UDC: 620.9:551.583]:338.1(497.11)
DOI: 10.2478/jcbtp-2024-0009

Journal of Central Banking Theory and Practice, 2024, 1, pp. 199-222
Received: 14 June 2023; accepted: 23 October 2023

***Nemanja Backović** [*], **Miomir Jakšić** [**], **Bojan Ilić** [***]*

[*] Faculty of Organizational Sciences, University of Belgrade, Belgrade Serbia

E-mail: nemanja.backovic@fon.bg.ac.rs

[**] Faculty of Economics, University of Belgrade, Belgrade, Serbia

E-mail: miomir.jaksic@ekof.bg.ac.rs

[***] Faculty of Organizational Sciences, University of Belgrade, Belgrade, Serbia

E-mail: bojan.ilic@fon.bg.ac.rs

The Impact of Energy on Climate and Economic Stability: Forecast for Serbia

Abstract: In the conditions of modern business environment of energy companies, studies of their impact on environmental protection are becoming increasingly important. The growing concern at the macro level of the resulting climate change due to energy production is justified. The ecological component in the business of energy entities is becoming a priority for the sustainable development of energy, and therefore must be thoroughly examined. The focus of this paper is to determine the impact of energy on climate change through the emission of Greenhouse Gases on the example of the Republic of Serbia. The paper also examines the long-term interdependence between key economic and energy indicators at the national level. The IPAT/Kaya identity was used for research purposes and three alternative scenarios of energy development in Serbia until year 2050 were developed. The obtained results point to different possibilities for the development of energy and its impact on climate. The importance of promoting renewable energy sources for environmental protection and overall economic stability is also pointed out through proposed alternative scenarios. Significant results were obtained for the predicted level of energy intensity for the observed period, suggesting how the development of energy in Serbia could affect economic stability until 2050.

Key words: Energy, Climate Change, Economic Stability, IPAT/Kaya Identity, Greenhouse Gases.

JEL Classification: C63, Q43, Q47, Q53.

Introduction

In the conditions of growing complexity of energy systems, shortcomings of regulatory policy on energy security, instability of energy supply, high potential of expanding the influence of the world energy crisis and many other challenges, the modern energy economy requires more and more advanced models for realistic assessment of future trends in the energy sector. In order to effectively remove the ongoing irregularities of the system, a methodological framework is necessary that could realistically follow the complex flows of using various technologies for the exploitation of energy sources. This task is much more difficult during constant changes and the possibility of an energy shock from the external environment, which is why the creators of energy policy especially rely on the analysis of the rational management of economic and social policy. Spillover effects on other sectors and the impact of shock on the stability of macroeconomics are also important, if it is considered that, from an economic point of view, these are energy supply shocks that cannot be easily neutralized by economic policy instruments (Jakšić & Ješić, 2021). Likewise, analysts from the field of energy economics must improve their knowledge and adapt them to software solutions for systemic interpretation based on input of economic indicators.

The observation of current trends in the energy sector and future projections of the system is unthinkable without detailed economic studies and economic evaluation of the use of forms of energy. The use of renewable energy sources is of special strategic importance, and therefore the definition of the optimal production mix for the mentioned sources is viewed through the prism of their economic profitability, and in the context of the introduction of efficient technologies and the reduction of total negative externalities. Hence, "allocative efficiency refers to the use of scarce economic resources to produce the combination of goods and services that is most needed from the point of view of society" (Milićević & Ilić, p. 108, 2014). Nowadays, major challenges for the field of energy economics that stand out are the increased risk of energy supply disruption, the threat of a negative impact of energy production and consumption on the environment, alongside with the persistence of energy poverty (Birol, 2007).

It can be stated that energy economics from the aspect of the field of study is close to being categorized as a sub-discipline of resource economics. Furthermore, the ecological assumption is that capital, labour, and energy are vital inputs to economic production, for which they can create multiplier and synergistic effects, along with improving economic productivity (Sorrell, 2009). Recent research into the use of renewable energy sources supports this approach, which is gaining importance along with the integration of the ecological component within primary and secondary energy production. As former US Secretary of State Henry Kissinger pointed out, the problem of the climate crisis that we failed to assess after the energy crisis of 1973-74. year is not only a moral dilemma, but also a complex problem of immediate importance for security and economy on a global scale (Ikenberry, 1988).

Although it is expected that the new regulatory policies supporting renewable energy sources (RES) will cause an increase in social well-being, the results of certain analyzes such as the "green paradox" show quite the opposite. Namely, Sinn indicated the occurrence of a decrease in general social welfare in the case when the carbon tax rate grows faster than the interest rate in the observed period (Sinn, 2012). The regulation defined in this way would increase the current exploitation of fossil energy reserves more than can be expected in the future, while reducing the present value of the net benefits of the use of RES. More precisely, companies that use or produce conventional fuels will, under the pressure of new energy policies, accelerate the use of these sources in the short term, which will lead to a paradoxical state of global warming growth due to greater promotion of green energy regulation. Such and similar outcomes suggest that examining the economics of energy under the auspices of resource economics could gain importance, along with growing concerns about environmental protection and the impact of energy systems on global warming.

The constant changes that occur in the energy sector and the need to understand the related movements of political, economic, and natural factors point to the need to examine the endogeneity of newly created market conditions. For the needs of advanced research in the energy sector, it is especially important to identify the temporal and spatial factor of the investigation, then to balance between uncertainty and transparent reporting, to point out the problem of the growing complexity of the energy system and to include the components of consumer behavior to reduce the social risks of the development of the energy sector (Pfenninger, Hawkes & Keirstead, 2014). It is assumed that "the actions of market participants in relation to price formation, production, resource allocation, investments, horizontal, vertical integration and other market conditions depend on the so-called institutional arrangements" (Correljé & de Vries, 2008, p. 67). Considering the hybrid character of modern energy markets, the evolution of arrangements from the aspect of institutional economics of energy is gaining more and more importance. There are numerous factors that are listed as possible criteria for the optimization of the energy system, such as gross income, gross production, profit, amount of energy, gross national product, energy performance and others, assuming the existence of limiting factors of electricity production (Jebaraj & Iniyan , 2006).

Accordingly, it is very important to examine in detail the future trends within the energy sector and what is their interdependence with macroeconomic trends and general environmental protection conditions. To determine this, it is necessary to choose an appropriate methodology that could establish the long-term relationship between energy development and its impact on environmental pollution through the prism of economic analysis and preservation of financial stability in the country. This gives importance to the sustainable development of energy, and the focus of research is redirected towards environmentally acceptable growth of modern energy processes and stable change of energy intensity, depending on the energy needs of society.

1. Current state of energy industry in Serbia

In order to carry out an analysis of overall impact of energy on climate change and economic stability in the Republic of Serbia, it is important to check the production capacities that are currently available, the commercial quality of energy sources and the consistency of delivery. Realized modelling of energy sector categories is based on a realistic forecast of the needs of the entire population, with a view to fulfilling the requirements of the regulatory policy of sustainable development and decarbonisation of energy production processes. Adequate projections cannot be realized if all the limiting factors of the energy system growth are not previously included, which points to the importance of investigating the competitiveness of public companies and the investment activities of distribution system operators. Research using the scenario method was conducted in accordance with the established situation in the energy sector of the Republic of Serbia and potential opportunities for strategic reconfiguration of the sector, and according to the postulates of energy sustainability. Since this is a relatively short period of time for strategic planning of the energy sector, three alternative scenarios were modelled with the aim of creating a state of the energy sector that can be reached in relation to the observed market conditions until 2050.

According to the report of the Energy Agency, the total installed capacity of power plants in the Republic of Serbia for 2021 was 8,516 MW (Energy Agency of the Republic of Serbia, 2022). Based on the review of the data from the aforementioned report, it is noted that the sector's high dependence on the stability of the lignite thermal power plants, which accounted for more than 50% of the total installed power, is still noticeable. Hydropower plants are in second place in terms of total power with 2,941 MW, which is mainly made up of run-of-river hydropower plants with high nominal active power. They are the dominant source of energy production from non-conventional fuels. As for other renewable energy sources, small hydropower plants and wind power plants accounted for only 7.3% of the production capacity structure in 2021, while the installed capacity of wind power plants did not change compared to 2020 and amounted to 373 MW (Energy Agency of the Republic of Serbia, 2022). Solar power plants did not have a share in the delivered electricity in the transmission system, and the same applies to waste power plants and geothermal energy. When it comes to new production capacities that are connected to the distribution system, small hydropower plants lead the way, followed by power plants with combined fossil fuel production, as well as biogas power plants.

The largest producer of electricity in the territory of the Republic of Serbia is the public company "Elektroprivreda Srbije" (EPS) with a share of over 90% in the total installed capacity and significant capacity for the combined production of electricity and heat (Fiscal Council of the Republic of Serbia, 2019). In addition to its position as a leader in the electricity market of the Republic of Serbia, EPS is also a guaranteed supplier of electricity to households and small customers. An important process of alignment with the regulatory framework of the energy policy of the Republic of Serbia was realized in 2020, when the process of energy distribution and management of the distribution system was finally separated from the operations of EPS. This created the conditions for the much-needed independence of the distribution system from the dependent companies of EPS, with the aim of creating transparent and fair business conditions for all economic entities on this market.

Observing the achieved annual electricity production, the situation in the existing system of the Republic of Serbia has not changed significantly since 2012. The exception is the example of thermal power plants, which produced a total of 630 GWh in 2021, which is more than the total production for 2019 and 2020 combined (Energy Agency of the Republic of Serbia, 2022). Big changes were also noted among independent licensed producers of electricity, which had an unnoticeable share in annual production until 2018. Nevertheless, the mentioned share still amounts to less than 10% of electricity production originating from coal-fired thermal power plants.

If we exclude wind power plants and small hydropower plants with a percentage participation of 2.8% and 2.5% in the annual production of electricity in Serbia, respectively, significant structural changes have been absent so far (Energy Agency of the Republic of Serbia, 2022). The annual production of electricity did grow from 2017 to 2021, but the growth depended on the production of thermal power plants and good hydrology, which was particularly favourable during 2018 and 2021. Additional engagement of new RES plants is necessary because pursuant to paragraph 40 of Article 3 of the Law on Energy Efficiency and Rational Use of Energy, "energy efficiency measures include the production of electricity or thermal energy using renewable energy sources, provided that the produced electricity or thermal energy is uses at the place of production" (Law on Energy Efficiency and Rational Use of Energy, 2021).

The revitalization and modernization of power plants, as well as the introduction of new production technologies to improve energy efficiency, are considered the most important activities for expanding existing energy capacities (Fiscal Council of the Republic of Serbia, 2019). Investment activities also include the connection of the distribution and transmission systems, and progress has also been made in the regional connection of the commissioning of new transmission lines. Also, the new distribution facilities of hydropower plants should contribute to the security of electricity supply in the coming period.

2. Model description

2.1. Scenarios description

The "Business as usual" (BAU) scenario was developed for research purposes and is an adapted version of the state reference scenario of the Republic of Serbia, defined within the "Energy Development Strategy of the Republic of Serbia until 2025, with projections until 2030" (Ministry of Mining and Energy of the Republic of Serbia, 2015). The reference scenario describes the examination of the option of further development of the country's energy system in the absence of the implementation of new energy policy measures, additional rationalization of energy consumption and measures to improve energy efficiency. This scenario includes activities that can promote a coordinated approach to the creation of regulated conditions for the energy market, but essentially does not include innovative packages of regulatory policy measures, whereby the route of energy development that the country has been on until now is not changed. From the point of view of future energy consumption, it is important to point out that the reference scenario is a projection that excludes the introduction of new regulatory policies or measures aimed at reducing demand and carbon emissions, that is, all harmful gases from the energy sector (Feng & Zhang, 2012). For the modelling of the reference scenario, data were taken from official sources of the institutions of the Republic of Serbia for the period up to 2030, until which data are available on the proposed projection. The scenario was then adapted to the current trends in the energy sector, global changes, and the growing threat of energy poverty at the national level. All available data on short-term macroeconomic trends that were considered relevant for creating scenarios were entered. It is important to point out that this, as well as other scenarios, did not include variable factors resulting from the energy crisis since it was not possible to determine with certainty the further level of its development.

Supplementing the assumptions of the scenario for the period after the last available energy balance for 2020 was made in accordance with the relative change in final energy consumption, import dependence of the energy sector, primary energy consumption per unit of GDP and current energy flows. Since the strategy of energy development in Serbia was published back in 2015, there have been major changes at the global and national level, according to which it was necessary to harmonize this scenario. In the meantime, a lot has been done regarding the promotion of clean energy, the growth of investments in more efficient technologies, and work on the general stabilization of the country's energy system. The way to a simpler establishment of companies in the field of energy has been opened and a far greater number of activities of energy entities in the field of application of new technologies for the use of renewable energy sources has been observed. However, the Republic of Serbia also faced numerous challenges caused by late reactions to threats to energy security such as the use of outdated technology, mining of relatively low-quality coal, and high dependence on energy imports. Slow economic growth during the global coronavirus pandemic only made the situation in which the energy sector found itself in even more difficulty. The research showed that "the COVID-19 pandemic, causing a shock on the side of aggregate supply and aggregate demand, disrupted the balance of supply and demand for energy products, generating fluctuations in their prices" (Praščević & Ješić, 2022, p. 140). In accordance with the above, an important starting point for further projections is the comparison of the reference scenario from the aforementioned strategy and the energy balance data for 2020. Deviations were determined, which were also taken into account and on the basis of which the scenario for the period up to 2050 was adjusted.

The scenario of moderate use of renewable energy sources (abbreviated: SMRES scenario) is a scenario that was completely independently developed for the needs of the projection of the development of the energy system of the Republic of Serbia until 2050, with the entry of data until 2020, the last year for which final data for the sector is available of energy. The developed model enabled creation of a comprehensive scenario from the aspect of macroeconomic and microeconomic analysis of future developments. The goal of creating the SMRES scenario is to examine the additional introduction of RES technologies in the energy system of the Republic of Serbia, and at the same time consider the potential, obstacles and challenges of the mentioned process. The SMRES scenario can also be seen as an improved version, that is, an extension of the BAU scenario, adapted to the modern needs of the energy consumption sector. Special emphasis is placed on reducing carbon emissions from the energy sector and on options for minimizing the use of harmful types of fuel. The SMRES data is taken over and adjusted by the following alternative scenario that promotes intensive use of renewable energy.

The scenario of intensive use of renewable energy sources (abbreviated: SIRES scenario) is the last of the three alternative scenarios modelled for the purposes of the conducted research. The SIRES scenario inherits data from the SMRES scenario which is then modified according to the research requirements. The SIRES scenario is a projection of the development of the energy sector with an analysis of integration of the highest degree of possible use of renewable energy sources in the Republic of Serbia for the period up to 2050, with reference to all the limitations of the existing energy system. Generally speaking, it is assumed that renewable energy sources will not be able to completely replace conventional sources for the needs of primary energy production until 2050. The goal of creating this scenario is the projection of the use of renewable energy sources to the greatest extent possible for the observed time period. In order to prove a more realistic assumption of the gradual integration of RES and partial replacement of the use of non-renewable energy sources, these two different options for the use of RES are considered. The perspective of energy development is defined within the limits of possible achievable values for selected energy indicators. In this regard, the scenario setting incorporates adequate measures to increase energy efficiency and support the development of RES use.

Unlike the previous alternative scenario, SIRES examines both the economic costs and benefits of changing the current RES adoption, that is, to incentivise preferential and temporarily preferential electricity producers. The adjustment of the proposed incentive purchase prices is seen in the context of financial justification and adaptability of the system to the level of growth of incentive purchase prices, with the aim of increasing investments and reducing the final consumption of primary energy per unit of GDP. The promotion of the use of RES was also observed through the effects of reducing the emission of Greenhouse Gases, reducing the costs of all environmental externalities and the effects of the overall reduction of social costs that may arise from the use of conventional forms of energy. The creation of the SIRES scenario pointed out the real possibilities of adapting the energy system of the Republic of Serbia to the modern conditions of the use of RES, with economic justification for market participants and preserving the country's macroeconomic stability.

The selected scenario intends to simulate the use of the full available capacity of power plants from the field of renewable energy sources. This means that the production facilities of those power plants will be engaged up to the full available capacity, regardless of the level of demand of the energy transformation module or the demand from the side of final energy consumption. Thus, the focus would be on an export-oriented energy system. Satisfying domestic demand for energy remains defined as a priority in the model, but the modelling approach itself leads to major differences when testing this versus another alternative scenario.

Consideration of the obtained results is useful from the point of view of analysing the costs and benefits of installing new RES systems, the way they are used and the percentage potential of replacing the old technology. It is important to examine in detail both options for the implementation of energy development strategies, in order to provide a timely answer as to whether the energy sector of the Republic of Serbia is ready for the intensive use of renewable energy sources and to what extent.

2.2. Description of the data

The key economic and demographic assumptions of the proposed research are:

- Gross domestic product (GDP)
- Annual GDP growth
- Total population of the Republic of Serbia
- Growth rate of the total population of the Republic of Serbia

The key assumptions on the basis of which the projection will be carried out are based on forecasts of economic and demographic trends on the example of the Republic of Serbia for the time period up to 2050. The definition of the growth rates and the differences between the assumptions under the alternative scenarios are explained below.

The industrial structure in the Republic of Serbia, the energy intensity of each sector and the structure of final energy consumption by consumption sector were determined by interpolation of trends from historical data.

Table 1: Key indicators of the research

Data type	Specific indicators
Economic data	gross domestic product, real growth rate of gross domestic product
Demographic data	total population, growth rate of the total population
Data from the field of energy	final energy consumption, primary energy consumption, greenhouse gases emission, primary energy production

Source: Author's analysis

2.2.1. Gross domestic product

For the long-term forecast of economic trends in the Republic of Serbia, measured by the real growth rate of the gross domestic product, annual national accounts were used, as well as the summarized complex announcements "Economic Trends - Assessment" of the Statistical Office of the Republic of Serbia.

Based on available data from administrative sources, regular statistical surveys, and available data from the statistical system, the "Macroeconomic projection model for testing long-term debt sustainability and growth performance, 2019-2030" was created (Statistical Office of the Republic of Serbia, 2019), which was also of great importance for projections of real GDP growth.

For all three alternative scenarios, a real GDP growth rate of 3.2% for 2022, 2.7% for 2023 and 2.8% for 2024 was determined, in accordance with the revised report of the World Bank for the Western Balkans. (World Bank, 2022). Starting from 2025 until the last year of calculation, a real GDP growth rate of 3% was determined for the BAU scenario. Within this scenario, no additional potential contraction of foreign demand, possible overcomposition of sources of financing and increase of the multiplier effect of the sector in the context of changes in the sectoral structure of investments are expected. The challenges of low external liquidity and the creation of pressure on the balance of payments may affect the decline in the coverage of imports of goods and services by foreign exchange reserves. Conversely, a more optimistic approach is taken within SMRES and SIRES scenarios, where a real GDP growth rate of 4% was determined.

2.2.2. Total population of the Republic of Serbia

Data on the projection of the total population were obtained based on the official data from the Fiscal Council of the Republic of Serbia (2013).

The study published by Statistical Office of the Republic of Serbia titled "Population projections for the period from 2011 to 2041" is also significant for this research (Statistical Office of the Republic of Serbia, 2011). Here, population projections were given in five different variants: low, medium, high, constant fertility variant and zero migration balance variant. Since in this publication it was pointed out that the number of inhabitants will most likely change in accordance with the assumptions of the medium fertility variant projection, and bearing in mind that the Energy Development Strategy of the Republic of Serbia is based on the mentioned variant of the projection, the report was considered for the creation of BAU scenario for the period up to year 2041. However, that option was rejected for the purposes of research within the paper because it was considered that authoritative results of the impact of energy on the climate and economic stability will be reached if all three alternative scenarios have the same projection of the number of inhabitants for the observed period. As stated earlier, only different real GDP growth is proposed according to the created scenarios.

The study of the Fiscal Council of the Republic of Serbia, published in June 2013 under the title "Population Projections of Serbia from 2010 to 2060", was used to enter projection variants of the total population movement for the BAU, SMRES and SIRES scenarios. The study divides the projections into eight variants: variants of low, medium, high, constant fertility, then the variant of constant mortality, zero migration balance, constant variant, and the last prognostic variant. For the purposes of creating these scenarios, the variant of average fertility was adopted, which does not follow the projection of average fertility from the aforementioned study of the Statistical Office of the Republic of Serbia.

Table 2: Key economic and demographic assumptions of alternative scenarios

Key economic assumption	BAU scenario		SMRES scenario		SIRES scenario	
	Rate of growth 2025-2050	Projections for 2050	Rate of growth 2025-2050	Projections for 2050	Rate of growth 2025-2050	Projections for 2050
GDP (in million Serbian dinars)	3%	20385758	4%	24731426	4%	24731426
Key demographic assumption	Rate Growth 2041-2050	Projections for 2050	Rate Growth 2041-2050	Projections for 2050	Rate Growth 2041-2050	Projections for 2050
Total population	-3,6%	5761378	-3,6%	5761378	-3,6%	5761378

Source: Authors` analysis, based on available data

2.2.3. Greenhouse gas emissions from the energy sector in Serbia

The collection of relevant data on the emission of GHG (Greenhouse Gases) in the Republic of Serbia is difficult, given that there are no comprehensive publicly available data from state institutions on specific emissions from the energy system. Although the "Second Report of the Republic of Serbia according to the United Nations Framework Convention on Climate Change" (Ministry of Environmental Protection, 2017) can serve as an important guideline for further investigations, the projections presented therein of the emission of all direct harmful gases that may arise from activities of the energy sector are not completely specified. In addition, by reviewing the literature, it can be concluded that such a projection has not been observed for the period up to 2050.

The empirical findings of this section will serve as a kind of contribution to the long-term projection of the emission of harmful GHG gases from the energy sector. From the perspective of the considered area of analysis, the focus of creating alternative scenarios is the monitoring of carbon dioxide emissions and the proposal to replace inefficient technologies that cause environmental pollution. The "Annual report on the state of air quality in the Republic of Serbia" of the Environmental Protection Agency of the Republic of Serbia is also important for analysing pollution emissions by type of power plants (Serbian Environmental Protection Agency, 2020).

In order to formulate the projection for the emission of GHG direct gases, three different sources were considered in the first iteration of the research: (1) the projection of carbon dioxide emissions until 2030 within the "Energy Development Strategy of the Republic of Serbia until 2025 with projections until 2030. year" (for model validation); (2) World Bank database (based on: Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States); (3) guidelines of the United Nations Framework Convention on Climate Change and, based on the guidelines, the first and second reports for the Republic of Serbia.

In the case of using the full capacity of electricity production technologies from renewable sources, the SIRES scenario shows a significant reduction of GHG emissions from the energy sector compared to the reference scenario, so that only 47.82% of the total value of GHG emissions that would be realized in 2050 was projected in the BAU scenario. Details about the proposed projection can be found in table 3.

Table 3: Projections of Greenhouse Gases Emissions for different scenarios in Serbia (in millions of metric tons of CO2 equivalent)

Year	BAU scenario	SMRES scenario	SIRES scenario
2050	87,4	55,5	41,8
2049	86,7	55,6	42,5
2048	85,9	55,6	43,2
2047	85,1	55,7	43,9
2046	84,4	55,7	44,2
2045	83,7	55,6	44,9
2044	83,0	55,7	45,6
2043	82,2	55,5	45,8
2042	81,4	55,4	46,1
2041	80,7	55,2	46,6
2040	80,0	55,1	46,9
2039	79,3	55,2	47,5
2038	78,5	55,1	47,8
2037	77,8	55,0	48,1
2036	77,0	54,9	48,3
2035	76,3	54,8	48,6
2034	75,6	55,0	48,9
2033	74,9	55,1	49,4
2032	74,2	55,3	49,8
2031	73,5	55,3	50,0
2030	72,8	55,2	50,2

Source: Authors` analysis, based on available data

3. Methodology

Kaya and IPAT identities, as well as the decomposition methodology based on the Kaya factor, were used to examine the correlation between key assumptions of the model and relevant energy indicators. By combining the aforementioned identities, an attempt is made to comprehensively examine the interdependence of indicators, that is, the relationship between the projected movements of economic and demographic data and the results obtained based on the development of the energy system.

The focus is on the analysis of the economic characteristics of the system and the approximation of the movement of macroeconomic indicators. Special attention was given to the economic basis for the greenhouse gases reduction. Thus, the original form of the Kay identity of the decomposition of carbon dioxide emission C from energy processes is shown as (Kaya, 1990):

$$C = \frac{C}{E} \times \frac{E}{B} \times \frac{B}{P} \times P \tag{3.1}$$

where E is energy use, B is gross domestic product and P is total population.

For examining multiple sectors of consumption, the mathematical identity can be formulated as (Gao et al., 2016):

$$C = \sum_j C_j + \sum_k C_k \tag{3.2}$$

$$= \sum_j \left[\left(\sum_i emi^i \times \frac{E_j^i}{E_j} \right) \times \frac{E_j}{B_j} \times \frac{B_j}{B} \times \frac{B}{P} \times P \right] + \sum_k \left[\left(\sum_i emi^i \times \frac{E_k^i}{E_k} \right) \times \frac{E_k}{P_k} \times \frac{P_k}{P} \times P \right]$$

$$= \sum_{n \in \{j,k\}} \left[\left(\sum_i emi^i \times \frac{E_n^i}{E_n} \right) \times \left(\frac{E_j}{B_j} \times \frac{B_j}{B} \times \frac{B}{P} + \frac{E_j}{P_k} \times \frac{P_k}{P} \right) \times P \right]$$

$$= \sum_{n \in \{j,k\}} \left[es_n \times (e_j \times int_j \times b) \times p \right]$$

where *j, k, i* show the economic sector, type of energy and type of households (urban and other areas), respectively; E_j^i describes fuel consumption *i* in sector *j*; the expressions *emi, b, int, e, es* represent the carbon dioxide emission factor, GDP per capita, share of GDP for a specific sector, energy intensity of the sector and share of a specific form of energy in the consumption sector, respectively.

Accordingly, aggregated carbon dioxide emissions can be decomposed by general economic sector and by energy consumption sector, to examine five key drivers of correlation: (1) energy efficiency, (2) economic growth, (3) economic structure, (4) energy structure and (5) total population.

The IPAT identity considers the impact of human activities on the environment (I - Environmental Impact) as a product of three factors: population (P - Population), wealth expressed in the form of average consumption per inhabitant (A - Affluence) and technology (T - Technology). By applying combined identities based on the factor decomposition, results were given for alternative scenarios to investigate the impact of energy on climate change and economic stability in Serbia until year 2050.

4. Empirical findings and discussion on results

The descriptive summary of variables is given in tables 4, 5 and 6 for scenarios between the period from 2030 to 2050. The report describes in detail the decomposition reports that indicate the impact of the energy sector on key assumptions about economic and demographic trends. The observed differences in projections give an overview of the potential of energy development and its impact on economic stability and the occurrence of climate changes caused by the emission of Greenhouse Gases from the production of electricity and thermal energy at the national level.

The forecast of the emission of GHG arising from the energy sector is necessary, in order to analyze, control and prevent the occurrence of harmful gases when using new technologies. The asymmetry of social and economic factors of GHG emissions from the energy sector shows that economic growth is the biggest driver of their emission growth (Yin, Xiong, Ullah & Sohail, 2021). One should also consider so called transition risk, form of financial risk that can emerge when carbon-intensive assets are dismissed due to the shift towards a green economy. This could create even more problems for the economy that is relying on conventional energy sources, as shareholders of carbon-intensive companies would have substantial losses, which would reduce their debt repayment potential (Fabris, 2020). Therefore, various subventions covered by the state in the form of green finance instruments (renewable equity, green bonds, green mortgages, renewable energy credits etc.) would create a sustainable and competitive business environment for low GHG emissions based on the use of efficient resources (Martin, 2023).

According to the results of the decomposition report for the energy sector of the Republic of Serbia using the IPAT/Kaya identity, a significant drop in energy intensity that would occur in the case of the realization of the SMRES and SIRES scenarios is noticeable. As for the amount and share of final energy consumption in the gross domestic product, it was observed that it decreases in proportion to the expected real GDP growth. The key assumptions of the model on economic growth and the total number of inhabitants of the Republic of Serbia indicate an adequate level of development of the sustainability of the energy sector.

Table 4: Decomposition report for the energy sector in Serbia using the IPAT/Kaya identity - BAU scenario

Indicator	Units	2030	2032	2034	2036	2038	2040	2042	2044	2046	2048	2050
Population	Citizens	6379056	6289206	6199356	6119308	6049061	5978815	5930493	5882171	5838684	5800031	5761378
Gross Domestic Product	Million RSD	11287100	11974484	12703730	13477388	14298161	15168919	16092706	17072751	18112482	19215532	20385758
Final Energy Consumption	Million GJ	561	570	580	590	600	610	623	636	649	662	675
Primary Energy Consumption	Million GJ	844	860	874	892	912	933	954	977	1000	1025	1050
Greenhouse Gases	Million tonnes	72	73	74	76	77	79	80	82	83	85	86
Primary energy production	GWh	137339	139394	140987	143744	147017	150286	153071	156223	159242	162628	166013
PEP/GHG	GWh/Million Tonne	1916	1907	1893	1896	1902	1907	1910	1913	1917	1924	1930
POP	GWh	9636	-10042	-10291	-10540	-10131	-9722	-9518	-9518	-9518	-9518	-9518
GDP/POP	GWh	492241	533711	577525	623992	672616	724226	779208	837756	899869	965764	1035673
FEC/GDP	GWh	-419586	-456385	-495684	-537434	-581797	-629147	-678566	-731346	-787551	-847399	-911260
PEC/FEC	GWh	-26515	-26621	-27037	-26547	-25757	-24804	-25008	-24523	-24209	-23563	-22692
GHG/PEC	GWh	-83740	-85082	-86155	-88404	-90855	-93469	-96282	-99525	-102924	-106633	-110564
PEP/GHG	GWh	-7107	-7870	-9053	-9004	-8740	-8480	-8445	-8303	-8106	-7706	-7309
BAU	GWh	137339	139394	140987	143744	147017	150286	153071	156223	159242	162628	166013

Source: Authors` calculation

Table 5: Decomposition report for the energy sector in Serbia using the IPAT/Kaya identity - SMRES scenario

Indicator	Units	2030	2032	2034	2036	2038	2040	2042	2044	2046	2048	2050
Population	Citizens	6379056	6289206	6199356	6119308	6049061	5978815	5930493	5882171	5838684	5800031	5761378
Gross domestic product	Million RSD	11287100	12208127	13204311	14281782	15447176	16707665	18071011	19545605	21140527	22865594	24731426
Final energy consumption	Million GJ	495	498	502	506	510	515	521	528	534	541	548
Primary energy consumption	Million GJ	718	723	723	726	732	736	742	750	755	759	764
Greenhouse Gases	Million tonnes	54	54	54	54	54	54	54	55	55	55	54
Primary Energy Production	GWh	137148	138905	138616	139191	140603	141291	142926	144773	145654	146262	146895
PEP/GHG	GWh/ million tonnes	2530	2557	2570	2584	2600	2613	2629	2648	2664	2681	2697
POP	GWh	-21545	-23942	-26338	-28473	-30346	-32220	-33509	-34798	-35957	-36988	-38019
GDP/POP	GWh	504150	561569	623477	689979	761473	838648	921382	1010763	1107203	1211288	1323783
FEC/GDP	GWh	-449733	-503179	-561114	-623633	-691135	-764314	-842845	-928018	-1020328	-1120360	-1228798
PEC/FEC	GWh	-30577	-30786	-32352	-33348	-33802	-34943	-36075	-36968	-38629	-40369	-42066
GHG/PEC	GWh	-84765	-85894	-86677	-87692	-88924	-89906	-91081	-92490	-93820	-95324	-96854
PEP/GHG	GWh	27936	29456	29938	30677	31655	32344	33371	34602	35504	36333	37167
SMRES	GWh	137148	138905	138616	139191	140603	141291	142926	144773	145654	146262	146895

Source: Authors` calculation

Table 6: Decomposition report for the energy sector in Serbia using the IPAT/Kaya identity - SIRES scenario

Indicator	Units	2030	2032	2034	2036	2038	2040	2042	2044	2046	2048	2050
Population	Citizens	6379056	6289206	6199356	6119308	6049061	5978815	5930493	5882171	5838684	5800031	5761378
Gross domestic product	Million RSD	11287100	12208127	13204311	14281782	15447176	16707665	18071011	19545605	21140527	22865594	24731426
Final energy consumption	Million GJ	482	484	485	486	487	487	490	493	496	500	503
Primary energy consumption	Million GJ	457	541	539	541	555	553	574	576	571	569	564
Greenhouse Gases	Million tonnes	49	49	48	47	47	46	45	45	43	42	41
Primary Energy Production	GWh	127639	130279	130687	131971	132992	132866	133434	134608	133862	134528	134234
PEP/GHG	GWh/million tonnes	2594	2668	2728	2786	2839	2893	2954	3017	3094	3183	3279
POP	GWh	-21545	-23942	-26338	-28473	-30346	-32220	-33509	-34798	-35957	-36988	-38019
GDP/POP	GWh	504150	561569	623477	689979	761473	838648	921382	1010763	1107203	1211288	1323783
FEC/GDP	GWh	-455227	-509733	-568719	-632645	-701906	-776836	-857016	-943830	-1037676	-1139142	-1249001
PEC/FEC	GWh	-95641	-73364	-74523	-74457	-70928	-71920	-67456	-68075	-71037	-73099	-76109
GHG/PEC	GWh	-24269	-47842	-49054	-50637	-55597	-56818	-64071	-65846	-67034	-68589	-69865
PEP/GHG	GWh	28488	31910	34162	36522	38614	40330	42422	44711	46682	49376	51762
SIRES	GWh	127639	130279	130687	131971	132992	132866	133434	134608	133862	134528	134234

Source: Authors` calculation

In the case of the forecast of emissions of GHG gases from the energy sector, the possibility of a significant reduction of the mentioned emissions in three alternative scenarios compared to the reference scenario was demonstrated. Thus, the SIRES scenario shows a significant reduction of harmful gases, with only 47.82% of the total value of harmful gas emissions projected for the year 2050 based on the example of the BAU scenario. With a detailed presentation of the results from this research area, it can be noted that there would be potentially large economic savings for the energy system of the Republic of Serbia in the case of formation of prices for carbon emissions on the example of the SMRES and SIRES scenarios. Therefore, in accordance with the above, great developments are expected in this matter, if these scenarios are implemented. On the other hand, for the BAU scenario, an increase of as much as 21.13% was projected for the same period. These findings are also important from an economic point of view, since a detailed analysis examined how the reduction of the mentioned emissions reflects on economic indicators of the development strategy of the energy sector.

Data on macroeconomic projections of economic development indicate that final energy consumption would reduce the share in GDP from -449,733 GWh to -1,228,798 GWh on the example of the SMRES scenario for the period from 2030 to 2050. In percentage terms, the difference would be a full 63.4%. Primary energy production would grow at a faster rate than primary energy consumption, while the reduction of the total population according to the average fertility rate would be reflected in a slightly lower rate of final energy consumption, despite the intensification of activities within the industrial sector.

Additionally, the level of emissions of harmful greenhouse gases would not change to a large extent, since the installation of renewable energy source equipment in the given scenario would be at an insufficient level to completely replace fossil fuels as input fuels for the needs of energy production by transformation. This would lead to the continuation of the negative trend of air pollution, which is above the planned level of sustainable energy development in the long term. Although the projected GHG emission is lower by 37.2% compared to the BAU scenario for year 2050, it is evident that more could be achieved by adequately replacing energy sources and assuming the balancing responsibility of privileged electricity producers. Nevertheless, the decomposition report for this scenario shows the potential of establishing a high degree of fiscal stability in the long term. The substitution of conventional forms of energy, followed by the adequate development of the system for the transmission and distribution of electrical energy, indicates the importance of the gradual integration of renewable energy sources. It should be noted that the RES utility factor is often low and has a seasonal character, which could endanger energy systems and cause energy blackouts in case the transition to the green energy is not done properly. Also, empirical findings have pointed out that "in numerous cases it has proven more financially profitable to continue supplying a cost-inefficient power plant with a conventional energy source than to shut down its operation, which suggests that the power plant requires management of unforeseen costs" (Backović & Ilić, 2023, p. 346).

The stated difference in the share of final energy consumption in GDP would be slightly higher in the SIRES scenario, at the level of a difference of 63.55% for the period from 2030 to 2050. However, primary energy production would be 8.61% lower in the case of this scenario.

Based on the results, it could be concluded that the movements within the energy sector would have a more favourable impact on the country's macroeconomic stability on the example of the SMRES scenario. An overview of the results according to the IPAT/Kaya identity are based on the created model.

5. Conclusion

The assessment of the model is that the analysed level of incentive purchase prices would contribute to the reduction of social costs in the field of energy, more efficient use of technologies and, in a wider context, sustainable development of energy. New regulations would reallocate funds to a low-carbon economy and, consequently, prevent major economic disruptions from carbon assets and overall climate change (Schellhorn, 2020).

According to the results of the IPAT/Kaya identity, there would be a drop in energy intensity if the energy sector development projections according to the SMRES or SIRES scenario were realized. Based on to the forecasted real GDP growth, a decrease in the amount and share of final energy consumption in the gross domestic product is expected. As previously mentioned, the obtained results point to the fact that the realization of the SMRES scenario would have the most favourable impact on macroeconomic stability from the perspective of the impact of the development of the energy sector on economic growth in the Republic of Serbia.

Based on the obtained results, the importance of the IPAT/Kaya identity for examining the impact of energy on climate change was pointed out. The decomposition report provided an insight into the interdependence of the projection of the movement of economic and energy indicators, which is of great importance for the analysis of potential of sustainable energy development. Limiting factors from the power market could influence the research to take a new form, with the assessment of the impact of energy production on environmental protection not significantly changing. Further directions of research should also include the limitations of the current energy crisis, the movement of energy prices and the division of emissions into individual greenhouse gases. The research has defined the basis for future studies in this area on the example of the Republic of Serbia, giving a concrete scientific contribution to this insufficiently researched economic topic so far.

References

1. Backović, N. and Ilić, B. (2023). Managing Costs of Renewable Energy Companies for Sustainable Business. In Mihić, Marko, Jednak, Sandra and Savić, Gordana (Eds.) Sustainable Business Management and Digital Transformation: Challenges and Opportunities in the Post-COVID Era, *Lecture Notes in Networks and Systems*, Volume 562, pp. 343-359. Springer. https://doi.org/10.1007/978-3-031-18645-5
2. Birol, F. (2007). Energy Economics: A Place for Energy Poverty in the Agenda? *The Energy Journal*, Volume 28(Number 3), 1–6. https://econpapers.repec.org/RePEc:aen:journl:2007v28-03-a01
3. Correljé, A.F. and de Vries, L.J. (2008). Chapter 2 - Hybrid Electricity Markets: The Problem of Explaining Different Patterns of Restructuring, In *Elsevier Global Energy Policy and Economics Series, Competitive Electricity Markets*, Sioshansi, F. P. (Ed.), Elsevier, p. 65-93, https://doi.org/10.1016/B978-008047172-3.50006-4.
4. Energy Agency of the Republic of Serbia (2022). *Energy Agency Annual Report for 2021*. https://www.aers.rs/Files/Izvestaji/Godisnji/Izvestaj%20Agencije%202021.pdf
5. Fabris, N. (2020). Financial Stability and Climate Change. *Journal of Central Banking Theory and Practice*, 9(3) 27-43. https://doi.org/10.2478/jcbtp-2020-0034
6. Feng, Y. Y. and Zhang, L. (2012). Scenario analysis of urban energy saving and carbon abatement policies: A case study of Beijing city, China. *Procedia Environmental Sciences*, 13, 632–644. https://doi.org/10.1016/j.proenv.2012.01.055
7. Fiscal Council of the Republic of Serbia. (2019). Business analysis and recommendations for EPS reform and investment increase. http://www.fiskalnisavet.rs/doc/analize-stavovi-predlozi/2019/Analiza_poslovanja_i_preporuke_za_reformu_i_povecanje_investicija_EPS-a.pdf
8. Fiscal Council of the Republic of Serbia (2013). Population projections of Serbia from 2010 to 2060. https://www.fiskalnisavet.rs/doc/istrazivacki-radovi/studija-projekcije_stanovnistva_srbije_od_2010-2060-penev.pdf
9. Gao, C., Liu, Y., Jin, J., Wei, T., Zhang, J. and Zhu, L. (2016). Driving forces in energy-related carbon dioxide emissions in east and south coastal China: commonality and variations. *Journal of Cleaner Production*, 135, 240–250. https://doi.org/https://doi.org/10.1016/j.jclepro.2016.05.131
10. Ikenberry, G. J. (1988). The Oil Shocks and State Responses. In *Reasons of State: Oil Politics and the Capacities of American Government*, 1–20. Cornell University Press.

11. Jakšić, M. and Ješić, M. (2021). Komparativna analiza stanja na tržištu električne energije sa osvrtom na makroekonomske posledice. *Ekonomske Ideje i Praksa*, 43, 15–29.
12. Jebaraj, S.and Iniyan, S. (2006). A review of energy models. *Renewable and Sustainable Energy Reviews*, 10(4), 281–311. https://econpapers.repec.org/RePEc:eee:rensus:v:10:y:2006:i:4:p:281-311
13. Kaya, Y. (1990). *Impact of Carbon Dioxide Emission Control on GNP Growth: Interpretation of Proposed Scenarios*. IPCC Energy and Industry Subgroup, Response Strategies Working Group.
14. Law on Energy Efficiency and Rational Use of Energy (2021). Official Gazette of RS no. 40/2021. https://www.mre.gov.rs/sites/default/files/2021/05/zakon_o_energetskoj_efikasnosti_i_racionalnoj_upoterebi_energije_0.pdf
15. Martin,V. (2023). Green Finance: Regulation and Instruments. *Journal of Central Banking Theory and Practice*, 12(2) 185-209. https://doi.org/10.2478/jcbtp-2023-0019
16. Milićević, V. and Ilić, B. (2014). Ekonomika poslovanja. Fakultet organizacionih nauka Univerziteta u Beogradu.
17. Ministry of Environmental Protection. (2017). The second report of the Republic of Serbia according to the United Nations Framework Convention on Climate Change.
18. Ministry of Mining and Energy of the Republic of Serbia. (2015). *Energy development strategy of the Republic of Serbia until 2025 with projections until 2030*. Official Gazette 101/15.
19. Pfenninger, S., Hawkes, A. and Keirstead, J. (2014). Energy systems modeling for twenty-first century energy challenges. *Renewable and Sustainable Energy Reviews*, 33, 74–86. https://doi.org/10.1016/J.RSER.2014.02.003
20. Praščević, A. and Ješić, M. (2022). Cene energenata kao značajni šokovi ponude: primer država bivše SFRJ i Višegradske grupe. *Ekonomski horizonti* Vol. 24 (2), 139–159.
21. Schellhorn, C. (2020). Financial System Stability, the Timing of Climate Change Action and the Federal Reserve. *Journal of Central Banking Theory and Practice*, 9(3) 45-59. https://doi.org/10.2478/jcbtp-2020-0035
22. Serbian Environmental Protection Agency. (2020). *Annual report on the state of air quality in the Republic of Serbia in 2020*. http://www.sepa.gov.rs/download/izv/Vazduh_2020.pdf
23. Sinn, H.-W. (2012). *The Green Paradox - A supply-side approach to global warming*. The MIT Press.

24. Sorrell, S. (2009). Jevons' Paradox revisited: The evidence for backfire from improved energy efficiency. *Energy Policy*, 37(4), 1456–1469. https://doi.org/10.1016/J.ENPOL.2008.12.003
25. Statistical Office of the Republic of Serbia (2019). *Macroeconomic projection model for testing long-term debt sustainability and growth performance, (2019–2030)*, Stančić, K. (Ed.). Belgrade: Statistical Office of the Republic of Serbia.
26. Statistical Office of the Republic of Serbia (2011). *Projections of the population of the Republic of Serbia 2011-2041*. Belgrade: Statistical Office of the Republic of Serbia.
27. World Bank. (2022). Western Balkans Regular Economic Report no. 21, Spring 2022: Steering Through Crises. Western Balkans Regular Economic Report;21. World Bank. https://openknowledge.worldbank.org/handle/10986/37368
28. Yin, Y., Xiong, X., Ullah, S. and Sohail, S. (2021). Examining the asymmetric socioeconomic determinants of CO2 emissions in China: challenges and policy implications. *Environmental Science and Pollution Research*, 28(40), 57115–57125. https://doi.org/10.1007/s11356-021-14608-9