

Angelo Leogrande^{1*}^o

*LUM University Giuseppe Degennaro, Casamassima, Bari, Puglia, Italy, EU

^oLUM Enterprise s.r.l., Casamassima, Bari, Puglia, Italy, EU

Energy Productivity in Europe

It increased between 2000 and 2021 by 56.99% on average for the analyzed countries

The indicator measures the quantity of output produced per unit of energy available gross. The gross available energy represents the amount of energy products necessary to satisfy the demand on a geographical level. The variable is calculated as Euro per kilogram of equivalent oil.

Ranking of countries for energy productivity value in 2021. Ireland is in the first place for energy productivity value with a value of 24.45 euros per kilogram of equivalent oil, followed by Denmark with an amount of 16.89, and Luxembourg with a value of 12.82. In the middle of the standings there are Slovenia with 6.78, followed by Belgium with a value of 6.47, and by Croatia with an amount of 6.13 euros. Serbia closes the ranking with an amount of 2.49, followed by Bulgaria with a value of 2.47, and from Iceland with an amount of 2.23.

Ranking of countries by the value of the percentage variation of energy productivity between 2000 and 2021. Ireland is in first place for the value of the percentage variation of energy productivity between 2000 and 2021 with a value of 180.39 % equal to an amount of 15.73 euros, followed by Romania with a value of 131.60% equal to an amount of 3.04 units, and from Lithuania with a value of 108.13% equal to a value of 2, 66 units. In the middle of the standings there are Sweden with an amount of 52.28% equal to a value of 3.21 units, followed by Hungary with a value of 51.88% equal to an amount of 1.66 units, followed by Luxembourg with a value of 47.87% equal to an amount of 4.15 units. Italy closes the ranking with an amount of 14.32% equal to an amount of 1.27 units, followed by Austria with a value of 11.51% equal to an amount of 1.00 units, followed by Iceland with a value of -5.11% equal to an amount of -0.12 units. Between 2000 and 2021 the value of energy productivity is a value of 56.99% equal to an amount of 2.59 units.

Clusterization with k-Means algorithm optimized with silhouette coefficient. Below is a clusterization with k-Means algorithm optimized with the silhouette coefficient. Two Clusters are identified or:

- Cluster 1: Czech Republic, Poland, Lithuania, Hungary, Malta, Estonia, Slovakia, Romania, Northern Macedonia, Latvia, Serbia, Bulgaria, Iceland, Croatia, Slovenia, Finland, Belgium;
- Cluster 2: Italy, Austria, Luxembourg, Norway, Germany, France, Spain, Denmark, Sweden, Ireland, Portugal, the Netherlands, Greece, Cyprus.

From the median point of view, it appears that the value of the 2-C2 cluster is higher than the value of the 1-C1 or C2 = 9.52 > C1 = 4.86 value. From a strictly geographical point of view, we can see that the western Europe cluster is higher than the value of Eastern Europe.

¹Professor of Economics at LUM University Giuseppe Degennaro and Researcher at LUM Enterprise s.r.l. Email: leogrande.cultore@lum.it, Strada Statale 100 km 18, Casamassima, Bari, Puglia, Italia.

Network analysis with the Euclidean distance. A cluster analysis is made below optimized through the use of the Euclidean distance. Three simplified network structures are identified and two complex network structures. There is the following complex network structure or:

- The Czech Republic has a connection with Poland with an amount of 0.15 units;
- Poland has a connection with the Czech Republic with an amount equal to 0.15 units, with Slovakia for an amount of 0.4 units, with Romania equal to an amount of 0.38 and with Lithuania with a value of 0.4 units;
- Slovakia has a connection with Poland for an amount of 0.4 units, with Romania for an amount of 0.22 units, and with Lithuania with a value of 0.28 units;
- Romania has a connection with Slovakia for an amount of 0.22 units, with Lithuania for an amount of 0.29 units and with Poland for an amount of 0.38 units;
- Lithuania has a connection with Poland for an amount of 0.4 units, with Slovakia for an amount of 0.38 units and with Romania for an amount of 0.29 units.

There is the following complex network structure or:

- Finland has a connection with Slovenia for a value of 0.42 units, and with Croatia for an amount of 0.42 units;
- Croatia has a connection with Finland for an amount of 0.42 units, and with Slovenia for a value of 0.21 units;
- Slovenia has a connection with Croatia for an amount of 0.21 units and with Finland for an amount of 0.42 units.

In addition, there are the following structures with simplified networks or:

- Hungary and Latvia have a connection for a value of 0.3 units;
- Serbia and Bulgaria have a connection for a value of 0.1 units;
- France and Spain have a connection for a value of 0.2 units.

Conclusions. The value of energy production in Europe between 2000 and 2021 has grown on average for the European countries of an amount of 56.99%. This trend means that the ability to generate added value in euros has increased by maximizing the energy output. Obviously, this ability is higher for western European countries compared to the corresponding values of Eastern Europe for motivations that are connected to the ability of production and industrial systems to be efficient in the sense of the optimization of energy. It is necessary to invest in new technologies that allow to increase the surrender of the energy produced to meet the needs of environmental sustainability. The investment in research and development could increase the probability of finding new forms of industrial production that work at low energy consumption or to introduce new sources of energy that are able to increase the value of the energy output.

Declarations

Data Availability Statement. The data presented in this study are available on request from the corresponding author.

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Declaration of Competing Interest. The author declares that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication.

Software. The authors have used the following software: Gretl for the econometric models, Orange for clusterization and network analysis, and KNIME for machine learning and predictions. They are all free version without licenses.

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Appendix













