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Thesis statements of the dissertation

Tackling Energy Inequality in the EU Member States for a Just Transition

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1 Introduction

Energy has become a significant concern, impacting environmental, societal, and economic dimensions. It is the primary contributor to greenhouse gas emissions (Wu et al., 2012), and developing strategies for a sustainable energy transition is crucial for the future. Sustainable energy involves generating and using energy efficiently without endangering future generations' ability to meet their needs. This requires slowing energy demand growth, improving service efficiency, and increasing renewable energy use.

The European Union (EU) has set targets to reduce greenhouse gas emissions, improve building energy efficiency, and increase renewable energy sources. The EU has developed various plans and strategies, such as 'Energy 2020,' which aims to reduce energy consumption and emissions to levels outlined by the European Commission (EC) in 2010 (Langsdorf, 2011) and increase renewable energy use and efficiency. By 2020, the EU had achieved its three primary climate and energy targets with the assistance of the COVID-19 pandemic (European Environment Agency, 2023).

To sustain these initiatives, the European Green Deal (EGD) was introduced in December 2019 to transform the EU into a carbon-neutral economic region by 2050 while fostering a more equitable and prosperous society (Tsetsos, 2021). The EGD aims to establish a modern, resource-efficient, competitive economy that decouples growth from resource use.

The EGD proposes elevating the EU's climate targets for 2030 and 2050, with the 'Fit for 55' initiative introduced in 2021. This initiative aims to broaden the EU's Emission Trading Scheme (ETS) scope to include households and the transportation sector, incentivizing further reductions in carbon dioxide emissions. However, expanding the ETS could increase energy costs and utility bills, potentially putting economically disadvantaged individuals at risk.

The Cold War led to the formation of two groups of European countries (LaBelle et al., 2022): the old (pre-2004 EU-Member States) and the post-communist (post-2004 EU-Member States). The old Member States have better economic and living conditions but consume more energy. Transitioning to sustainable energy sources is crucial for these states, which have historically contributed to carbon emissions (Goddard and Farrelly, 2018). They have more financial resources to support this transition than their post-communist counterparts, where energy poverty remains prevalent.

The current European energy transition framework overlooks the disparities in energy use among households and Member States. Also, expanding the EU ETS to include the household sector is expected to put more households in energy poverty and widen energy inequality.

Researchers and policymakers need to incorporate the disparities in energy use among the EU Member States into the European regulatory framework of energy transition. Identifying the socioeconomic drivers behind these disparities to mitigate them is also overlooked. Therefore, the objective of this research involves a comprehensive evaluation of disparities in household energy consumption across the 27 EU Member States, coupled with identifying the underlying factors contributing to these disparities. This investigation places a particular emphasis on economic and social dimensions. The research seeks to quantify the influence of these determinants on overall energy consumption inequality and strives to offer valuable insights for its mitigation.

This study also examines the impact of energy price increases between 2021 and 2022 on energy inequality and the advancement of a just transition. Several factors contributed to Europe's energy crisis during this period, beginning with the surge in energy demand due to economic recovery after the COVID-19 pandemic, which was significantly worsened by the ongoing conflict between Russia and Ukraine. As a result, coal and natural gas prices in Europe rose sharply, leading to higher electricity prices, as these fuels are crucial to electricity generation (Szép et al., 2022). In response, European national energy policies have been significantly reshaped, with EU Member States implementing both short- and long-term strategies. Short-term strategies focus on diversifying gas supplies, increasing LNG imports, developing new LNG infrastructure, switching from gas to coal for electricity generation, delaying gas consumption reductions, and extending the operation of nuclear power plants (REPowerEU Plan, 2022). Long-term policies emphasize advancing the energy transition through renewable energy, energy conservation, and improving energy efficiency (REPowerEU Plan, 2022). Consequently, assessing the progress of a just energy transition in the context of this energy price increase is essential.

Furthermore, this research explores the interplay between household energy consumption, energy efficiency, and human development. It aims to clarify the connection between increased energy use and higher levels of human development and vice versa.

Finally, the research intends to offer policy recommendations to reduce energy inequality while decoupling economic growth from residential energy consumption. The study advocates for an inclusive energy transition in the EU, aiming to protect low-income households and promote human development, especially in regions with low human development indicators.

The research explores several interconnected theories and employs diverse statistical methods to test the hypotheses. The research summary, depicted in Figure 1, outlines the theories, hypotheses, and primary methodologies used.

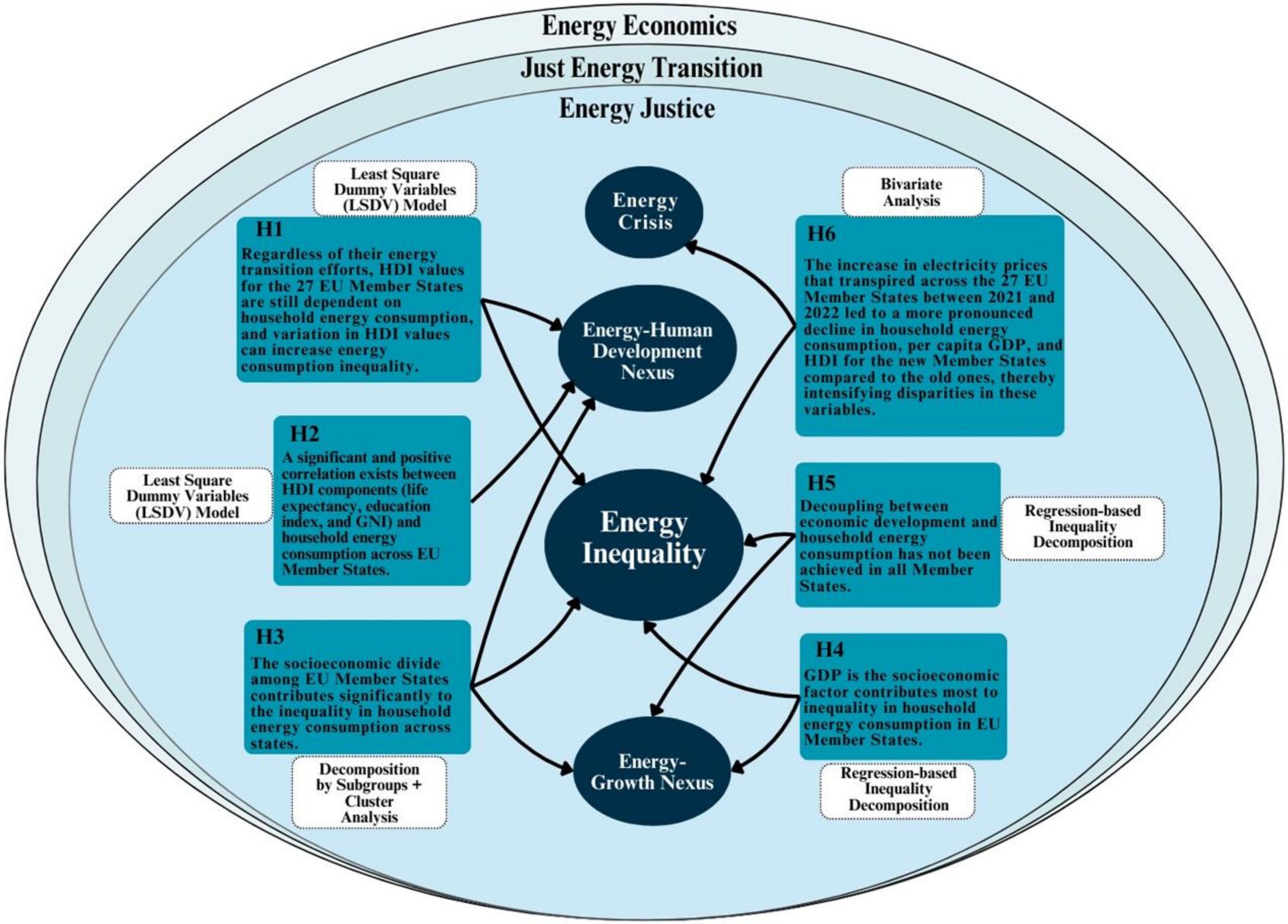

Figure 1 Research Summary
Source: Author's compilation

2 Energy inequality: Concept and theoretical foundations

This chapter provides information about energy inequality and defines the most important terms used in this research to be easily identified by readers. Subsequently, it introduces and discusses the economic theories related to energy inequality to place it within a precisely articulated field.

2.1 The concept of energy inequality

Energy, derived from Greek roots, refers to the capacity to perform work or induce change and is a fundamental concept in various scientific disciplines. It can be transformed into multiple forms, such as thermal, mechanical, electrical, and chemical (Koevering, 1986). Energy is used in engineering to study the ability to perform work and its transformation, while in economics, it is a factor of production used to create products and services. Economists study energy generation, consumption patterns, and the impact of energy prices on economic dynamics.

This research investigates energy from an economic perspective, focusing on its use. Energy consumption can be categorized into primary and final consumption, depending on who uses it and how it is used. Primary consumption quantifies the overall domestic energy demand, while final consumption pertains to what end users actually use. The key distinction lies in the energy sector's requirements and losses incurred during transformation and distribution processes (Eurostat, 2020).

Energy consumption, especially in residential settings, can be further classified into direct and indirect categories based on consumer lifestyle approaches (Ding et al., 2017). Direct energy consumption refers to the energy consumed directly by a device or process, such as lighting or heating spaces. In contrast, indirect energy consumption refers to the energy embedded in household goods and services (GuangwuChen, 2019). In this research, energy consumption is only mentioned when it relates to the final and direct consumption.

Energy consumption inequality refers to the unequal energy usage by consumers, households, or nations, affecting both within and between countries. It occurs within countries when different income deciles consume different amounts of energy based on utility bills, appliances, and access to energy sources. It also happens between countries when energy consumption variations occur due to weather conditions, economic state, and industrialization. The ultimate goal is to achieve equality in energy consumption, where everyone has access to an equitable allocation of energy resources.

Energy inequality has significant societal, economic, and environmental implications, with various academic disciplines exploring different dimensions of it. These inquiries include determining factors, socioeconomic and health impacts, effects on vulnerable societal segments, environmental sustainability consequences, and policy measures and strategic approaches to foster equitable energy access. The ultimate goal is to achieve equality in energy consumption, where everyone has access to an equitable allocation of resources to meet their energy needs (Volodzkiene and Streimikiene, 2023).

2.2 Theory background

The 'just transition' is transitioning from a fossil fuel economy to a clean-energy one while protecting low-income communities and carbon-intensive industries. This transition can take various forms, such as phasing out coal, introducing energy efficiency standards, and reducing the carbon intensity of the electricity grid. The transition can take different forms, such as phasing out coal, introducing energy efficiency standards for buildings, and reducing the carbon intensity of the electricity grid (Zinecker et al., 2018). According to McCauley and Heffron (2018), the just transition can integrate climate, energy, and environmental justice concerns to create a more comprehensive framework for understanding and promoting justice and equity during the transition from fossil fuels. The concept of a just transition, which supports aspects of equity and justice in addressing energy, environmental, and climate challenges, is gaining recognition among many scholars (Kenfack, 2018; Newell and Mulvaney, 2013; Snell, 2018; Stevis and Felli, 2015).

The environmental justice movement emerged in the 1980s due to the growing environmental threats faced by communities of color and working-class communities in the US (Bullard et al., 2007). The movement focuses on more equitable distribution of development costs and participation in all aspects of environmental laws, regulations, and policies. Climate justice began globally in the 1990s, with calls for climate policies aimed at preventing climate harm to low-income communities and communities of color and their participation in climate-change-related discussions (Jenkins, 2018). Both environmental and climate justice movements aim to address the challenges faced by communities of color and working-class communities in transitioning from fossil fuels.

Nevertheless, environmental shortcomings persisted. This persistence has spurred a growing interest in creating new, targeted justice frameworks, as evidence suggests that the influence of environmental and climate justice on decision-making is insufficient, leading to the emergence of the concept of energy justice (Jenkins, 2018). This concept aims to ensure everyone has access to secure, affordable, and sustainable energy resources, regardless of location. It calls for fair treatment of people and communities in energy-related decisions (McCauley et al., 2013). Energy justice is linked to environmental and climate justice, as the most vulnerable groups face energy burdens. These concepts are interlinked and essential to implementing a just transition. Energy justice integrates democracy and collaboration, addressing equality issues within the current energy system, and is critical to the just transition framework (Baker et al., 2019).

Energy justice is a concept that focuses on the distribution, procedural, and recognition justice of energy resources (McCauley et al., 2013). Distributional justice involves the fair distribution of economic goods among individuals, procedural justice focuses on the fairness of procedures and processes, and recognition justice acknowledges inequalities in specific communities. Energy inequality, which includes inequalities in energy supply, distribution, access, and consumption, is a crucial distribution aspect. Energy consumption equality is essential for a just transition, as it promotes the distributional aspect of energy justice and is integral to the just transition framework. Figure 2 shows the connection between energy consumption equality and the just transition.

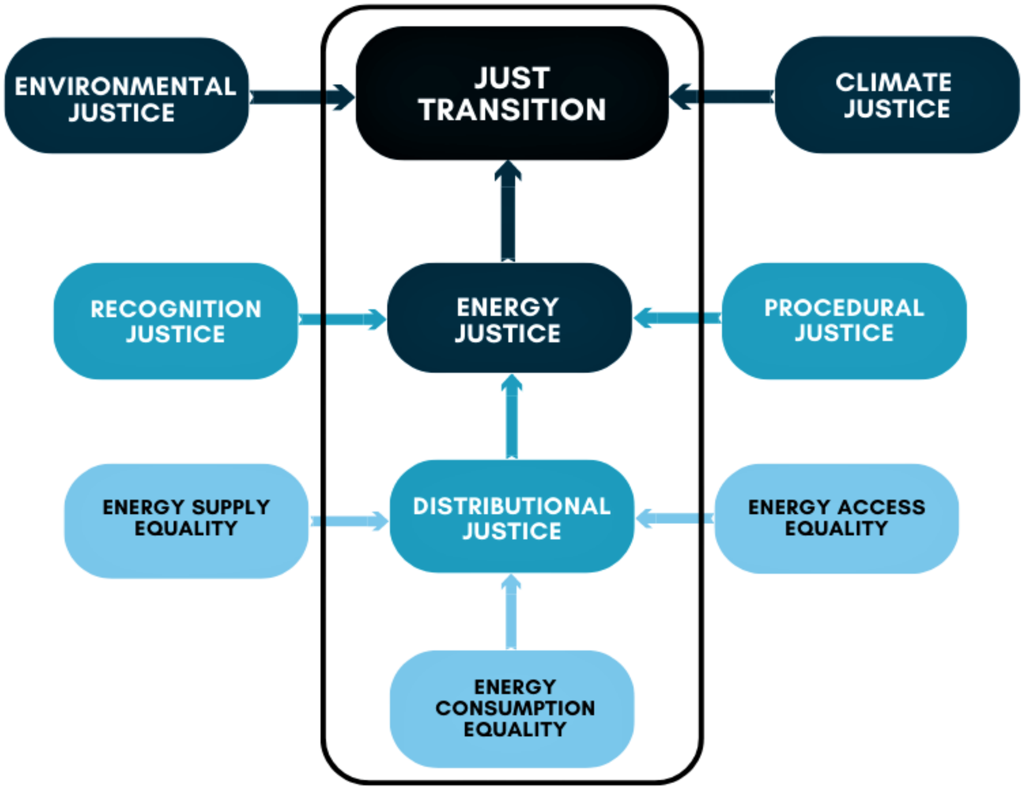

Figure 2 Energy consumption equality in relation to the just transition.
Source: Author's compilation.

This research is testing the following hypotheses:

H1	Regardless of their energy transition efforts, HDI values for the 27 EU Member States are still dependent on household energy consumption, and variation in HDI values can increase energy consumption inequality.
H2	A significant and positive correlation exists between HDI components (life expectancy, education index, and GNI) and household energy consumption across EU Member States.
H3	The socioeconomic divide among EU Member States contributes significantly to the inequality in household energy consumption across states.
H4	GDP is the socioeconomic factor contributes most to inequality in household energy consumption in EU Member States.
H5	Decoupling between economic development and household energy consumption has not been achieved in all Member States.
H6	The increase in electricity prices that transpired across the 27 EU Member States between 2021 and 2022 led to a more pronounced decline in household energy consumption, per capita GDP, and HDI for the new Member States compared to the old ones, thereby intensifying disparities in these variables.

3 Results and discussion

3.1 Energy inequality and HDI

To better understand inequalities, this study employed the Lorenz curve and Gini coefficient to divide the Member States into three groups based on the per capita household energy consumption values (unadjusted for climate) in 2020. See Table 1 and Figure 3. The first group accounts for 22.7% of the total population and consumes only 14.3% of total household energy. The second group of countries accounts for 48.9% of the total population and consumes 49.0% of total household energy. The third group of countries accounts for 28.4% of the total population and consumes 36.7% of the total household energy. The highest per capita energy consumption values measured in kilograms of oil equivalent are 956 in Finland, 790 in Luxembourg, 781 in Austria, and 735 in Denmark. Meanwhile, the lowest values measured in kg of oil equivalent are 208 in Malta, 293 in Portugal, 294 in Cyprus, and 307 in Spain. A Gini index of 0.139 in these results generally suggests an acceptable level of energy inequality among the 27 EU Member States.

Notably, most countries in the first group are in southern Europe, and most countries in the third group are in northern Europe. As long as the weather in northern Europe is colder than that in the south, those countries in the north consume more energy for residential heating spaces than those in the south. This is one possible factor contributing to these results.

The other possible factor is the human development level of the country; it is evident that all countries in the third group are the most developed in the EU. Table 1 also shows that the average HDI value for the first group of countries that consume a low amount of energy is 0.867; for the second group of countries that consume a moderate amount of energy, it is 0.891; and for the last group of countries that consume a high amount of energy, it is 0.924. This result shows how much these two variables correlate with each other.

Table 1 Population, typical household energy consumption shares, and average HDI in 2020 for the EU-27 Member States

EU Member States	Population (%)	Household Energy Consumption (%)	Average HDI
Malta, Portugal, Cyprus, Spain, Bulgaria, Greece, Romania, Slovakia	22.7	14.3	0.867
Lithuania, Italy, Slovenia, Netherlands, Poland, Croatia, France, Latvia, Hungary, Ireland	48.9	49.0	0.891
Czech Republic, Belgium, Sweden, Germany, Estonia, Denmark, Austria, Luxembourg, Finland	28.4	36.7	0.924

Source: Author's analysis

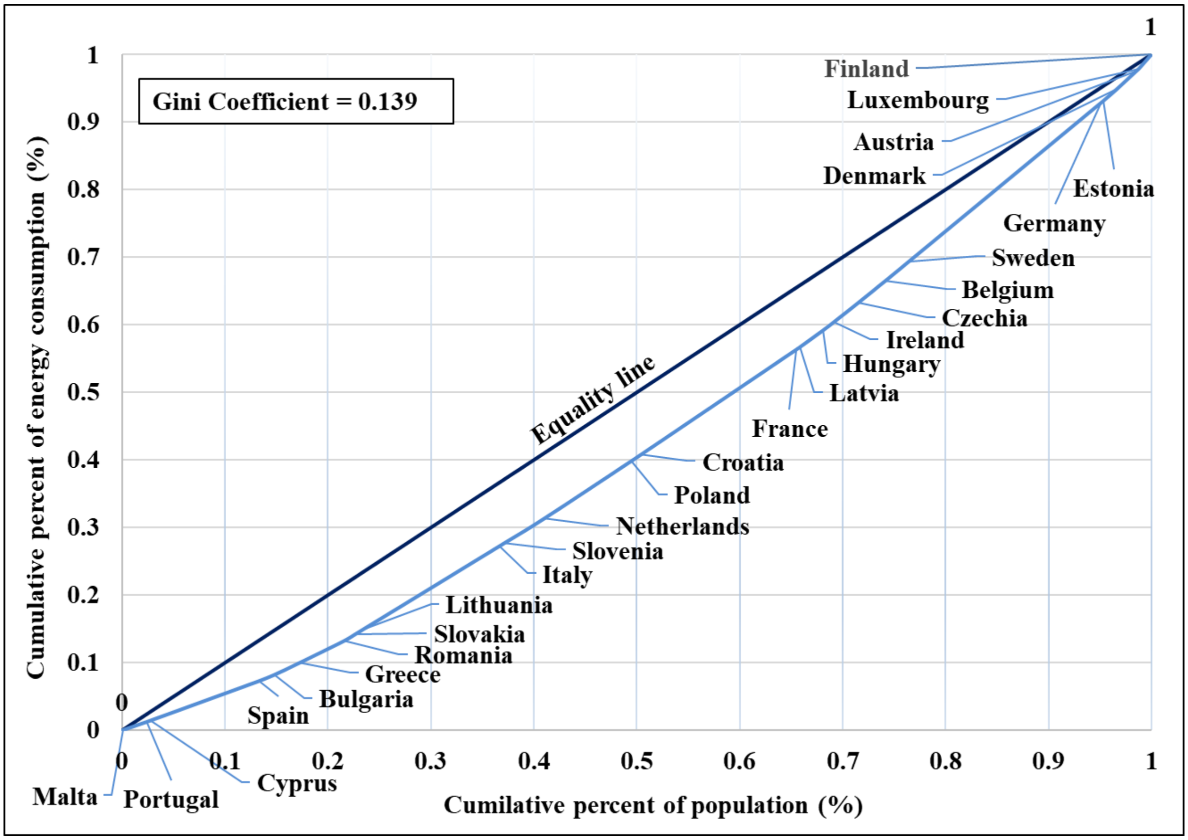

Figure 1 Lorenz curve and Gini coefficient for the typical household energy consumption for the EU-27 Member States in 2020

Source: Author's analysis

To examine the impact of the HDI on residential energy consumption, Table 2 presents the results of the Least Squares Dummy Variable (LSDV) model for climate-adjusted residential energy consumption and HDI values for the 27 EU Member States from 2010 to 2020, with Malta identified as an outlier. The panel regression is conducted using the variables' natural logarithmic transformation to address normality and heteroskedasticity issues while estimating relative elasticity. The results of normality and autocorrelation tests support the null hypothesis, confirming that the error terms follow a normal distribution and exhibit no autocorrelation. The null hypothesis for the heteroskedasticity test is rejected, suggesting that the error variance is not constant across units. The table indicates a positive relationship between energy consumption and HDI, with a 1% increase in HDI corresponding to a 3.17% rise in climate-adjusted energy consumption (CEC). The first hypothesis is accepted.

Table 2 LSDV model for climate-corrected residential energy consumption and the HDI values for the EU-27 Member States from 2010 to 2020

Dependent variable: log_CEC			
Variable	**Coefficient**	**Std. Error**	**p-value**
Constant	−1.24078	0.0338873	**3.05e-023** ***
log_HDI	3.17344	0.278205	**2.11e-011** ***
Effects Specification			
LSDV R-Squared	0.350	**Durbin–Watson**	**2.116**
Joint test on named regressors - Test statistic: F(1, 25) = 130.115 with p-value = P(F(1, 25) > 130.115) = 2.11259e-11			
Distribution free Wald test for heteroskedasticity - Null hypothesis: the units have a common error variance Asymptotic test statistic: Chi-square(26) = 45.9284 with p-value = 0.036837			
Test for normality of residual - Null hypothesis: error is normally distributed Test statistic: Chi-square(2) = 5.41019 with p-value = 0.0668639			
Wooldridge test for autocorrelation in panel data - Null hypothesis: No first-order autocorrelation (rho = -0.5) Test statistic: F(1, 25) = 0.20747 with p-value = P(F(1, 25) > 0.20747) = 0.652689			
Hausman test - Null hypothesis: GLS estimates are consistent Asymptotic test statistic: Chi-square(1) = 0.151778 with p-value = 0.696842			

*Significant at 10% **Significant at 5% ***Significant at 1%

Source: Author's analysis

3.2 The influence of HDI components on energy consumption

For an in-depth analysis, the relationship between climate-corrected residential energy consumption and the three HDI components for the EU-27 Member States from 2010 to 2020 is shown in Table 3. The climate-corrected energy consumption is the dependent variable, whereas the HDI components are the independent variables. The variables values are transformed to natural logarithims to measure the relative elasticity. Considering the individualism of each Member State, Malta and Luxembourg are detected outliers in the data. The correlation matrix in the table shows no robust correlations between the independent variables, and the Variance Inflation Factors are less than 3 indicating no harmful multicollinearity. The null hypothesis for the normality and autocorrelation tests is accepted, indicating that the error is normally distributed and there is no autocorrelation. In addition, the null hypothesis for the heteroskedasticity test is rejected, indicating that the units do not have a common error variance. The table shows positive regression coefficients between energy consumption and the three HDI components. Except for the education index, the probability values for the independent variables are less than 0.05, indicating a significant relationship with energy consumption. The R-squared value is 0.487, which is acceptable, meaning that the independent variables can explain 48.7% of the variation in the dependent variable. The second hypothesis is partially accepted.

A high life expectancy means that people live more and consume more energy. A study by Steinberger et al. (2020) showed that the increase in energy consumption in 70 countries (80% of the world population) between 1971 and 2014 accounted for a 25% increase in life expectancy. Another study confirmed these results by presenting two variables moving in the same direction for four developing countries (China, India, Brazil, and Indonesia) over 50 years (Lloyd, 2017). Consistently, the results showed a positive relationship between energy consumption and life expectancy. This result is highly dependent on the energy mix used in the Member States. The greener energy is used, the more the direction of the relationship is shifting from negative to positive. This is mainly because high life expectancy requires an advanced health system and a green environment with fewer pollutants and emissions.

Regarding education, the literature has shown that the education level in developed countries might have an adverse effect on energy consumption, as improving technology in education will lead to declining energy use (Inglesi-Lotz et al., 2017). Most EU Member States are advanced countries with high-quality educational systems. Furthermore, education influences the behavior of households to become more energy-conservative (Liu et al., 2015). However, the results show that education in Europe does affect residential energy consumption, but the relationship is not significant.

Consistent with the works of Cayla et al. (2011) and Chen et al. (2022), GNI positively impacts energy consumption. The cumulative reduction in EU energy consumption from a combination of outsourcing activities and efficiency gains since 1990 has been significant, resulting in approximately 40% less energy use, half of which is due to deindustrialization (Moreau and Vuille, 2019). Therefore, prospects for decoupling economic growth and energy are limited. Given the non-achievement of absolute decoupling and for a specific income range, the more income households have, the more they will spend on energy and use it.

Table 3 LSDV model for climate-corrected residential energy consumption and the three HDI components for the EU-27 Member States from 2010 to 2020

Dependent variable: log_CEC			
Variable	**Coefficient**	**Std. Error**	**p-value**
Constant	−17.2694	1.34481	**3.03e-012 *****
log_Life Expectancy	3.20392	0.398372	**2.87e-08 *****
log_Education Index	0.0679350	0.137380	**0.6254**
log_GNI	0.136732	0.0348794	**0.0006 *****

Effects Specification

LSDV R-Squared	0.487	**Durbin–Watson**	**1.857**

Joint test on named regressors -
Test statistic: F (3, 24) = 106.826
with p-value = P (F (3, 24) > 106.826) = 5.09814e-14

Distribution free Wald test for heteroskedasticity -
Null hypothesis: the units have a common error variance.
Asymptotic test statistic: Chi-square (25) = 42.9235
with p-value = 0.043493

Test for normality of residual -
Null hypothesis: error is normally distributed
Test statistic: Chi-square(2) = 0.582292
with p-value = 0.747407

Wooldridge test for autocorrelation in panel data -
Null hypothesis: No first-order autocorrelation (rho = -0.5)
Test statistic: F(1, 24) = 0.309493
with p-value = P(F(1, 24) > 0.309493) = 0.583142

Hausman test -
Null hypothesis: GLS estimates are consistent
Asymptotic test statistic: Chi-square(3) = 6.38931
with p-value = 0.0941315

Correlation coefficients,
5% critical value (two-tailed) = 0.1138 for n = 275

	log _LifeE	log _GNI	log _EducationI
log_EducationI	0.5397	0.4733	1.0000
sq _GNI	0.7860	1.0000	
sq _LifeE	1.0000		

Variance Inflation Factors
Minimum possible value = 1.0
Values > 10.0 may indicate a collinearity problem

log_LifeE	2.890
log_EducationI	1.424
log_GNI	2.640

*Significant at 10% **Significant at 5% ***Significant at 1%

Source: Author's analysis

3.3 Energy efficiency and HDI

The decoupling of economic growth and energy consumption can be achieved using different tools, one of which is to improve the energy efficiency of buildings and appliances. Figure 14 displays the average HDI values for the study period (2010–2020) and the residential energy efficiency scores for all Member States. This score varies from 0 to 1 and combines three energy efficiency measures: current level, performance since 2000 (trend), and strength of policies. Energy efficiency is a critical factor that should be considered when examining the effects of human development on energy consumption. It reduces the energy required to deliver a product or a service. At the same time, it offers a range of other benefits, including improved economic performance and competitiveness, job growth, energy security, and better health. As a result, it helps reduce energy consumption and increase human development.

Figure 4 shows that old Member States have a higher energy efficiency score than post-communist Member States. Ireland, Finland, France, Netherlands, and Germany have the highest energy efficiency scores. All these states are amongst the highest energy consumers in the EU. If all the states had a similar efficiency level, the residential energy use gap between these states and others would be more significant. In addition, most of these states have very high HDI values and per capita incomes.

On the left side of the graph, Croatia, Poland, Italy, Estonia, and Hungary have the lowest energy efficiency scores. These states have relatively lower HDI values and income per capita than the first group, and their households, except Estonia, consume less energy.

Finally, the last group in the middle of the graph has average energy efficiency scores. These countries have moderate HDI and income values and consume more energy than the second group.

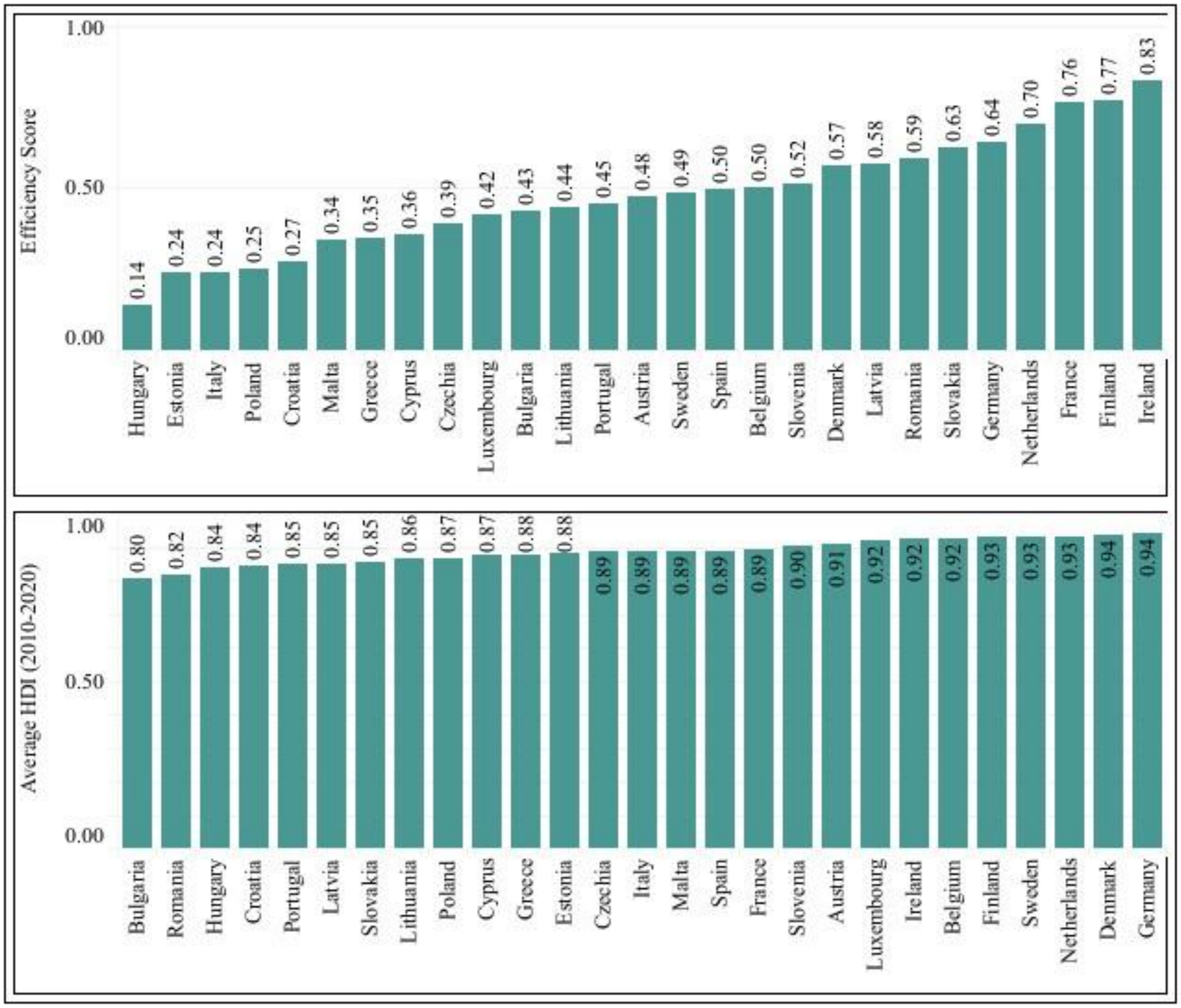

Figure 2 Average HDI value for the study period (2010–2020) and residential energy efficiency scores for all Member States

Source: Author's analysis

3.4 The impact of the socio-economic gap on energy inequality

The main objective of using cluster analysis is to capture the socioeconomic differences between the Member States to test the third hypothesis. The 27 EU Member States are classified based on the average values of CEC, GDP per capita, HDI, and electricity prices during the study period in Table 4. All Member States are included in the analysis except Luxembourg, which is an outlier. The Member States were classified into four subclusters: A, B, C, and D. Subcluster A includes states with the highest values. The values decrease from subclusters A to D, so the states in subcluster D have the lowest values. Based on these results, the Member States can be divided into two major clusters. The first group is called "Leaders" and consists of subclusters A and B, while the second is called "Laggards" and consists of subclusters C and D. The table also includes the average ETI value for states in each subcluster in 2020.

Table 4 K-Means clustering for the EU Member States based on their average values for climate-adjusted per capita household energy consumption (CEC), GDP per capita, HDI, and electricity prices over the period 2010–2020

Cluster	Subcluster	Member States	Average ETI 2020
Leaders	A	Belgium, Denmark, Germany, and Ireland	64.5
	B	Austria, Cyprus, Finland, France, Italy, Netherlands, Spain, and Sweden	65.1
Laggards	C	Croatia, Czech Republic, Estonia, Greece, Hungary, Malta, Poland, Portugal, and Slovenia	57.6
	D	Bulgaria, Latvia, Lithuania, Romania, and Slovakia	57.1

Source: Author's analysis, ETI data is extracted from World Economic Forum (2023)

The average standardized scores (Z-scores) for the variables in each subcluster are shown in Figure 5. For each variable, the Z-scores represent the difference between the mean of the variables in the subcluster and the mean in the whole sample. All differences are measured in standard deviations. The zero line in the figure shows the mean values of the variables for the 26 Member States included in the analysis. The Z-scores for subclusters A and B (Leaders) are above the zero line, and those for subclusters C and D (Laggards) are below. Based on this result, the distinction between the two clusters (Leaders and Laggards) was made. Subcluster B boasts the highest ETI at 65.1, followed by A at 64.5, C at 57.6, and D at 57.1. The cluster analysis outcomes align with the ETI metrics the World Economic Forum provided and reflect the system performance and readiness for energy transition. Because of Ireland and Belgium's underperformance or deviation from expectations in energy transition, subcluster A is not clinching the highest ETI score. However, the gap in the scores between Leaders and Laggards is evident.

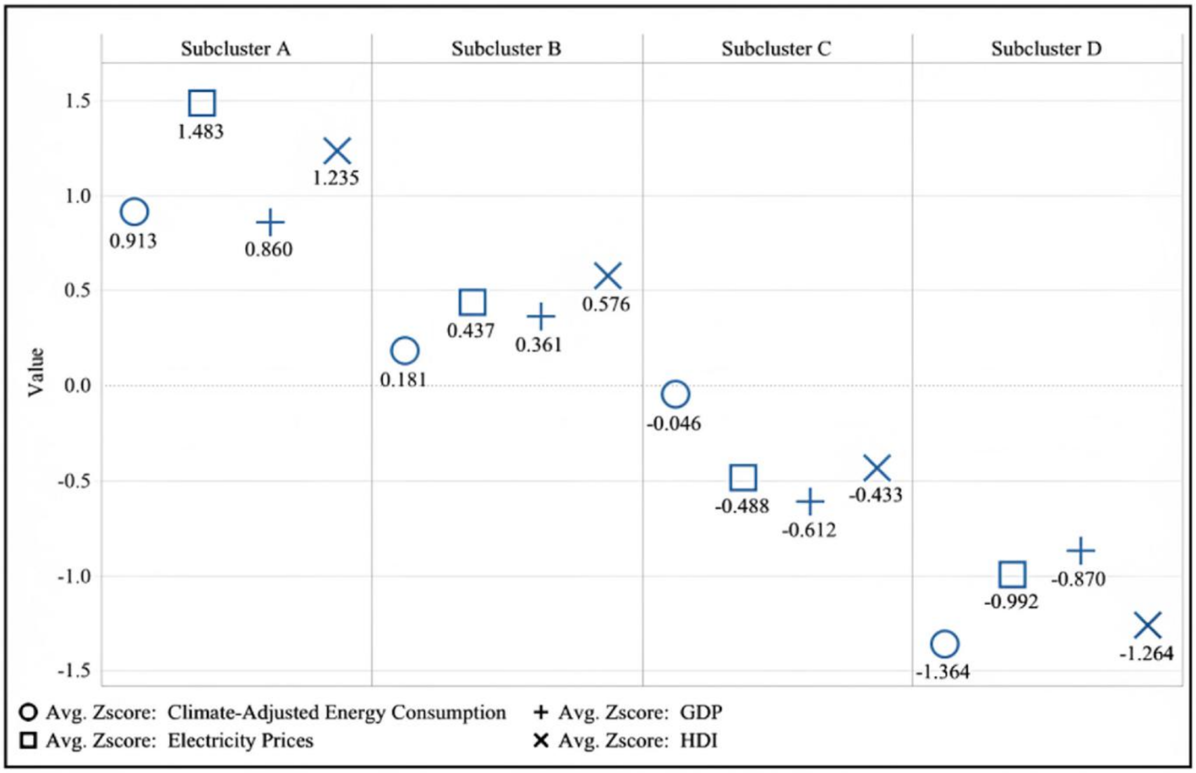

Figure 3 Average standardized scores (Z-scores) for climate-adjusted per capita household energy consumption (CEC), GDP per capita, HDI, and electricity prices in each subcluster
Source: Author's analysis

To examine the impact of socioeconomic differences between Member States on inequality in energy consumption, inequality within each subcluster is calculated, and the share of inequality within and between subclusters of overall inequality is compared. Gini and Theil values are shown in Figures 6 and 7, respectively. The figures show the same inequality fluctuations and trends with different values. Since the Theil values, unlike the Gini values, have no upper limit, they cannot provide helpful information on how profound inequality is.

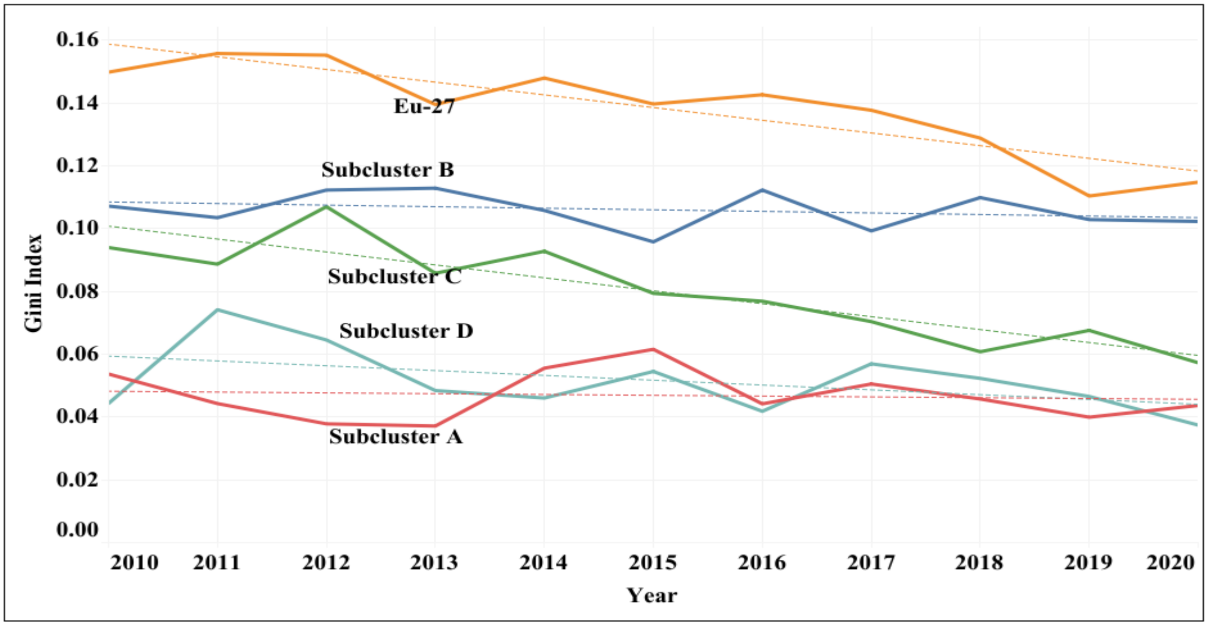

Figure 4 Inequalities in climate-adjusted per capita household energy consumption (CEC) for the EU-27 Member States and subclusters from 2010 to 2020, measured using the Gini index
Source: Author's analysis

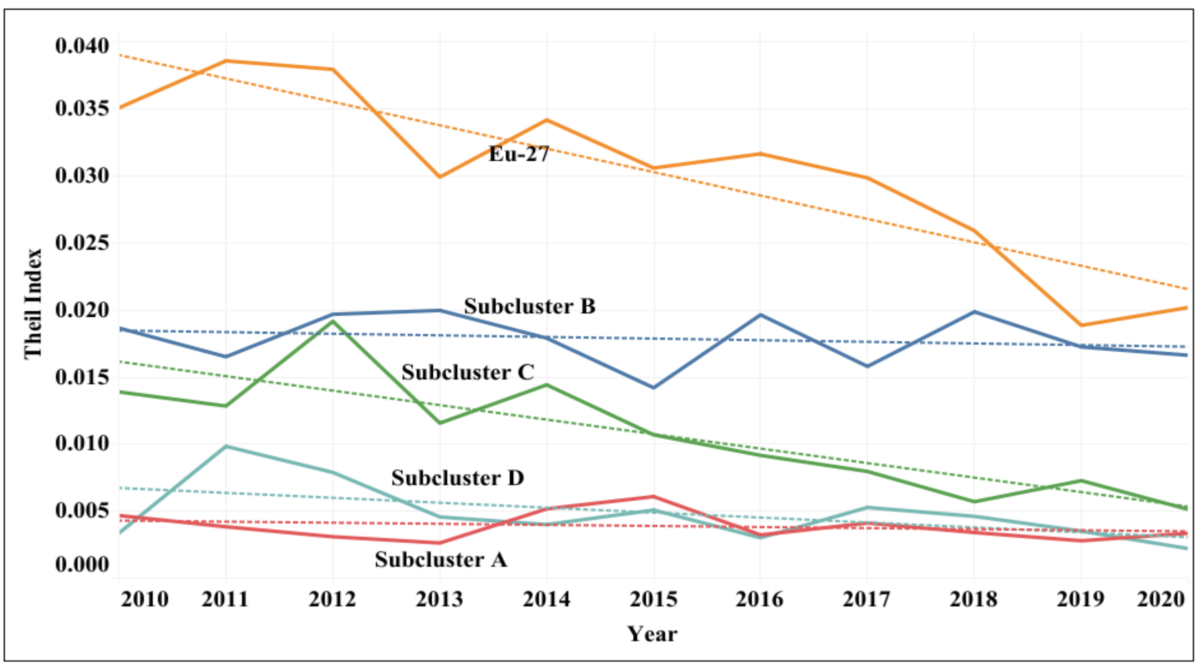

Figure 5 Inequalities in climate-adjusted per capita household energy consumption (CEC) for the EU-27 Member States and subclusters from 2010 to 2020, measured using the Theil index
Source: Author's analysis

The trend lines (dashed lines) in Figures 6 and 7 are downward sloping to varying degrees for the EU-27 Member States and all subclusters, indicating a downward trend in energy consumption inequality over this period. While the pattern of inequality values in subclusters A and B is almost stagnant, the significant downward trend for the EU-27 Member States could be related to the patterns in subclusters C and D (Laggards). In these states, the values of energy consumption converge. However, knowing the values and patterns of inequality within each subcluster does not indicate how much each contributes to overall inequality. To determine the contribution of inequality of each subcluster to overall inequality, the Theil index is decomposed by subclusters, as shown in Figure 8. Inequality *between* subclusters contributed the most in all years, with an average of 60%. In other words, the leading cause of overall inequality is inequality *between* subclusters, not inequality *within* subclusters. This result suggests that the socioeconomic gap between the Member States significantly impacts energy consumption inequality.

Moreover, the highest share was 64.4% in 2011, and the lowest was 50.3% in 2019. As mentioned above, the highest and lowest levels of energy consumption inequality were recorded in these years across the EU-27 Member States, confirming the significant impact of inter-subcluster inequality on overall inequality. On the other hand, the average contribution share of intra-subcluster inequality is around 40% over the whole study period, indicating a less measurable impact. The third hypothesis is accepted.

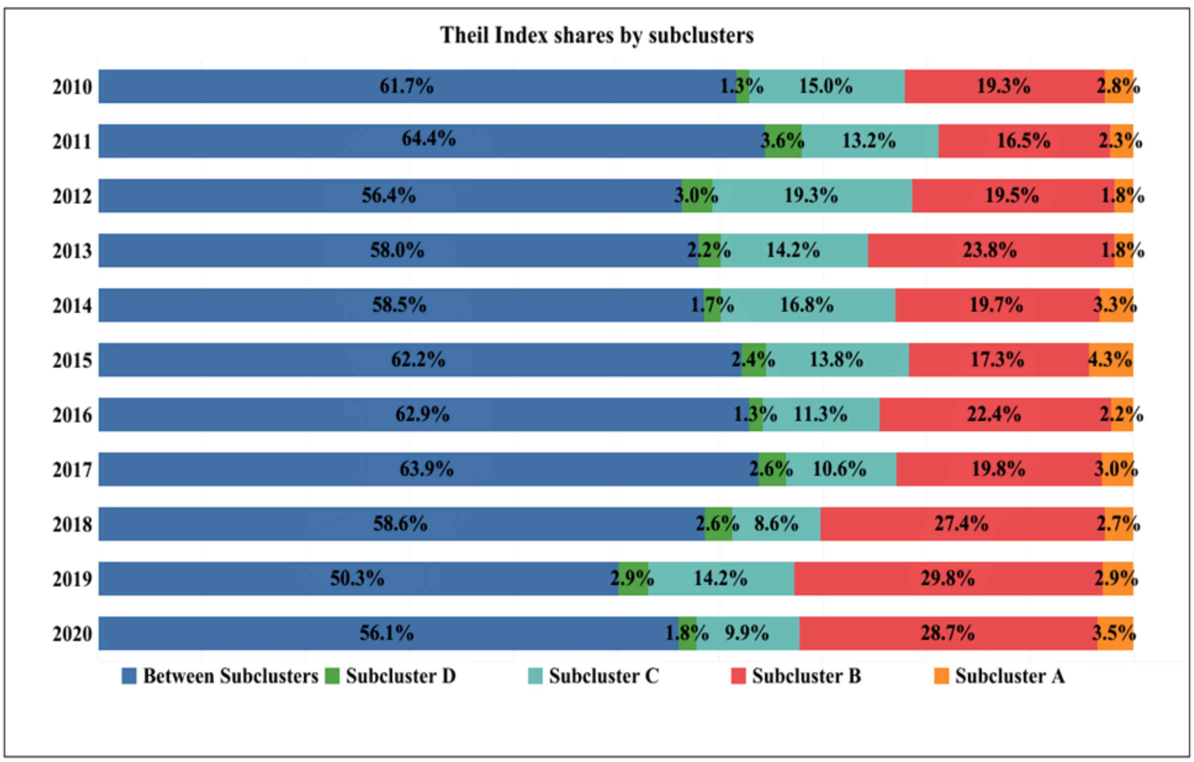

Figure 6 Shares of inequality within and between subclusters of overall inequality from 2010 to 2020
Source: Author's analysis

3.5 Contributions to energy inequality

Regression-based inequality decomposition is used with the Shapley value framework to test the fourth research hypothesis (which socioeconomic factor contributes most to inequality in household energy consumption in the EU Member States). Table 5 shows the socioeconomic factors' relative and absolute contributions for the 27 EU Member States from 2010 to 2020.

Table 1 Relative and absolute contributions of climate-adjusted per capita energy consumption (CEC) inequality determinants (GDP, HDI, and EP) for the EU-27 Member States from 2010 to 2020

Year	*Contributon*	*GDP*	*HDI*	*EP*	*Unexplained Inequality (Other Variables)*	*Overall Inequality (Gini Index)*
2010	Absolute	0.0621	0.0166	0.0166	0.0545	0.1499
	Relative	41.47%	11.07%	11.06%	36.40%	100%
2011	Absolute	0.0823	0.0175	0.0057	0.0503	0.1558
	Relative	52.80%	11.26%	3.64%	32.30%	100%
2012	Absolute	0.0756	0.0182	0.0038	0.0575	0.1553
	Relative	48.72%	11.75%	2.47%	37.06%	100%
2013	Absolute	0.0550	0.0175	0.0118	0.0551	0.1395
	Relative	39.44%	12.56%	8.49%	39.51%	100%
2014	Absolute	0.0563	0.0148	0.0244	0.0525	0.1480
	Relative	38.05%	10.03%	16.47%	35.45%	100%
2015	Absolute	0.0564	0.0161	0.0154	0.0518	0.1397
	Relative	40.38%	11.50%	11.06%	37.06%	100%
2016	Absolute	0.0557	0.0158	0.0167	0.0545	0.1427
	Relative	39.02%	11.09%	11.69%	38.20%	100%
2017	Absolute	0.0580	0.0147	0.0193	0.0458	0.1377
	Relative	42.08%	10.67%	13.99%	33.25%	100%
2018	Absolute	0.0443	0.0154	0.0184	0.0507	0.1289
	Relative	34.35%	11.98%	14.31%	39.36%	100%
2019	Absolute	0.0230	0.0153	0.0243	0.0478	0.1104
	Relative	20.79%	13.87%	22.01%	43.33%	100%
2020	Absolute	0.0336	0.0166	0.0176	0.0470	0.1148
	Relative	29.29%	14.49%	15.32%	40.89%	100%

Source: Author's analysis

The main contributor to this inequality is GDP, the factor responsible for the largest share in most years. The most significant contribution was 52.8% in 2011, and the smallest was 20.79% in 2019, the same years when energy consumption inequality was the highest and lowest. This shows that GDP has a significant impact on energy consumption inequality. To a lesser extent, HDI and electricity prices contribute to inequality in energy consumption. The fourth hypothesis is accepted.

Cumulatively, these socioeconomic factors explain more than 59% of inequality in all years. In contrast, other determinants explain the remaining unexplained inequality. Household energy consumption is influenced by several demographic, social, and energy-related factors in addition to economic ones. Factors such as urbanization rate (Nie et al., 2018), health status (Longhi, 2015), age, gender, marriage (Frederiks et al., 2015), family composition (Mansouri et al., 1996), household size (Kialashaki and Reisel, 2013), and house type (Zhao et al., 2016) influence household energy consumption. Nevertheless, the economic and social factors included in the analysis have the most significant influence. This result shows how much these factors influence the inequality of energy consumption in the 27 EU Member States. However, do they influence inequality equally in leading and lagging states?

To answer this question and test the fifth research hypothesis, Figure 9 presents a more comprehensive overview. It shows the average contribution (share) of socioeconomic factors in energy consumption inequality for the EU-27 Member States, Leaders, and Laggards. Socioeconomic factors explain 18.02% of overall inequality in Leaders and 41.94% in Laggards. Since leading states have better economic conditions and higher living standards, the disparities in GDP, HDI, and electricity prices have little impact on the inequality values in energy consumption. Other factors are the main determinants of this inequality. As lagging states may further develop, the contribution of socioeconomic factors to their energy consumption inequality is more significant. Given the economic and social differences between these two groups of countries, the contributions of GDP, HDI, and electricity prices to energy consumption inequality are the greatest when all Member States are considered.

Furthermore, for all Member States, variations in GDP contribute 38.76% to energy consumption inequality, variation in HDI 11.84%, and variation in electricity prices 11.86%. These figures imply that GDP is the primary determinant of European household energy consumption and that decoupling has not yet been achieved in all Member States. For Leaders, the contribution of GDP is the smallest of all the determinants at 2.58%, confirming that these states have decoupled their energy consumption from their economic growth. In contrast, it is highest for Laggards at 17.58%, most likely because they have not yet achieved absolute decoupling. The fifth hypothesis is accepted.

Finally, the HDI and electricity prices are secondary determinants due to their average contributions. In all Member States, inequalities in HDI and electricity prices contribute almost equally to inequality in energy consumption. Regarding human development, the contribution of HDI is relatively small for the Leaders and Laggards and relatively large for all Member States, highlighting the economic and social gap between the two groups of countries. The contribution of electricity prices to the energy consumption inequality of lagging states is the largest among all country groups at 16.71%, illustrating the energy price sensitivity of households in these states.

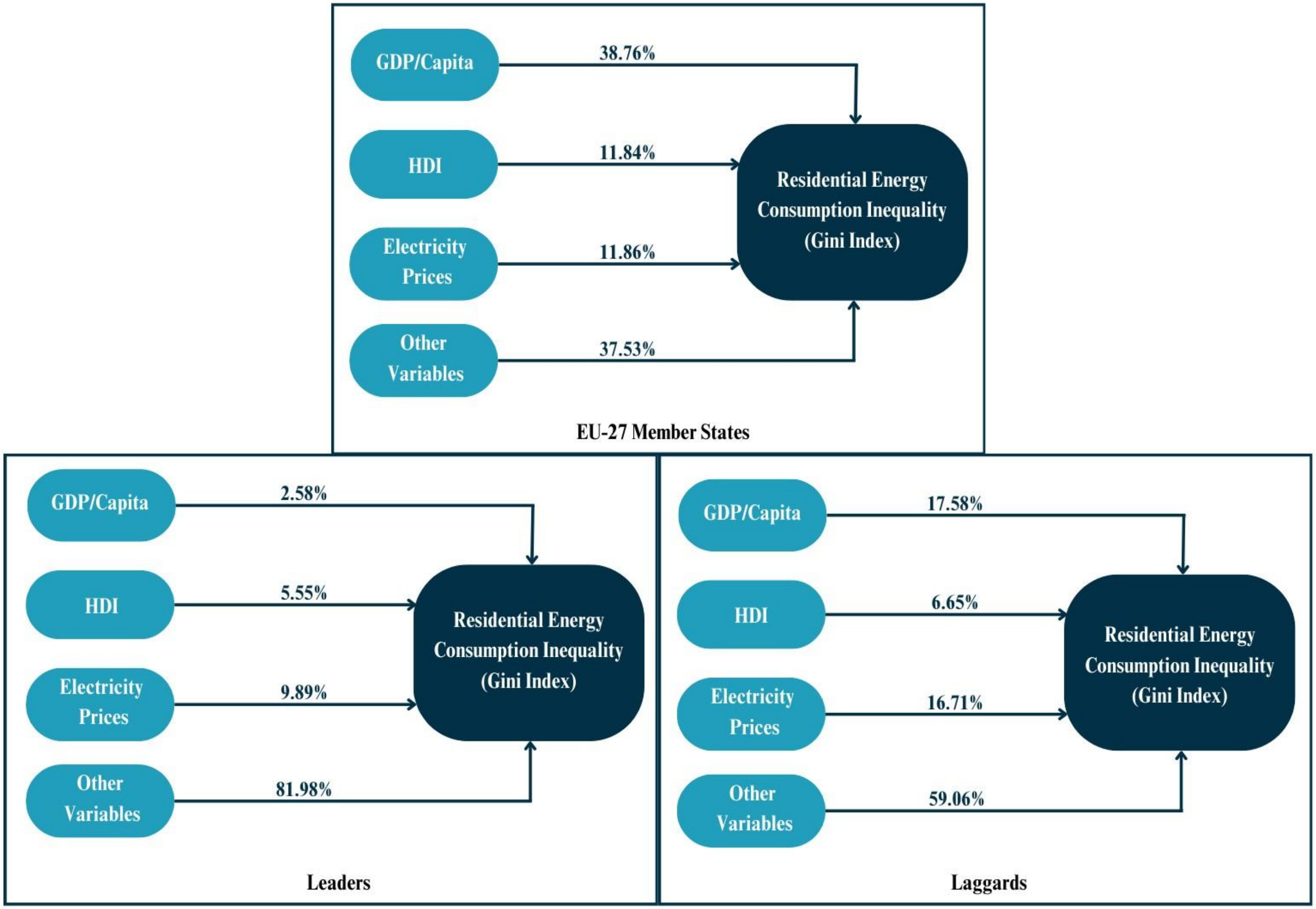

Figure 7 Average contribution of GDP, HDI, and electricity prices to the inequality of climate-adjusted per capita energy consumption for the EU-27 Member States, Leaders, and Laggards
Source: Author's analysis

3.6 Analyzing the impact of the rise in electricity prices on energy inequality

While a year may not comprehensively analyze the correlation between rising energy prices and other variables, valuable insights can be gained into how this price surge impacts old and new Member States differently. It should be noted that the analyses assume the price increase is the sole driver for changes in other variable values. Additionally, Malta was excluded from the analyses due to a decrease in electricity prices between 2021 and 2022.

Regarding the relationship between electricity prices and energy consumption, a decrease in energy consumption across all EU Member States is anticipated due to the higher electricity prices. Figure 10 illustrates the trends in these variables for the EU Member States during 2021 and 2022, with Luxembourg and Finland excluded as outliers. Initially, electricity prices were relatively similar across all states in 2021, with an inequality measure (Gini index) of 0.134. This homogeneity is attributed to the liberalized energy market in the EU. Beginning in the 1990s, the EU and its Member States agreed to gradually liberalization their national gas and electricity markets, progressively opening them to competition. This process underwent various phases from 1996 until 2022 (European Parliament, 2024). However, by 2022, price increases varied significantly among states, resulting in a rise in the Gini index to 0.217. States that experienced less pronounced price hikes in 2022 tended to have lower prices in 2021, such as Hungary, Poland, and Bulgaria. This discrepancy is attributed to differing state interventions during the energy crisis. Following the Russian invasion of Ukraine and the disruption of gas supply to Europe, the EU implemented REPowerEU to address the crisis, incorporating exceptional and structural measures in the electricity and gas markets (European Parliament, 2024). In exceptional circumstances, the EU permitted Member States to establish retail prices for households and micro-enterprises, resulting in different electricity prices among the Member States.

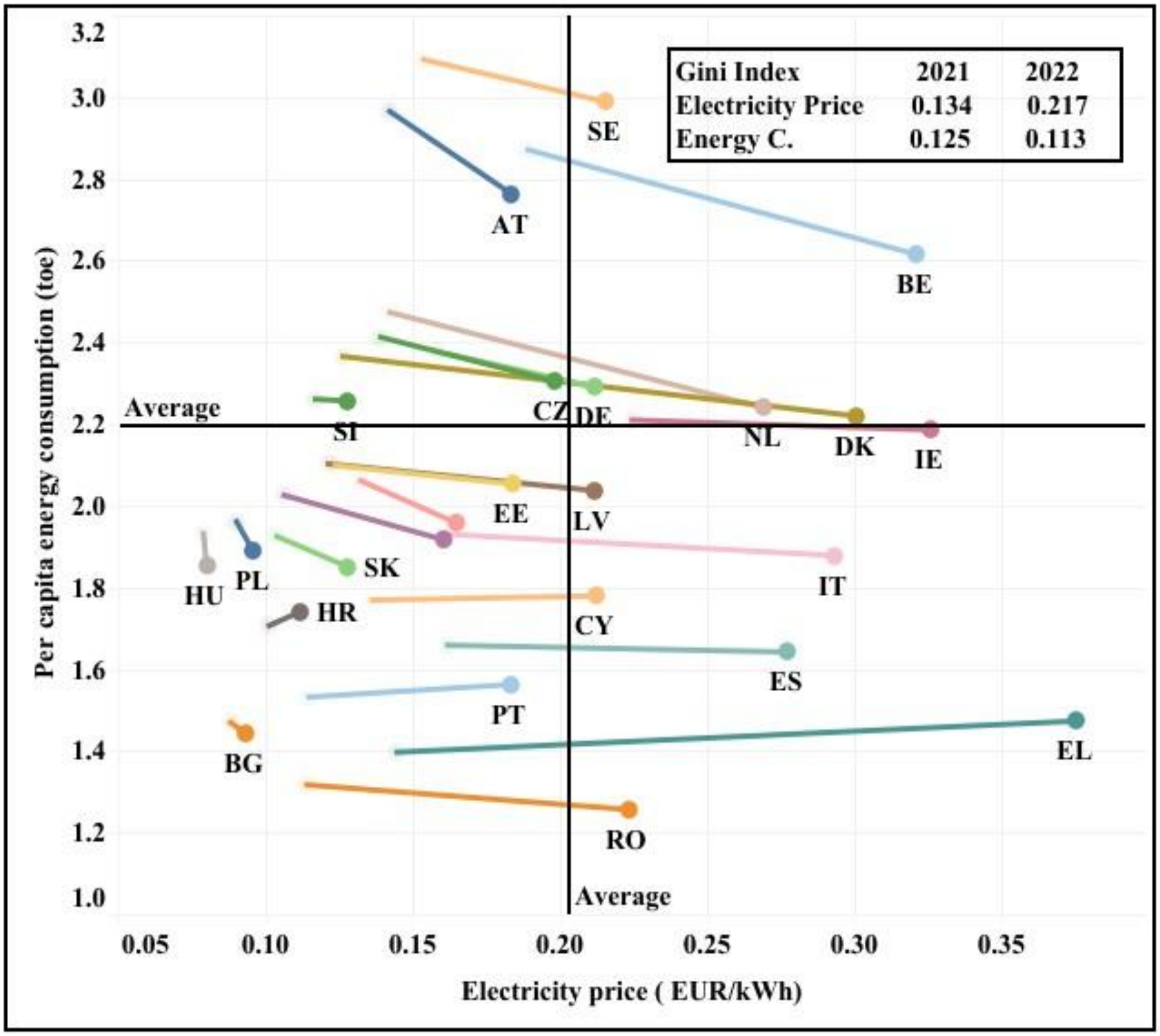

Figure 8 Electricity prices and per capita household energy consumption for the EU Member States in 2021 and 2022

Source: Author's Compilation

Energy consumption values also fluctuated, decreasing Gini values from 0.125 in 2021 to 0.113 in 2022. Countries like Greece, Croatia, Portugal, and Cyprus witnessed increased energy consumption despite higher electricity prices, potentially attributed to their warmer climates. It's essential to acknowledge that energy consumption values are not climate-adjusted, which may explain these countries' rise in energy use.

Unexpectedly, the rise in electricity prices did not correspond to an increase in energy inequality, as energy consumption values tended to converge irrespective of price hikes. However, this convergence occurred due to varying degrees of price increases, leading to a significant rise in price inequality between the two years. Generally, states with higher energy consumption witnessed more substantial decreases, possibly because they experienced greater price hikes. These states might have had energy overconsumption before the price surge. Conversely, except for

Southern states that increased their energy use despite significant price hikes, most states with low energy consumption experienced minimal price increases, indicating their inability to cope with substantial price hikes and lack of energy overconsumption. Consequently, the price increase in the EU contributed to reducing energy inequality among the states.

Regarding the relationship between electricity prices and GDP, Figure 11 displays the EU Member States' values in 2021 and 2022, with Luxembourg and Ireland excluded as outliers. The inequality in GDP decreased from 0.268 in 2021 to 0.251 in 2022, indicating a more significant decline in more developed states than less developed ones. Notably, this decline was observed primarily in states with higher GDP values, such as the old Member States, while those with lower values, such as the new ones, saw an increase. Similarly to energy consumption trends, more developed states experienced a more significant price increase, potentially explaining the decrease in their GDP values. Conversely, despite considerable price hikes, most Southern states experienced increased GDP values. Another group, including Hungary, Poland, and Bulgaria, faced relatively minor price increases, resulting in minimal impact on GDP. Their GDP values also increased. However, it was unexpected that GDP values increased for these states despite reduced energy usage. This suggests a weak connection between energy and GDP for these states compared to more developed ones. This observation contradicts the conclusions drawn earlier.

Nonetheless, it's crucial to note that this analysis covers only one year, overlooks climatic factors, and assumes electricity prices are the sole driver of other variables. Moreover, the drop in energy consumption and GDP values for the most developed states in one year does not hinder long-term economic growth. It suggests the economy's long-term resilience, as mentioned in the literature review. Therefore, including more years after the price shock in the analysis is recommended for more precise and comprehensive conclusions.

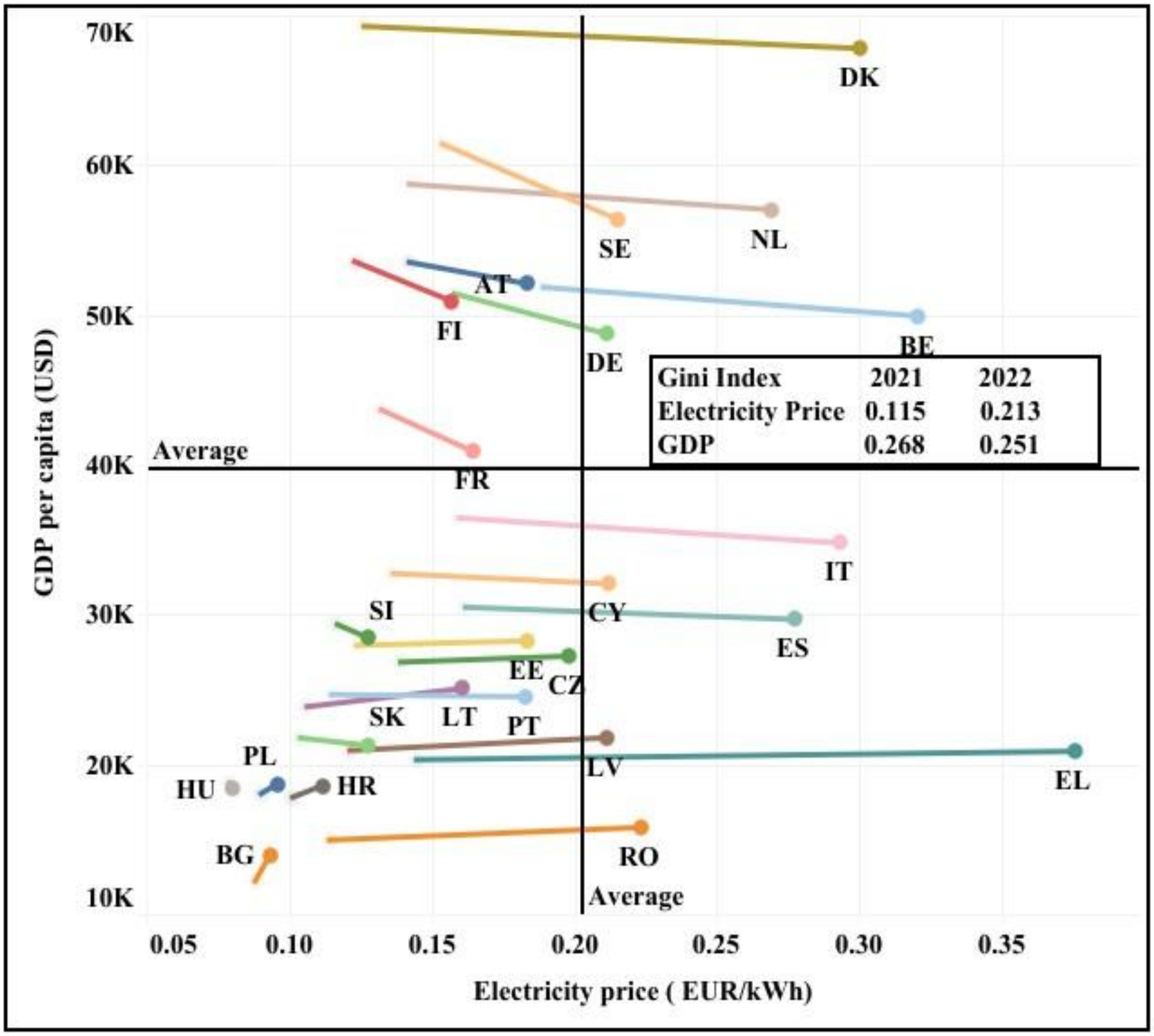

Figure 9 Electricity prices and per capita GDP for the EU Member States in 2021 and 2022
Source: Author's Compilation

For electricity prices and HDI, Figure 12 shows the values for the EU Member States between 2021 and 2022, excluding Romania and Bulgaria as outliers. Interestingly, all countries witnessed an uptick in their HDI values despite rising energy prices. However, the degree of HDI increase varied among countries, leading to a slight decrease in inequality from 0.205 to 0.195. Notably, nations with higher HDI values, including Denmark, Sweden, Germany, and Ireland, exhibited less pronounced increases than those with lower HDI values. This phenomenon suggests that these countries might have approached a saturation point where significant further increases in HDI become challenging to achieve. Overall, the data depicted in the figure indicates a lack of correlation between electricity prices and HDI across the EU Member States.

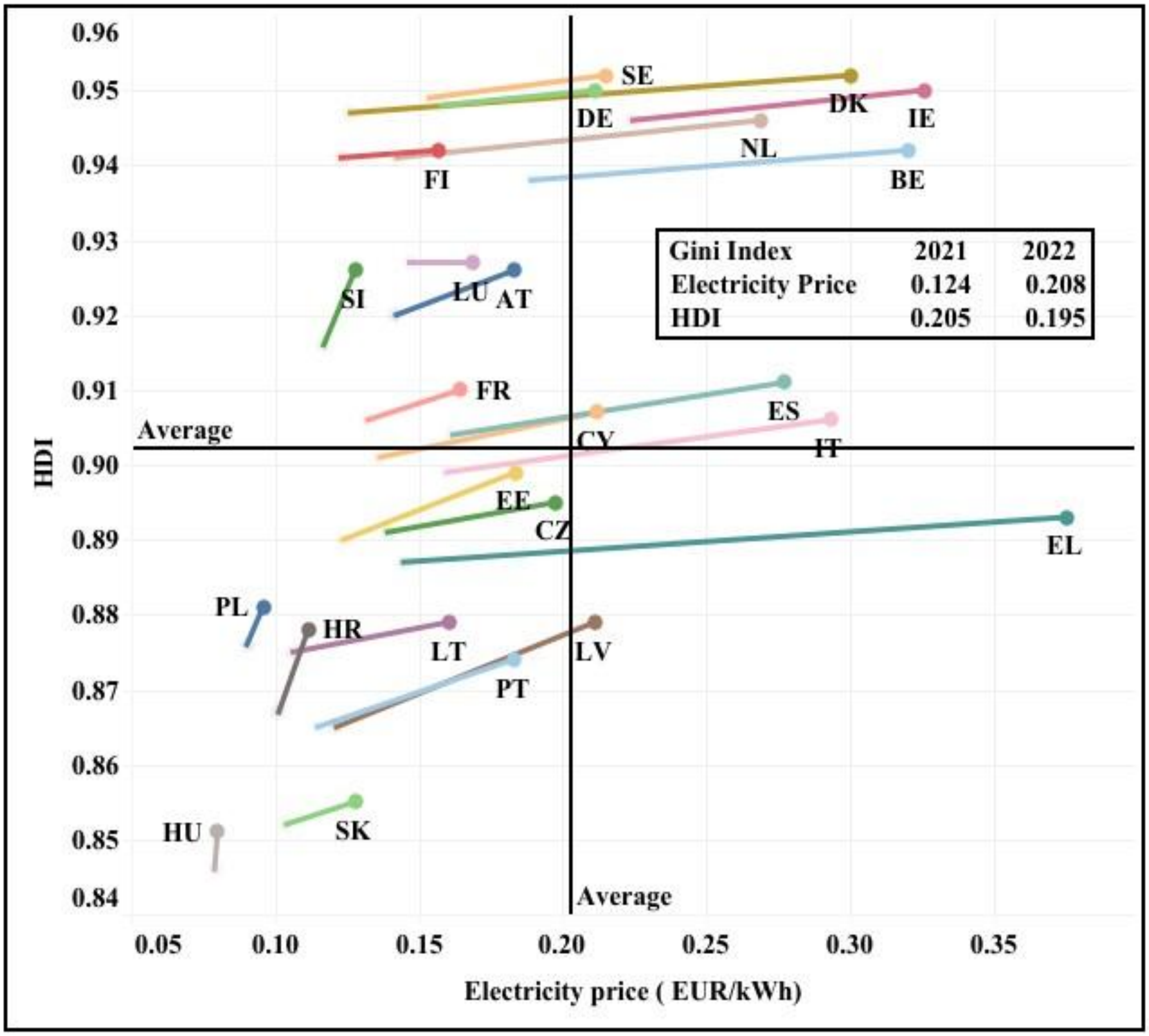

Figure 10 Electricity prices and HDI for the EU Member States in 2021 and 2022
Source: Author's Compilation

4 Conclusion and recommendations

4.1 Hypotheses One and Two

Human development is mandatory for citizens' well-being and quality of life. The provision of affordable and clean energy sources can improve this process. Thus, energy consumption plays a vital role in increasing a nation's level of human development. Nonetheless, the relationship between the two variables is nonlinear and depends on the energy consumed. The panel regression result showed that the HDI and its components positively correlate with household energy consumption. Thus, decision-makers in each state, particularly those with HDI values less than 0.9, and the EU should consider the influence of human development on energy inequality for the household sector by improving the education and health sectors and putting more effort into decoupling economic growth and energy consumption.

Energy efficiency should be considered when considering the decoupling process and raising the level of human development. Three groups of countries resulted based on the energy efficiency scores and HDI values of the 27 EU Member States. The first group, Ireland, Finland, France, the Netherlands, and Germany, has high energy efficiency scores and HDI values. Consequently, it is preferable to introduce the extended EU ETS as a pilot system in these states. These nations consume more energy, have higher energy efficiency levels, and have a higher income per capita than the other Member States. Hence, it is better to start reducing their high household energy consumption. In addition, households in such states can withstand the predictable increase in energy prices and utility bills as they have a high income.

The second group, Croatia, Poland, Italy, Estonia, and Hungary, has low energy efficiency scores and relatively low HDI values. Policymakers in such states should put more effort into improving their energy efficiency performance with the help and support of the EU. The EU ETS for the residential sector should not be applied in these states to avoid energy poverty and ensure energy justice because households here cannot handle rising energy prices.

The third group, which comprises the rest of the countries, has average energy efficiency scores and HDI values. To reduce their residential energy consumption and reach climate policy goals, they should improve their energy efficiency performance and strengthen their energy taxation framework. This could be achieved by changing the current minimum tax rates for the states under the Energy Taxation Directive and modifying the fuel type.

The correlation between increased energy consumption and higher human development has undergone reevaluation in light of mounting concerns about climate change and the imperative of energy efficiency. While essential for a wide range of activities, energy is also a primary contributor to greenhouse gas emissions, posing significant environmental threats. Consequently, the energy mix a nation uses plays a pivotal role in determining the direction of this relationship. For the EU Member States, there appears to be a trend towards higher-quality energy products over time, particularly aided by climate and energy policies. As a result, the quality of energy has reached a level where increased household energy consumption positively impacts life expectancy. This indicates that energy usage within the EU contributes more to advancing human development than it does to environmental degradation.

Furthermore, as nations progress, the correlation between these factors becomes less robust, and the significance of human development may diminish. In the context of the 27 EU Member States, it is evident that HDI positively impacts household energy consumption. States with higher HDI values tend to exhibit greater energy consumption in households.

The positive correlation between the HDI components and household energy consumption reinforces this relationship. Households in states with higher life expectancy, education indices, and GNI tend to consume more energy. The following theses are concluded:

T1	T2
HDI values are still dependent on residential energy consumption among the 27 EU Member States and its variation increases energy consumption inequality. This observation supports the conservative and growth hypotheses.	The correlation between the HDI and residential energy consumption is substantiated by the positive impact of specific HDI components, life expectancy, education index, and GNI, on residential energy consumption within the 27 EU Member States. Nevertheless, the conservative hypothesis is partially supported, as the education index exhibited a non-significant correlation.

4.2 Hypotheses Three, Four, and Five

The distribution of energy resources can lead to significant social, environmental, and economic inequalities. A major challenge for policymakers worldwide is how to distribute the costs and benefits of policies to address such problems (Wu et al., 2012). In Europe, the just transition approach is used to address this challenge. This approach aims to eliminate greenhouse gas emissions by 2050, decouple economic growth from resource consumption, and ensure no individual or region is left behind. Although the transition process entails a reduction in household energy consumption, the differences in household energy consumption across Member States and their social and economic consequences are often not considered in the context and regulatory framework of the just transition. To this end, this study assesses the role of socioeconomic differences between EU Member States in this inequality, calculates the share of each determinant (GDP per capita, HDI, and electricity prices) in overall inequality, and examines the decoupling between economic development and energy consumption.

To test the third hypothesis, the study divided the Member States into four subgroups and two main groups based on socioeconomic factors and energy consumption: Leaders (concentrated in the West and North) and Laggards (concentrated in the East). Leaders typically have better economic conditions and a higher standard of living than Laggards. Households in this group consume more energy than the EU average, while households in Laggards consume less energy than the EU average. The results show that inequality *between* subclusters contributes more to overall inequality than inequality *within* subclusters (the former accounting for the largest average contribution share in all years, at around 60%). This finding highlights the gap between the states allocated to these subclusters, leading to greater energy consumption inequality. In other words, the socioeconomic gap between EU Member States significantly impacts energy consumption inequality. This makes it necessary to consider this gap in all policy decisions. A multi-pronged strategy based on the sufficiency principle – the idea that everyone must have enough, not an equal share of benefits and burdens (Shields, 2019) – should be pursued to ensure that the lagging states with relatively low per capita energy consumption are treated differently. Referring to an earlier proposal of the present author, introducing the EU ETS as a pilot system in states with higher energy consumption, higher energy efficiency, and higher per capita income would be a viable short-term solution if applied to the EU leading Member States.

National governments can also adopt this strategy to reduce inequality in energy consumption at the country level. Hungary is an excellent example in this respect. The utility cost reduction program initiated by the Hungarian government to keep utility prices low in 2013 resulted in an additional consumption of 13.2 PJ by 2018 (Weiner and Szép, 2022). However, the latter was unevenly distributed across income strata. Low energy prices favored members of the higher-income strata more than those of the lower-income strata, who often use low-quality market fuels and live in inefficient housing (Weiner and Szép, 2022). Nevertheless, in response to the energy price storm in 2022, the Hungarian government revised the program to specify an official price for gas and electricity for every consumer to the national household average consumption level. Beyond this level, everyone must pay the market price. The Hungarian government's multi-tier pricing strategy, designed to alleviate the budgetary pressure caused by the energy crisis, is expected to reduce the inequality of household energy consumption between Hungarian population groups.

Regarding the contribution to overall inequality (hypothesis four), variation in GDP per capita has the most significant impact, followed by electricity prices and the HDI. The average contribution shares of these variables to overall inequality are 38.76%, 11.86%, and 11.84%, respectively, showing that GDP significantly impacts energy inequality. Therefore, decoupling GDP and energy consumption could be the most effective strategy for reducing inequality in household energy consumption in the EU Member States. For Leaders, the contribution share of GDP is the smallest of all variables, with a negligible value of 2.58%. In contrast, it is highest for Laggards at 17.58%. This result confirms that the decoupling of economic growth from household energy consumption has not been achieved in all Member States. Two primary strategies can be pursued to attain absolute decoupling:

First, lagging states may strive to increase their energy consumption, increasing their level of economic development. This would enable these states to better align their economies with those of the Leaders, which have already achieved decoupling.

Alternatively, the energy efficiency of buildings in lagging states could be increased, thereby decreasing energy consumption. This strategy would ensure that any decline in energy consumption would not merely be a reaction to rising energy prices, which impede economic development.

Given the consequences of the 2021-2022 energy crisis, which raised questions about energy security and the urgency of reducing fossil fuel imports, the second proposal is more realistic, especially as it aligns with European climate and energy policy goals. According to a report by the European Commission in 2021, about 75% of buildings in the EU are energy inefficient (EC, 2021). Accordingly, it is proposed to prioritize renovating old buildings in lagging states to improve energy efficiency. Addressing the preexisting problems of energy inequality that could widen the gap between the two groups of countries and disproportionately affect lagging states would be a step towards a just transition in the EU.

Finally, concerning the connection between energy consumption and GDP (fifth hypothesis), despite advancements in energy quality and technological improvements, such as increased energy efficiency levels within the EU, there remains a connection between energy usage and GDP in some Member States. Complete decoupling has yet to be attained across all Member States, confirming the viewpoint of opponent economists. The following theses are concluded:

T3	T4	T5
The pronounced socioeconomic disparities among EU Member States, as reflected in differences in GDP, HDI, and energy prices, play a pivotal role in shaping the disparities in household energy consumption across these states. The empirical evidence supports the conservative hypothesis.	GDP is the primary driver of inequality in household energy consumption within the EU Member States. This analysis underscores the pronounced economic-centric nature of development within the EU, as evidenced by GDP's significant impact on household energy consumption.	The decoupling of economic development from household energy consumption remains elusive in all Member States. This analysis disproves the neutrality hypothesis yet underscores the enduring link between GDP and household energy consumption.

4.3 Hypothesis Six

The sixth hypothesis explores the impact of rising energy prices on energy consumption, GDP, and the HDI for EU Member States, aiming to validate the hypothesis that economically weaker states are more adversely affected.

Notably, the surge in electricity prices did not uniformly translate into reduced energy consumption across the region, with differing degrees of price increases contributing to varying outcomes. Moreover, the findings regarding the relationship between electricity prices and GDP reveal unexpected nuances, particularly in states with lower energy consumption. Despite minimal price hikes, these states experienced GDP increases, highlighting a potentially weak link between energy consumption and economic output compared to more developed counterparts. However, it's essential to interpret these findings within the context of the study's limitations, including its focus on a single year, oversight of climatic factors, and the assumption of electricity prices as the primary driver of change.

All in all, the increase in energy prices due to the energy crisis in 2021-2022 decreased the inequality in energy consumption, GDP, and HDI, mainly because the increase was not uniform among the states. As a result, the sixth hypothesis is rejected. To get more precise results, further analysis is required by calculating and comparing the variables’ change rates between the states and including more years after the price shock in the study. Still, this result confirms that every state must have enough, not an equal share of benefits and burdens. That is why the higher increase in energy prices in the old Member States led to a decrease in energy inequality in the EU.

5 Summary

The distribution of energy resources creates social, environmental, and economic inequalities. Policymakers globally face the challenge of equitable distribution of costs and benefits in addressing these issues. The EU employs the just transition approach to tackle this challenge, striving for zero greenhouse gas emissions by 2050 and decoupling economic growth from resource consumption. However, the inequality in household energy consumption and its social and economic implications are often neglected in the EU just transition's regulatory framework. Understanding energy consumption inequality and its determinants is crucial to address this challenge effectively.

Economic growth emerges as a prominent determinant, with scholars identifying four key elements influencing the energy-growth nexus: substitutability of energy and capital, innovation in energy efficiency, changes in energy input composition, and output shifts. While economic growth is vital for sustainable development, its benefits do not automatically translate into improved living standards for all individuals, necessitating a comprehensive approach that prioritizes human well-being. The development process brings about not only economic but also societal changes that result in lasting improvements. Its main aim is to enhance human well-being. Since the HDI includes health and education indicators, it is widely regarded as the leading measure of human well-being, emphasizing the essential role of basic needs in enhancing quality of life.

This research evaluates inequalities in household energy consumption across the 27 EU Member States from 2010 to 2020. It examines the underlying economic and social factors contributing to these inequalities (GDP, HDI, and electricty prices). Additionally, it investigates the impact of electricity price increases between 2021 and 2022 on energy inequality and the progress of just transition.

Regarding the energy-HDI relationship, the results indicate that HDI exhibits a positive correlation with residential energy consumption among the 27 EU Member States between 2010 and 2020. As a result, the first hypothesis is accepted.

The correlation between the HDI and residential energy consumption is substantiated by the results that showed that all HDI components, life expectancy, education index, and GNI, positively correlate with household energy consumption.

Regarding investigating energy inequality and its driving factors in the EU, including more socioeconomic factors to the HDI, such as GDP and electricity prices, the study divided the Member States into two main clusters (Leaders and Laggards) and four subclusters based on energy consumption and these socioeconomic variables. The results show that the socioeconomic divide contributes significantly to the inequality in household energy consumption, as the inequality *between* subclusters is higher than the inequality *within* subclusters. As a result, the third hypothesis is accepted.

Among these socioeconomic factors, the per capita GDP is the main contributor to the energy inequality in the EU, with an average contributing share of 38.76%, followed by electricity prices and HDI, with contributing shares of 11.86% and 11.84%, respectively. This validates the fourth hypothesis and means that the economic aspects of development in the EU have a more robust connection to energy than the social aspects, and decoupling GDP and energy consumption could be the most effective strategy for reducing inequality in household energy consumption.

In leading states, GDP contributes the least among all variables, accounting for 2.58% of the total. Conversely, it holds the highest share in lagging states at 17.58%. This finding confirms that the decoupling of economic growth from household energy consumption has not been achieved in all Member States. This analysis reinforces the persistent correlation between GDP and household energy consumption. As a result, the fifth hypothesis is accepted.

Regarding the impact of the energy price rise that occurred during the 2021-2022 energy crisis on energy inequality, the increase in electricity prices caused a more notable decrease in household energy consumption, per capita GDP, and HDI in the old Member States compared to the post-communist ones, thereby mitigating inequalities in these indicators. Consequently, the sixth hypothesis is rejected. This unforeseen outcome is linked to the more significant price increase experienced by the old Member States, leading to a more substantial reduction in these indicators.

Moreover, the findings regarding the relationship between electricity prices and GDP reveal unexpected nuances, particularly in states with lower energy consumption. Despite minimal price hikes, these states experienced GDP increases, highlighting a potentially weak link between energy consumption and economic output compared to more developed counterparts. This outcome challenges the fifth hypothesis's conclusion, positing that GDP in old Member States contributes less to energy consumption than in new ones. However, it's crucial to contextualize these results within the study's limitations outlined in Chapter Three, which include a focus on a single year, oversight of climatic influences, and the assumption that electricity prices are the only driver of change. Consequently, further analysis is warranted to obtain more precise insights by calculating and comparing variable changes across regions over multiple years following the price shock.

The relationship between household energy consumption and GDP in the EU presents an intriguing aspect. The connection between these variables is expected to be robust for other sectors, particularly the industrial one, given that GDP primarily reflects production activities. However, the findings revealed a strong correlation for the household sector, despite the consideration of direct energy use only. The embodied energy in goods and services is not calculated. Considering energy quality variations and including other variables in the model, causality analysis between these two variables is advisable for future research. The research culminates with Table 6, which comprehensively summarizes the research outcomes.

Table 6 Comprehensive summary of research outcome

#	Hypothesis	Result	Thesis
1	Regardless of their energy transition efforts, HDI values for the 27 EU Member States are still dependent on household energy consumption, and variation in HDI values can increase energy consumption inequality.	Accepted	HDI values still dependent on residential energy consumption among the 27 EU Member States, and their variation increases energy consumption inequality. This observation supports the conservative and growth hypotheses.
2	A significant and positive correlation exists between HDI components (life expectancy, education index, and GNI) and household energy consumption across EU Member States.	Partially Accepted	The correlation between the HDI and residential energy consumption is substantiated by the positive impact of specific HDI components, life expectancy, education index, and GNI, on residential energy consumption within the 27 EU Member States. Nevertheless, the conservative hypothesis is partially supported, as the education index exhibited a non-significant correlation.
3	The socioeconomic divide among EU Member States contributes significantly to the inequality in household energy consumption across states.	Accepted	The pronounced socioeconomic disparities among EU Member States, as reflected in differences in GDP, HDI, and energy prices, play a pivotal role in shaping the disparities in household energy consumption across these states. The empirical evidence supports the conservative hypothesis.
4	GDP is the socioeconomic factor contributes most to inequality in household energy consumption in EU Member States.	Accepted	GDP is the primary driver of inequality in household energy consumption within the EU Member States. This analysis underscores the pronounced economic-centric nature of development within the EU, as evidenced by GDP's significant impact on household energy consumption.
5	Decoupling between economic development and household energy consumption has not been achieved in all Member States.	Accepted	The decoupling of economic development from household energy consumption remains elusive in all Member States. This analysis disproves the neutrality hypothesis yet underscores the enduring link between GDP and household energy consumption.
6	The increase in electricity prices that transpired across the 27 EU Member States between 2021 and 2022 led to a more pronounced decline in household energy consumption, per capita GDP, and HDI for the new Member States compared to the old ones, thereby intensifying disparities in these variables.	Rejected	None

Source: Author’s analysis

5.1 Policy implications for the EU: Insights from research

The current conceptual and regulatory framework of the EU just transition lacks a focus on inequality in household energy consumption. While the EU's just transition acknowledges carbon dependency considerations, a socioeconomic gap among EU Member States is often overlooked in policy formulation and decision-making processes. This socioeconomic gap significantly influences energy consumption inequality, necessitating its incorporation into all policy decisions.

A multifaceted approach based on the sufficiency principle should address this issue and ensure that the lagging states with relatively low per capita energy consumption are treated differently. National governments can also implement similar strategies to mitigate energy consumption disparities domestically. For instance, the Hungarian government's response to the 2022 energy price surge through a multi-tier pricing strategy exemplifies the application of the sufficiency principle.

In this context, findings revealed that the liberalization of national gas and electricity markets among EU Member States initially led to a reduction in energy price disparities from the 1990s until the 2021-2022 energy crisis. However, by 2022, price hikes varied considerably among states due to differing interventions, resulting in increased energy price inequality. Notably, prices rose more in leading states than in lagging ones, prompting a more substantial decline in household energy consumption in the former. Consequently, this led to decreased energy consumption inequality, serving as another manifestation of the sufficiency principle. Given their overconsumption of energy, leading states have the priority of curtailing their energy consumption.

The EC proposed reforming the electricity market design on March 14, 2023, in response to the energy crisis (European Parliament, 2024). The reform aims to reduce the dependency of electricity prices on fossil fuel costs and enhance consumer protection by expanding the availability of fixed-price and fixed-term contracts. It also allows consumers to choose dynamic pricing with multiple or combined contract options. Additionally, the reform ensures that governments can better regulate household retail prices to protect vulnerable consumers. Furthermore, it seeks to streamline the integration of renewable energy sources into the system. This initiative aims to maintain price stability and achieve ambitious climate targets simultaneously. The reform addresses national-level policy implications but overlooks the socioeconomic disparities among EU Member States.

The EU ETS was implemented in the industrial and power generation sectors in various phases, commencing with the first phase from 2005 to 2007, which served as a pilot phase for system testing. This phase was a pilot phase to test the system. During this phase, most carbon allowances were distributed free of charge, with Member States retaining autonomy over the allocation process. However, after the first year of operation and the publication of real-world emission data, it became evident that an excess of allowances had been issued, resulting in a surplus and subsequent decline in their price. The following phases saw a tightening of the emissions cap and a consequent rise in allowance prices.

At the beginning of phase three in 2012, changes were made to allocating carbon allowances. While the power generation sector transitioned to an auction-based allocation system, the industrial sector continued to receive allowances free of charge, determined by a benchmark linked to the installation's output or input. Initially, installations were granted 80% of the allowances according to the benchmark allocation, gradually decreasing annually to 30% by 2020 (Chandreyee and Velten, 2021). Industries vulnerable to carbon leakage, wherein production relocates from regions with strict climate policies to areas with less stringent regulations, were allocated 100% of allowances throughout the trading period. As a result, this allocation approach led to a more pronounced reduction in greenhouse gas emissions within the power generation sector than in the industrial sector by the end of the phase in 2020.

The phased implementation of the EU ETS, starting with an initial pilot phase, is recommended when the system is extended to the household and transport sectors. Furthermore, the differentiation in the allocation methods of the carbon allowances between the power generation and industrial sectors is also recommended to be applied to the leading and lagging states based on the amount of energy households consume.

Regarding the goal of decoupling energy consumption from economic growth, the study affirmed that leading states have successfully achieved this, whereas not all lagging states have. Consequently, two main strategies can be pursued to achieve absolute decoupling. Firstly, lagging states could aim to increase their energy consumption, thereby boosting their economic development to align more closely with leading states. Alternatively, improving the energy efficiency of buildings in lagging states could reduce energy consumption, ensuring that any decrease in consumption is not solely due to rising energy prices, which can hinder economic growth.

Considering the consequences of the 2021-2022 energy crisis and the imperative to enhance energy security while reducing fossil fuel imports, the latter proposal appears more feasible. With approximately 75% of buildings in the EU identified as energy-inefficient, there is a suggestion to prioritize renovating older buildings in lagging states to enhance energy efficiency.

5.2 Future research plan

1. Investigating the household energy-GDP nexus in the EU using causality analysis and incorporating a model that includes energy quality considerations and other determinants such as capital, labor, and technical change.
2. Investigating the energy-GDP nexus for all sectors in the EU while assessing the just transition progress by analyzing the shifts in the autonomous energy efficiency index.
3. Assessing the feasibility of the EU's climate policy targets by constructing future scenarios based on historical data, projecting energy inequality and its underlying drivers.
4. Conducting comparative analyses between energy inequality trends and policy responses within the EU and other regions or countries worldwide.
5. Investigating the long-term impact of energy prices in the EU on household energy use and other socioeconomic factors.
6. Developing a conceptual framework to explore the relationship between energy inequality and energy poverty in the EU, supported by empirical investigation.

List of publications

1. Kashour, M. (2023). A step towards a just transition in the EU: Conclusions of a regression-based energy inequality decomposition. Energy Policy, 183, 113816. (IF: 9; Q1).
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