

# Dependence of public health on energy consumption: a cross-regional analysis

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**Abstract.** The authors test the hypothesis that there is a link between the consumption of non-renewable resources of the leading economies in the European region in terms of value-added industry and health. They performed a ranking correlation analysis on key indicators of population health and volumes of consumption of renewable and non-renewable resources in individual countries. The researchers assumed a slight relationship between the rate of healthy years of life and the production of renewable energy resources, making a positive contribution to the country's environmental situation. Among the compared countries, those characterized by high consumption of primary energy resources are proportionally more productive and renewable energy resources. The analysis shows that differences in the health indicators of the regions' population cause other more important factors than the studied ones. Some dependencies can be seen in analyzing the causes of death among the population of countries, for example, by cardiovascular diseases. The risk factor for this illness is air pollution caused by excessive consumption of non-renewable energy resources. The authors recommend considering the indicator of ecological footprint in the ratings of life quality in the regions. Compared to countries with lower welfare rankings, this parameter is too high for leaders. Under investigation, the authors considered the x3 weight for the health indicator in the Legatum Prosperity Index.

## 1 Introduction

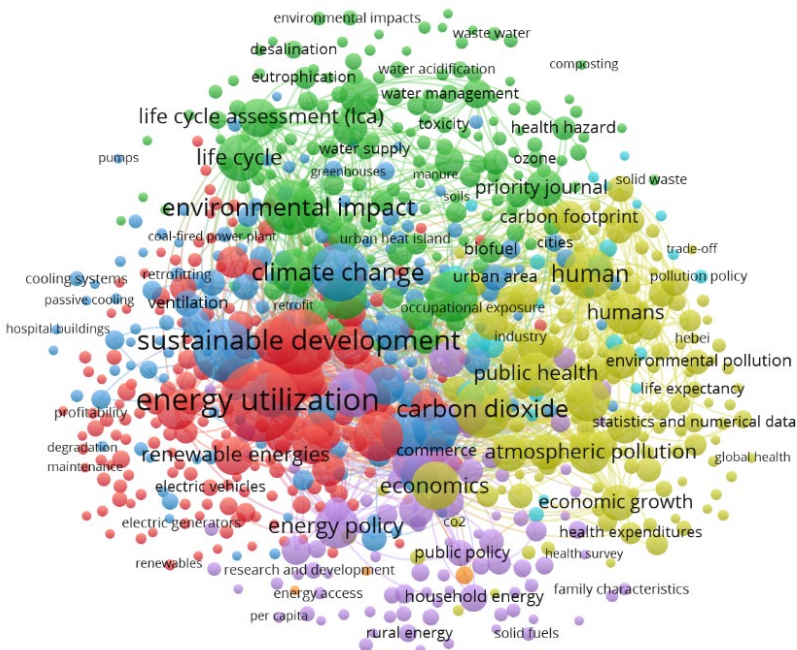
Health is an integral indicator of the success of the development of the world community. It is an inalienable right of every human being and an essential component of well-being. Under the current conditions of the COVID-19 pandemic, humanity needs to provide an uninterrupted power supply as never before. After all, the enormous efforts of medical personnel worldwide depend on electrical equipment, which is vital to enable people to overcome the disease. Achieving high-quality public health is possible by eliminating risk

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factors. Risk factors create a negative background that contributes to disease. The risk factor is environmental pollution. The unity and struggle of opposites in the context of public health determines the use of energy resources – non-renewable and renewable sources, which ultimately determines the state of a particular region's environment. When to increase the effectiveness of sustainable development policy, there is a complex dilemma when society needs to spend a significant amount of energy resources on maintaining a decent standard of living in the country. Simultaneously, to preserve the environment, it is appropriate to limit the consumption of energy resources as much as possible. A comparison of existing approaches to assessing the quality of life of the population of a particular region showed that the set of parameters of the country's ecological state and public health considers the method of calculating The Legatum Prosperity Index. Such standard methods of assessing the quality of life as the Human Development Index and the International Happiness Index do not consider the energy factor.

Bibliometric analysis [1, 2] showed a significant interest in the research question. The review of 1211 publications from the Scopus database (1992–2020) was conducted. Three combinations of words with the logical operator ("health" AND "renewable energy" AND "energy consumptions") were used. The "title, abstract, keywords" field of search in the Scopus database was done. The visualization of the results was made using VOSviewer program to graphically map the material. The Scopus screening tools showed that in 2009 the number of articles that focused on public health and energy consumption began to increase. Using the VOS viewer program were identified the main 7 clusters of the scientific papers (Fig. 1).



**Fig. 1.** The results of network relationships analysis of the key categories in scientific publications on (composed by the authors using VOSviewer 1.6.16)

Thus, the analysis showed the existence of the four most important conditional clusters related to the categories "energy utilization", "environmental impact", "carbon dioxide". The first (red) cluster "energy utilization" (occurrences – 299, total link strength – 3834) includes such basic concepts: "sustainable development", "health", "renewable energy", "health risks",

"fossil fuels". Second (green) cluster "environmental impact" (occurrences – 147, total link strength – 2158) includes such basic concepts: "energy consumption", "life cycle assessment", "life cycle", "life cycle analysis". The third main (blue) cluster "energy efficiency" (occurrences – 180, total link strength – 2175) includes such basic concepts: "climate change", "energy use", "air quality", "indoor air pollution". Yellow cluster "carbon dioxide" (occurrences – 162, total link strength – 2691) includes such basic concepts: "human", "air pollution", "economics", atmospheric pollution".

The analysis results show the closeness of the concepts of "health", "environment", "energy", "pollution", "life cycle", "economy", which once again confirms the relationship between the use of renewable or non-renewable energy resources and the environment, life expectancy, as well as the overall development of the country's economy, which is also associated with available resources and human health characteristics.

On the international level, the investigated area was represented by the next countries: China, United Kingdom, the United States, India, Pakistan, Italy [3–6].

Among Ukrainian scientists [7–13], issues of environmental, economic, energy and social security are also widely studied. In [14–18] the main aspects of environmental, communication management are identified, the analysis of marketing tools that serve as a tool for interaction with energy consumers and other participants in the energy market and health care. Researchers [19–27] actively analyze the issues of public administration, instruments of influence on the region's development, the country's development, provide key parameters of the country's development and the main factors of influence, ecologic startups. Innovations in the energy market, the relationship between renewable energy and energy efficiency, the state of smart grids implementation and the role of stakeholders in this process, including cross-regional, are discussed in the following studies [28–30]. The authors [31–38] also consider the relationship between the effects of the COVID-19 pandemic and public health and economic growth, the reasons for the differentiation of morbidity in the regional context, search for factors of economic vulnerability. The authors [39–40] consider energy management from the standpoint of efficiency in the field of green investment

The study aims to determine the dependence of public health on the growth of consumption of such energy resources as renewable instead of non-renewable energy resources in different national economies and determine the environmental impact of different world regions.

## **2 Materials and methods**

The authors used the European structural indicator Healthy life years expectancy (HALE) (the number of years that a person will continue to live in a healthy condition) as the initial comparable public health level parameter. In other words, it is the number of healthy years that a newborn will live in the country, taking into account the disease. Besides, they included Disability-adjusted life year (DALY) as an indicator of lost years of life due to disease. One point of this indicator is equal to one lost year of a person's life. During the correlation analysis, the relationship between these indicators will be inversely proportional.

Comparative research (to compare the characteristics of national economies in the investigated field) and mathematical statistics (correlation analysis using the software Statistica 10 Version) were used. The basis of the study is national data and data of international organizations on the measured indicators.

The authors formed several hypotheses of the study:

H1: The DALY indicator is higher and the HALE indicator is lower in the regions with significant non-renewable energy consumption.

H2: Countries with higher non-renewable energy resources tend to have proportionally higher values of renewable energy production.

H3: The economies of higher welfare countries leave a larger ecological footprint than countries with lower welfare rates.

The researchers performed several iterations to confirm or refute them.

### 3 Empirical model

To check the absence of a statistically significant correlation between the analyzed parameters, the authors check the formula:

$$H : \tau_{kj}^S = 0. \tag{1}$$

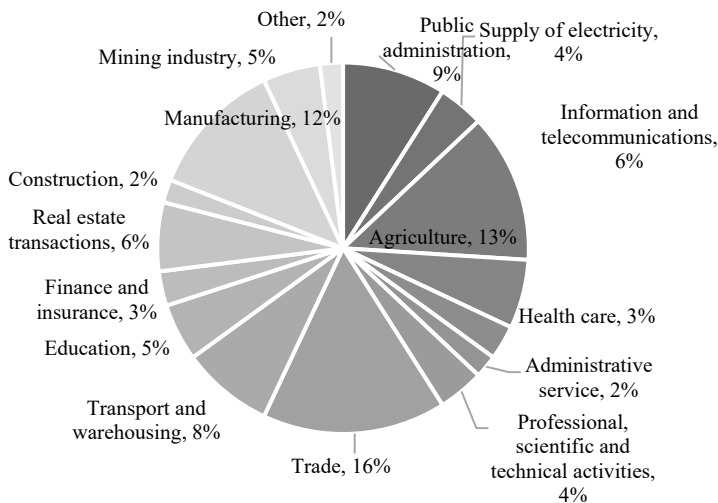
The proof is accepted at the level of significance  $\alpha$ , if:

$$t = \frac{\hat{\tau}_{kj}^S}{\sqrt{1 - (\hat{\tau}_{kj}^S)^2}} \sqrt{n - 2} < t_{\gamma, f}, \tag{2}$$

where  $t_{\gamma, f}$  – threshold value of the Student's distribution with parameters  $\gamma = 1 - \alpha/2$ ,  $f = n - 2$ . Otherwise, the evidence is not confirmed.

### 4 Results and discussions

An essential indicator of the competitiveness of the national economy is GDP. Capital Times [41], a finance and investment consultant, analyzed the structure of Ukraine's GDP in the dynamics in terms of economic sectors with projected values for 2022. The processing industry is one of the most energy-intensive sectors of Ukraine's economy. According to the forecasts of the Capital Times, a high share of the processing industry will remain. Figure 2 shows the contribution of sectors to GDP by 2022.



**Fig. 2.** Forecast structure of Ukraine's GDP until 2022 (developed using [41])

Ukraine has a high energy intensity of GDP, which indicates the need for significant reforms to reduce energy consumption. One of the effective ways to replace primary energy resources is their gradual partial replacement with renewable energy sources. The authors decided to compare Ukraine with the European region countries, in which production also plays a significant role in the economy. Table 1 demonstrates the results of analyzing indicators of the manufacturing sector of the European region.

**Table 1.** Key indicators of manufacturing of the countries of the European region in 2017 (formed using [42])

Country	Number of enterprises	Number of persons employed	Turnover	Value added
	thousands		EUR million	
Germany	190.5	7,409.6	2,193,357.5	592,027.2
Italy	383.6	3,744.3	965,031	241,413.9
France	197.7	3,103.6	1,021,247.9	240,268.1
Spain	168.7	1917.7	505,350.9	110,841.4
United Kingdom	136.7	2,556.4	700,030.8	102,841
Ireland	16.7	219.8	226,192.9	97,262.2
Netherlands	66.7	698.5	345,979.9	70,850.4
Switzerland	20.1	656.7	298,061.2	57,276.1
Belgium	36.8	500.8	267,652.4	56,092.4
Czech Republic	175.9	1319.4	178,105.9	39,930.5
Austria	25.5	638.6	191,203.9	35,641.8
Denmark	15.3	310.4	115,938.8	35,623.4
Sweden	53.7	610.2	213,355.3	35,480.7
Poland	198.8	2,654.8	321,925.9	34,119.7
Hungary	50.8	757.8	109,581.7	24,176
Finland	20.2	332.9	123,675.7	16,890.3
Norway	17.0	221.9	85,695	14,658.6
Portugal	67.6	711.7	90,310.8	12,402.2
Romania	49.8	1,215.9	83,852.6	11,707.5
Greece	57.4	320.5	54,119.8	11,521.2
Slovakia	72.6	501.3	76,382.2	7,900.2
Bulgaria	31.3	556.1	33,370.8	7,767.2
Croatia	19.5	268.7	21,497.5	6,126.4
Slovenia	19.4	204.9	29,353	4,940.2
Lithuania	20.3	216.5	20,257.7	4,552.7
Luxemburg	0.8	34.1	13,703	3,125.2
Estonia	7.5	110.1	12,474.7	3,018.2
Latvia	10.9	119.5	8,409	2,333.9
Cyprus	5.0	31.9	3,411.4	1,077.6
Iceland	2.1	22.8	6,566.6	1,552.4

The authors sorted the analyzed countries by value added of the sphere of production in the economy and singled out countries with the most significant manufacturing industry contribution. These countries are Germany, Italy, France, Spain, United Kingdom, Ireland, Netherlands, Switzerland, Belgium, Czech Republic. Then it is appropriate to compare some countries with Ukraine in terms of research parameters to confirm or refute the author's hypotheses (Table 2).

**Table 2.** Researched indicators by country in 2019 (formed using [43–46])

Country	Primary energy Supply (non-renewable), ktoe	DALY, Years	Renewable energy generation, GWh	Healthy life years, years
Germany	235,833	20,075	199,889	69.5
Italy	116,269	18,648	97,464	71
France	114,736	18,782	108,142	71.2
Spain	87,673	17,086	97,438	71.3
United Kingdom	132,694	20,957	84,526	68.9
Ireland	11,784	10,755	10,553	70.1
Netherlands	63,733	18,888	16,667	70.4
Switzerland	11,571	17,635	43,073	71.7
Belgium	38,866	20,170	14,673	69.5
Czech Republic	30,839	21	6,161	68.5
Ukraine	67,033	34,975	10,225	61.7

The correlation analysis results (Table 3) show that the relationship between the variables on the consumption of renewable and non-renewable energy resources is statistically significant. That is, highly energy-intensive countries tend to consume more of both types of resources. It is essential that, in the long run, renewable energy resources predominate in such regions' energy consumption [47]. One can hypothesize a link between healthy life expectancy and renewable energy production in a country (the higher the production, the potentially better the state of the environment, and naturally, the population's state of health).

**Table 3.** The results of correlation analysis of the initial parameters of the study

Spearman Rank Order Correlations (Spreadsheet1) MD pairwise deleted Marked correlations are significant at $p < 0,05000$				
	Primary energy supply	DALY	Renewable energy generation	HALE
Primary energy supply	1,000000	0,218182	0,727273	-0,132119
DALY	0,218182	1,000000	-0,354545	-0,842827
Renewable energy generation	0,727273	-0,354545	1,000000	0,523919
HALE	-0,132119	-0,842827	0,523919	1,000000

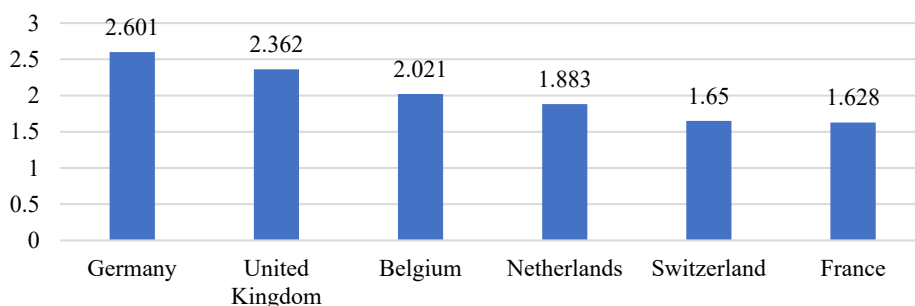
Figure 3 shows the results of the calculation to test this assumption. The figure proves that a significant relationship between these parameters did not come true ( $p$ -value in the pair Renewable energy generation & HALE is less than the accepted norm of 0.05).

The authors assumed that the dependencies would be in the case of structural analysis of the causes of reduced years of healthy life due to various diseases, in particular, due to cardiovascular diseases, which are significant due to possible adverse effects of the adverse environment (Fig. 3).

For countries with significant consumption of non-renewable energy resources (Germany, United Kingdom), the DALY indicator for this type of disease is higher than countries where these energy resources' consumption is low.

Spearman Rank Order Correlations (Spreadsheet1)				
MD pairwise deleted				
Marked correlations are significant at $p < .05000$				
Pair of Variables	Valid N	Spearman R	t(N-2)	p-value
Primary energy supply & Primary energy supply				
Primary energy supply & DALY	11	0,218182	0,67070	0,519248
Primary energy supply & Renewable energy generation	11	<b>0,727273</b>	<b>3,17888</b>	<b>0,011205</b>
Primary energy supply & HALE	11	-0,132119	-0,39986	0,698582
DALY & Primary energy supply	11	0,218182	0,67070	0,519248
DALY & DALY				
DALY & Renewable energy generation	11	-0,354545	-1,13753	0,284693
DALY & HALE	11	<b>-0,842827</b>	<b>-4,69816</b>	<b>0,001123</b>
Renewable energy generation & Primary energy supply	11	<b>0,727273</b>	<b>3,17888</b>	<b>0,011205</b>
Renewable energy generation & DALY	11	-0,354545	-1,13753	0,284693
Renewable energy generation & Renewable energy generation				
Renewable energy generation & HALE	11	0,523919	1,84529	0,098083
HALE & Primary energy supply	11	-0,132119	-0,39986	0,698582
HALE & DALY	11	<b>-0,842827</b>	<b>-4,69816</b>	<b>0,001123</b>
HALE & Renewable energy generation	11	0,523919	1,84529	0,098083
HALE & HALE				

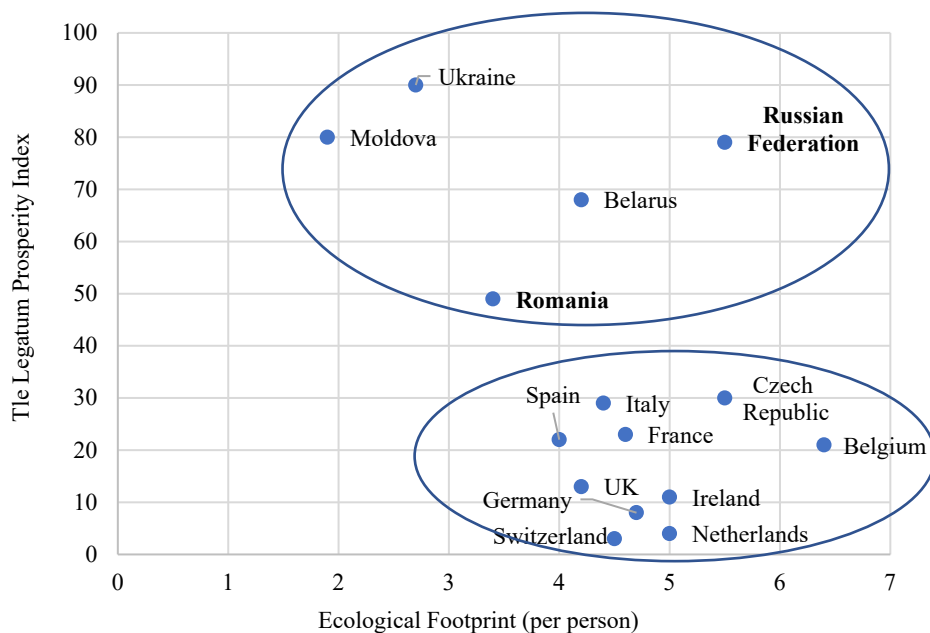
**Fig.3.** In-depth analysis of comparable indicators by the p-value criterion



**Fig. 4.** Add rate of DALY due to cardiovascular diseases, per 100,000 population in 2019 (based on [46])

Another comparison of two parameters will help formulate a vision on energy consumption, environmental conditions and regional indicators of quality of life. Figure 5 demonstrates the map of the ratio of the leading countries' positions in the ranking of The Legatum Prosperity Index and countries at the lower levels of the rank. The pairwise construction of the map is relative to the second important indicator – Ecological Footprint. The welfare ranking has manually removed environmental indicators and added x3 weight to the region's health component.

The map shows that the Legatum Prosperity Index's best positions do not mean that the country is frugal in consumer products, including energy, and careful in waste management. The authors suggest paying more attention to the indicators of lean energy consumption, particularly the use of renewable energy sources. The future in the direction of development of the region in a healthy vector includes such ratings of human development ecological footprint.



**Fig. 5.** Map comparing countries in The Legatum Prosperity Index with the national ecological footprint (built using [48–49])

## 5 Conclusions

The hypotheses of the authors after the study were partially confirmed. The hypothesis of DALY and HALE indicators' dependence is directly proportional and inversely proportional, respectively, was not confirmed. The results refuted the hypothesis about a relationship. However, the researchers confirmed the hypothesis that countries with higher rates of non-renewable energy use are also producers of higher amounts of renewable energy sources. It is due to the need for production capacity and economies' focus on achieving sustainable development goals. A comparative analysis has not confirmed that countries with higher welfare have a smaller environmental footprint worldwide. The authors proposed to thoroughly approach the assessment in the framework of human development ratings considering the environmental impact parameters from excessive consumption of non-renewable resources. Prospects for further research are the search for a neutral index that will consider both those indicators that already exist in calculating the quality of life and welfare of the population of individual regions and those that indicate positive changes in society in promoting renewable energy sources.

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