The Implication or Validity of the Rebound Effect in Present European Energy Sector

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Abstract

Energy efficiency is one of the most important and global topics which is explored and studied. As a result of those studies, rebound effect has become important phenomenon due to failure of previous energy policies in stabilizing energy consumption levels. Based on rebound effect phenomenon, every energy legislature does not improve energy efficient, on the contrary it creates reverse effects. Recent energy policies are aimed to achieve a successful transition from conventional energy sources to renewables. Meanwhile, environmental challenges have increased the urgency and importance of latest steps. EU governance bodies have ratified several policies in tackling energy problems including rebound effect. This article explores how this phenomenon can result in undesired outcomes by studying possible effects of several variables in final energy consumption levels. These variables have been picked based on the potential impact factors on energy. We will implore desktop secondary research methodology to investigate to what extent EU energy policies have been successful in recent years to achieve energy efficiency. Afterwards, we can answer to our question whether rebound effect phenomenon is actual.

***Keywords**: renewable energy, rebound effect, energy consumption*

JEL code: Q20, Q42, Q49

Introduction

Nowadays, the energy efficiency issue attracts everybody's attention all over the world. It is strongly linked with the climate change problem, and a series of solutions and recommendations are offered and prepared to meet these challenges. Recent energy policies are aimed to achieve a gradual and successful transition from conventional energy sources to alternative ones. The main intention is to achieve energy efficiency alongside decreasing the impact of production on the environment. However, historical trends suggest that usually similar policies have been ostensible, as they have only caused an increase in the amount of total energy consumption, rather than to achieve the aforementioned aim. The Jevons Paradox about energy efficiency was resurrected to analyze the reflections and implications of the implemented energy policies which results in rebound effect. Based on this concept, the same question arises in connection with the recent energy policies. Will the transition to alternative energy sources increase energy efficiency and decrease the increased usage (and waste) of available energy? Correlation analysis indicates that renewable energies have largely taken the place of fossil fuels. In the majority of EU countries, coal has been substituted by renewable sources.

Coal is the most environmentally damaging fossil fuel due to its high carbon dioxide emissions. However, the transition away from gas and oil is progressing more slowly compared to coal. This is because gas is crucial for heating and electricity generation, while oil is essential for transportation

(Bozsik et al., 2023) Despite all these positive trends, the potential success of EU energy policies is questionable.

The aim of this article is to analyze whether *current energy efficiency policies may also achieve a reverse and undesirable outcome and result in the increase of the overall energy consumption at EU-level due to implications of rebound effect*. It is widely believed that this transition would decrease the precarious repercussions of massive production. However, it is debatable whether this transition would achieve energy efficiency. Since history suggests a reverse trend, it is important not to repeat past mistakes for the countries of the European Union. The reason for choosing the EU as a center of my research is that this continent is having a leading position in both transition and energy efficiency questions and is meeting its set goals.).

Jevons (1865) has explained that achieving energy efficiency can instigate economic growth. He claimed that the remaining energy could be used in other ways which can increase production which can lead to usage of more energy.

York and McGee (2016) have attempted to formulate the well-known paradox: it occurs when the rebound effect exceeds 100 %, meaning that there is an actual increase in resource consumption.

The *rebound effect* refers to the phenomenon where improvements in energy efficiency lead to lower energy costs, which can paradoxically increase overall energy consumption. This occurs because the economic savings or increased efficiency often encourage greater use of energy services, offsetting the anticipated reductions in energy usage. For example, a more fuel-efficient car might result in people driving more, thereby reducing or even negating the energy savings from improved efficiency. Understanding the rebound effect is crucial for designing policies that effectively reduce total energy consumption rather than merely improving efficiency.

The Jevons Paradox notion can be directly attributed to a more specific rebound effect in which there is a rebound of more than 100 % engineering saving, which ultimately causes the increase rather than decrease in the consumption of a specified resource. (Foster et al., 2010) But it is difficult to calculate the extent and magnitude of the magnitude of rebound effect since different estimates demonstrate strikingly different results for energy efficiency policy. The rebound effect can be defined as the recurring energy consumption, which emerged due to changes in behavioral and other systemic responses to Energy Efficiency Improvements (Cansino et al., 2019). The rebound effect is expressed as a percentage of the forecasted reduction in energy use that is 'lost' due to the sum of consumer and market responses (Gillingham et al., 2015). The main problem of achieving energy efficiency was that lowering energy prices trigger businesses and customers to spend their remaining additional income on other things that also consume energy. Businesses usually want to expand their operations further. They have lower costs, and by the time they also achieve economies of scale and economies of scope by further production, so actual energy consumption increases.

Fouquet and Pearson (2006) demonstrated one example of the rebound effect. Their research had concluded that in the UK for over seven centuries, per capita consumption of lighting services had increased more than per capita GDP as a result of decreasing price per lumen hour. Certainly, this decrease had been achieved as a consequence of increasing efficiency and technological innovation.

Gunderson and Yun (2017) conducted their research in South Korea to identify the connection between green growth and Jevons Paradox. Korea accepted a national strategy for green growth, and they aim to realize energy efficiency by giving a green stimulus package, price-based policies, and green research and development to achieve a technological upgrade in all sectors to accomplish energy efficiency. Gunderson and Yun (2017) have identified that energy consumption levels and greenhouse gas emissions also increased as a result of these policies. York and McGee (2016) had also conducted research on the links between the trends in energy efficiency (GDP/energy use) and energy consumption (energy use per capita). They figured out a positive correlation between two variables.

Bozsik et al. (2023) examines the evolution of Hungary's electricity sector from 2010 to 2020, with an emphasis on the growing influence of renewable energy. Using a Pearson correlation matrix, the study investigates the relationships between various energy sources such as coal, natural gas, nuclear, bioenergy, and renewable energies. The authors find that renewable energy sources are expected to play an increasingly significant role, impacting both Hungary's electricity import-export dynamics and the operation of its power plants. It is quite curious to see whether energy innovation in Hungary can lead to increase in energy consumption levels.

Meyer, Magda, and Bozsik (2021) investigated the impact of renewable energy in the newer EU member states, focusing on how their energy consumption patterns have evolved, particularly with regard to renewable energy integration. The authors assess the gross inland energy consumption of these countries from 2010 to 2016 using a comparative time-series method. The study shows that the increased use of renewable energy in many of these countries is largely attributed to the decline in the consumption of coal, oil, and nuclear power. For instance, renewable energy has largely replaced coal in nations like Bulgaria, the Czech Republic, and Cyprus, while in Lithuania, it has taken the place of natural gas. However, Hungary stands out as an exception, as the study did not find a clear correlation between the rise in renewable energy consumption and a reduction in the use of non-renewable sources during this period.

There are two types of rebound effects. The first one is the direct effect. Daniel Khazzoom (1980) defined the first direct rebound effect as improvements in technical efficiency in the usage of energy cause an increase in demand for energy services. Moreover, the 'direct rebound effect' can also be defined as the change in energy use resulting from the combined substitution and income effects on the demand for the energy-efficient product (Sorrell et al., 2008). As it was mentioned above, when the cost of energy gets lower, it instigates the demand, and as a result of it, more customers use it. If we compare this from the microeconomic perspective, this is quite straightforward. To reach the new equilibrium point, the supply curves shift right, and as a result of it, the quantity of energy consumption increases. Price elasticity also affects to energy consumption. If the demand for energy is inelastic, then achieving efficiency will not alter much of the customers' behavior. However, if the demand for energy is elastic, then as the efficiency is realized, customers consume more than gains, and as a result of it, Jevons' Paradox occurs.

The second rebound effect is the indirect effect. This is more complicated to explain and measure. As the cost of energy reduces, more income remains for the customers to spend. Not all customers decide to save this money, as they are inclined to spend it on other goods and services which usually require energy. Therefore, it is quite complex to track the customers' purchases, and as a result, the impact of indirect energy rebound.

It is very difficult to estimate the scale of the rebounding effect since it is impossible to foresee and to track how consumers react with their remaining incomes, which are generated by energy efficiency policies. Giampietro and Mazuko (2006) pointed out three significant conceptual challenges in perceiving improvements in energy efficiency and rebound effect thoroughly:

- How to define and measure energy efficiency
- How to distinguish energy efficiency due to a change in technological coefficients from a price-induced substation
- How to separate the effect of an increase in population from energy efficiency at the macroeconomic level

However, several methods and formulas were developed to calculate these effects based on certain conditions.

$$\vartheta\alpha(XE)=\vartheta\alpha(SE)-1$$

In this formula, $\vartheta\alpha(XE)$ is the efficiency elasticity of the demand for energy, and $\vartheta\alpha(SE)$ is energy efficiency elasticity of the demand for useful work for energy service. When the energy efficiency elasticity of the demand for useful work for an energy service is equal to zero, there is no direct rebound effect. Rebound effect can be derived from price-elasticity of energy demand, only if certain hypotheses are followed: (Khazzoom, 1980; Berkhout et al., 2000; Sorrell, 2007):

- Consumers' reactions do not vary to an energy efficiency improvement other than a reduction in energy prices.
- Energy prices do not have any impact on energy efficiency.

$$\vartheta\alpha(XE)=-\vartheta PE\ (XE)-1$$

In this formula, $\vartheta PE\ (XE)$ is the price elasticity of the demand for energy. Two hypotheses are necessary for this formula: (Khazzoom, 1980; Binswanger, 2001; Berkhout et al., 2000; Dimitropoulos and Sorrell, 2008; Sorrell, 2009)

- Symmetry assumption, which is about the reaction towards decreasing energy prices, are not different from reactions to energy efficiency.
- Exogeneity assumption which indicates that energy prices do not change energy efficiency.

A demand model for residential energy uses beneficial in the estimation of own price elasticities. Even though other econometric methods and functional forms can estimate these own price elasticities, the estimation of a logarithmic model is more reliable in applying these estimates and getting robust estimated parameters: (Sorrell, 2009).

$$\ln E= \beta0+\beta1 \ln Pe+\beta2 \ln Pi+ \beta3 \ln Y+ \beta4 \ln C+ \beta5 \ln Z+ u$$

This econometric model explains the relationship between dependent variable demand of energy E and independent variables the price of energy Pe, the prices of other goods and services Pi, the disposable income Y, the weather conditions C and other factors Z. In this formula, β1 is the own price elasticity of the demand for energy which is directly related to the direct rebound effect (Freire-Gonzales, 2017).

This is a general econometric model where the demand of energy E depends on the price of energy Pe, the prices of other goods and services Pi, the disposable income Y, the weather conditions C and other factors Z. In this specification, the value of β1 provides the own price elasticity of the demand for energy, and then, a proxy of the direct rebound effect.Sorrell (2009) claims that the indirect rebound effect can come from two sources:

- Energy content: This is the required energy to be produced and used on the measures that achieve energy efficiency. Certainly, this effect should be considered since it has been duly used in this research.
- Secondary effects: These effects are formulated as a consequence of energy efficiency measures. Usually, energy efficiency measures are exposed to indirect energy consumption. These effects are calculated by taking into consideration the impacts of both direct and indirect energy consumptions.

There are various models that will help to calculate the extent of the indirect rebound effect, such as the energy input-output model and the re-spending model. A vector of sector intensities in the use of energy and Leontief models are incorporated in order to get the input-output model

(Leontief, 1970; Leontief and Ford, 1972; Chapman, 1974; Bullard and Herendeen, 1975; Casler and Wilbur, 1984; Proops, 1988; Alcántara, 1995; Lenzen et al., 2004).

e=E(1-A)-1f

This formula explains the relations between the dependent variable of direct and indirect energy consumption (e) and independent variables of changes in consumption patterns (f) and the inverse matrix of Leontief. This is a straightforward way to obtain a formula that provides direct and indirect energy consumption (e) of the economic system from changes in consumption patterns (f). It can also be expressed in variation terms, so changes in final demand lead to changes in total energy use. In order to know the value and variations off after an energy efficiency improvement, the next section details the re-spending model that provides changes in consumption patterns.

Material and method

This study focuses on the current relevance of energy issues in the European Union (EU) and the significant challenges posed by climate change. A key concern is the rebound effect, where energy efficiency policies, instead of reducing consumption, may inadvertently lead to increased overall energy use. The research examines the current energy landscape in the EU, analyzing factors influencing energy consumption and their connection to the rebound effect. Insights from this analysis are intended to inform energy policy improvements globally, particularly in light of ongoing revisions to energy frameworks. The aim of the research is to analyze the current EU energy policies with consideration of the rebound effect and to examine how these policies contribute to achieving sustainable energy consumption.

This study employs desktop research, utilizing secondary data and statistics to derive conclusions about EU energy consumption trends and policies. The research was conducted through the following stages: The research theme was selected after a review of relevant energy and climate change literature, focusing on the implications of the rebound effect in the context of EU policies. Official databases, particularly Eurostat, were the primary sources for energy statistics, including metrics on energy consumption, prices, and policy outcomes. Publications and reports from the European Commission and European Environment Agency provided additional context on policy directives and their impacts. Peer-reviewed articles and seminal works on the rebound effect, energy policies, and economic impacts contributed to the theoretical framework and analysis. Following necessary variables are used: Socioeconomic indicators: GDP per capita, population changes. Sectoral data: Transportation trends (e.g., mileage, flights), building construction metrics (e.g., square meters per capita). Energy and economic metrics: Energy prices over time, trade intensity, consumption patterns. Based on literature review which we have inspected, we have deduced that these articles can have a direct impact on energy consumption levels.

Trends in energy consumption and efficiency were examined using summary statistics and visualized with tables and graphs. Variations in energy metrics were analyzed across time and member states. Differences in policy impacts among EU member states were evaluated to assess the success of renewable energy initiatives. The relationship between energy consumption and influencing factors (e.g., GDP, population, transport) was assessed to understand the drivers of the rebound effect. Findings were contextualized within existing theories of energy economics, including Jevons' Paradox and related rebound effect studies. Based on the analysis, conclusions were drawn about the effectiveness of EU renewable energy policies and recommendations were made to mitigate rebound effects. This comprehensive framework ensures that findings are robust and provide actionable insights into the EU's energy policies and the rebound effect.

Results

In this section, we will explain how the rebound effect incurs in the EU. There are various reasons for this process, and it will be supported by the facts and data. Moreover, we will give more information regarding the energy efficiency situation in the EU and depict the current outlook in this region. Rebound effect and other factors compensate for the positive sides of energy measures, which are accepted by EU governance bodies.

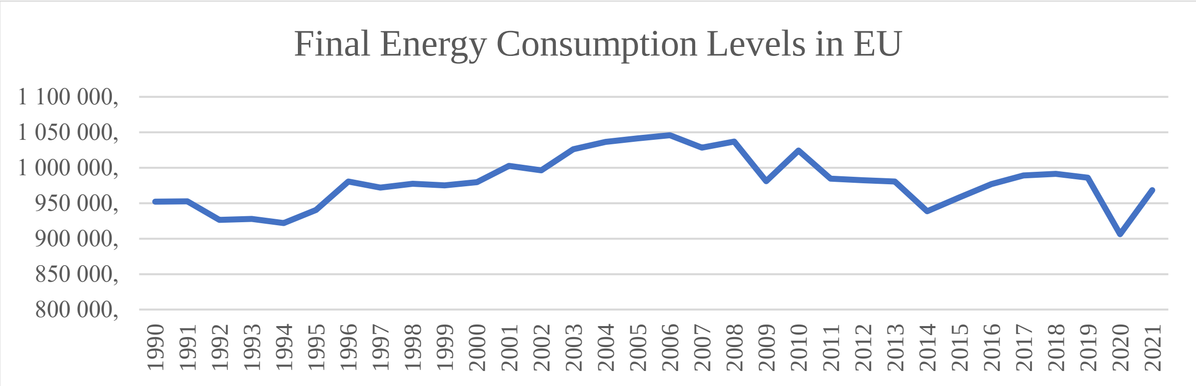

Figure 1. Final Energy Consumption levels in EU

Source: Eurostat 2024 (Author, unit of measure is in thousand tons of oil equivalent)

Figure 1 gives information regarding final energy consumption levels of energy. Energy consumption levels haven't changed significantly from 1990, even though we observe certain volatilities over time. Moreover, it demonstrates that the energy policies of EU governance bodies were partially successful. Their policies have impeded the increase in final energy consumption. However, they have not achieved to decrease to desirable levels. In figure 1, it would be worth highlighting that although energy consumption is stagnant, this does not necessarily indicate a shift toward sustainable development when considering factors such as population growth or economic activity.

There are several factors that affect the increase in overall energy consumption. These factors are essential to be studied in order to understand the possible extent of energy policies in overall energy consumption.

- Changes in the GDP/capita –those being under the poverty line. When people have more income, they will spend more, which results in an increase in final energy consumption levels.
- An increase in the population – more people mean more people demand energy.
- Construction of the buildings – changes in square meter per capita. The construction and maintenance of the buildings consume a vast amount of energy.
- Transport sector – the usage of different transportation modes has a significant impact on energy consumption levels.
- The amount of mileage by riding cars
- The number of flights in the EU

- Trade intensity, the level of trade – increase in the level of trade implies more production of goods and services which require energy.
- Consumption of products – an indicator that shows the structure and the level of consumption.
- Energy prices table – how it changed in the last 20 years within the EU. From a microeconomic perspective, lower the price stipulates a higher level of energy. Thus, EU governance bodies regulate prices to control consumption levels.

Changes in the GDP/capita

There is a mutual causality between GDP and energy consumption. The increase in GDP is also one of the direct causes of the expansion of energy consumption.

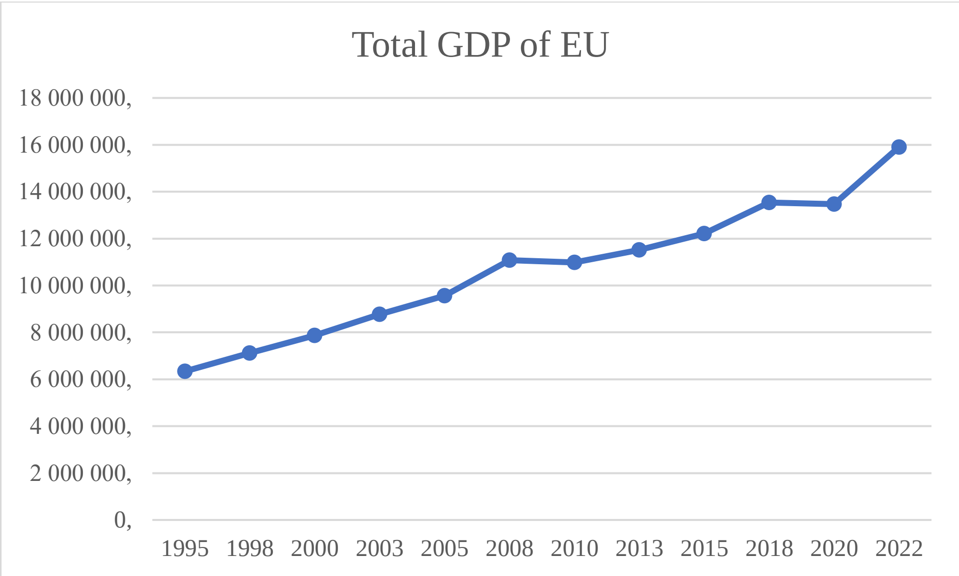

Figure 2. The GDP levels in EU
Source: Eurostat 2024 (Author, unit of measure is current prices, million euro)

Figure 2 indicates the increase of total GDP in EU over time. Increased total GDP indicates more goods and services were produced in EU. This process happens due to an increase in the production of goods and services. Certainly, this correlation is quite logical since the manufacturing process demands energy. As most of the countries experience a positive increase in GDP per year, the increase in energy consumption is inferential.

Increase in population

Certainly, the increase of the population automatically causes the total energy consumption to increase. Particularly, after the surge of the industrial revolution, the population of the whole world began to surge significantly. Therefore, it becomes extremely hard to realize the aim of energy efficiency as the demand for energy increases. It is also important to note that most of the population fertility happens in developing countries. Still, if we pay attention to the data, we can notice that there was a slight increase in the population of Europe, even though some of the Member States experience population loss.

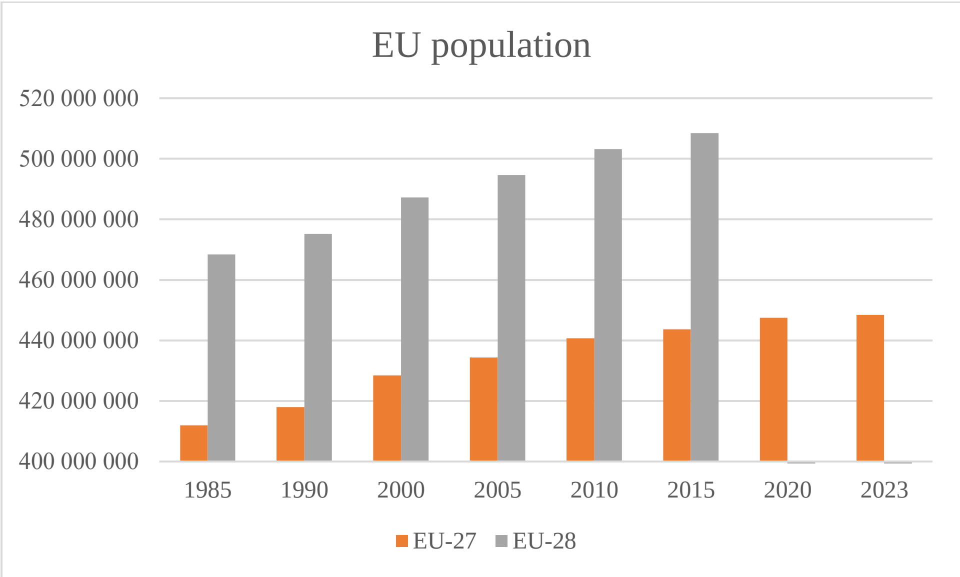

Figure 3. The Population of EU
Source: Eurostat 2024 (Author)

Figure 3 takes into consideration Brexit as well, and it both contains the total sum of the EU's 28 countries and 27 countries separately, even though at not all times, these 28 countries were a part of the EU. In the 1980s, the amount of population was more than 460 million, and it continued to increase in future intervals. In 2019, Europe's population equaled 513 471 676. However, contrary to general premises, in the EU's case, the total energy consumption has not changed significantly. It is a very interesting finding since this fact is the opposite of the global trend, even though population has increased over time.

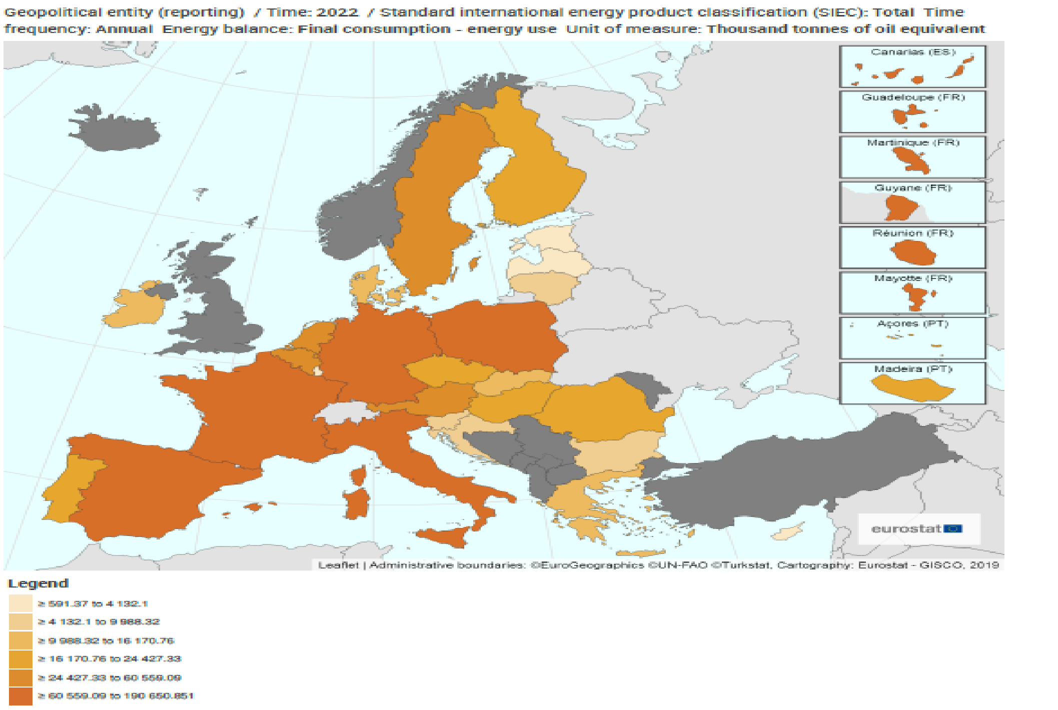

Figure 4. Final Energy Consumption by Product in 2022

Source: Eurostat 2024 (Unit of measure is thousand tonnes of oil equivalent)

Figure 4 indicates which countries used energy most in Europe. The dark orange areas indicate the energy was most used in those countries, whereas when the color gets lighter, then it means that those countries have consumed less energy.

It is quite an interesting finding. Unlike developing countries, the increase in the population does not cause an increase in final consumption. In 2014, the number even hit the lowest point in 35 years period. Therefore, we can derive this conclusion that the increase in the population is not an influential factor in the increase of total energy consumption in the EU. Not only total consumption has not changed, but also energy consumption per persona has shrunk even more. This finding confirms that energy efficiency measures by EU governance bodies offset the impact of increasing population on energy consumption levels.

The Construction of the Buildings

The energy performance of the buildings is one of the key components that affect total energy consumption. 40 % of the total energy consumption and 36 % of carbon emissions are exposed from the buildings (European Commission, 2019c). European Commission (2019c) also reports that 35 % of the buildings in the EU are over 50 years old, and 75 % of the building stock is quite energy inefficient, and only around 0.4-1.2 % of the buildings stock are renovated each year. Given these circumstances, the EU decided to issue new legislative measures such as the Energy Performance of Buildings Directive 2010/31/EU (EPBD) and the Energy Efficiency Directive 2012/27/EU in order to achieve better energy efficiency in terms of old and new buildings management. Their main targets are the following:

– Accomplishment of a highly energy-efficient and carbon-free building stock by 2050
– A more safe and balanced environment investment decisions

- Educating consumers and businesses more regarding saving money and energy (European Commission, 2020d)

EPBD urges countries to accept cost-optimal minimal energy building principles for newly constructed buildings and for the renovated old buildings. Furthermore, those new buildings should meet NZEB (Nearly zero-energy building) criteria starting from 31 December 2020.

The Usage of Different Transportation Modes

Government regulations certainly affect the usage of energy consumption. If the government increases the prices of energy products, then people would be more efficient. For example, if they increase the price of gasoline, then people will use fewer cars and shift to other transportation modes. Similarly, EU governance bodies urge countries to shift their energy- mix policies by implementing rewarding and punitive reinforcement tools. Presumably, they need to be careful not to impose very high prices, which can cause distress in their citizens, so these policies should not damage routine life significantly.

The European Union (EU) has achieved notable progress in improving fuel efficiency, driven by stringent policies and technological advancements. International Energy Agency (2021) has released certain updates on their report as a part of Global Fuel Economy Initiative 2021.

1. Fuel Efficiency Progress: Between 2005 and 2019, the average fuel consumption of light-duty vehicles (LDVs) in the EU fell from 7.0 to 6.0 litres of gasoline equivalent per 100 kilometres. This represents an annual reduction rate of about 1%. The introduction of stricter CO_2 standards, such as the 2020 mandate limiting passenger car emissions to 95 g CO_2/km, contributed to significant advancements, including an 11% drop in average emissions for new LDVs between 2019 and 2020.

2. Rise of Electric and Hybrid Vehicles: The EU has seen a steady growth in hybrid and electric vehicle adoption. By 2019, hybrids accounted for 3% of the market, with electric and plug-in vehicles comprising 2% and 1%, respectively. These trends reflect policy-driven incentives to transition to cleaner technologies.

3. Market Shifts: The market share of diesel vehicles, traditionally dominant in the EU, declined from 56% in 2015 to 40% in 2019, influenced by emissions regulations and the 2015 diesel emissions scandal. At the same time, SUVs, which typically consume more fuel, have gained popularity, increasing their market share to 36% by.

4. Policy Impact: EU regulations, such as mandatory CO_2 standards and car labeling directives introduced in 1999, have been pivotal. These measures not only encourage manufacturers to innovate but also help consumers make environmentally conscious choices (International Energy Agency, 2021).

As a result, they use less energy than they did before when they drive. It should also be mentioned that the EU urges its citizens to use more public transportation and bicycles for traveling to short distances. In the previous chapter, I have given information regarding the increase in the number of electric cars, which is efficient and environment-friendly. Given the high price of gasoline, all these changes are quite logical for most of the citizens in the EU. Therefore, it also causes the amount of mileage and carbon emissions to decrease.

Another reason is to travel by flight. The number of tourists increased significantly in recent times. The ratification of the Schengen agreement allowed the movement of people within the EU. This treaty was signed on 14 June 1985, and its first signatories were Belgium, France, Germany, Luxembourg, and Netherlands (European Commission, 2019b). After a period of time, more countries joined, and now 26 countries can issue Schengen visas. Particularly, this treaty abolished the borders and the control of the documents between those countries. Therefore the number of people who travel and migrate increased. Moreover, the availability of low-cost airlines such as WizzAir, RyanAir also contributes to the increase in the number of tourists. It is possible to purchase tickets from one European city to another at very low prices. Therefore the demand for traveling increases significantly. As more tourists fly, more planes are necessary to deliver the passengers to the desired destinations. Therefore, the demand for gasoline increases in order to make those planes work. Automatically, the demand for energy also surges, and this increase is another big obstacle for achieving energy efficiency.

Table 1. The number of passengers that used air transport in the whole EU

Air passenger transport by type of transport, 2022

(passengers carried)

	Total		National		International intra-EU		International extra-EU	
	Thousands	Change 2022/2021 (%)	Thousands	Change 2022/2021 (%)	Thousands	Change 2022/2021 (%)	Thousands	Change 2022/2021 (%)
EU (¹)	**819 838**	**119.3**	**135 380**	**57.5**	**299 323**	**111.5**	**385 135**	**163.2**
Belgium	27 874	106.5	15	-38.1	18 904	98.1	8 956	127.7
Bulgaria	8 808	74.5	239	14.9	5 856	69.8	2 713	94.9
Czechia	11 533	142.5	13	36.1	7 001	128.8	4 519	168.1
Denmark	26 650	146.3	1 578	44.4	15 542	128.5	9 530	226.1
Germany	155 303	111.0	9 426	97.7	80 967	100.7	64 910	127.9
Estonia	2 731	111.3	49	27.8	2 061	130.1	621	73.2
Ireland	32 406	256.2	123	225.5	16 686	213.6	15 597	317.2
Greece	57 894	79.5	9 075	56.4	32 111	64.6	16 708	140.8
Spain	199 571	117.2	40 917	57.5	94 313	107.0	64 342	215.9
France	136 561	106.8	26 504	39.6	55 032	112.3	55 025	160.4
Croatia	9 415	111.2	358	49.7	6 385	105.4	2 673	140.7
Italy	132 426	121.8	32 179	52.8	66 798	136.1	33 449	222.9
Cyprus	8 613	68.9	0	-	4 366	90.0	4 247	51.6
Latvia	5 368	129.8	0	-	3 815	146.1	1 554	97.7
Lithuania	5 334	116.4	0n	27.4	3 155	125.3	2 179	104.8
Luxembourg	4 057	102.6	0	-	3 301	86.9	755	218.2
Hungary	12 394	165.6	0n	-89.3	7 933	155.6	4 460	186.0
Malta	5 862	130.1	0	-	4 293	129.1	1 569	132.6
Netherlands	61 290	110.7	4	85.8	32 749	87.3	28 537	146.1
Austria	26 381	137.5	222	93.9	17 190	137.3	8 970	139.3
Poland	39 348	108.3	1 603	116.5	21 618	111.5	16 126	103.3
Portugal	57 082	155.4	6 174	97.6	30 533	139.7	20 375	214.3
Romania	19 536	88.1	990	45.9	12 577	91.0	5 969	91.2
Slovenia	969	131.0	0	-	453	81.4	516	204.0
Slovakia	1 943	202.5	1	31.5	1 031	184.5	910	226.6
Finland	13 813	203.3	1 709	96.9	8 557	231.4	3 546	221.2
Sweden	25 039	131.9	4 200	89.9	14 459	132.2	6 380	170.5

(-) not applicable

(¹) Double counting is excluded in the intra-EU and total EU aggregates.

0n: less than 500 passengers carried

Source: Eurostat (online data code: avia_paoc)

Source: Eurostat 2022.

Table 1 depicts the number of passengers that used air transport for their needs. We can clearly see that in 2022 more people have used air transport than 2021, even though change varies by countries. Overall, the change is 119.3 %. Increase in the number of passengers indicate increased usage of planes which triggers energy consumption levels directly.

The Level of Trade

An increased level of trade is one of the catalyst factors which instigate further energy consumption. The countries export additional goods and services after satisfying local markets' demands. Therefore, more exports and imports will require more production, which demands the usage of energy.

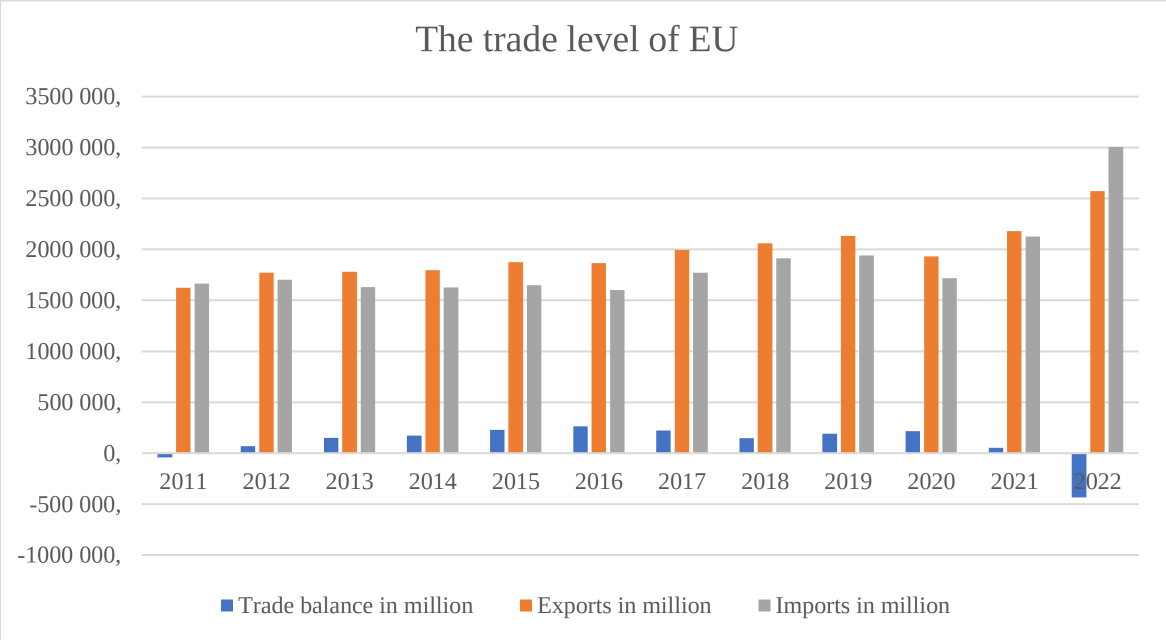

Figure 5. The Trade Level of EU

Source: Eurostat 2024 (Author and the measuring unit is millions of EUR)

Figure 5 demonstrates the increase in the trade level of EI even though it was not a dramatic increase. The increase in the trade level is one of the key reasons for an increase in total energy consumption. Free trade policies cause the level of trade to increase, as the manufacturers are stimulated to produce more. So, the elimination of tariffs and quotas affect the level of trade. Automatically, the production of more goods and services requires more energy to be used. Furthermore, most of the time, those goods are delivered through cargos which are delivered via various transportation modes. Those transportation modes such as planes and railways also demand energy to operate. Since the Industrial Revolution, the level of trade around the world continued to be multiplied, and therefore, one chunk of total energy consumption increased solely due to this reason. Globalization has become and important phenomenon which multiplied the level of trade across the world. Nowadays, a lot countries exchange goods and services more freely than in the past which instigated further production. Meanwhile, ratification of policies such as the principle of free movement of goods in EU, abolition of customs fees and quotas led to further cooperation. All these events had caused energy consumption to increase, since more energy was required for further production. In the graph, the level of imports, exports, and some of them were depicted in the second decade of the 21st century. Clearly, we can see an increasing trend over the years, and the increase is huge. Basically, in only 10 years, the level of imports, exports, and total trade increased by 34.3, 50.61 and 41.96 % respectively.

Energy Prices

Energy prices are one of the most important factors which influence energy consumption. From the macroeconomic perspective, the EU's governance bodies can regulate prices to control the level of energy consumption. Even though energy is inelastic, high prices of energy can decrease the usage of energy. Before going through prices, it is important to take into account the income level of households.

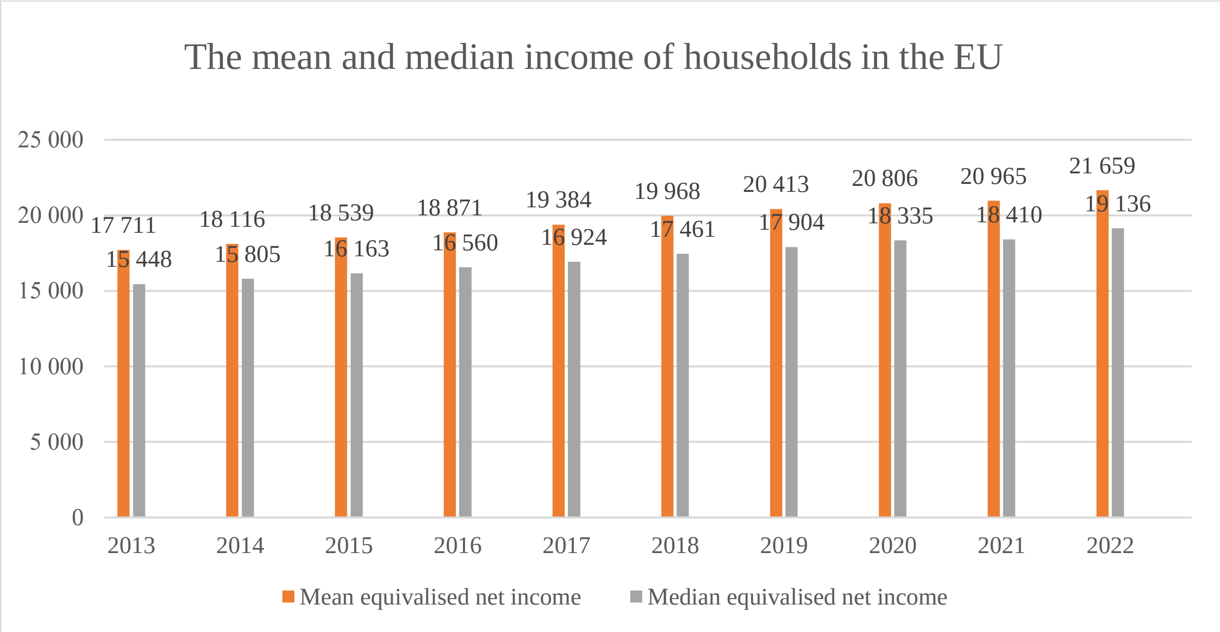

Figure 6. The mean and median income of households in the EU
Source: Eurostat 2024 (Author and unit of measure is in euro)

Figure 6 demonstrates the mean and median income values of households in the EU. The nominal value of income has increased every year for EU countries since 2013 and 2022. Over the course of 10 years, both the mean income and the median income have increased. With taking into consideration inflation levels, EU governance bodies should control energy prices, as the people in the EU get richer year by year. Therefore, they will have more disposable income, which they can spend in buying more goods and services. The increased demand will stimulate more production, which will require the utilization of energy. Thus, EU governance bodies should regulate the prices and production levels in a way to prevent the usage of more energy consumption in the production process.

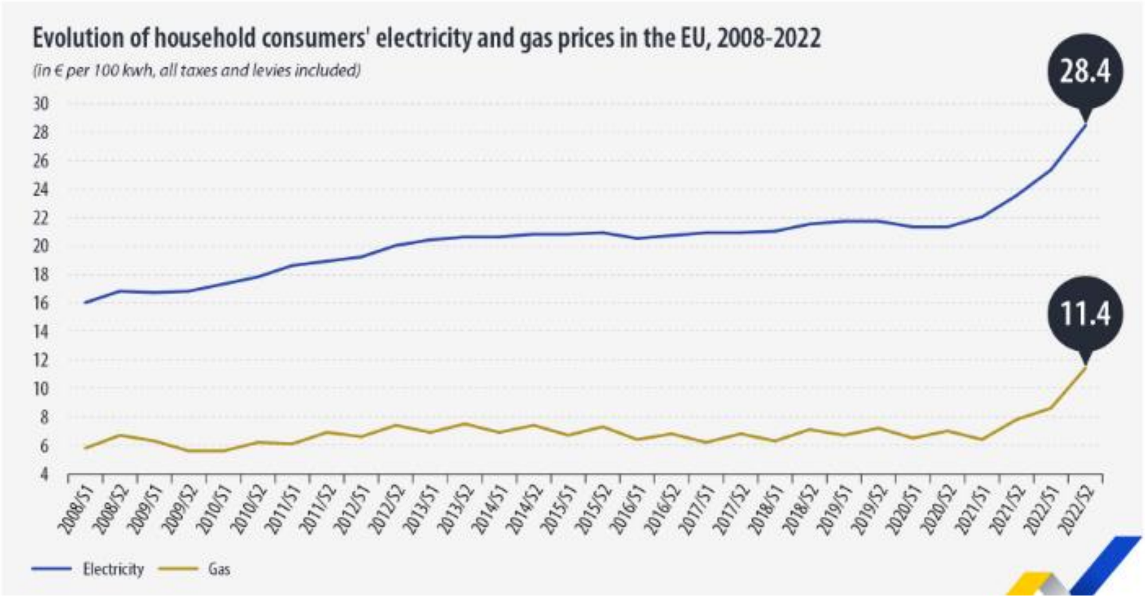

Figure 7. Evolution of Household Electricity and Gas Prices in the EU

Source: Eurostat 2024 (Unit of measure is in euro per 100 KWH)

Electricity and natural gas costs have been rising sharply since before the Russian invasion of Ukraine, but they have now started to level off, in part because of EU government policies and initiatives. The price increases began before the invasion and continued to rise until the second semester of 2022. This increase can have a negative impact on energy consumption levels. EU nations choose to implement a range of policies, including price controls, temporary tax waivers for consumers, reductions in taxes and fees, lump sum support, voucher distribution to end consumers, and controlled pricing in certain case.

With all EU nations implementing governmental allowances and subsidies or lowering taxes and levies to mitigate high-energy costs, the share of taxes in the electricity bill fell sharply from 36% to 16% (-18.3%) and in the gas bill from 27% to 14% (-15.8%) when compared with the second half of 2021. Although these government actions have reduced energy costs for the end user, they have put a strain on government coffers.

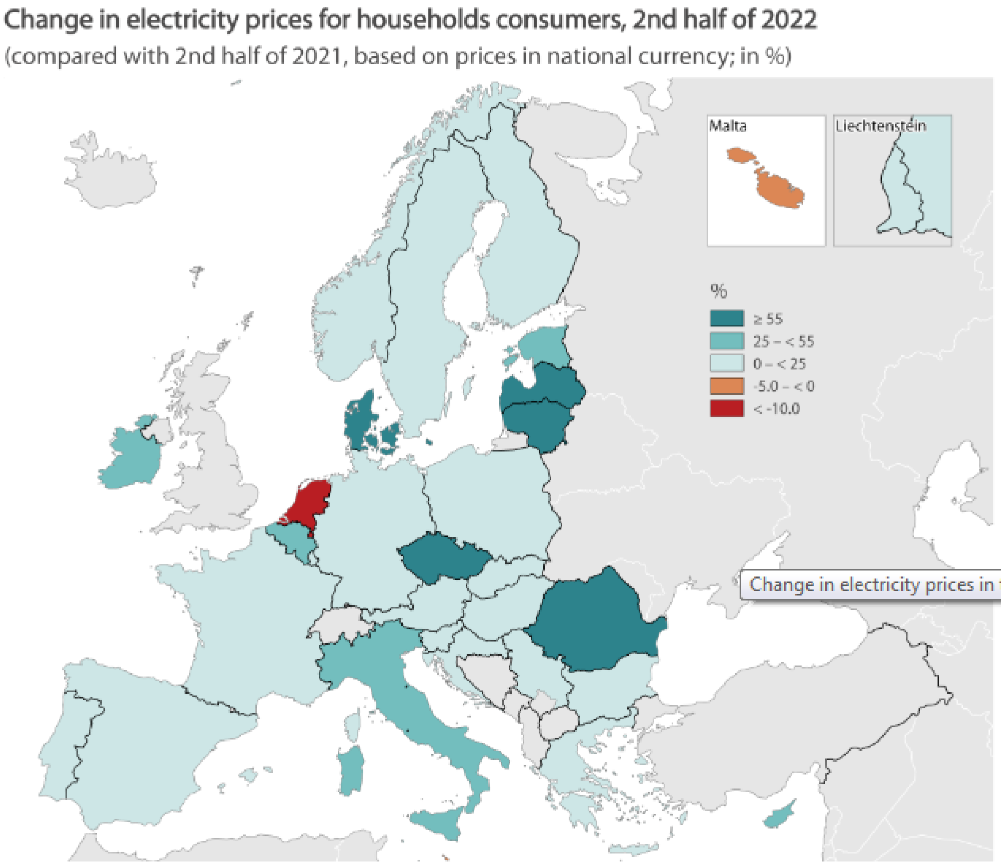

Figure 8. Evolution of Household Electricity and Gas Prices in the EU
Source: Eurostat 2020

Figure 8 demonstrates the evolution of household electricity and gas prices in EU. In the second half of 2022, household energy costs increased throughout all EU nations, with the exception of Malta (-3% in national currencies) and the Netherlands (-7%), as compared to the same period in 2021. Malta has set prices, and the Dutch government offers consumers tax breaks and lump sum payments as support. Romania (+12%), Czechia (+97%), Denmark (+70%), Lithuania (+65%), and Latvia (+59%) had the largest gains, while Luxembourg (+3%), Austria and Germany (both +4%), Poland, and Bulgaria (both +5%), and Latvia (+59%) had the lowest household costs.

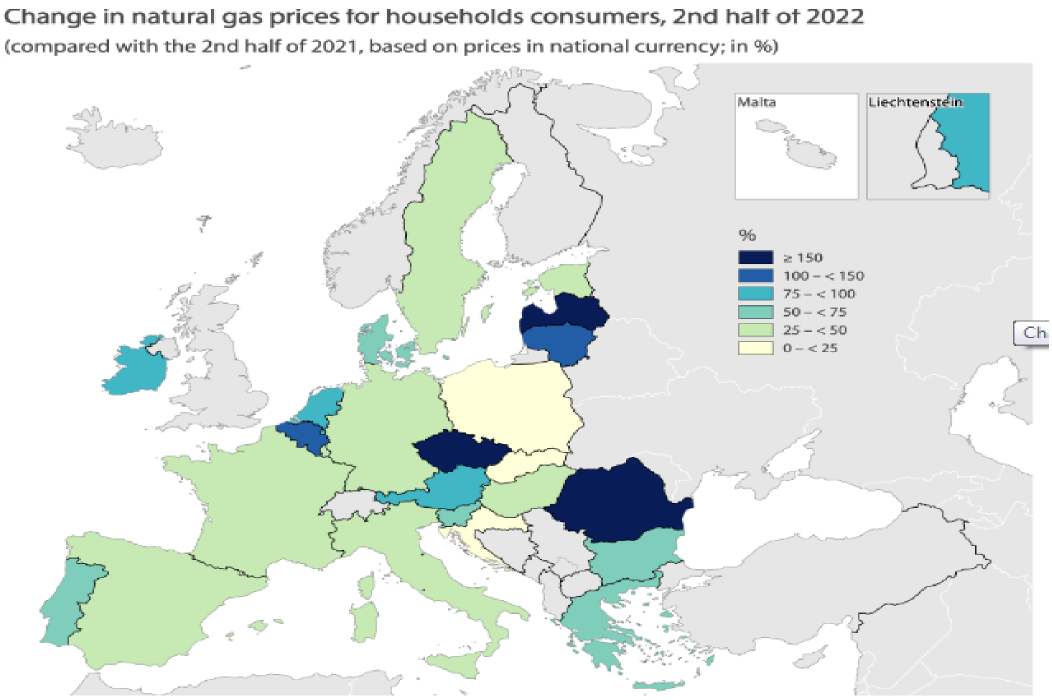

Figure 9. Change in Natural Gas Price for Households

Source: Eurostat 2020

Figure 9 reflects the change in natural gas price for households. In all 27 EU member states, gas prices rose in the second half of 2022 compared to the second half of 2021. The countries with the biggest increases in gas prices (in national currencies) were Portugal (+165%), Latvia (+157%), Lithuania (+112%), Czechia (+231%), and Belgium (+102%). Only two rises fell short of the 20% mark: 14% in Croatia and 18% in Slovakia. The recent energy crisis is the primary cause of all price hikes in the energy and supply sectors.

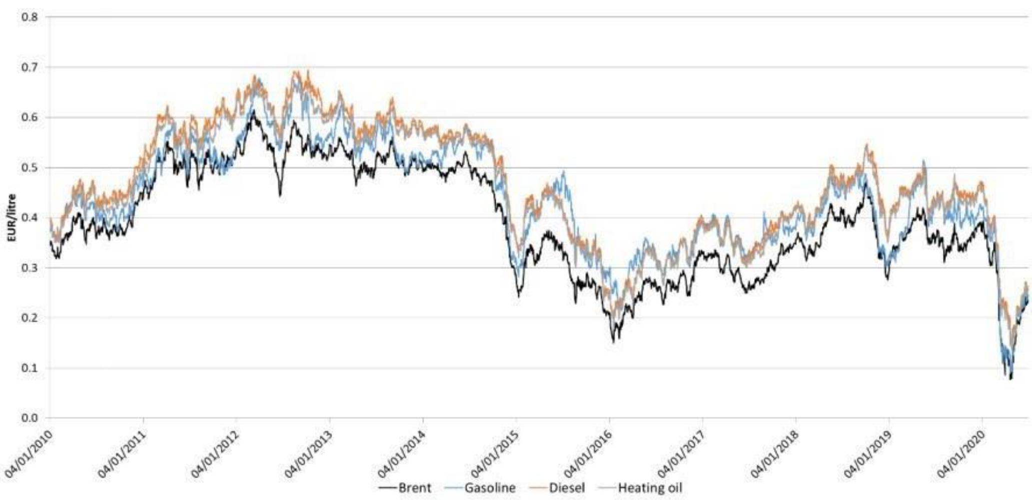

Figure 50. The Oil Prices from 2010 to 2020

Source: European Commission 2020b (Unit of measure is litre per euro)

In Figure 10, we can see the changing dynamics of oil prices over a decade. Over this decade, European countries' dependence on fossil fuels has slightly decreased, as they continue to intensify their actions to organize a transition to gas and renewables. It is completely understandable, as we see the fluctuations in oil price. In 2015, due to the US booming oil production and increasing geopolitical concerns in the Middle East, the price of oil sharply fell. In 2019, there was a major disagreement between Saudi Arabia and Russia over the supply of oil production, which caused the level of oil prices to plummet again. Moreover, the Covid-19 pandemic also impacted the economy significantly. Therefore, European countries are eager to decrease dependence on the imports of oil and produce energy within their territories through other sources.

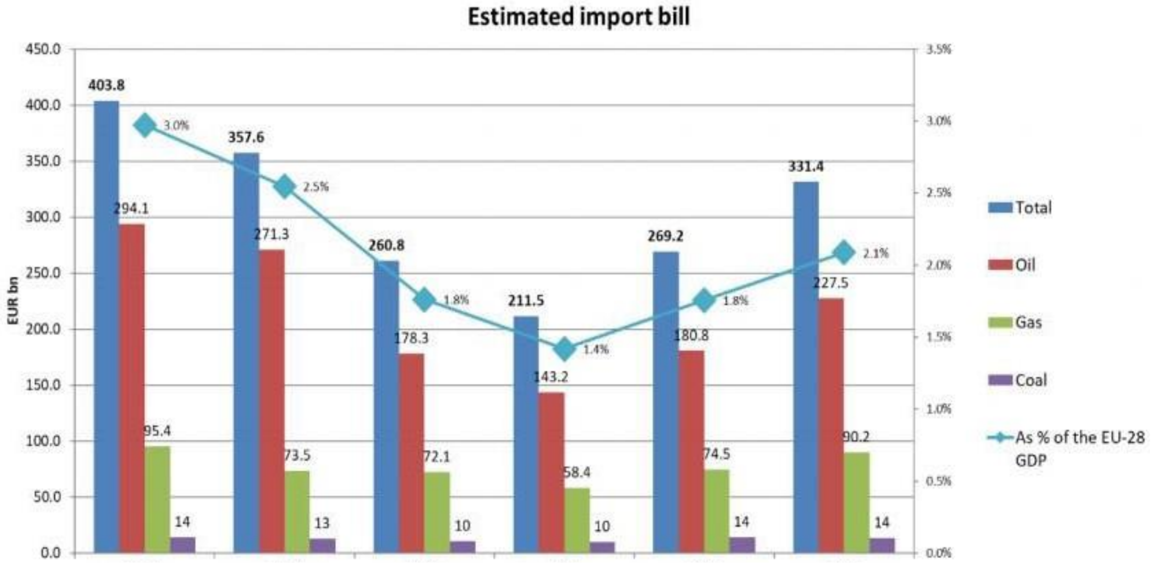

Figure 11. Estimated import bill

Source: European Commission 2020b (Unit of measure is billion euro)

This figure demonstrates how much the EU has spent on energy imports from other countries. From 2013 to 2016, there was a big decrease. However, afterward, the energy import again started to increase. It is forecasted that this number will fall this year because the Covid-19 pandemic stagnated economic activities in the EU, and it impacted overall trade activities in the world. Moreover, in the near future, this amount will fall further in the case of achieving a successful transition from fossil fuels to renewables and gas.

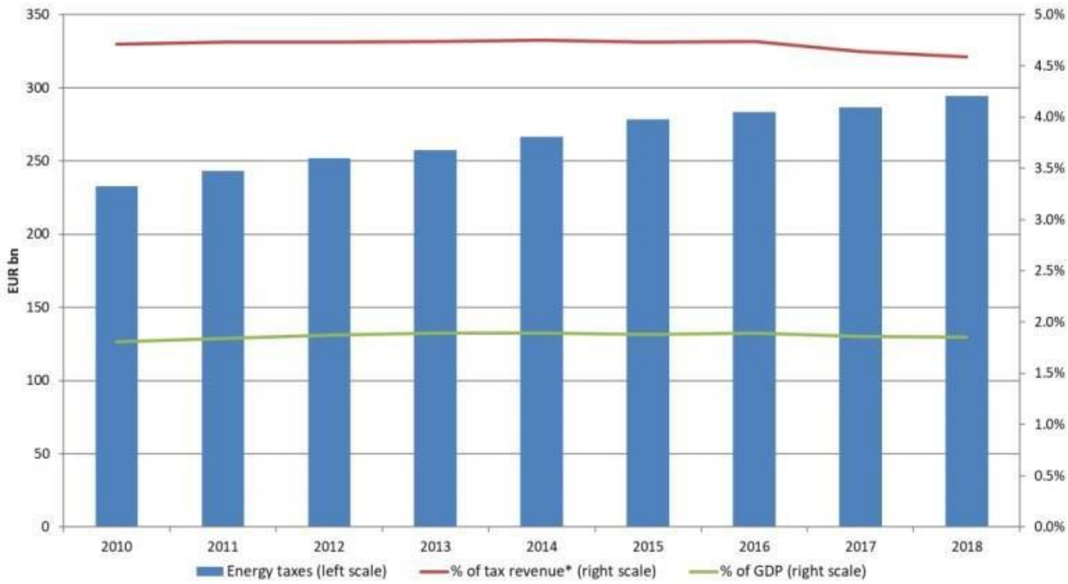

Figure 12. Energy Taxes

Source: European Commission 2020b (Unit of measure is billion euro)

Figure 12 provides information regarding energy taxes in EU. EU governance bodies increased tax and levies to regulate energy consumption and decrease their usage of fossil fuels following the terms of the European Green Deal. Moreover, energy taxes provide significant revenues to Member States budgets. Energy taxes amounted to 294 billion EUR in 2018 (European Commission, 2020b). Usually, they constitute circa 2 % of the GDP of the Member States. Energy tax represented 4.6 % of their total tax revenues. Excise duties on oil imports are circa 80 % of this total amount. Energy taxes are very important in compensating for the potential impacts of fluctuating and volatile oil prices. More importantly, they accelerate the energy transition and prevent countries from exploiting energy recklessly and decrease environmental damage.

Taxes and levies amount to 41 % and 30-34 % of households and industrial electricity prices, respectively, and for 32% and 13-16% of the households and industrial gas prices (European Commission, 2020b). Moreover, they also account for 50 % of heating oil prices, 60 % of gasoline, 56 % of diesel. The types and amount of taxes and levies are determined by the Member States on different factors; therefore, it varies on sectors.

Conclusion

Energy efficiency and achieving a successful transition from conventional energy sources to renewables are some of the most important aims of EU governance bodies. While achieving energy efficiency, they should be very careful in managing energy consumption levels. As the Jevons Paradox phenomena suggest, due to rebound effects, energy efficiency measures do not achieve the desired means. Instead, it causes energy consumption levels to rise.

Given the EU's strictness and stout decisiveness in achieving energy efficiency, in the short-term, some degree of energy efficiency would be achieved in the case of the energy transition. Even now, certain organizations suggest that the usage of renewables over conventional energy sources can generate energy efficiency. Furthermore, as the price for the construction of the dams decreases over the evolution of the technology, the usage of renewables over costly conventional energy sources would benefit nearly all stakeholders. Moreover, contrary to conventional energy sources, it is possible to produce renewable energies domestically and to sell the remaining, which the house owners do not need. Thus, other commercial enterprises will not be able to put high prices on energy since it can be produced by the customers themselves, and it will lead a fairer and more transparent competition. In the short-term, energy efficiency can be achieved with accurate and strict policy-making. In recent years, EU governance bodies' policies regarding energy consumption levels and energy efficiency have been partially successful, as slowly the transition happens, and energy consumption levels stayed stable, however these are not enough to tackle current energy challenges. For future, more assertive and direct approach is needed.

The analysis highlights critical considerations for the EU's transition toward sustainable energy consumption. Based on the data and arguments presented, the following conclusions can be drawn: Policy Reformation for Sustainable Energy Consumption: The EU must implement well-defined policies that prioritize reducing overall energy consumption, not just improving energy efficiency. The Jevons Paradox indicates that energy efficiency alone is insufficient, as rebound effects often result in increased energy consumption. Prioritization of Renewable Energy Development: Transitioning from conventional energy sources to renewables is vital but must be approached pragmatically. While the short-term goals of energy efficiency and partial transitions to renewables are achievable, the long-term goal of full sustainability requires substantial advancements in technology and infrastructure. Investment in Infrastructure and Technology: Significant investments are needed to develop renewable energy infrastructure, such as dams and other energy facilities. These require careful planning to minimize rebound effects and ensure the energy output is sufficient to replace conventional sources.

Support for Decentralized Renewable Energy Systems: Encouraging the domestic production of renewable energy, such as solar or wind, can empower consumers, reduce reliance on large-scale commercial energy providers, and foster fairer competition within energy markets. Behavioral and Institutional Changes: Technological advancements alone cannot address the broader sustainability challenges. Institutional frameworks and consumer behavioral changes are essential to align energy usage patterns with sustainability goals. Gradual Transition Strategy: Given the complexities of economics, technology, and politics, a sudden transition to renewables is not feasible. The EU should aim for a phased approach, balancing current energy demands with long-term sustainability. Addressing Climate Change Urgency: The adverse impacts of climate change necessitate an expedited yet balanced energy transition. Failure to act decisively risks exacerbating economic, environmental, and social consequences. Need for Further Research: To effectively manage energy consumption and transition strategies, additional research and modeling are required to predict future energy consumption trends and refine policy decisions. They need to be very assertive, otherwise recent figures suggest current energy policies cannot be sufficient to prevent past failures which triggers Jevons Paradox. By combining technological, institutional, and behavioral solutions, the EU can overcome the challenges outlined in the analysis and achieve a more sustainable energy future.

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