5	868	22955	18.367
JapWind	3027.024	5	9927	5161	1.876
JapSol	20346.3	377	48085	35974	31.17
MexWind	3526.138	14.5	835	8745	7.295
MexSol	105.703	7	917	245.6	0.1965
SAfrWind	1163.162	3.6	396	2484	1.176
SAfrSol	726.479	17.3	412	2531	1.87
SKorWind	936.782	8.7	10621	1366	1.176
SKorSol	2208.765	2.4	24183	3979	1.87
SpainWind	24732.55	17.4	3295	49325	41.14
SpainSol	4372.316	13.3	1618	13859	11.22
TurkWind	4854.234	52.9	117	11652	9.72
TurkSol	152.75	12.7	30	197.1	0.1333
UKWind	15405.7	41.1	1925	40310	33.68
UKSol	5613.257	16.9	1639	7561	6.065
USWind	78233.69	102.5	18145	190719	159.09
USSOL	14323.06	247.1	44272	34442	27.64

Table 4: Model features and DEA results

DEA model = DEA-Solver LV8.0/ CCR(CCR-O)
Problem = Sample
No. of DMUs = 34
Returns to Scale = Constant (0 =< Sum of Lambda < Infinity)
No. of Input items =3
Input(1) = Cost
Input(2) = Empl
Input(3) = Tech
No. of Output items = 2
Output(1) = Elec Gen
Output(2) = Avoided

Statistics on Input/Output Data

	Cost	Empl	Tech	Elec Gen	Avoided
Max	139749.8	1973	49210	190719	159.09
Min	14.00412	0.4	30	66.26	0.0506
Average	14838.22	115.0029	8183.412	27086.76	21.95428
SD	26828.38	341.4709	13977.43	43745.39	36.39359

Correlation

	Cost	Empl	Tech	Elec Gen	Avoided
Cost	1	0.297307	0.406507	0.948015	0.947998
Empl	0.297307	1	0.698193	0.301696	0.248351
Tech	0.406507	0.698193	1	0.421538	0.392115
Elec Gen	0.948015	0.301696	0.421538	1	0.998187
Avoided	0.947998	0.248351	0.392115	0.998187	1

No. of Efficient DMUs = 9
No. of Inefficient DMUs = 25

The results of comparison and evaluation of the efficiency of both wind and solar technologies for each country have been presented in the figure below.

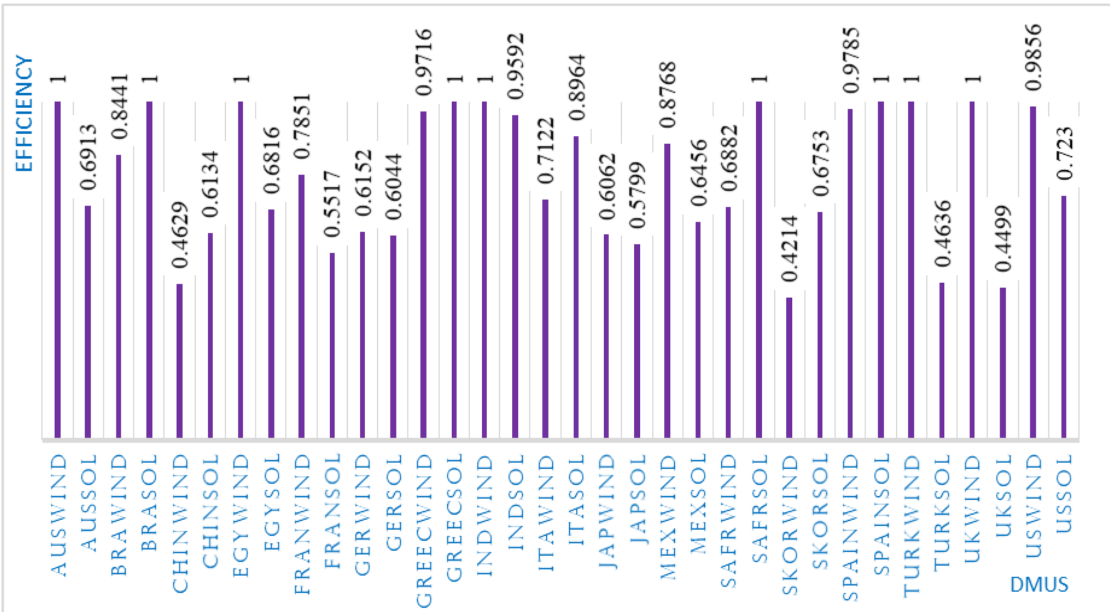

Figure 1: Comparison of wind and solar technology efficiency in each country

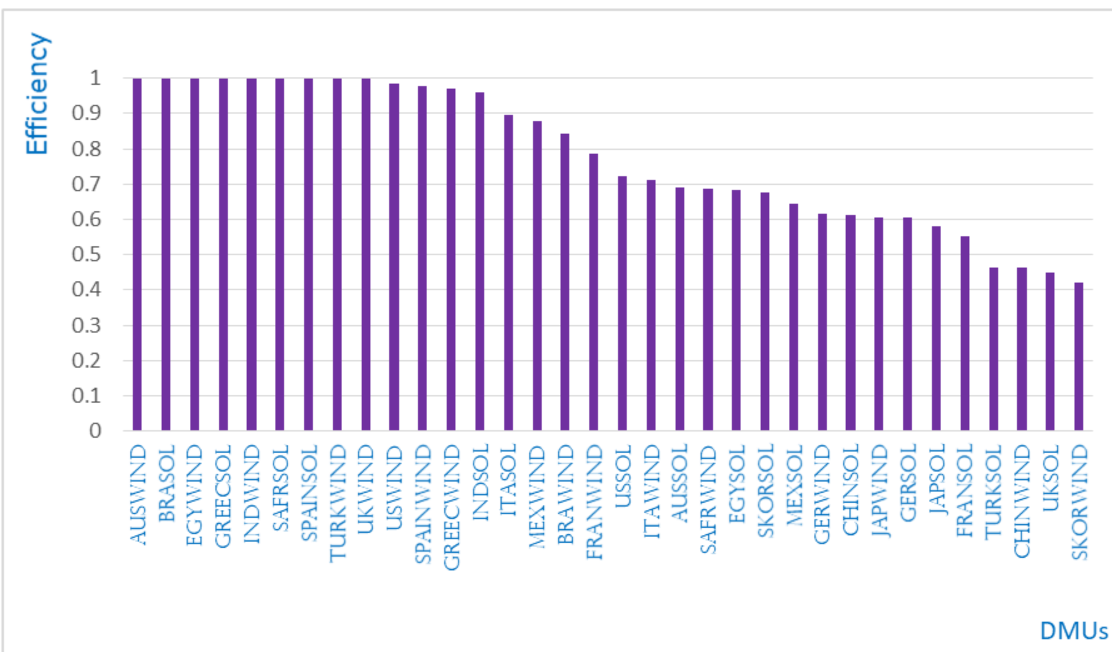

Figure 2: Descending efficiency ranking of wind and solar technologies of countries

To determine how each country evaluated in the statistical population has performed in the development of wind and solar technologies, and as a result, to identify which technology has a better technical and economic justification, and finally better energy policy and technical development power between the two existing key technologies of wind and solar in every country has existed, data envelopment analysis model was used and efficient and inefficient units of each country were achieved separately for wind and solar technology, which provides a relative criterion for judgment. Efficient units are rated equal to one and the rest of the units are rated to less than one.

Conclusion

The aim of this study is to compare the effects of renewable technologies, effective in the performance of countries in the field of clean energy. Due to the need to determine the rate of efficiency and effectiveness and the use of multiple inputs and outputs, the data envelopment analysis technique DEA (CRS-Output Oriented) was made used of. Because the fixed-scale return model more rigorously introduces more efficient units compared to the variable-scale, or VRS, and provides a better benchmark. The results in Figure (1) indicate that the efficiency of wind and solar technologies in each country has been evaluated and they determine which technology performs better in each country. Numerical values equal to one are efficient units, and values below one are considered inefficient in descending order. As data envelopment analysis has the nature of input and output and is somehow considered production function in which the numerical ratio between data and output has been taken into account. In data envelopment analysis results, as in Figure (2), it sometimes identifies some units as efficient that seem logically unexpected. Because it does not correspond to the multidimensional and macro-view, and by introducing inputs and outputs, it considers the issue only as minimizing the cost or inputs and maximizing the output. For instance, if a country has spent money on knowledge and technology but has not yet produced and developed the product, it will be declared as inefficient, and contrariwise, a country that has low cost of research, knowledge production, and trivial patent registration may be introduced as efficient because of to its lower cost in proportion to its output. While it is not simple to always look at multidimensional and macro issues with an economic perspective and cost reduction, particularly in the areas of sustainable development and the environment. Therefore, it can be perceived that for evaluating performance from a multidimensional perspective, multi-criteria decision making techniques provide better results than data envelopment analysis.

References

[1] Strantzali E, Aravossis K. Decision making in renewable energy investments: a review. Renewable and Sustainable Energy Reviews. 2016 Mar 1; 55:885-98.

[2] Haddad B, Liazid A, Ferreira P. A multi-criteria approach to rank renewables for the Algerian electricity system. Renewable Energy. 2017 Jul 1; 107:462-72.

[3] Santos MJ, Ferreira P, Araújo M, Portugal-Pereira J, Lucena AF, Schaeffer R. Scenarios for the future Brazilian power sector based on a multi-criteria assessment. Journal of Cleaner Production. 2017 Nov 20; 167:938-50.

[4] La Rovere EL, Soares JB, Oliveira LB, Lauria T. Sustainable expansion of electricity sector: Sustainability indicators as an instrument to support decision making. Renewable and Sustainable Energy Reviews. 2010 Jan 1; 14(1):422-9.

[5] Nerini FF, Howells M, Bazilian M, Gomez MF. Rural electrification options in the Brazilian Amazon: a multi-criteria analysis. Energy for Sustainable Development. 2014 Jun 1; 20:36-48.

[6] Jayaraman R, Colapinto C, La Torre D, Malik T. Multi-criteria model for sustainable development using goal programming applied to the United Arab Emirates. Energy Policy. 2015 Dec 1; 87:447-54.