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Electricity Generation from Renewables and Targets: An Application of Multivariate Statistical Techniques

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Abstract**—**Renewable energy is referred to as "clean energy" and common popular support for the use of renewable energy (RE) is to provide electricity with zero carbon dioxide emissions. This study provides useful insight into the European Union (EU) RE, especially, into electricity generation obtained from renewables, and their targets. The objective of this study is to identify groups of European countries, using multivariate statistical analysis and selected indicators. The hierarchical clustering method is used to decide the number of clusters for EU countries. The conducted statistical hierarchical cluster analysis is based on the Ward's clustering method and squared Euclidean distances. Hierarchical cluster analysis identified eight distinct clusters of European countries. Then, non-hierarchical clustering (k-means) method was applied. Discriminant analysis was used to determine the validity of the results with data normalized by Z score transformation. To explore the relationship between the selected indicators, correlation coefficients were computed. The results of the study reveal the current situation of RE in European Union Member States.

Keywords**—**Share of electricity generation, CO_2 emission, targets, multivariate methods, hierarchical clustering, K-means clustering, discriminant analyzed, correlation, EU member countries.

I. Introduction

ENERGY use is one of the most important indicators affecting economic development and energy is an expensive input in industry production for all industrialized countries. Energy related discussions and policy regulations, energy efficiency measures or targets are mostly related to the definition of energy saving targets on primary energy values. These values show the energy consumption of a country or the energy demand of a system.

RE tends plays an important role in many countries around the world. RE is a form of energy obtained from natural resources which are eligible for obtaining sustainable energy. Electricity and heat produced from RE sources are mostly considered more environmentally friendly than other sources, and include hydroelectricity, biomass, wind, solar, ocean energy and geothermal energies. RE provides electricity with very low levels of greenhouse gas emissions and minimal damage to the environment.

The building sector accounts for approximately one-third of the total global energy demand. Around 40% of all energy consumed by buildings is used for heating and cooling, for example, cooking, air conditioning, water heating, lighting, and appliances [1]. Transportation accounts just under 30% of the total global energy demand [2]. While in industry, 40% of the total global energy consumed is for power and heating needs [3].

Due to the increase of urbanization and access to modern energy sources in developing countries, global growth in the use of traditional biomass for heating has stopped rising [4]. Energy consumption from modern renewable sources in the heating sector has risen by an average of 2.4% annually from 2007 to 2013 [5]. Energy use for heat was reported to account for about half of the total global energy consumption in 2014 [6]. RE supplied only around 8% of that total energy needed for heat. Correspondingly, the heating power obtained from renewables contributes to the final energy consumption of RE. Thus, there is huge potential especially for low-temperature heating applications [7]. The estimated RE share of global energy consumption is shown in Fig. 1.

According to Fig. 1, RE accounted about 19.1% of total global energy consumption. In 2013, hydropower was reported for an estimated 3.9%; while other renewable power sources comprised of 1.3%; renewable heat energy accounted for approximately 4.1%; and transport biofuels provided around 0.8% [8].

The renewable power capacity data are given in Fig. 2 (not including hydropower) for the World, EU-28, BRICS, and the Top Seven Countries, 2014. According to Fig. 2, the United States, China, Brazil, Germany and Canada remain as the top countries for total installed renewable electricity capacity [8]. China is home to about one-fourth of the world's renewable power capacity, including around 280 GW of hydropower [9].

RE sources continue to play an ever increasing and important role in some countries. Within the EU, Denmark leads the way with 57% of power coming from renewables, followed by Portugal (30%), Spain (26%), Italy (24%), Germany (23%) and UK (18%) [10].

RE sources are important contributors to reducing greenhouse gas emission. The European Council in 2014 agreed on renewable policies and energy efficiency targets for 2030 among all EU countries. The EU adopted an Energy Union in 2015. The strategy was developed to ensure that Europe has secure, affordable and climate friendly energy and achieves its climate and energy goals for 2030.

CO_2 emissions are an important contributor to global warming. They are affected by factors such as population, industrial activities and economic growth. Average CO_2 Emissions (per unit of total primary energy supply) of the top five emitting countries and the EU can be seen in Fig. 3 [11].

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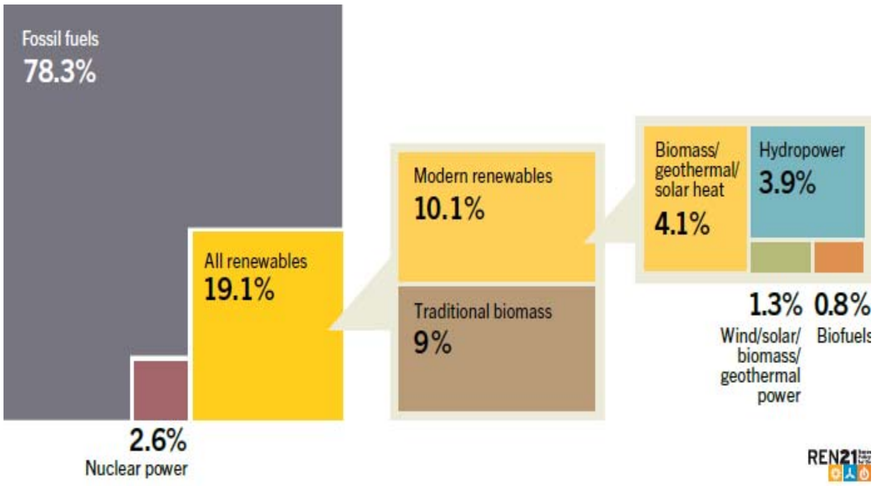

Fig. 1 Estimated RE share of global energy consumption, 2013 [8]

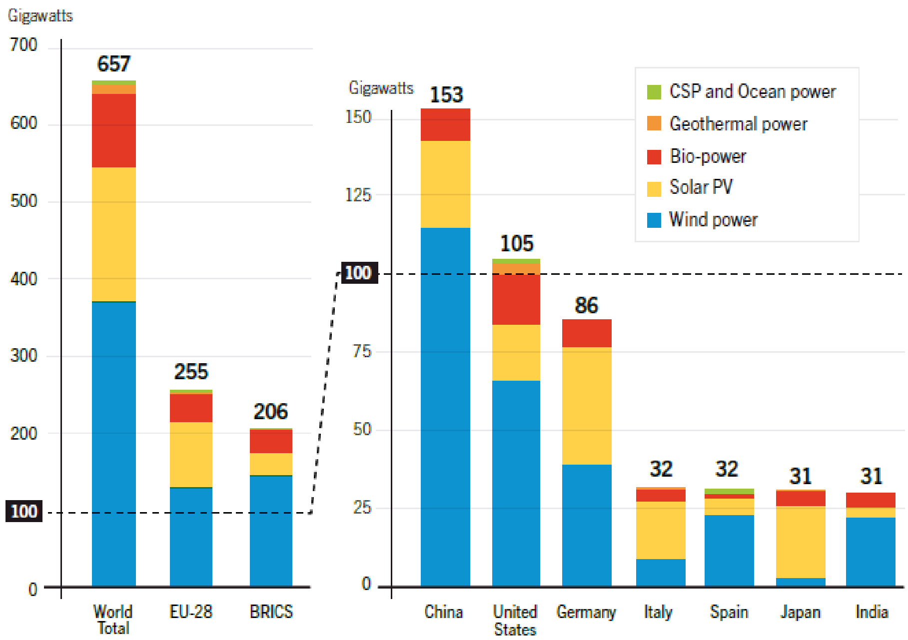

Fig. 2 Renewable power capacities, 2014 [8]

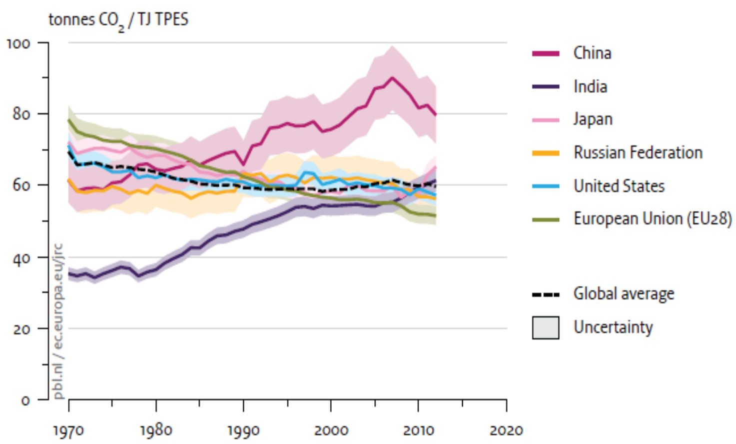

Fig. 3 Average CO2 emissions, 2014

Due to supportive policies, presently 164 countries, two thirds of which are countries without yearly national emissions reporting, have RE targets.

II. Literature

Recent researches show that RE is an attractive topic for many researchers because of the primary importance of energy based problems. Researchers are trying to discover new ways of providing continuous clean energy by considering customer demand and environment boundaries.

Supplying energy from the mainland to islands is a huge problem, especially in the Pacific Ocean. According to a comparison between the current status of islands and possible outcomes, the main difference is related to development of RE supplied island grids. The main goal would be generating sufficient energy supply from local renewable resources [12]. On the other hand, there are many challenges to the deployment of RE in Pacific Island Countries. The main one is distributing the development finances among the cooperation of software and hardware factors. In [13], a framework was proposed to balance the expenditure between these factors and remove other barriers, such as international issues. For example, removal of financial barriers depends on amount of donor funding which is especially necessary for Pacific island countries. In order to comprehend the emergent condition, donor funding flow between 1990 and 2012 is adequate to be analyzed [14].

In addition to Pacific Island countries, African nations are also looking for alternatives to the use of fossil fuels. The results of [15] show that, RE driven development can obtain better outputs for growth in African countries. In a comparison with other regions, Eastern and Central African countries are more RE dependent. The benefits of nuclear energy have recently come into question because of its potential danger. Beside this important point, its necessity and effects on the growth of countries is an also considerable factor.

The use of alternative energy resources and investment for REs are considered as a primary solution, despite the lack of short-term financial return. In order to eliminate the financial disadvantages, governments should consider regulations for RE deployment policies and support RE investment. A proposal for supportive policy regulation for Gulf Cooperation Council (GCC) countries could be shown as a model to encourage all countries to respond to emerging energy demands and accelerate their economic growth [16].

In order to regulate the environmental impact of the use of energy, a combination of different RE resources should be used in local energy networks. Different scenario exercises unrolled the relation between energy consumption and its environmental impacts. In order to minimize the impacts of energy usage and energy generating cost, an optimum point must be found between the use of energy resources [17].

RE resources also have environmental impacts and researchers have to take these into account when assessing the current conditions regarding agencies or countries. The "Finnish National Renewable Energy Target for 2020 Report" is a good example for this type of consideration with assessments for overall environmental impacts of each resource type [18].

In addition to researches looking at alternatives to the use of fossil fuels, studies for country comparison are also important to observe the current RE status in regard to countries.

Developing countries are at the center of many researches with their key factor profiles. Global economic growth is dependent on economic growth in developing countries and recent studies revealed that it is also dependent on the use of RE. However, this relationship would show different characteristics for the considered country [19].

In [20], RE and CO_2 emission with nuclear energy are considered by their effects on growth and GDP for nine developed countries over the period 1990-2013.

In addition to RE usage, CO_2 emission levels are also an important indicator for comparison researches. Indicators such as real income, RE consumption, non- RE consumption, trade openness and financial development affect carbon emission. In order to reveal the relationship between these factors, the panel estimation technique was applied [21] and results show that increases in RE consumption, trade openness and financial development decrease carbon emissions.

In order to find a balance between potential profits, carbon taxes and legislation of RE, renewal policies are evaluated in [22] for 16 East Asia Summit countries. Five criteria including market, profitability, legislation, technology and financial resources are used to build a quantitative index.

Organization for Economic Co-Operation and Development (OECD) countries are also investigated [23] to show impacts of RE on economic growth between 1990 and 2012 by using time series pattern to establish an estimation. The results show that an increase in economic growth is related to RE consumption.

Effects of RE usage on economic growth between 1991 and 2012 are also investigated in [24] for over top 38 RE consuming countries to estimate long-run output elasticity by using time series analyzes.

All of these studies show that there is a considerable relationship between RE consumption and long-term economic growth, especially in developing countries. In addition, a negative correlation is observed between carbon emissions and the use of RE.

III. Study Data

Data from the Renewables 2015 Global Status Report, the share of electricity generation from renewables and the targets (% by 2020) were used for this paper [25].

CO_2 data are the latest annual per-capita carbon dioxide (CO_2) emissions, metric tons of CO_2 per capita (CDIAC) by country (2011), from the United Nations Millennium Development Goals Indicators Carbon Dioxide Emissions, total, per capita and per $1 GDP (PPP) [26].

Another indicator used is the rate between electricity consumption and the electricity produced for 2014. This ratio shows the contribution of electricity produced from RE sources to the national electricity consumption (2014). Electricity generation from RE sources contains the electricity produced from hydro plants excluding electricity from biomass/wastes, solar, pumping, wind and geothermal [27].

The indicators' values were needed to be transformed as the three variables were not measured on the same scale. Z-scores, which are two most common transformation options, were used.

IV. Statistical Methods

To decide the number of clusters, the hierarchical clustering method is used, and then the k-means (non-hierarchical) method is applied to band the EU countries into clusters. Discriminant analysis is a recommended way to verify the classification accuracy of clusters; the analysis tool IBM SPSS 22.0 was used for this study.

A. Cluster Analysis

Cluster analysis is a classification technique concerning the number of groups or group structure. A cluster is a group of relatively homogeneous cases or observations. Cluster analysis is concerned with the similarities of distances (dissimilarities) using the variable values observed in each individual [28].

Cluster analysis is usually represented as a vector of measurements, or a point in a multidimensional space into clusters based on similarity. This technique determines optimum partitions based on certain similarities and/or dissimilarities function that measures the global error extent between data points and cluster centers in a feature space. There are various algorithmic approaches such as partitional algorithm, hierarchical clustering algorithm, graph-theoretic methods, fuzzy clustering algorithm, etc. [29], [30].

One of the many applications of cluster analysis is agglomerative hierarchical clustering. Agglomerative hierarchical methods start with individual objects. The results of the agglomerative hierarchical method are displayed in the form of a two-dimensional diagram known as a dendogram. The dendogram shows the mergers or divisions which have been made at successive levels [31].

The k-means cluster method is the basic method for clustering. K-means cluster analysis is a non-hierarchical clustering method and is based on the assignment of the unit, in the classification of n units into k clusters, to a core cluster that is illustrated in the p dimensional space and reflects the profile of the majority of the units. The k-means cluster method only clusters the units and provides parameter estimates of the resulting clusters [29].

B. Discriminant Analysis

Discriminant Analysis is a multivariate statistical technique, it is concerned with separating distinct sets of observations and with allocating new observations to previously defined groups. A function (discriminants) is a linear discriminant function and classifies the sample into the group with the highest score. The higher the correct classification rate, the greater the degree of group discrimination achieved by the canonical functions.

In this study, discriminant analysis was used to verify the k-means cluster analysis results [32].

V. Study Results

A. Results of Correlation Analysis

The value of correlation between the variables included in the study are as shown in Table I. Correlation is a statistical technique that can show how strongly pairs of variables are related to each other. The calculation of Pearson's correlation coefficient ranges from -1 to 1. A perfect positive linear relationship indicates +1. Correlation coefficients are identified by significant at the different levels.

Table I shows that the correlation between "Share of Electricity Generation from Renewables, Target (%)" and "Electricity Generated from Renewable Sources - % of Gross Electricity Consumption" is significant (p=0,000<0,05), the correlation between "Share of Electricity Generation from Renewables, Target (%)" and "Per-Capita Carbon Dioxide (CO_2) Emissions" is significant (p=0,090<0,10).

The relationship between "Share of Electricity Generation from Renewables, Target (%)" and "Per-Capita Carbon Dioxide (CO_2) Emissions" shows a negative result, with a Pearson coefficient of -0,333. The relationship between "% of Gross Electricity Consumption" and "Per-Capita Carbon Dioxide (CO_2) Emissions" shows a negative result. A negative correlation shows that there is an inverse relationship between two indicators (r= -0.398). There is a statistically significant correlation between two indicators ($p < .05$).

TABLE I
THE VALUE OF CORRELATION

Correlation		Share of Electricity Generation from Renewables, Target (%)	Per-Capita Carbon Dioxide (CO_2) Emissions	Electricity Generated from Renewable Sources - % of Gross Electricity Consumption
Share of Electricity Generation from Renewables, Target (%)	Correlation Sig. (2-tailed)	1.00	-.333 .090	.854** .000
Per-Capita Carbon Dioxide (CO_2) Emissions	Correlation Sig. (2-tailed)	-.333*** .090	1.00	-.398* .040
Electricity Generated from Renewable Sources - % of Gross Electricity Consumption	Correlation Sig. (2-tailed)	.854** .000	-.398* .040	1.00

* Correlation is significant at the 0.01 level (2-tailed)
**Correlation is significant at the 0.05 level (2-tailed).
***Correlation is significant at the 0.10 level (2-tailed)

In addition, the relationship between “Share of Electricity Generation from Renewables, Target (%)” and “Electricity Generated from Renewable Sources - % of Gross Electricity Consumption” shows a positive result, with a Pearson Coefficient of 0,854.

B. Results of Hierarchical Cluster Analysis

The results of the hierarchical cluster analysis obtained by clusters selected EU Member States. The dendrogram plot illustrated how far or close cases were when they were combined. The plot rows show each case on the Y axis and the X axis, which is a rescaled distance coefficient. Cases with low distance or high similarity are close together.

Fig. 4 shows the country clusters based on the indicators using the hierarchical and Ward’s method.

From the dendrogram, it can be seen that the cluster analysis has placed Greece, Ireland, Germany, United Kingdom, Finland and Netherland in the first group; Belgium, Poland and Czech Republic in the second group; Hungary and Malta in the third group; Bulgaria, Slovakia, France and Lithuania in the fourth group; Estonia, Luxemburg in the fifth group; Latvia, Sweden and Austria in the sixth group; Slovenia, Spain and Italy in the seventh group; and, Croatia, Romania, Portugal and Denmark in the eighth group.

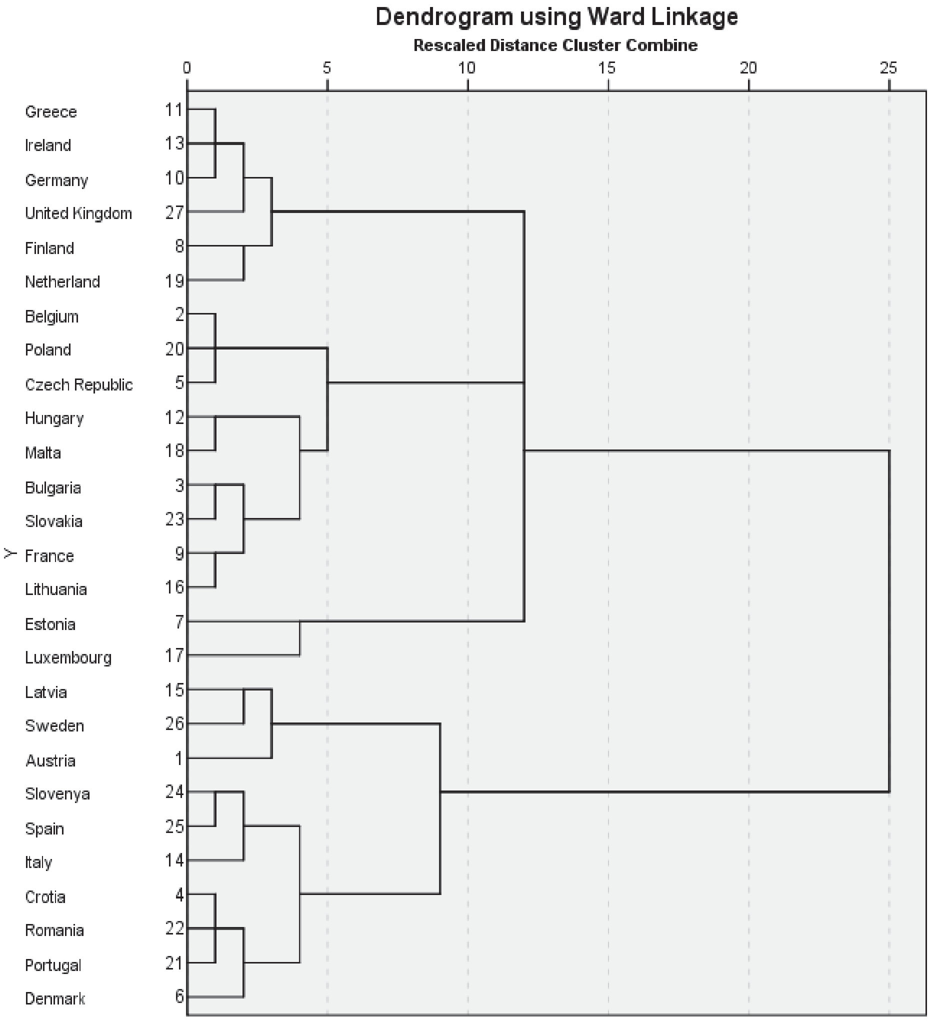

Fig. 4 Dendrogram using the Ward’s method

Austria, Sweden and Latvia have the highest Share of Electricity Generation from Renewables, Target (%) in the sixth cluster. Hungary and Malta have the lowest Target (%) in the third cluster. The lowest Per-Capita Carbon Dioxide (CO_2) Emissions are in France and Lithuania in the fourth cluster.

C. Results of K-Means Cluster Analysis

The results obtained by k-means are shown in Table II.

According to the analysis, variables are homogeneous in means of units. The significantly effective variables in the clustering of N=27 units is, in order of effectiveness, “Share of Electricity Generation from Renewables, Target (%)”, “Per-Capita Carbon Dioxide (CO_2) Emissions “and “Generated from Renewable Sources - % of Gross Electricity Consumption ($P<0,05$). The cluster averages on indicators are given in Table III.

TABLE II
THE CLUSTER (K-MEANS) MEMBERSHIP

Cluster	Countries
1	Austria, Sweden
2	Hungary, Malta
3	Germany, Ireland, Greece, United Kingdom, Netherland
4	Denmark, Croatia, Romania, Portugal, Slovenia, Spain
5	Latvia
6	Luxemburg
7	Belgium, Estonia, France, Czech Rep., Lithuania, Bulgaria Poland
8	Finland, Italy, Slovakia

Austria and Sweden (first cluster) have the highest electricity generated from renewable sources and target. Latvia and Romania have the lowest per capita emissions within the EU.

D. Results of Discriminant Analysis

Discriminant analysis is used to verify the classification accuracy of cluster analysis. The covariance matrices are equal ($p>0.05$). Canonical discriminant function is used in the analysis (Eigenvalue>1). According to results, the function found to be statistically significant ($p<0.05$). Table IV presents the results of the classification results.

TABLE III
INITIAL CLUSTER CENTERS

	Cluster							
	1	2	3	4	5	6	7	8
Target (%)	66,75	7.35	42.40	42.40	60.00	11.80	20.16	27.67
CO_2 Emission	6.73	5.37	8.32	5.64	3.76	20.98	8.35	7.68
Gross Electric Consumption (%)	66.65	5.30	20.12	43.22	51.10	5.90	15.03	29.27

TABLE IV
CLASSIFICATION RESULTS

	Predicted Group Membership								Total
	1	2	3	4	5	6	7	8	
Count	2	0	0	0	0	0	0	0	2
	0	2	0	0	0	0	0	0	2
	0	0	5	0	0	0	0	0	5
	0	0	0	6	0	0	0	0	6
	1	0	0	0	1	0	0	0	1
	0	1	0	0	0	1	0	0	1
	0	0	0	0	0	0	7	0	7
	0	0	0	0	0	0	0	3	3
%	100.0	.0	.0	.0	.0	.0	.0	.0	100.0
	.0	100.0	.0	.0	.0	.0	.0	.0	100.0
	.0	.0	100.0	.0	.0	.0	.0	.0	100.0
	.0	.0	.0	100.0	.0	.0	.0	.0	100.0
	.0	.0	.0	.0	100.0	.0	.0	.0	100.0
	.0	.0	.0	.0	.0	100.0	.0	.0	100.0
	.0	.0	.0	.0	.0	.0	100.0	.0	100.0
	.0	.0	.0	.0	.0	.0	.0	100.0	100.0

In conclusion, all countries (27) were correctly classified.

VI. CONCLUSION

As result of the cluster analysis, the EU countries were divided into eight groups which have similar indicators. Discriminant analysis was used to determine the validity of the results and the conclusion is that all countries were correctly classified.

The relationship between "Electricity Generated from Renewable Sources" and "Per-Capita Carbon Dioxide (CO_2) Emissions" shows a negative result which supports evidence for the role of RE in the society. RE sources contribute to reducing total global carbon dioxide emissions which has an enormous impact on the wellbeing of humanity. These sources continue to play an important role in some EU countries and RE investment continues to increase. Electricity production potential from renewable sources has been increasing. Many countries focus on achieving 20% of their overall energy consumption generated by REs by 2020. Evidence that steps are being taken to meet the targets can be shown up by the rise in the share of energy generated from renewable sources.

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