“Managing the EU energy crisis and greenhouse gas emissions: Seasonal ARIMA forecast”

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MANAGING THE EU ENERGY CRISIS AND GREENHOUSE GAS EMISSIONS: SEASONAL ARIMA FORECAST

Abstract

Changes in the logistics of energy resources and their potential shortage are causing a review of the EU energy policy. The energy sector significantly affects the progress toward achieving climate policy goals due to significt greenhouse gas emissions. The REPowerEU plan, implemented in the EU27 to overcome the energy crisis, requires new forecasts of greenhouse gas emissions due to a change in European energy policy.

This paper aims to examine the consequences of the management of the energy crisis caused by Russia's invasion of Ukraine on EU climate policy. This study focuses on forecasting greenhouse gas emissions in the EU until 2030 and uses the Seasonal ARIMA model based on quarterly time series in the EU27.

Depending on energy management and changes in energy policy to overcome the energy crisis, a positive or negative scenario for greenhouse gas emissions may occur. An important parameter that should be considered when determining the scenario of the EU energy development according to climate policy was defined by correlation analysis.

According to the negative scenario and under the influence of the effects of the Russian invasion of Ukraine, the value of greenhouse gas emissions in the EU at the beginning of 2030 will be 0.752911 tons per capita. The positive scenario shows greenhouse gas emissions can be reduced to 0.235225 tons per capita.

The study results proved two extreme scenarios of greenhouse gas emissions, depending on how to overcome the energy crisis.

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INTRODUCTION

For several decades, the world community has sought to minimize the harmful effects of human activity. Sustainable development goals are designed to systematize this activity. Several programs have been developed to achieve each of the sustainable development goals (SDGs). The implementation of the programs involves state and local authorities, enterprises, organizations, institutions, and households. As a rule, progress in achieving one of the goals of sustainable development has a positive effect on obtaining positive results in other areas. This creates a synergistic effect that brings humanity closer to realizing the concept of sustainable development. However, suppose sustainable development goals are interconnected and influence each other. In that case, it can be assumed that a regression in achieving one of the sustainable development goals will lead to negative consequences in other areas.

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The economies of the EU countries have already suffered losses related to the destruction of logistical connections and the humanitarian disaster in Ukraine. European countries have accepted millions of refugees from Ukraine, which requires significant budget expenditures. Such a situation will affect the socioeconomic situation in EU countries. However, the effects of the food and energy crises, which stimulate inflation and threaten economic growth, are even more tangible. The energy situation, which has become a tool of Russia's political influence on the EU, needs special attention (de Jong, 2022). In its resolution 2463, PACE condemned Russia's practice of "using energy as a blackmail tool." Considering that the "leadership of the Russian Federation has increased threats of nuclear warfare", constantly threatens to use nuclear weapons, and also violates human rights and international law, PACE declared "the current Russian regime as a terrorist one" (PACE, 2022). Energy wars have been a common practice of the Russian regime since the Cold War. The new cold war between the USA and Russia is creating unstable situations on the territory of foreign countries. The EU has already felt the consequences of hybrid energy wars that have affected the energy supply's security. The Syrian war clearly showed the implications of the clash of geostrategic interests of international players over limited energy resources. The Eastern Mediterranean region is believed to have become a common battleground for revenge. Significant gas reserves were discovered in this region, which are planned to be exported to European countries. EU countries have been trying to diversify the supply of energy resources and become less vulnerable to Russia for quite a long time. Since the dispute between Russia and Ukraine in 2005, the EU has financed pipeline projects in the Eastern Mediterranean that could reduce energy dependence on Russia (Ghoble, 2019).

However, European efforts to obtain oil and gas from alternative sources (especially Central Asia) face opposition and pressure from Russia. And the energy crisis is exacerbated not only by the import dependence of European countries on energy resources supplied by Russia. And also, to a significant extent, Russian companies have already acquired energy networks and European energy distribution systems (Walker, 2007). Russia has been increasingly using energy weapons against European countries in recent years. Energy resources and monopolized infrastructure are a means of Russian economic and political pressure on many countries, including the Czech Republic, Estonia, Lithuania and Ukraine (Butler, 2018).

The policy of the European Union is focused on achieving sustainable development goals. It is implemented through long-term energy and climate programs and incentive mechanisms (Bardy & Rubens, 2022; Kurbatova et al., 2019, 2014). The EU has a strategy for developing the energy sector and its diversification, which has been successfully implemented for a long time. The indicators planned to be achieved based on assumptions regarding the development of the economic situation and societal changes following existing trends and already achieved results. However, the assumptions underlying the EU development programs did not consider the consequences of the biggest war in Europe since the Second World War. No country in the modern world can function in isolation from others. The global economy, where everyone is connected to everyone else, felt the impact of the war. This is true for economic and social processes.

The time has come when energy development, at least in the short term, will take an unplanned path. However, how ready is the EU for such a development? Now politicians, economists, entrepreneurs, and scientists are observing the negative effect of Russia's war against Ukraine. It is difficult to predict the future development of events. No one knows when the war will end and how catastrophic its consequences will be. However, you cannot just react to the changes that have been happening for a long time. Considering the developed circumstances, taking the situation under control and taking action is necessary to achieve medium and long-term goals in the economy and social sector.

The EU considers its impact on climate conditions in each of its policies. This emphasizes the importance of countering unwanted climate change. Changes in energy policy and management of the econ-

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omy's energy sector in response to the current energy crisis will change the volume of greenhouse gas emissions. The emissions will depend on the actions of governments, energy companies, and other energy market participants, who will combine measures to diversify the supply of traditional energy resources with renewable energy development. Projected data on the volume of greenhouse gas emissions should be among the key factors considered when making short-term anti-crisis and strategic decisions in the energy sector.

1. LITERATURE REVIEW

In the scientific literature, there are many studies of the energy transition from traditional fuel types to renewable energy. Scientists are investigating this issue from the standpoint of energy efficiency, climate change, and energy security. Such studies are particularly relevant for policymakers today, given the need to respond to challenges in the energy sector.

The EU introduced the REPowerEU plan to stabilize the acute energy crisis in Europe caused by Russia's invasion of Ukraine (EC, 2022). Implementation of this plan requires coordinated actions of all energy market participants. Now the energy transition of the EU from Russian hydrocarbons to alternative energy sources is inevitable (Shagina, 2022). However, reducing the EU energy dependence by expanding renewable energy sources will not necessarily reduce greenhouse gases. The production and use of certain renewable fuel sources can be a source of growth in greenhouse gas emissions in both the short-term and long-term periods (Fitts et al., 2022). Therefore, existing sustainable development programs in the EU may be unrealistic. The impact of the Russian invasion of Ukraine on the EU's ability to achieve planned progress on the Sustainable Development Goals, especially on reducing greenhouse gas emissions, should be assessed. In addition, capital investments to overcome the energy crisis can reduce the motivation of private businesses to implement technologies that ensure sustainable development (Eltoum et al., 2022). However, corporate social responsibility and transparent reporting can minimize this effect (Venugopala Rao et al., 2022).

Managerial decisions to overcome the energy crisis, which are taken by the governing bodies of the EU and key participants in the energy market, may lead to the realization of one of the probable scenarios of energy development in the foreseeable future. The expected scenario for overcoming the energy crisis includes two stages. In the first stage, measures are taken to diversify the supply of fossil energy resources (mainly oil and gas) to avoid shock effects on the economy in the short term (Kagerl et al., 2022). At this stage, the costs aim to find new suppliers and implement the necessary infrastructure. This leads to high costs and takes time. However, it is expected that the time for diversification of fossil fuel supply will be much shorter compared to the development of renewable energy to such a level that it is possible to replace the lost Russian energy resources. Reducing energy consumption and modern energy management approaches in energy-intensive industries can alleviate the problem. However, some studies have shown skepticism about the possibility of the rapid replacement of natural gas from Russia (Lambert et al., 2022), even if a systematic approach is taken to solve this problem (Halser, 2022). After all, the share of Russian gas in the EU in 2021 was 32%, compared to 25% in 2009. Polak and Polakova (2022) state that gas consumption during this period did not increase, but its production decreased, and imports compensated for the deficit. So far, this approach could create problems for the EU's energy independence.

Researchers and participants of the energy market consider several directions of anti-crisis actions. In support of the policy of development of gas transport infrastructure in the EU, the thesis is put forward on the need to create a single energy network to counteract emergencies, including political ones, which may lead to the absence of gas as an essential energy resource in some EU countries (Sesini et al., 2022). A joint energy network, i.e., gas and gas transport infrastructure and a single policy of mutual assistance, will increase the EU's energy security. This thesis is the basis for the Gas Network Optimization Model for Europe (GNOME), which is designed to optimize investments in the European gas infrastructure to reduce the risks of gas supply interruptions (Lochran, 2021).

It is obvious that in these conditions, we are not talking about achieving previously established indicators in the energy and climate policy of the European Union. At the same time, the deviation between actual and planned indicators can be significant. This is a serious concern. The EU resorted to manipulation to smooth the expected gap and speed up the exit from the energy crisis. In particular, natural gas was recognized as green energy. The small CO2 emissions from natural gas combustion are often used as an argument for such a decision (Belucio et al., 2022). On paper, such a decision can positively impact renewable energy indicators as a component of the EU energy policy. However, authoritative research suggests that methane emissions from natural gas use are significantly higher than expected (Schwietzke et al., 2022). These emissions can potentially undermine EU climate policy goals (Pedersen et al., 2022). If we consider gas leaks in its production fields, then its safety for the environment becomes entirely doubtful (Hausfather, 2015; Caulton et al., 2014). Similarly, methane emissions have a more destructive impact on climate preservation than CO2 emissions (Zhang et al., 2016; Lenton et al., 2019). This should be taken into account in the environmental tax system (Sedmíková et al., 2021; Samusevych et al., 2021; Khalatur & Dubovych, 2022) to maintain a reliable mechanism for ensuring environmental, energy, and economic security (Štreimikienė et al., 2022; Vysochyna et al., 2020). Tong et al. (2019) note that even the operation of the existing energy infrastructure during the regulatory period will lead to the release of approximately 658 GtCO2. This is significantly higher than the permissible emissions to limit global warming to 1.5 °C. Such a situation may negatively affect renewable energy prospects in the EU (Hoffart et al., 2021). After all, investors will seek to protect already made investments in gas transport infrastructure instead of investing in renewable energy, despite the availability of promising mechanisms for investing in renewable energy (Versal & Sholoiko, 2022; Keliuotytė-Staniulėnienė & Daunaravičiūtė, 2021) and smart technologies (Fasoranti et al., 2022). Moreover, the prospects of the economic efficiency of the transition to renewable energy are still doubtful (Hoffart et al., 2021; Schubert et al., 2015), and many factors need to be taken into account (Polcyn et al., 2022).

The energy issue is so important that a study by Johannesson and Clowes (2022) claims that it lies at the heart of Russia's aggression against Ukraine. On the one hand, Russia is interested in exporting energy resources to Ukraine and the EU. On the other hand, energy reserves in Ukraine can potentially produce, create competition and undermine Russia's key role as the leading supplier of energy resources, particularly natural gas, to the EU. In addition, Ukraine has significant opportunities to develop renewable energy (Naumenkova et al., 2022) and increase the competitiveness of the economy (Hakhverdyan & Shahinyan, 2022).

Diversification of the supply of traditional energy resources and significant investments in gas transport infrastructure may negatively affect the prospects for the development of renewable energy, contrary to the expectations of experts and the statements of the political elite about significant capital investments and coordination of efforts for the intensive development of renewable energy until 2030.

Under this scenario, plans for the development of renewable energy may partially collapse, and the green transition will be in jeopardy (de Vincenzo, 2022). This approach is not supported by the public, which would like to see renewable energy safer for humanity as an alternative to Russian energy resources (Steffen & Patt, 2022; Lyulyov et al., 2021; Matvieieva & Hamida, 2022; Artyukhova, 2022). However, in this case, economic expediency will prevail over public opinion. Existing and future energy projects are financed from various funds. There are fears that these funds will be reduced due to the need to eliminate the consequences of the energy crisis created by Russia's aggression against Ukraine. Thus, a possible reduction in funding will lead to a gap between the actual figures for renewable energy production and the planned ones. This is a significant negative consequence of the energy crisis, which will affect the non-fulfillment of tasks related to achieving the seventh goal of sustainable development. Given the link between renewable energy and climate change, it can be argued that the situation will harm the achievement of energy and climate policy goals. It should also be noted that this can affect innovative activities (Oe et al., 2022).

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The second negative effect, which is capable of restraining the achievement of the goals of climate policy and of destroying the positive result achieved by considerable efforts in combating climate change, is the replacement of fossil fuels, in particular, gas, with much more ecologically dirty coal. Such a step will cause a significant increase in harmful emissions into the atmosphere and contribute to undesirable climate changes. However, this risk is increasingly less likely and local.

National governments and the governing bodies of the European Union have focused on minimizing the economic damage from the energy crisis provoked by Russia. Current economic interests have pushed renewable energy and the fight against climate change to the background. Research (Meng et al., 2022; Marcel, 2022) confirms that sufficient energy to power the economy, regardless of whether it is produced from renewable or non-renewable sources, contributes to economic growth and improves the state of the economy. In addition, while diversifying the supply of oil and natural gas, the EU pursues another critical goal such as financial pressure on Russia to make its economy unable to support the war. This may in the future encourage Russia to pay attention to the development of the non-raw economy (Aliyeva, 2022). However, the most significant losses for the EU due to the Russian invasion of Ukraine are related to energy. Logistic connections and routes are easier to replace, and trade between the EU and Russia is not of significant economic importance for EU countries (Astrov et al., 2022a; Astrov et al., 2022b). However, revenues from the sale of energy carriers are the most significant for the Russian Federation and determine its ability to wage war against Ukraine and thereby destabilize the situation in Europe (Astrov et al., 2022a; Astrov et al., 2022b; Shagina, 2022).

Given the poverty of fossil energy resources in most EU countries, renewable energy is an alternative way to develop the energy sector. Thus, there will be at least two reasons for accelerating the implementation of renewable energy projects. The first reason is the need to ensure the energy independence of individual countries and the European Union. The second reason is the need to compensate for recourse in climate policy, which will be obtained due to the priority of economic goals over climatic (Singh et al., 2022).

Accordingly, the second stage, after resolving the diversification of the supply of fossil energy resources, will be aimed at the rapid development of renewable energy in all countries of the European Union. The market response to the energy crisis, when the cost of renewable energy companies has increased with deterioration in the energy market (Umar et al., 2022), indicates that renewable energy is considered the basis of the energy system of the future.

Combating climate change is a component of sustainable development. Modern studies of sustainable development cannot be imagined without analyzing scenarios and forecasts that consider the actual situational determinants of such development. Scientific works use various methods and models to predict energy transition and climate change (Table 1).

Researchers use both complex scenario models and simpler and more flexible models to predict the determinants of sustainable development. Popular comprehensive EU scenario models currently actively used for forecasting have mostly been funded under Horizon 2020 and Horizon Europe projects. Such scenario models are unrestricted for use by the general public, supported by simulation software, and may contain ready-made datasets. Despite numerous advantages, there are also disadvantages of complex models. In addition to their complexity to use, the main disadvantage of complex models is their aging. After Horizon 2020 projects are completed, the software is generally no longer updated, nor are the datasets in the models. Considering this, it is worth treating forecasts that do not operate on current data with caution. In addition, when many factors affect the trend, it will not be easy to develop an accurate forecast.

When the economic shocks will be overcome and energy supply and cost issues will be under control, policymakers will pay more attention to correcting the harmful climate effects caused during the crisis. Questions of overcoming energy poverty and elimination of energy gaps (Vasylieva et al., 2020) will become dominant to ensure national and economic security (Vasylieva et al., 2021) and economic performance (Lahouirich et al., 2022).

Table 1. Summary of recent research on sustainable development pathways

Study	Country	Variables	Data	Scenario prediction	Method
Sun et al. (2020)	China	Social and economic parameters	2000–2019	2020–2030	SD method
Samsó et al. (2020)	EU28	27 parameters	1995–2015	2050	MEDEAS Europe energy-economy-environment model
Solé et al. (2020)	EU, world	Social, energy and environmental indicators	1995–2009	2050	Pymedeas
Liu et al. (2021)	China	Trade growth, economic and fiscal growth, population growth, technological innovation, public service levels, and environmental quality	2000–2017	2035	System dynamics method
Yang et al. (2021)	China (Zhangjiakou)	Resource supply, conversion, end-use demand, demand prediction, environmental impacts and cost-benefit analysis indicators	2016	2022, 2030, 2040, 2050	LEAP-Zhang model
Javed et al. (2021)	Not specified	Technical, economic, and environmental criteria	Not specified	Not specified	Hybrid AHP–TOPSIS model
Lopez et al. (2021)	Bolivia	108 technology components	2015	2020–2050	LUT Energy System Transition model
Potrč et al. (2021)	EU-27	Technical and economic criteria	Not specified	2030, 2040, 2050	Mixed-integer linear programming (MILP) model
Gaur et al. (2022)	Ireland	Energy supply and demand indicators	2018	2020–2050	TIMES-Ireland Model
Kumari and Singh	India	CO_2 emission	1980–2019	2030	ARIMA, SARIMAX, Holt-Winters model

Greenhouse gas emissions, economic growth and sustainable development are related factors that underlie decision-making on how to exit the energy crisis. At the same time, the volume of emissions is very vulnerable, because they can be sacrificed in exchange for economic growth. However, the damage from this will be long-lasting and significant. This study provides information for policymakers regarding the possible consequences of anti-crisis management in the energy sector.

The purpose of the paper is to determine the consequences of management actions to overcome the energy crisis based on forecast possible volumes of greenhouse gas emissions by the energy sector due to energy policy and management changes.

This paper aims to examine the consequences of the management of the energy crisis caused by Russia's invasion of Ukraine on the EU climate policy. This study focuses on forecasting greenhouse gas emissions in the EU until 2030 and uses the Seasonal ARIMA model based on quarterly time series in the EU27.

2. METHODS

Given the availability of data for forecasting scenarios, forecasts were developed based on the Seasonal ARIMA model. Time series testing, modeling, and data visualization of this study were performed using built-in libraries of the Python programming language.

This study used quarterly greenhouse gas emissions data for 27 European Union countries. The data were downloaded by the authors on October 16, 2022, from the European Commission – Eurostat database "Air emissions accounts for greenhouse gases by NACE Rev. 2 activity – quarterly data". This Eurostat database contains 5291 values and covers data from 2010-Q1 to 2022-Q1. That is, data for 49 time periods are available for download. Greenhouse gas emissions were calculated in tons of CO2 per capita (tons per capita) and contained total equivalents of CO2 emissions, together with emissions of N2O, CH4, HFC, PFC, SF6, NF3.

For the data on greenhouse gas emissions, it is possible to write an ARIMA model containing differentiation, autoregression, and moving average components in a general form as (1)

$$y_t = c + \varphi \cdot y_{t-i} + \theta . \varepsilon_{t-j} + \varepsilon_t, \quad (1)$$

where y_t, y_{t-i} – the value of the greenhouse gas emissions variable, respectively, in periods t and $t-i$; c – scale coefficient; φ – autocorrelation parameter; θ

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– a parameter of the moving average; ε_{t-j}, ε_t – error values in periods t and $t-j$, respectively.

To take into account the seasonal effects of quarterly data, the Seasonal ARIMA model should be chosen (2)

$$y_t = c + \varphi . y_{t-i} + \theta . \varepsilon_{t-j} + \theta_s . \varepsilon_s + \varepsilon_t, \qquad (2)$$

where θ_s is the parameter of the moving average seasonal effect s; ε_t is the error value of the seasonal effect s.

When constructing the time series model, the assumption of endogenous temporality was considered. The forecast was created using machine learning using the Python programming language. The seasonal effect was added to the model in an additive way.

3. RESULTS

Greenhouse gas emissions in the Eurostat database are reported according to the statistical classification of types of economic activity in the European Community (NACE Rev. 2). An estimate of the cumulative volume of greenhouse gas emissions is presented in Figure 1.

In the EU27, the largest amount of greenhouse gases for 2010-Q1 – 2022-Q1 was received as a result of the economic activity of Section D and Section C, as well as the activity of households. A general description of the data is presented in Table 2 and Figure 2. Most economic activity is characterized by an increase in greenhouse gases in 2022-Q1 compared to 2021-Q1. Figure 3 shows a trend with seasonal variation for the greenhouse gas emissions of the energy sector.

Table 2. Sectors responsible for greenhouse gas emissions (by economic activity)

Indicator	Indicator description	Unit of measure
Households	Total activities by households	Tons per capita
Section_A	Agriculture, forestry and fishing	Tons per capita
Section_B	Mining and quarrying	Tons per capita
Section_C	Manufacturing	Tons per capita
Section_D	Electricity, gas, steam and air conditioning supply	Tons per capita
Section_E	Water supply; sewerage, waste management and remediation activities	Tons per capita
Section_F	Construction	Tons per capita
Section_H	Transportation and storage	Tons per capita
ections_G_U	Services (except transportation and storage)	Tons per capita

Source: Based on Eurostat data (EU, 2022).

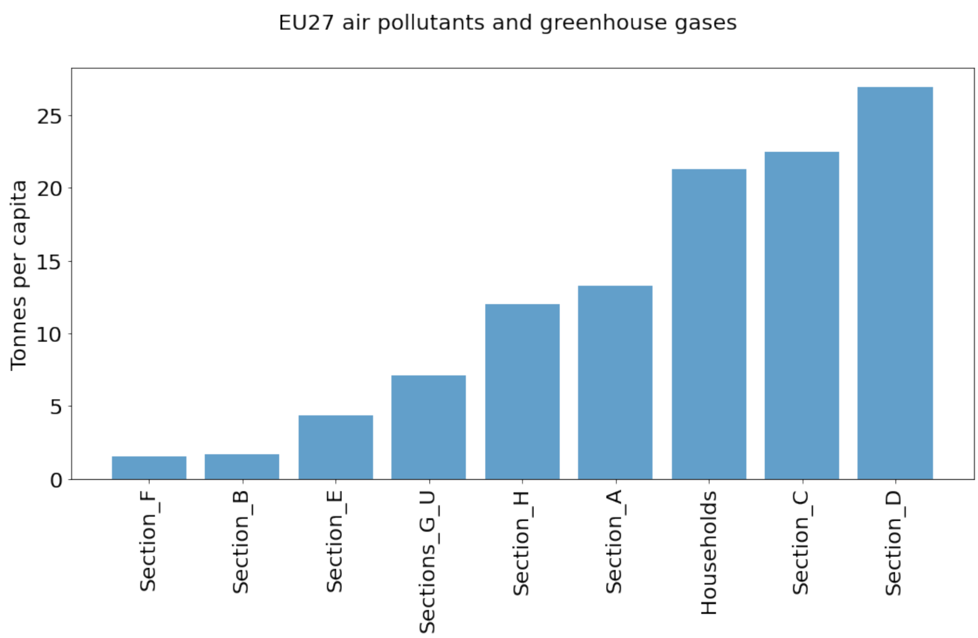

Figure 1. Cumulative greenhouse gas emissions by economic activity (in tons per capita), EU27, 2010-Q1 – 2022-Q1

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Source: Based on Eurostat data (EU, 2022).

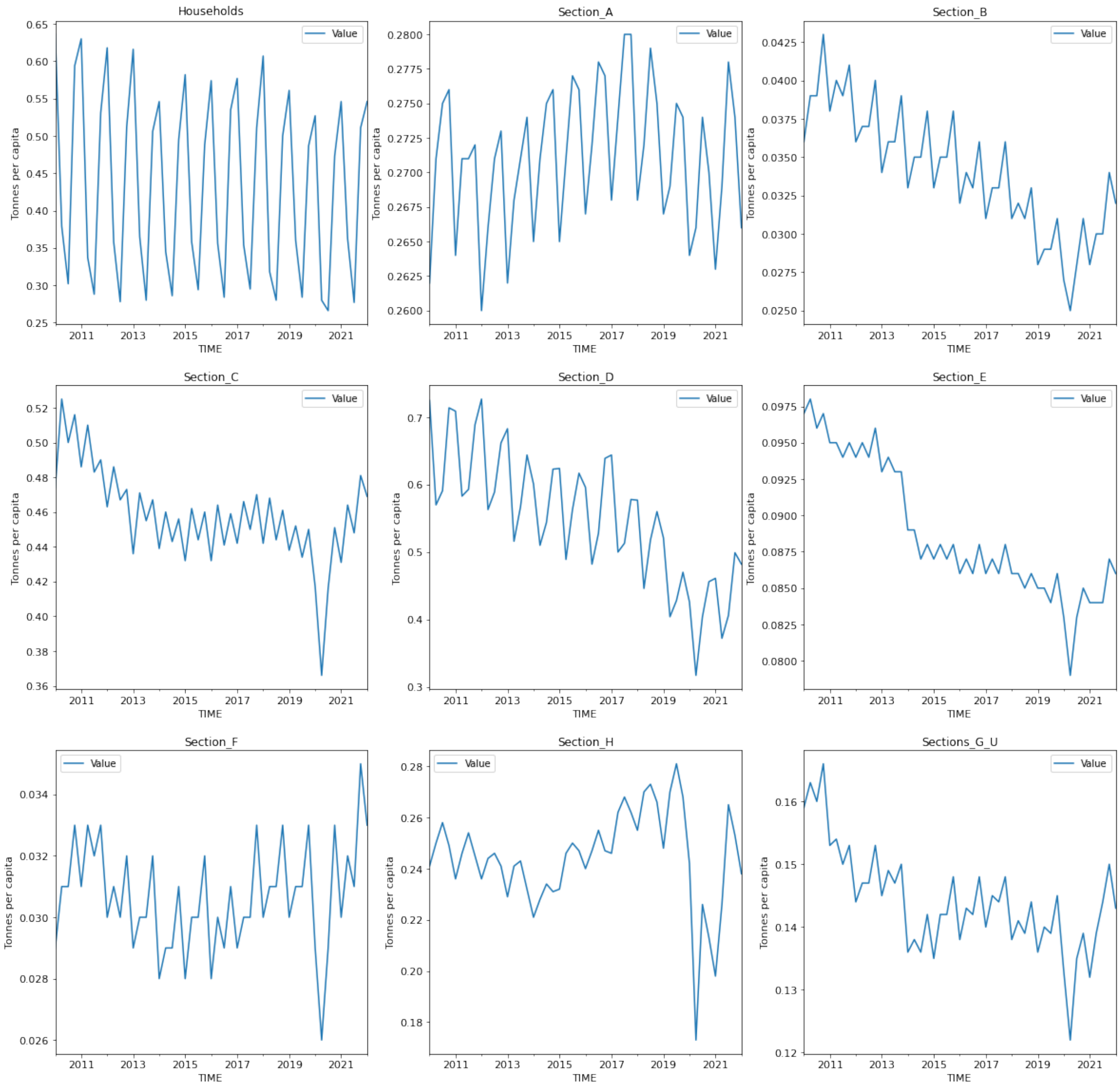

Figure 2. Greenhouse gas emissions by economic activity (tons per capita), EU27, 2010-Q1 – 2022-Q1

Additive time series decomposition was performed to develop a time series model of greenhouse gas emissions in the energy sector (Figure 4), and the hypothesis of data stationarity (1) was tested. The results of testing the stationarity of the decomposed data using the extended Dickey-Fuller test are presented in Table 3. Strong evidence against the null hypothesis allows us to reject it: the decomposed data do not have a unit root, so they are stationary.

$$H_0 : \pi = 0;$$
$$H_a : \pi =< 0, \quad (3)$$

where π is a unit root.

Table 3. Augmented Dickey-Fuller test of the decomposed data (Greenhouse gas emissions by electricity, gas, steam, and air conditioning supply activity (tons per capita), EU27, 2010-Q1 – 2022-Q1)

Source: Based on Eurostat data (EU, 2022).

Indicator	Value
Test Statistic	–5.577172
p-value	0.000001
#Lags Used	3.000000
Critical Value (1%)	–3.600983
Critical Value (5%)	–2.935135
Critical Value (10%)	–2.605963

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Source: Based on Eurostat data (EU, 2022).

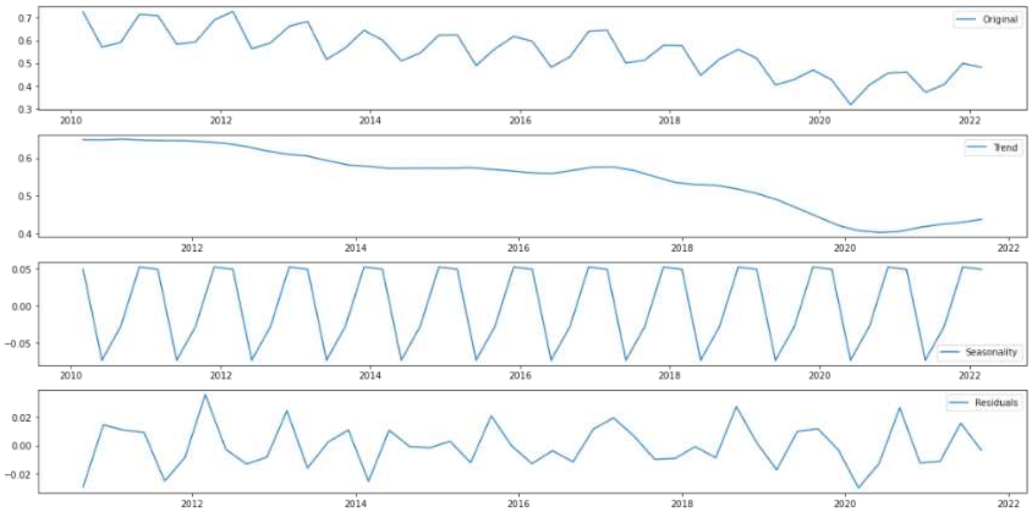

Figure 3. Greenhouse gas emissions by electricity, gas, steam, and air conditioning supply activity (top) and its three additive components (tons per capita), EU27, 2010-Q1 – 2022-Q1

Source: Based on the Eurostat's data (EU, 2022).

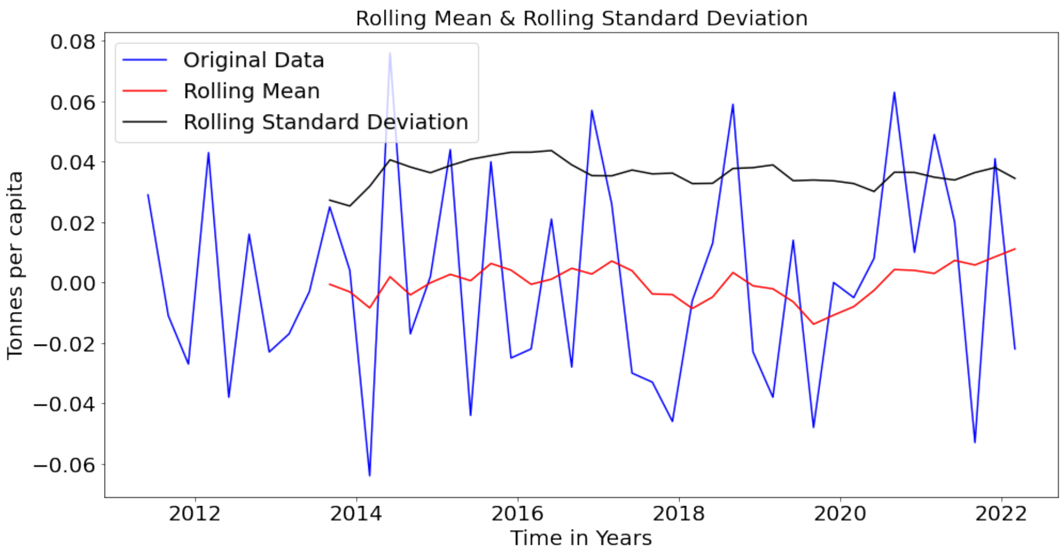

Figure 4. Greenhouse gas emissions by electricity, gas, steam, and air conditioning supply activity (tons per capita), EU27, 2010-Q1 – 2022-Q1: the rolling mean (red), the rolling standard deviation (black), and the decomposed data (blue)

The results of modeling greenhouse gas emissions from electricity, gas, steam, and air conditioning activities based on the Seasonal ARIMA model are presented in Table 4. Column P > |z| shows that the value of each weight of the function P equals 0. It is, therefore, appropriate to include all functions in the model of greenhouse gas emissions from electricity, gas, steam, and air conditioning activities. Visualization of the diagnosis of the Seasonal ARIMA model is presented in Figure 5.

Table 4. Results of building the Seasonal ARIMA model

Indicator	Coef	Std err	z	P > |z|	[0.025	0.975]
ar.L1	0.9114	0.073	12.555	0.000	0.769	1.054
ma.S.L4	–0.6906	0.175	–3.936	0.000	–1.034	–0.347
sigma2	0.0007	0.000	3.576	0.000	0.000	0.001

Figure 5 shows that the forecast errors deviate slightly from a straight line. This indicates that the ideal model for distributing errors in this fore-

Source: Based on Eurostat data (EU, 2022).

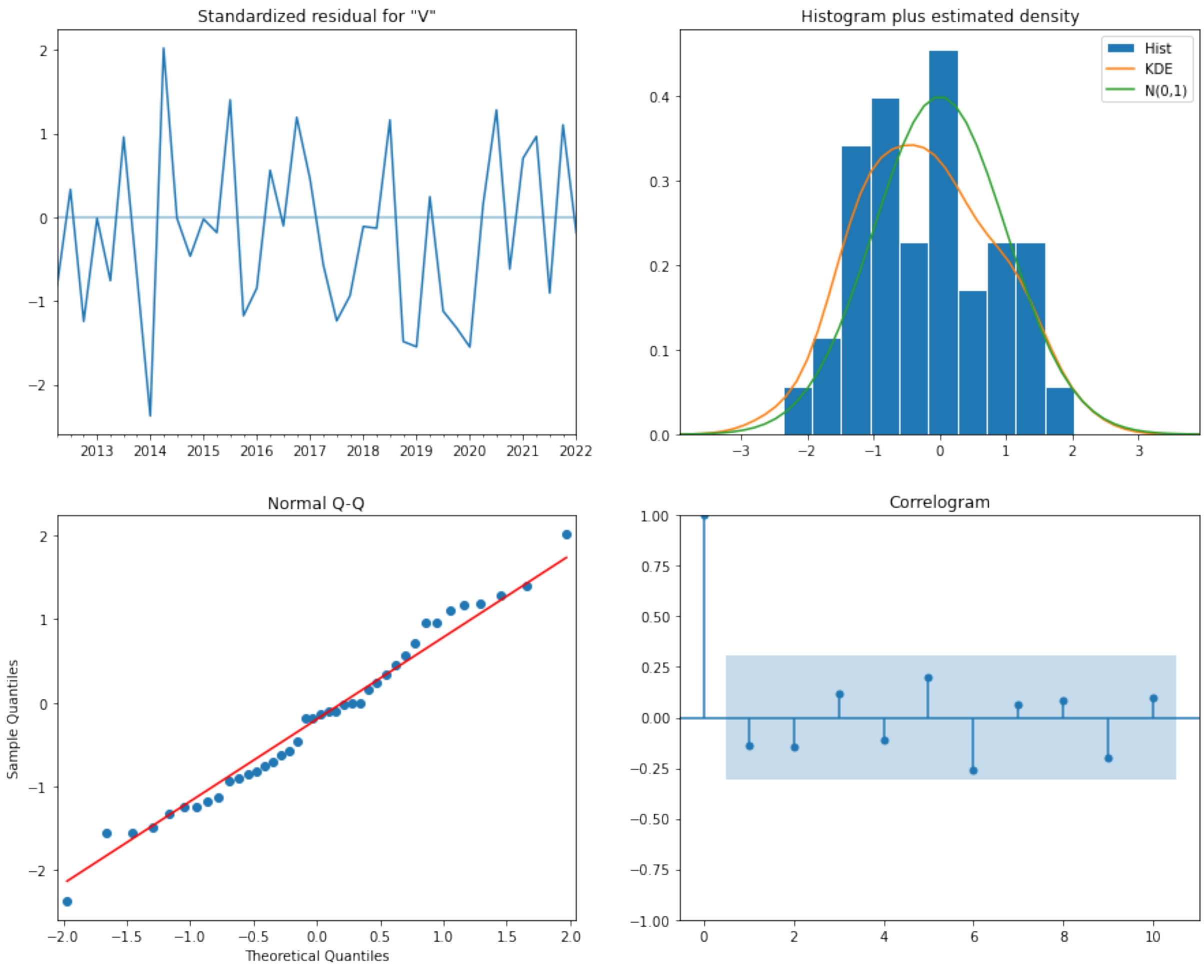

Figure 5. Seasonal ARIMA model diagnostics

cast of greenhouse gas emissions is not the normal distribution. The "Normal Q-Q" diagram shows that the ordered distribution of the residuals corresponds to the linear trend of the samples. The graph of the correlogram confirms this statement. In general, the results of the model diagnostics allow us to conclude that the model provides a satisfactory possibility of forecasting the future values of greenhouse gas emissions from the activity of supplying electricity, gas, steam, and air conditioning in the EU27.

The resulting model for the time series of greenhouse gas emissions from electricity, gas, steam, and air conditioning activities was used to forecast greenhouse gas emissions in the EU in 2030. The forecasting results are presented in Figure 6. Figure 6 shows the real and predicted values of the time series of greenhouse gas emissions and their confidence intervals. In general, it is predicted that in the EU27 in 2030, greenhouse gas emissions from activities in the supply of electricity, gas, steam, and air conditioning will continue to grow. According to the negative scenario and under the influence of the effects of the Ukrainian-Russian war, the value of greenhouse gas emissions in the EU at the beginning of 2030 will be 0.752911 tons per capita. The positive scenario shows that greenhouse gas emissions can be reduced to 0.235225 tons per capita.

Table 5 shows the results of the correlation analysis for some important parameters that should be considered when determining the scenario of the EU energy industry development in the future. The moderate dependence between the consumption of natural gas and renewable energy indicates that the global substitution of fossil fuels (in this case, natural gas) is not as effective as it would be in achieving climate policy goals. This is important to consider when returning to the most obvious scenario of ex-

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Source: Based on Eurostat data (EU, 2022).

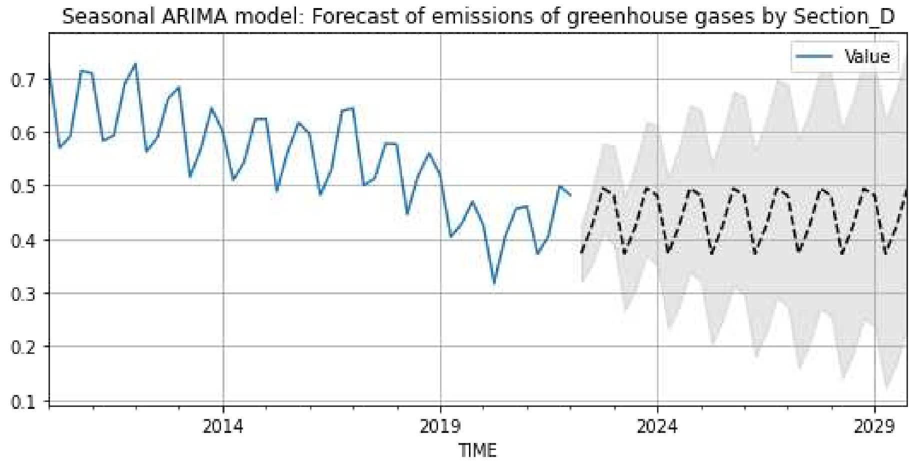

Figure 6. Forecast of greenhouse gas emissions by electricity, gas, steam, and air conditioning supply activity (tons per capita) by 2030, EU27

Table 5. Relationship between energy consumption and CO2 and greenhouse gas emissions

Correlations					
Indicator		Consumption_ natural_gas	Consumption_ renewables	CO_2_emissions	GHG_emissions
Consumption_natural_gas	Pearson Correlation	1	0.302	0.075	–0.050
	Sig. (2-tailed)	–	0.099	0.690	0.791
	N	31	31	31	31
Consumption_renewables	Pearson Correlation	0.302	1	–0.847**	–0.906**
	Sig. (2-tailed)	0.099	–	0.000	0.000
	N	31	31	31	31
CO_2_emissions	Pearson Correlation	0.075	–0.847**	1	0.989**
	Sig. (2-tailed)	0.690	0.000	–	0.000
	N	31	31	31	31
GHG_emissions	Pearson Correlation	–0.050	–0.906**	0.989**	1
	Sig. (2-tailed)	0.791	0.000	0.000	–
	N	31	31	31	31

Note: ** Correlation is significant at the 0.01 level (2-tailed).

iting the energy crisis caused by Russia's invasion of Ukraine and using natural gas for political blackmail of the EU. Theoretically, the easiest way out of a difficult situation in the energy sector is to replace Russian natural gas with the same energy resource from other suppliers. Moreover, covering additional energy needs by increasing the natural gas supply is a common regulatory tool in the energy market.

4. DISCUSSION

This paper examines the prospects of management decisions on the transformation of energy to overcome the energy crisis in their relationship with achieving the combating climate change policy goals through reducing greenhouse gas emissions. The results obtained show two extreme scenarios of greenhouse gas emissions, depending on the actions of the authorities, regulators and other energy market participants to implement the most obvious scenario for overcoming the energy crisis. The use of the Seasonal ARIMA model for forecasting the volume of emissions is justified by the need to consider the seasonal needs in energy resources, the shortage of which can significantly affect the adoption of anti-crisis decisions in the energy sector. Seasonal models are an effective means of forecasting, particularly in alternative energy research (Li et al., 2023). The dataset was formed to consider current trends in the energy sector, including implementing technologies to reduce greenhouse gas emissions. That is, it characterizes the situation in which management decisions will be made at the initial stage of overcoming the energy crisis.

Unlike other studies of the energy crisis in Europe, which explore the risks of the systemic risks dynamics in the energy market (Zhou & Wang, 2023) or focus on the energy substitution issues and renewable energy development (Liao, 2023), this study focuses on the impact of energy changes on the environment and climate policy. This issue is sensitive because environmental aspects can temporarily take a back seat to contain adverse economic and social effects. This study makes its scientific contribution to several studies on EU energy and climate policy after the Russian invasion of Ukraine (Mišík & Nosko, 2023). It allows politicians and energy market participants to get complete information about the consequences of their decisions to overcome the energy crisis. According to the results, the volume of greenhouse gas emissions can vary significantly. A strategic decision regarding the future of natural gas is an essential factor influencing the trajectory of the situation. The paper raises some caveats in this regard that require further investigation.

In particular, the key question remains how important natural gas will remain in the EU energy supply once ways of diversifying supply are found, and available supply increases significantly. One of the biggest arguments for expanding the gas supply, which its lobbyists will use, could be the environmental safety of gas. It has already been mentioned that this is not the case due to significant methane emissions during production. However, since most of the gas needed by the EU to cover its energy needs is and will be imported from other countries, only damage from gas consumption by consumers in the EU will be considered. The consumption of natural gas causes almost no CO2 or greenhouse gas emissions. This argument is so effective that natural gas has been recognized as clean energy in the EU. However, these calculations do not include methane emissions, especially those that occur at deposits. Such emissions are the largest and harm the climate. This influence is not local.

A comparison of the relationship between CO2 and greenhouse gas emissions from using natural gas and renewable energy favors renewable energy. This argument has played a key role in supporting renewable energy as a key factor in the future of the industry. However, the energy crisis makes adjustments to decision-making processes. The economic component becomes more important, and the environmental component is temporarily secondary. After all, the primary task is to preserve the economy and jobs, socially protect the population from shocks, and not allow the level of poverty to increase, leading to social instability in individual countries or the EU as a whole. In these conditions, a decision can be made to use natural gas in large volumes to ensure energy security and the stable functioning of the EU economy for a long time. At the same time, a rapid increase in the share of renewable energy will not occur, despite the significant financial resources allocated by the EU. It is also worth noting that these funds are allocated for developing clean energy, which now (from 2022) includes natural gas. This calls into question the course for the rapid development of renewable energy in the EU.

CONCLUSIONS

This paper aims to examine the consequences of the management of the energy crisis caused by Russia's invasion of Ukraine on the climate policy in the EU. For this purpose, forecasting of possible volumes of greenhouse gas emissions by the energy sector as a result of changes in energy policy was applied. Forecasting was carried out through the application of the seasonal ARIMA model, built on the basis of quarterly time series of greenhouse gas emissions in the EU27. As a result of the medium-term forecasting based on the Seasonal ARIMA model, two scenarios of greenhouse gas emissions were obtained. The negative scenario, which will exacerbate the consequences of the Ukrainian-Russian war, demonstrated that the value of greenhouse gas emissions in the EU at the beginning of 2030 would be 0.752911 tons per capita. A positive scenario based on the formed Seasonal ARIMA model shows that greenhouse gas emissions can be reduced to 0.235225 tons per capita.

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The significant discrepancy in emissions under the limit scenarios indicates the importance of today's decisions regarding the energy development strategy and the need to avoid ambiguous choices, such as adding natural gas to the list of clean energy types, which stimulates the growth of its use. Such decisions can lead to latent greenhouse gas emissions, in particular, methane, which are not taken into account in statistics, but are actually present.

The results of the study should be taken into account when making decisions about adjusting the existing energy and climate policy or developing a new one after overcoming the acute phase of the energy crisis.

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