Digital Modeling the Impact of EU Energy Sector Transformations on the Economic Security of Enterprises

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The main purpose of this position paper is to consider the prerequisites for digital modeling the impact of EU energy sector transformations on the economic security of enterprises. The energy security of the EU is a current issue for all member countries. The EU's energy policy aims for diversification of energy resources and energy independence. After 2022, this issue has worsened. The article analyzes the main risks to the energy security of EU countries and industries located in these countries. The dynamics of energy consumption by different sectors of the EU economy are considered and the impact of changes in the energy sector on the economic security of businesses is evaluated. Approaches to modeling the impact of transformations in the energy sector on the economic security of businesses are discussed. The most promising approaches for modeling catastrophic changes are highlighted.

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economic security,
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1 Introduction

The energy sector is a vital component of the European Union's economy and plays a significant role in ensuring economic security for enterprises. In recent years, the EU has undergone significant transformations in its energy sector, aimed at reducing its dependence on fossil fuels, increasing the use of renewable energy sources, and enhancing energy efficiency.

The shift towards cleaner energy sources has led to the creation of new business opportunities and the expansion of existing ones, particularly in the renewable energy and energy efficiency sectors. The increased investment in these areas has created jobs, stimulated innovation, and helped drive economic growth.

However, the transformation of the energy sector also presents challenges for enterprises. The transition to new energy sources and technologies can result in changes to traditional business models, leading to increased competition and reduced profits. It can also cause uncertainty for companies that are heavily invested in fossil fuels, leading to potential job losses and financial instability.

To mitigate these risks, the EU has implemented various measures, including providing financial support to companies, encouraging the development of new technologies, and promoting the adoption of energy-efficient practices. These initiatives aim to support enterprises in the transition to a more sustainable energy future and ensure their long-term economic security.

The EU is heavily dependent on energy imports from other countries, particularly for oil and natural gas. This dependence on energy imports leaves the EU vulnerable to price fluctuations and supply disruptions, which can have significant impacts on the economy and individual enterprises.

During a long time Russian Federation perceived as a reliable supplier of natural gas. However, 2022 marked the beginning of a hybrid economic war between the Russian Federation and the EU, during which the probability of a complete cessation of natural gas supplies from the Russian Federation to the EU increases significantly.

The war between Ukraine and the Russian Federation has already led to significant transformations in the energy sector of the European Union. Moreover, this process continues and the final configuration of the energy sector of the EU is still difficult to predict. But it is already clear that the energy sector transformations will greatly affect the economic security of industrial enterprises in Europe.

The main purpose of this article is to consider the prerequisites for modeling the impact of EU energy sector transformations on the economic security of enterprises. In order to accomplish this objective, we will conduct a literature review on the topic of the economic security of the EU, trends in the development of the European energy sector, and the modeling of their interrelationships. Subsequently, we will analyze the development of the energy infrastructure of the EU, and examine trends in the dynamics of energy consumption by the industrial sector. Based on the findings, we will identify approaches to model the transformations of the EU energy sector and their impact on the economic security of enterprises. In this regard, we will consider possible methods within the framework of inductive and deductive approaches.

2 Literature review

The close relation between the energy and economic security of the EU countries has been evident for a long time. Although the need for a dramatic transformation of the energy sector became critical only in 2022, the prerequisites for modeling such a situation were considered in the works of many scientists.

The authors (Sharples, 2013; Smiech, 2013) show the key aspects of economic security for the EU energy in the context of climate change. Their articles deal with the concept of energy security and economic problems for the EU countries. The problem of natural gas consumption as a 'green fuel' for Europe is considered.

The other group of authors (Jonsonn et al., 2015; Sytailo & Okhrimenko 2020) defines the key security indicators of the EU energy market in the next aspects: energy security, security of supply, security of demand and revenue, other political, social, technical and environment risk factors. Therefore, energy consumption in the context of low-carbon energy transitions described as not only technological problem, but also the consideration of market supply and demand aspects.

An important component of the economic security of the EU energy consumption is the development and implementation of renewable energy sources (Zherlitsyn et al., 2020). The authors consider the economic aspects of the implementation of the appropriate technological solutions, evaluate the forecasting and economic efficiency models for such projects.

The relationship between the EU foreign policy and energy strategies is the other part of economic security aspect (Youngs, 2020). In particular, the factors exogenous to energy policy can be significant and how these can contain contestation as well as generate it. These aspects have become key in 2022. Contemporary works show what the EU economic security needs to improve its external energy security. The author (Misik, 2022) shows that the EU's response in energy security policy have been rather slow and mainly towards the revision of the Union's internal mechanisms rather than the common external energy policy creation.

The study by Perdana et al. (2022) examines the economic repercussions of a complete ban on fossil fuel imports from Russia to European energy producers. Of particular interest is the analysis of the effects of cutting off energy imports from Russia for each individual EU country. Another study by Chachko and Linos (2022) evaluates the EU's energy consumption and identifies security and defense strategies in response to Russia's invasion of Ukraine. The outcome of the crisis revealed a lack of attention paid to the economic security aspects in the EU's energy sector.

As a result, early 21st-century authors placed a significant emphasis on the promotion of "green fuel" and diversification of energy sources for EU countries. Nonetheless, the outcome of partial and total embargoes on fossil fuel imports from Russia in 2022 exposed a deficiency of economic security in the energy sector for EU countries.

3 Results and discussion

Energy security is considered to be an important aspect of ensuring a stable and reliable energy supply for individuals, businesses, and governments. This includes ensuring the availability of resources such as oil, natural gas, and coal, as well as promoting the use of renewable energy sources and reducing dependence on single sources of energy. Energy security also involves protecting energy infrastructure and

addressing potential risks such as supply disruptions, price volatility, and environmental impacts. Thus, energy security is an important part of economic security.

Energy security refers to the availability, reliability, and affordability of energy supplies, as well as the stability of the energy systems and infrastructure that support them. It involves ensuring a consistent and sufficient supply of energy to meet the needs of individuals, businesses, and governments, while also mitigating the risks and impacts of energy production and consumption, such as price volatility, supply disruptions, and environmental degradation. The goal of energy security is to ensure a stable and sustainable energy system that supports economic growth and protects national economic security.

From the perspective of enterprises, energy security is the assurance that they have access to a reliable and cost-effective supply of energy to meet their operational needs and support their business goals. It involves minimizing the risks and uncertainties associated with energy prices and supply, and ensuring the resilience of the energy infrastructure that supports their operations. Companies may adopt strategies to improve their energy security, such as diversifying their energy sources, implementing energy-efficient technologies, and investing in renewable energy. In the economical context the ultimate goal for companies is to minimize their exposure to energy price volatility and supply disruptions, while ensuring the sustainability of their energy consumption and supporting their bottom line.

Energy security is a key concern for the European Union, as the bloc relies heavily on imported energy, particularly oil and natural gas. The EU has taken various steps to improve its energy security by diversifying its energy mix and reducing its dependence on single sources of energy. This includes promoting the use of renewable energy sources, such as wind and solar power, and increasing energy efficiency through the implementation of policies and regulations.

The EU has also established a number of initiatives aimed at improving energy security and the stability of the energy market. For example, the EU has established a single energy market, which facilitates the flow of energy between member states and helps to reduce dependence on single sources of energy. The bloc has also

established a number of interconnections between its national energy grids, which help to increase the security of energy supply and reduce the impact of disruptions.

The EU is also working to improve the security of its energy infrastructure, particularly in the context of increasing concerns about cyber security threats. The EU has established various initiatives aimed at enhancing the resilience of its energy systems, including the development of a comprehensive framework for the security of the electricity grid and the strengthening of emergency response mechanisms.

Overall, energy security is a high priority for the EU, and the bloc is taking a multi-faceted approach to address the challenges it faces in ensuring a secure, reliable, and sustainable energy supply, which is confirmed by the analysis below.

To assess the impact of changes in the energy sector structure on the economic security of enterprises, the dynamics of energy consumption by various sectors of the economy should be considered (Fig. 1).

The decline in energy consumption by the industrial sector, as shown in Fig. 1, is a noteworthy trend in the EU's economy. The reduction in energy consumption compared to 1990 levels, where the industrial sector consumed 79% of energy, to 77% in 2021 highlights the efforts made by the EU to improve energy efficiency and reduce its carbon footprint. The decrease in energy consumption in the industrial sector can be attributed to the implementation of energy-saving technologies, as well as increased awareness about the environmental impact of energy consumption.

On the other hand, the data in Fig. 1 shows that the other sectors of the EU economy have experienced a steady increase in energy consumption until 2006-2010. The subsequent decrease in energy consumption after this period can be attributed to the implementation of energy-efficient technologies and practices, such as the use of renewable energy sources and the development of more efficient buildings and appliances.

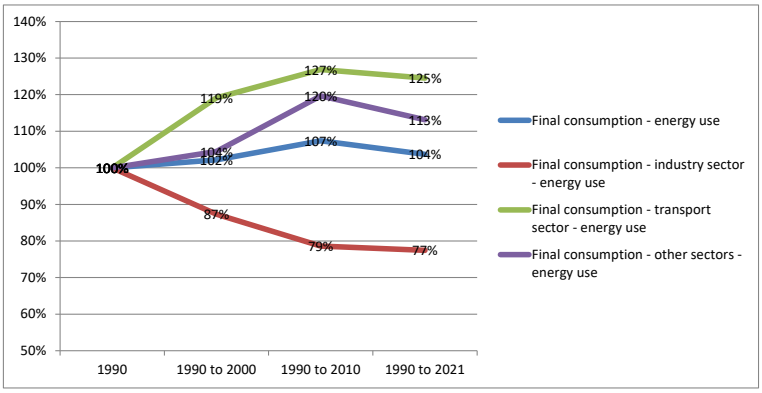

Figure 1: Dynamics of energy use by the groups of consumption, comparing with 1990.
Source: Authors' estimations and [2].

The changes in energy consumption by the industrial sector of EU countries began much earlier and can be traced back to the early 1990s. Fig. 2 provides a more detailed look at these changes, highlighting the specific industries that have seen the greatest reductions in energy consumption. Understanding the changes in energy consumption by industry is crucial for policymakers, as it provides valuable insights into the effectiveness of energy efficiency policies and the areas where additional efforts are needed to reduce energy consumption.

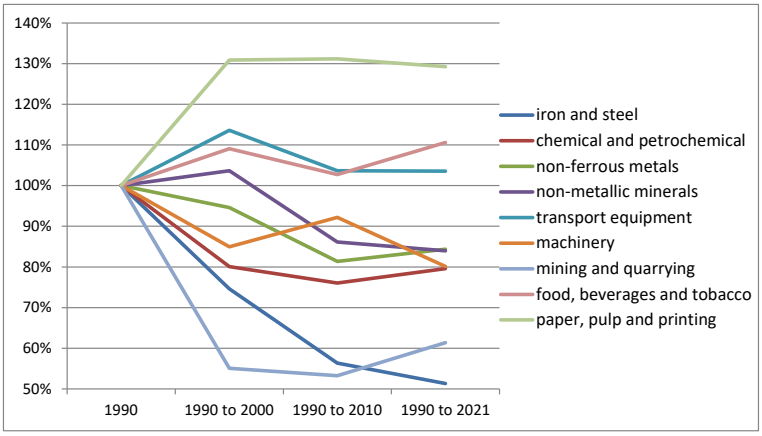

Figure 2: Dynamics of energy consumption by the groups of industries, comparing with 1990.
Source: Authors' estimations and [2].

The data shown in Fig.2 reveals that most industries have experienced a decrease in energy consumption. However, the printing, food, and transport industries show an exception, yet they have either seen a decrease or no increase in energy consumption since 2000.

Such dynamics, in the context of an increase in GDP in EU countries, could indicate that industrial enterprises had two main opportunities: or become more energy efficient or shutting down. An additional analysis of industrial production statistics showed that most industries have seen an increase in production over the period under review. This is even true for energy-intensive industries such as metal production (with a 5% increase from 1991 to 2021), motor vehicle production (with a 47% increase over the same period), mining, and others (Eurostat, 2022).

Let's consider the approaches to modeling the transformations of the EU energy sector and its impact on the economic security of enterprises. The positive influence in this case is the availability of sufficient statistical data reflecting the dynamics of the development of various industries in the EU and their energy consumption, including a breakdown by types of fuel used (Eurostat, 2022). This allows for sufficient use of such inductive models:

Statistical models, that use historical data to estimate the relationship between energy sector transformations and economic security can be used to make predictions about the future. This type of model can be used to estimate the impact of changes in energy prices, energy mix, and energy efficiency on the economy and individual enterprises.

Input-output models: This type of model looks at the flow of goods and services between different sectors of the economy, including the energy sector. By analyzing the interconnections between different sectors, input-output models can be used to estimate the indirect and spillover effects of energy sector transformations on the economy and individual enterprises.

Using inductive models allows us to establish and statistically confirm the main trends and interrelations in the transformation of the energy sector of the EU, which have historically arisen over the past decades. Unfortunately, inductive models cannot adequately predict the reaction of the research object in case of sharp changes

in external conditions. This is the situation that arose in 2022 when the EU countries were forced to sharply restructure the chains of energy carriers supplies and the structure of the energy market due to the start of the war in Ukraine and the "gas blackmail" by the Russian Federation. To model the transformations of the energy sector of the EU and their impact on the economic security of enterprises in this case, the following models based on a deductive approach can be used:

Scenario analysis: This type of analysis considers different future scenarios for the energy sector, taking into account different policy interventions and technological developments. Scenario analysis can be used to explore the potential impact of energy sector transformations on the economy and individual enterprises, allowing for a more comprehensive understanding of the risks and opportunities associated with the transition to a more sustainable energy future.

Simulation modeling: It's a broad class of models that includes system dynamics models, agent-evolutionary models, service system models, and others. The use of simulation models involves formulating assumptions about the structure, properties, and internal relationships of the modeled objects. By constructing virtual representations of real-world phenomena, simulation models enable us to experiment with different scenarios, identify cause-and-effect relationships, and make informed decisions about how to optimize and manage these systems. Based on these assumptions, the behavior of the object (energy sector, or industry) in the future is calculated, taking into account both random and planned deviations in its conditions of existence.

The deductive approach to modeling the impact of bifurcation changes in the energy sector on the economic security of enterprises does not exclude the use of inductive methods of modeling to confirm specific trends in the economies of EU countries. Economic development processes are to a sufficient degree inertial and it should be expected that even in the conditions of global catastrophes, the main vector of development will remain unchanged. Even a cursory analysis of statistics and literary sources allows us to note that the use of "green energy" and high energy efficiency in production is characteristic for EU countries. However, additional research is needed to more accurately establish the impact of these factors.

It's important to note that these models are just a tool and the results they provide should be interpreted with caution. The assumptions made, data used, and methodologies employed will impact the results, so it's essential to carefully consider these factors when using models to understand the impact of energy sector transformations on the economic security of enterprises.

4 Conclusion

The transformation of the EU energy sector presents both opportunities and challenges for enterprises. While the shift to cleaner energy sources offers new business opportunities, it also requires companies to adapt to changes in the market and the energy sector. Through various measures and initiatives, the EU is working to ensure that enterprises can thrive in a changing energy landscape and contribute to a more sustainable and economically secure future.

It is currently impossible to accurately predict all the consequences of the transformation of the EU's energy sector as a result of the military conflict between Ukraine and Russia. Industrial enterprises in the EU have long been focused on improving energy efficiency, which has helped to bolster their economic security against energy threats from Russia. The potential physical shortage of natural gas supply is driving the EU to increase its use of renewable energy and electric vehicles. The use of digital models will allow for the establishment of the most likely scenarios for event development and reduce the level of uncertainty for industries.

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