Energy-Intensive Industries - A Brief Overview of Milestones Supported by Diversity Index Data

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The production and consumption of energy is, in general, one of the main characteristics of technical development of a given economy. As the energy losses are defined as the ratio of energy produced and energy provided into the system, then it holds that the process of fewer transformations is the more efficient one. The mentioned physical law is valid for the process that is production, foremost in Energy-intensive industries (EII), e.g. construction, paper or chemical sector. The energy supply diversity index (based on the Herfindahl-Hirschman index principle) will be used to demonstrate the industry situation in countries in the European Union (EU). The comparison of milestones in changes of EII among EU countries allows us to observe that investment into sources and networks are governed by state regulation and natural facts (rivers, windy or sunny position of land) and not only by the market. Therefore, the mix of sources is imbalanced and has possible strategic and system risks for the future.

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1 Introduction

The energy strategy of any country or larger area or region plays a central role in the life of future generations. Decisions and activities that are made in the energy domain are long-term and overlap several generations. In the economy, there is an assumption of generation co-existence which is 21 years. Therefore, it is appropriate in this paper to use the thirty-year time frame to observe a change in the structure of sources in energy-intensive industries.

A coherent synthesis for energy consumption and efficiency for Shaanxi (205.000 square kilometres) province was published in PloS one (Yin, 2023). The author used, apart from other methods, the Shannon-Weiner (SWI) diversity index to calculate the diversity of the primary energy supply. While SWI is a logarithmic function, a similar index called Herfindahl-Hirschmann (HHI) is a quadratic function. The latter was used for the calculation of available data (Eurostat, 2024), most probably because it has an upper limit and allows comparison.

The Eurostat data are examined in line with criteria that are explained in section two of this paper, i.e., a literature review and following sections are devoted to methods. The main body of the paper is a presentation of the data analysis on energy-intensive industries (EII) in Europe. This way the paper makes a connection with the aforementioned paper, being aware that this analysis of EII is modest in comparison to the aforementioned paper. As Rubio-Varas and Muoz-Delgado (2019) stated, the energy intensity of China has declined. This could be a role model for the European Union (EU).

2 Theoretical Background / Literature Review

The importance of the diversity index in the context of energy is in the security of the country's inhabitants. Most of the demand (in general) is linked to the energy that has to be supplied. The greater the variety of sources or energy portfolio, the more secure the country is in respect of self-sufficiency. (De Rosa et al., 2022). The variation of source mix is not obvious if the observation is done on the scale of the EU as a whole standalone entity. Therefore, it makes sense to observe the diversity index from the regional point of view, and here the region is each European country. We may consider the question of how much the index converges within the EU

regions and, in this way, harmonizes the whole area. Specifically, the paper focuses only on energy-intensive industries, as these influence the consumption side of the energy balance.

The criteria for selection of industries were four pillars of modern society, i.e., cement, plastics, steel, and ammonia (Smil, 2025). Similar criteria are applied in the work of (Bähr et al., 2023). Thereupon we look at the construction industry/sector, paper pulp and printing industry, and chemical and petrochemical industry.

3 Methodology

The concept of diversity index comes from evolutionary and biological studies, where it is used to measure the structure of communities. In recent years, it has been introduced to measure the diverse structure of the energy sources used in a given area. Using data in energy balances, the index gives a value between 0 and 1. The lower the value, the better, because the variation of energy sources is greater. It is based on the Herfindahl-Hirschman index, which is a measure of competitive markets, and its value of 0.1 - 0.18 (Lopes Ferreira et al., 2011) is considered such one. Shares of items in the index are weighted by themselves. A certain issue of the index is that it is not a mathematical distance, therefore, the conclusions in comparing the results are difficult to make (Triguero-Ruiz et al., 2023). The authors suggest a new way to calculate the index, which will be discussed after the analysis.

The analysis has examined the HHI and additional sources of data from Eurostat, i.e., energy balances (EU Commission, DG Energy, Unit A4, 2024). From energy balances, the details specific to countries were searched so that the explanation of the milestones in the EII was possible.

4 Results

A general milestone for all countries was a transition from natural energy sources such as muscle, wood, and water to still natural but nonrenewable resources such as coal, oil, and gas (Gales et al., 2007). This transition was in each country related to the introduction of modern technologies. Although the excavation of coal and its burning was slightly overlapping the two eras. The coal age was in progress sooner in countries where taking advantage of peat was more common (the Netherlands,

for instance). Sweden is an example of use of thermal energy. By applying the technology of thermal energy storage, the country decreases its consumption (Sundarrajan et al., 2025). The pulp and paper industry is dependent on biofuels and electricity in Sweden.

Typical energy diversification started after the oil crisis in the 1970s, which could be considered another milestone that also influenced the industries development. The industry may grow more easily under the condition that the energy supply is uninterrupted and affordable.

Graph 1 illustrates the situation in EU countries.

- In 2022 was Malta heavily dependent on sources in the paper, pulp and printing industry, with the energy mix index reaching the value of 0.8016. The best energy mix was to achieve Hungary with 0.1951. Concerning the chemical and petrochemical industry, the best situation was in Bulgaria (0.1607) and the worst measure reached 0.6609 in Luxemburg. In the construction industry, three countries with similar diversity indexes are noticeable, i.e. 0.7951 and 0.7422 and 0.7005 for Croatia, Finland and Malta, respectively. The best situation was in Poland, 0.1703. Based on these results, we would conclude that most of the markets are concentrated. The closest to competitive markets are the following: Bulgaria, Hungary, and Poland (in alphabetical order).
- In 1992 the values for Malta were not at disposal, and so it is for Luxemburg in the pulp industry; this explains why it was substituted with zero value in the graph. The special case is Cyprus, which reached the value of 1 in all three industries. This country is dependent on oil supplies, which is supported by evidence (EU Commission, DG Energy, Unit A4, 2024). Sweden in the construction industry is also close to one, that is, 0.988. Greece is a similar region with 0.815 for the construction industry.

One can notice significant differences in thirty years of changes in adjusting the market of energy in energy-demanding sectors and industries. The largest increase in concentration was achieved in the construction sector in Denmark (difference of 0.26890). The minimum changes were again in the construction industry but in Sweden (difference of minus 0.6700).

The effect of inter-European energy exchange helps some countries increase the variation of their sources. This is not the case in Malta, as observed in the analysis. Our results are in line with De Rosa, Gainsford, Pallonetto, and Finn (2022), who claim that Malta has the greatest energy market concentration.

5 Discussion

The importance of the concentration index was proven in the study of EU countries in the period 1800 – 2010. The authors (Rubio-Varas & Muñoz-Delgado, 2019) showed the clusters of countries where firewood was dominant (Italy, Portugal, Sweden, and Spain) or coal dominant (Netherlands, Germany, United Kingdom and France). Each study has its limitations. The cluster analysis did not provide the observation of industries and their use of energy, as well as this study of industries did not provide the groups of countries that have a common strategy in energy use or a common feature.

Improvements in energy market analysis (be it factor analysis, descriptive statistics, or any other analytical tools) and development are possible. Suggested improvements are in the methods used to study diversity.

As the index anonymises the mix of energy sources, it is not possible to provide a better picture of the situation. The limitation can be overcome in other papers. This paper leaves the question open if there is a tool that allows us to avoid the problem of comparison by using another method instead, i.e. community dynamics metrics (codyn), where we only select the mean rank shifts. The diversity index, the number shows us the static situation. It is possible to capture the dynamics of the process of changes and substituting one source with another, such as coal energy power changed for solar. This means that a given area or country is introducing legal instruments that encourage the behaviour of inhabitants to use solar panels more frequently on the roof of their houses, despite the fact of somewhat higher initial costs and risks of taking care of all the types of equipment. Trying to look for the dynamics of this process, one can consider applying the codyn method and its function called rank shifts (Hallett et al., 2016).

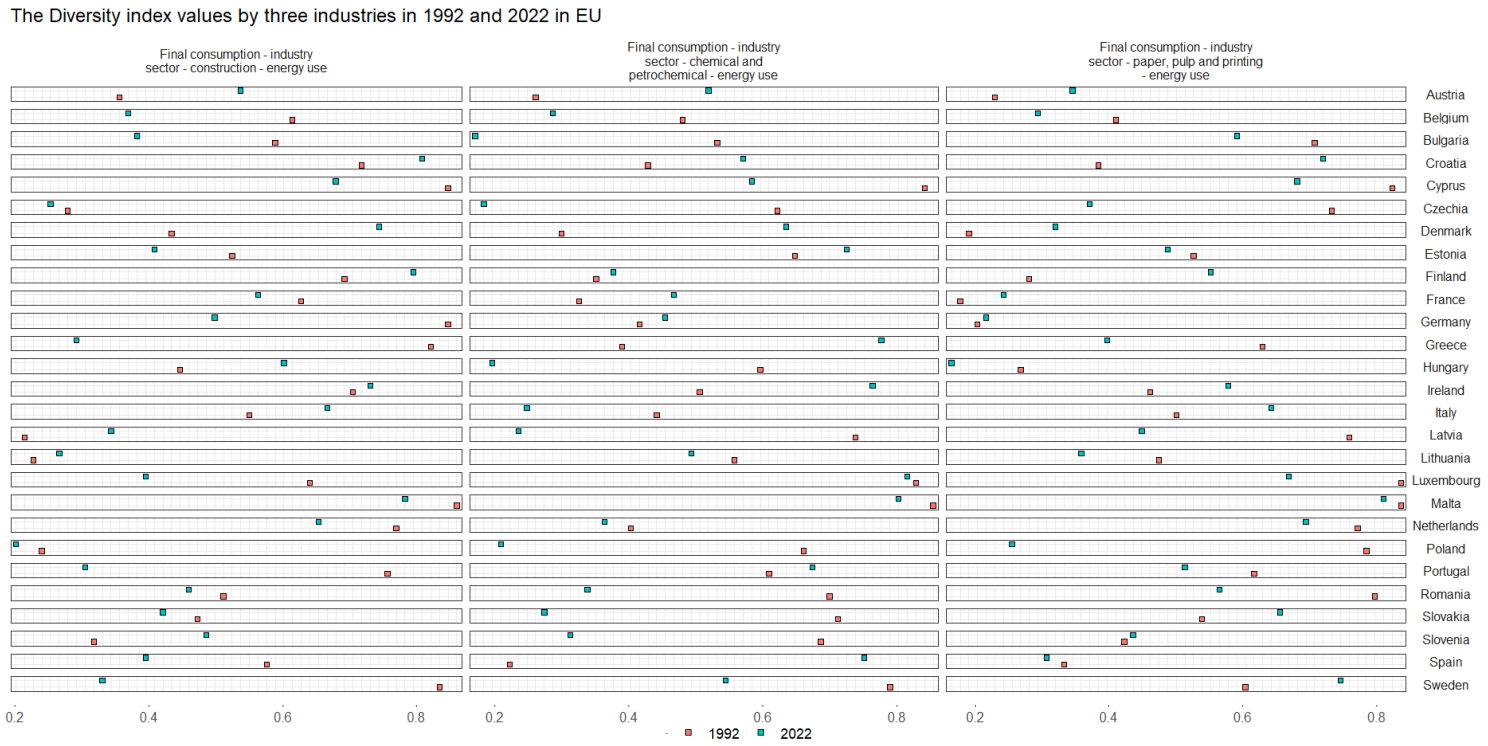

Figure 1: Comparison among industries and their use of energy

Source: Eurostat (2024), own processing

Note to Figure 1: Four observations were not available: Malta for the year 1992 all industries and Luxemburg in 1992 only for the paper, pulp, and printing industry. For obtaining the figure, the value zero was used.

6 Conclusions

The scarce resources that are employed in energy production are handled with a special focus on reducing carbon emissions. However, the political situation and pragmatic solutions to market imbalance or shortage make it difficult to shut off all coal power plants at once. The fastest phase-out of coal power is in Greece and the United Kingdom according to the World Institute of Resources (Jaeger, 2023). The Critical Raw Materials Act (European Critical Raw Materials Act - European Commission, 2023) emphasizes the diversification of suppliers of materials; however, cooperation on preventing climate change is based on overall contributors.

'The measurement of the power of all agents and consideration of the seven questions', writes Vojta (2025, p. 31) in his book on business strategy that is focused on Mister Sun tactics and strategies. In this measurement of power and in the questions, the idea of technical capacity as well as understanding the program, its acceptance, and most importantly belief is included. Concerning technical capacity and measurement, the paper and statistics presented have done humble but decent work. For the program itself, it can be considered as one piece of information to help better adjust the existing program. Regarding the belief, it might be assumed that we believe more easily in programs and strategies that are based on data, showing us what changes can happen in thirty years in industries that are quite complex in their technical processes.

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