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Determinants Of Energy Consumption In The European Union In 2022-2023

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Abstract

This study analyzes the effect of GDP per capita, electricity price, urbanization rate, and average temperature on energy consumption in 27 EU countries in 2022-2023, a time of energy crisis due to global geopolitical tensions. Energy consumption is defined as the total energy used for economic and household activities, measured in kilograms of oil equivalent (KGOE). Using panel data regression with Random Effect Model approach, the results show that GDP per capita and average temperature have a significant effect on energy consumption, where GDP increases and temperature decreases consumption. Electricity price also has a significant negative effect, reflecting the drive for energy efficiency, while urbanization is not significant. The R^2 value of 0.548491 indicates that the model is able to explain 54.85% of the variation in energy consumption, confirming the relevance of economic and climatic factors to energy dynamics in the region.

Keywords: Energy Consumption, GDP, Average Temperature, Electricity Prices, EU Energy Crisis.

INTRODUCTION

Energy is a key pillar of the global economy, supporting industry, transportation and basic human needs (Smil, 2017). Dependence on fossil fuels makes energy systems vulnerable to price fluctuations, conflicts, embargoes and pandemics, which can trigger energy crises and hamper economic recovery (Smal & Wieprow, 2023; Zhang et al., 2023). The energy crisis has again become a major issue with supply disruptions, price spikes and the unpreparedness of the energy system to cope with growing demand

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(Yergin, 2023). The crisis is triggered by interstate conflicts, natural disasters, and unsynchronized energy transition policies (Sovacool et al., 2020), as well as geopolitical pressures such as Russia's invasion of Ukraine that affect global energy supply (IEA, 2023b).

The energy crisis exacerbated energy poverty in the EU, with 9.3% of the population affected in 2022, particularly in Bulgaria, Lithuania and Greece (European Regions Research and Innovation Network, 2024; Slutins et al., 2025). Income inequality exacerbates the burden on low-income households who have to allocate more to energy (Simionescu, 2025). Countries' fiscal responses vary, with the UK providing broad subsidies and Germany preferring targeted transfers (CEPR, 2025). Electricity price spikes occurred in Belgium, the Netherlands and Italy, with significant regressive impacts (IEEP, 2023). On the other hand, extreme climate impacts, such as heat waves that caused more than 61,600 deaths in 2022, exacerbated the situation (Ballester et al., 2023; WMO, 2014), encouraging a faster energy transition despite infrastructure and affordability challenges (World Economic Forum, 2023).

The energy crisis triggered by the Russia-Ukraine conflict hampered the energy transition, especially in the European Union, which, despite being a pioneer of decarbonization, was forced to fall back on conventional energy such as coal to maintain domestic energy security. An 80% drop in Russian gas exports to Europe after the invasion contributed to supply disruptions and price spikes (Azmi et al., 2024; Nurhidayat Mahmuddin & Agussalim Burhanuddin, 2024). Countries such as Germany and Italy faced huge pressure from energy supply disruptions, which affected economic growth and inflation (Logayah et al., 2023).Energy consumption patterns in Europe vary widely, reflecting each country's adaptability to global energy pressures. High-income countries with better access to technology are generally more efficient and predominantly use renewable energy (Khairunnisa, 2017). In Western Europe, the high intensity of energy consumption reflects dense industrial and transportation activities. This makes it difficult for other countries to catch up (OECD, 2023).

Income disparities also affect access to and consumption of energy, especially electricity, which is a key household need. Urbanization exacerbates this, as large cities become hubs for electricity use, transport fuels, and heating and cooling systems. In a global energy crisis exacerbated by geopolitical conflicts and a green energy transition, cities' dependence on energy is a strategic issue. Without energy efficiency, urbanization can exacerbate supply pressures, especially during extreme seasons. Temperature

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trends also affect energy consumption. Although not widely analyzed, temperature as an environmental factor has great potential in determining energy consumption patterns.

This study uses the variables GDP per capita (X1), electricity price (X2), urbanization rate (X3), and average annual temperature (X4), which were selected based on their relevance to energy consumption. Previous research indicates a positive relationship between GDP per capita and energy consumption, as found by Aslan et al (2021) in G7 countries. Similar findings were presented by Nazer & Handra (2016) who showed that energy consumption increases with income, land size, and family size. In contrast, Fajarini & Hamzah (2019) found that per capita income does not have a significant effect on energy consumption, suggesting inconsistencies in empirical results.

In addition, electricity price is also shown to be a significant factor affecting energy consumption, as shown by Iryanto & Moeis (2022) in Indonesia and Al-Bajjali & Shamayleh (2018) in Jordan, where an increase in electricity price significantly reduces energy consumption. However, Rosadi & Amar (2019) found that while electricity tariffs have a negative effect on consumption, the effect is not statistically significant. The effect of urbanization on energy consumption also shows variations. Irawan & Hartono (2022) found a negative impact of urbanization on energy intensity in Indonesia, while Dev et al (2024) showed that urbanization has a significant impact on energy consumption in SAARC countries.Finally, average annual temperature also affects energy consumption, especially in temperate countries, where an increase in temperature contributes to a decrease in energy demand for heating (Auffhammer & Aroonruengsawat, 2011; Wenz et al., 2017). This research gap lies in the lack of studies that combine all four variables in the context of the European Union in the period 2022-2023. Therefore, this study titled “Determinants of Energy Consumption in the European Union in 2022-2023: Analysis of the Influence of GDP Per Capita, Electricity Prices, Urbanization Rate and Average Temperature” to fill the gap and examine the influence of the four variables on energy consumption in the European Union.

Objective

This article intends :

1. Analyzing the influence between GDP per capita and energy consumption in EU countries.
2. Analyzing the effect of electricity prices on energy consumption patterns in the European Union.

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3. Analyze the effect of urbanization rate on energy consumption in the European Union.
4. Analyze the effect of annual average temperature on EU energy consumption

LITERATURE RIVIEW

Energy Consumption

According to the official definition of the International Energy Agency (IEA, 2023a) energy consumption refers to the use of energy by final consumers, such as households, the industrial sector, and agriculture. This definition does not include energy used in the internal processes of the energy sector itself, including for electricity generation and distribution purposes. Thus, energy consumption describes the amount of energy that has passed through the production and distribution process, and is then utilized directly by end users without undergoing further energy conversion.

Gross Domestic Product (GDP)

Real Gross Domestic Product (GDP) per capita is an economic indicator that describes the total value of goods and services produced by a country within a certain period of time (usually one year), divided by the population, and corrected for the effects of inflation. This indicator is considered to be more reflective of the level of public welfare than nominal GDP (Mankiw, 2021).

Electricity Price

Electricity price refers to the rate that consumers have to pay for each kilowatt-hours (kWh) of electrical energy consumed from the service provider. In the study of energy economics, this variable is one of the key factors that influence the level of energy demand. In general, demand for electricity is elastic to price fluctuations, especially in the long run (Eurostat, 2023a).

Urbanization Rate

According to Munir (2010) the term urbanization refers to the increase in the population residing in urban areas, either due to population growth itself, the movement of people from villages to cities, or due to the expansion of urban boundaries. According to Kraft & Kraft (1987), increased energy consumption reflects economic growth, which often coincides with urbanization. Urbanization increases the city's population, industrial sector, and households which collectively increase energy demand.

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Annual Average Temperature

Annual average temperature is a statistical measure that shows the average air temperature in a region over a year, usually expressed in degrees Celsius (°C). It plays an important role in environmental, energy and climate change adaptation studies as it reflects the general thermal conditions of a region. According to the World Meteorological Organization (WMO, 2021), this temperature is calculated by summing daily temperature data for one year, then dividing to obtain the average value. This parameter is often used as a reference in climate research, energy demand planning, and climate adaptation strategies.

Theoretical Framework

Energy economics is a branch of natural resource economics that discusses how individuals and groups make decisions in utilizing limited energy resources efficiently and effectively (Yusgiantoro, 2000). Its main focus lies on the allocation of energy resources in the process of production, distribution and consumption, both for current and future needs.

Within the framework of demand theory, which is the main foundation of microeconomics, there is a negative relationship between the price of a commodity and the amount demanded by consumers (Mankiw, 2021). In the context of energy, when the price of electricity or fuel increases, energy consumption tends to decrease, assuming other factors remain constant (ceteris paribus). However, energy is classified as an inelastic good, so price changes do not necessarily lead to significant changes in its demand, especially in the short term.

Furthermore, energy transition theory highlights the importance of shifting from fossil energy use towards clean energy to maintain a balance between economic growth and environmental sustainability. IEA (2023) notes that global energy consumption has continued to increase post-pandemic, with fossil fuels dominating despite renewable energy showing an increasing trend. Therefore, energy consumption not only acts as an indicator of economic activity, but also reflects the extent to which a region or country is able to manage the energy transition to reduce carbon emissions and other environmental impacts.

METHODS

This research uses a quantitative approach with secondary data obtained from official institutions such as Eurostat, International Energy Agency (IEA), World Bank, and

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Climate Knowledge Portal (World Bank). The data is in panel form, which is a combination of cross-section data (27 EU member states) and time-series data (2022-2023). The population in this study is the European Union (EU27) member countries in the period 2022 to 2023. The population collection technique uses judgment sampling, which is purposive selection based on certain criteria that are considered relevant and representative of the research objectives.

In this study the authors used the panel data regression analysis method. Panel data is a combination of cross section data and time series data. Cross section data is data consisting of many objects observed in a period of time while time series data is data on one object observed in several periods of time. In the initial stage, descriptive statistical analysis of the data was carried out, then exploration of three panel data regression models consisting of fixed effect model, random effect model and common effect models. Furthermore, the best model selection is carried out using the chow test, hausman test and Lagrange Multiplier test. The best model selected is carried out classical assumption test and parameter test and the last stage is model interpretation. This research uses the eviews 12 analysis tool.

DISCUSSION

Table 1. Descriptive Data

	KEP (Y)	GDP	HRL	URB	SUHU
Mean	2109.556	35359.91	0233841	74.29389	11.53315
Median	1914.125	28369.11	0.222400	72.70500	11.29500
Maximum	4633.680	109714.9	0.455900	98.19000	20.34000
Minimum	1072.390	9352.327	0.045100	53.91000	3.270000
Std. Dev	748.8683	23593.38	0.091276	12.97459	3.943037
Observations	54	54	54	54	54

Source: Eviews 12 output, 2025

The study uses 54 observations from 27 EU countries over 2022-2023 and shows that energy consumption (Y) has an average of 2109.56 KGOE, with the highest value in Luxembourg due to high cross-border commuting activity and fuel tourism, while Malta records the lowest consumption due to its service-based economic structure and limited energy infrastructure. The average GDP per capita (X1) is €35,359.91, the highest in Luxembourg due to the dominance of the financial services sector and small population,

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and the lowest in Bulgaria; the variable household electricity price (HRL/X2) averages 0.2338 €/kWh, with Denmark recording the highest price due to the energy tax burden and energy transition financing, while the Netherlands has the lowest price.The urbanization rate (URB/X3) averages 74.29%, with Belgium highest due to its dense and decentralized structure of metropolitan areas and Slovakia lowest. The annual average temperature variable (TEMPERATURE/X4) is 11.53°C, with Malta as the hottest country due to its Mediterranean climate and Finland the lowest due to its geographical location in Northern Europe.

Table 2. Chow Test

Redundant Fixed Effects Tests
Equation: Untitled
Test cross-section fixed effects

Effects Test	Statistic	d.f.	Prob.
Cross-section F	116.079351	(26,23)	0.0000
Cross-section Chi-square	263.761284	26	0.0000

Source: Eviews 12 output, 2025

The Chow test results show a statistical F value of 116.079 with a probability of 0.0000, which means it is significant at the 5% level. Thus, the null hypothesis is rejected and the Fixed Effect model is chosen as the most appropriate model for this study than Common EFFect Model.

Table 3. Hausman Test

Correlated Random Effects - Hausman Test
Equation: Untitled
Test cross-section random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	5.702256	4	0.2225

Source: Eviews 12 output, 2025

The Hausman test results show a probability value of 0.2225> 0.05, so the null hypothesis is not rejected and the Random Effect model is more appropriate to use compared to the Fixed Effect model. This indicates that there is no significant correlation between individual effects and independent variables, so the Random Effect model is considered more efficient.

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Table 4. Lagrange Multiplier Test

Lagrange Multiplier Tests for Random Effects
Null hypotheses: No effects
Alternative hypotheses: Two-sided (Breusch-Pagan) and one-sided (all others) alternatives

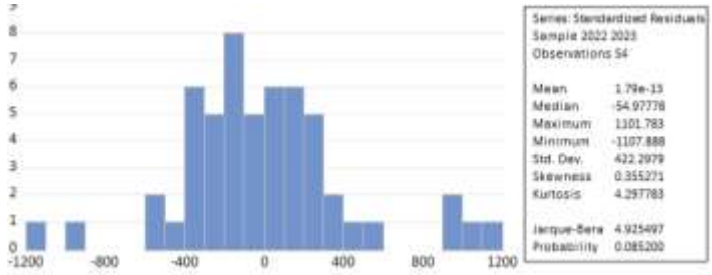
	Test Hypothesis		
	Cross-section	Time	Both
Breusch-Pagan	25.77312 (0.0000)	1.016977 (0.3132)	26.79010 (0.0000)

Source: Eviews 12 output, 2025

Based on the results above, it is known that the probability value for cross-section and both is 0.0000 or smaller than 5% (0.05) significance level. This indicates that there are significant individual effects in the data, so the null hypothesis (H_0) that there are no individual effects is rejected. Thus, the Random Effects model is more appropriate to use than the Common effect model.

Classical Assumption Test

Table 5. Normality Test



Source: Eviews 12 output, 2025

The Jarque-Bera test results show a p-value of 0.0852 > 0.05, so the null hypothesis is not rejected and the model residuals are declared normally distributed. Thus, the assumption of normality in regression is met, supporting the validity of statistical tests in the model.

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Table 6. *Multikolinearitas Test*

	GDP	HRL	URB	SUHU
GDP	1.000000	0.285185	0.434152	-0.166892
HRL	0.285185	1.000000	0.256563	-0.059458
URB	0.434152	0.256563	1.000000	0.038382
SUHU	-0.166892	-0.059458	0.038382	1.000000

Source: Eviews 12 output, 2025

Pearson correlation test results show that there is no multicollinearity between independent variables, all correlation values are < 0.80, so all variables can be used together in the regression model without significant collinearity problems.

Heterokedastisitas Test

To overcome heteroscedasticity in the random effects model (REM), White cross-section standard errors estimation is used. This method remains valid because the REM model has gone through a quasi-time demeaning transformation process, so the estimates remain valid for interpretation. This is in line with the views of Wooldridge (2002) and Millo (2017) who state that this procedure makes REM equivalent to pooled regression, allowing consistent use of the robust White estimator.

The best regression model produced is the Random Effect Model, with the results shown in the following table :

Table 7. Result Random Effect Model Cross Section White

Variable	Coefficient	Std. Error	t-statistic	Prob.
C	2053.463	269.6578	7.615068	0.0000
GDP	0.016951	0.000601	28.18197	0.0000
HRL	-319.5270	11.51892	-27.73931	0.0000
URB	7.543846	8.506697	0.886813	0.3795
SUHU	-89.22317	16.08678	-5.546365	0.0000
	R-squared		0.548491	
	F-statistic		14.88126	
	Prob(F-statistic)		0.000000	

Source: Eviews 12 output, 2025

Based on the Random Effect Model regression results, the regression model equation can be written as follows:

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$$KEP_{it} = 2053.463 + 0.016951GDP_{it} - 319.5270HRL_{it} + 7.543846URB_{it} – 89.22317SUHU_{it} + \varepsilon_{it}$$

KEP : Energy consumption (KGOE)
GDP: Gross Domestic Product per capita (Euro)
URB : Urbanization Rate (Percent)
SUHU: Annual Average Temperature (Celsius)

GDP Per Capita On Energy Consumption

The results of regression estimation with Random Effect Model show that the variable GDP per capita has a positive and significant effect on energy consumption in the European Union (coefficient = 0.016951; p-value = 0.0000), which indicates that an increase in people's income statistically leads to an increase in energy consumption. The t-statistic value of 28.18197 which exceeds the t-table of 2.01 at the 5% significance level ($\alpha = 0.05$), as well as the probability < 0.05, reinforces the decision to reject the null hypothesis (H_0) and accept the alternative hypothesis (Ha), thus concluding that the effect of GDP per capita on energy consumption is statistically significant across the 27 countries analyzed.

This finding is in line with the results of previous empirical studies by Aslan et al. (2021), Tran et al (2022), Nazer and Handra (2016), and Rezki (2012) that show a positive causal relationship between economic growth and energy consumption across regions and income levels. However, in some EU member states, an absolute decoupling phenomenon has been identified, where energy consumption has decreased even though GDP continues to increase. The studies of Wiedenhofer et al (2020) and Unnerstall (2022), as well as a report by the European Environment Agency (2023), confirm that the transition to a low-carbon economy, service sector-based structural reforms, and the implementation of strict energy efficiency policies have contributed to weakening the correlation between economic growth and energy consumption. These findings provide empirical evidence that absolute decoupling is not just a theoretical concept, but a real dynamic in the context of sustainable development in the European region.

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Energy Price On Energy Consumption

The t-test results show that electricity prices have a negative and significant effect on household energy consumption in the European Union, with a t-count value of -27.73931 (p-value 0.0000 < 0.05). The regression coefficient of -319.5270 indicates that every 1 kWh increase in electricity price decreases energy consumption by 319.5270 KGOE. This finding reflects the high elasticity of energy demand, especially in the midst of the 2022-2023 energy crisis due to the Russia-Ukraine conflict, which caused electricity prices to spike in most European Union countries (Eurostat, 2023b). Household consumption adjustments such as appliance reduction and energy efficiency are reinforced by evidence from Finland (Matschoss et al., 2025). Policies such as subsidies in Malta and the Netherlands, as well as the REPowerEU and Fit for 55 initiatives also accelerate the transition to renewable energy and energy efficiency. This result is consistent with microeconomic demand theory and supported by previous studies (Akmal & Stern, 2001; Al-Bajjali & Shamayleh, 2018) which found that rising electricity prices depress energy consumption, particularly in the household sector.

Urbanization Rate On Energy Consumption

This study shows that urbanization has a positive influence on energy consumption, although the effect is statistically insignificant. Every 1% increase in urban population is estimated to increase energy consumption by 7.543846 KGOE. Nonetheless, this result is in line with the findings of Wang et al. (2020) who stated that in highly urbanized regions, such as Europe and Latin America, urbanization does not have a significant impact on residential energy consumption.

Similar findings were also revealed by Ernie Hari Ismiyanti (2020), which showed that energy consumption tends to increase in the early stages of urbanization, but the effect gradually decreases along with increasing efficiency and technological integration. Meanwhile Purnama et al (2020), in their study titled “Effects of Energy Consumption, Economic Growth and Urbanization on Indonesian Environmental Quality”, confirmed that urbanization contributes to the decline of environmental quality in Indonesia. However, the impact is largely determined by the level of energy consumption and the rate of economic growth. The study also highlighted that efficient energy management and the use of renewable energy can significantly reduce the negative impact of urbanization on the environment.

In general, the findings show a pattern similar to that of the European Union, although there are considerable differences in the stage of development and energy

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policy capacity of each region. In the EU, proactive policy implementation-such as accelerating the transition to renewable energy, implementing emission reduction policies, and strengthening energy governance-has proven effective in mitigating the energy consumption impacts typically associated with the urbanization process. Therefore, it can be concluded that urbanization does not automatically lead to an increase in energy consumption, but is strongly influenced by the quality of policies and supporting infrastructure that can encourage energy efficiency.

Annual Average Temperature On Energy Consumption

This study aims to analyze the effect of average temperature on energy consumption using a linear regression approach. The results show that every 1°C increase in average temperature is significantly correlated with a decrease in energy consumption by 89.22317 KGOE, with a significance p-value of 0.0000. This finding indicates a strong negative correlation between temperature and energy consumption, supporting the hypothesis that temperature acts as an important factor in influencing energy demand, especially for heating needs. However, Sumardi (2013) notes that although high temperatures increase short-term energy consumption (e.g. for air conditioning), in the long run, there are behavioral adjustments and technology adoption that lead to a decrease in energy consumption.

This finding is also supported by a report from the Intergovernmental Panel on Climate Change (IPCC) (2023), which noted that the warmer-than-usual winter of 2022-2023 helped European countries such as Germany and France avoid an energy crisis, even though they experienced energy supply cuts due to the geopolitical conflict between Russia and Ukraine. Warmer temperatures reduce energy requirements for heating and increase the resilience of energy systems to external disturbances, as well as accelerate the adoption of energy transition policies, such as the REPowerEU program. Theoretically, this finding is in line with the climate adaptation theory proposed by (Smit & Wandel, 2006).They state that social and ecological systems adapt to climate change through behavioral and structural adjustments to reduce vulnerability. In the context of energy, this adaptation can take the form of reducing the use of heating systems, optimizing natural ventilation, adopting energy-saving technologies, and improving building efficiency.

This result is supported by a number of relevant international studies. (Isaac & van Vuuren, 2009) modeled global energy demand for heating and cooling in the context of climate change, and found that rising global temperatures significantly reduce energy

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demand for heating, especially in countries with temperate climates. In addition, Auffhammer & Aroonruengsawat (2011) showed that warmer winters in California resulted in a decrease in household electricity consumption. De Cian et al (2013) also reinforced these findings, suggesting that the trend of rising temperatures favors increased energy efficiency globally. Thus, temperature is not only a climate indicator, but also a strategic variable in long-term energy policy.

CONCLUSION

The conclusion of this study shows that factors such as GDP per capita, electricity price, urbanization rate, and average temperature significantly affect energy consumption in the 27 EU countries studied. Increases in GDP and urbanization tend to increase energy consumption, although the effect of urbanization is not always statistically significant. Electricity prices have a significant impact on reducing energy consumption, with price increases encouraging efficiency and reduced energy use. Average temperature shows a significant negative correlation with energy consumption, with rising temperatures reducing the need for heating, especially in temperate countries, although in tropical regions higher temperatures increase energy consumption due to air conditioning use. This is indicated by the regression model showing a very high F-statistic (14.88126) with a significance level of 0.0000, which indicates that the model significantly explains variations in energy consumption. The R-squared value of 0.548491 indicates that 54.85% of the variation in energy consumption can be explained by the independent variables tested, while the rest is influenced by other factors

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