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Scenario Analysis of a Coal Reduction Share in the Power Generation in Bosnia and Herzegovina until 2050

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Abstract: This paper is effectively a scenario analysis of the energy system of Bosnia and Herzegovina (BiH) from the perspective of the possible future reduction of greenhouse gas (GHG) emissions in the power generation sector, with the aim to become climate neutral by 2050, in compliance with the Green Agenda for the Western Balkan. According to the data from 2016, the share of power generation in the total GHG emissions in BiH was approximately 50%. By using the LEAP (Long-range Energy Alternatives Planning) energy model, two scenarios—the "gradual transition scenario" and the "climate neutral" scenario—have been analyzed for the period 2018–2050, and each scenario included decarbonization measures such as the extensive use of Renewable Energy Sources (RES). Unlike the climate neutral scenario, the gradual transition scenario includes the replacement of certain parts of the old, currently-in-operation Coal-fired Power Plants (CFPPs) with the new CFPP, which is more efficient. In the climate-neutral scenario, that part of the existing CFPPs is replaced by a mix of RESs. The results from the first scenario suggest that the share of CFPPs in electricity generation has gradually decreased from 69.3% to 16.3% in 2050, and CO_2 emissions from the power generation sector in 2050 will be 2.2 million tons—roughly 83.5% less than in 2014. According to the second scenario, the emphasis is strongly on the growth and promotion of RESs, which have significantly taken over the roles of major producers of electricity, encouraging the low-carbon development of BiH. Analysis results show that, in 2050, there will be no CO_2 emissions from power generation. It can be concluded that specifically designed energy models for the optimization of capacities and CO_2 emissions through convergence towards RESs could be an optimistic and promising option for BiH to become climate neutral while meeting increasing energy demands. The results show the required RES capacities needed for achieving climate-neutral power generation by 2050, with the current rate level of power generation. Based on the results, RES investment needs can be estimated. Overall, the results of the scenarios can be used for the strategic planning of the power generation sector in BiH until 2050.

Keywords: coal-fired power plants; carbon-dioxide emissions; climate neutrality; renewable energy sources

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1. Introduction

1.1. Energy Sector and Emissions of Greenhouse Gases

From the Industrial Revolution to the present day, the development of the global economy has consequently been accompanied by the excessive exploitation of natural resources due to the ever-increasing energy demands. As a result, this unsustainable approach to the use of environmental resources has led to a serious global problem, which is one of the main factors that contribute to the climate crisis [1,2]. An already known outcome is the rise in the average global temperature by more than 1.18 °C compared to the pre-industrial period, which unfortunately resulted in inevitable climate changes, causing some irreversible consequences and risks for the infrastructure, economy, environment, and human health, along with the slow disappearance of natural resources worldwide [3,4].

The industrialization, population, and economic growth of countries have been showing a remarkable increase in recent years, and such rapid development can only be accompanied by the continuous growth of energy demands and consumption, leading to the fact that the excessive burning of fossil energy, together with the emissions of greenhouse gases (GHGs), are viewed as the most important drivers of climate change [3,5–7].

The interdependent relationship between the energy demands and economic growth can be observed in industrially developed countries, where energy consumption has become approximately ten times higher than the consumption of the average inhabitant of the planet as a whole and where most of the energy demands are related to meeting increasing needs of the construction (residential and commercial), industry, and transport sectors [7]. Yuan et al. stated that "unrestricted GHG emissions will most likely cause a loss of global Gross Domestic Product (GDP) by 25%, while the cost of restriction will only account for about 1% of the global GDP" [3] (p. 3).

The excessive burning of fossil fuels, besides having an influence on climate parameters through rising emissions of GHGs, also influences the change in the global energy landscape, where unavoidable energy insecurities along with the CO_2 emissions reach the point where there is an urgent need to establish strict boundaries and change the pattern of energy production and consumption based on the fossil fuels such that insatiable needs for energy do not further induce climate and environmental breakdown [3–7].

Although the energy sector is one of the main contributors to industrial growth, based on the side effects of that growth, it can also be considered to be the central point of any emission responsible for air pollution and climate changes [8]. The production and use of energy in all economic sectors account for more than 75% of the GHG emissions, meaning "that fossil fuels combustion is the largest single contributor to the greenhouse effect" [8,9] (p. 10).

Data on the world's total primary energy supply from 2018, represented in Figure 1, show that a large percentage of energy needs of the countries is satisfied by the use of fossil fuels (coal and lignite, oil, and gas). According to this diagram, the share of coal, as one of the primary significant components of the primary energy supply, amounts to 27.2%, and about 20% of EU power generation for the same year was based on the usage of coal [10]. Dong et al. stated that "about 55% of cumulative global carbon emissions originate from the power sector, and coal-fired generation accounts for more than 80%" [6] (p. 2), while, according to Cai et al., "GHG emissions from energy consumption reached 33.89 billion tons of CO_2eq, with a 2.0% annual growth rate" [7] (p. 1). It is estimated that at least 80% of coal reserves must remain unused in order to prevent an increase in global temperature of more than 2 °C.

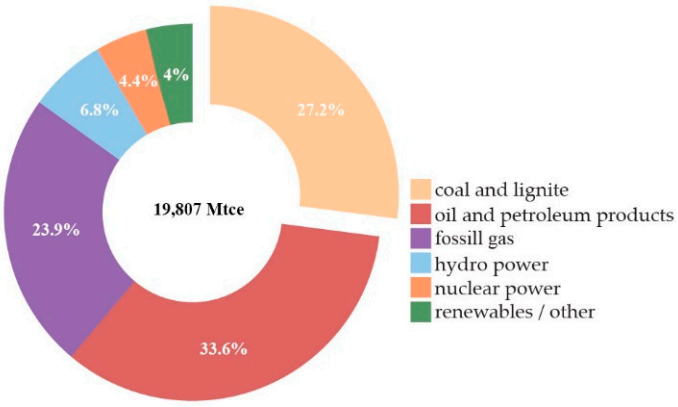


Figure 1. Share of fuel in the primary energy supply in the world, 2018 [10].

In 2018, about 592 TWh of net electricity generation in the EU came from solid fuels (284 TWh from hard coal, 294 TWh from lignite, and the rest from oil shale and peat). Figure 2 illustrates the world's electricity generation by fuel for 2018.

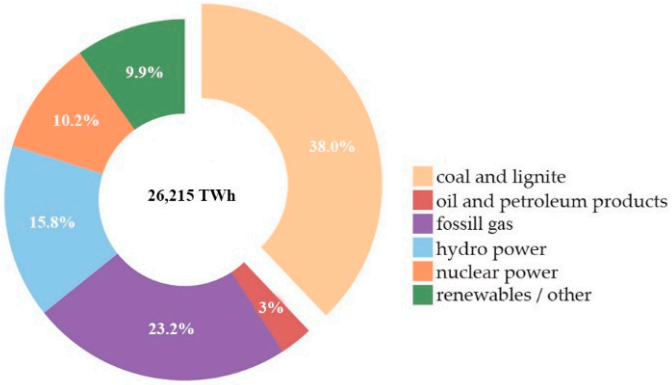


Figure 2. World electricity generation by fuel, 2018 [10].

Georg Zachmann et al., in their study, emphasize that "almost three-quarters of the EU energy system relies on fossil fuels, where oil dominates the EU energy mix (with a share of 35%), followed by natural gas (24%) and coal (14%)" [9] (p. 10). The share of renewable energy sources (RES) has been increased in total but still plays a limited role (14%). In 2020, the European Commission (EC) predicted that, in 2030, fossil fuels will still contribute to half of the EU's energy mix in 2030 [9].

Based on Eurostat's overview of the energy statistics for the period between 1990 and 2020, the share of solid fossil fuels in final energy consumption dropped significantly, from 9.6% in 1990 to 2.8% in 2010 and 2.1% in 2020. The final energy consumption in the EU in 2020 amounted to 37,086 PJ, 5.6% less than in 2019 [11].

When it comes to coal, as the most polluting element in the energy mix, it is considered that coal is responsible for less than a fifth of the EU's electricity and heat generation and for half of the associated GHG emissions. Hard coal-fired power plants in the EU have a total capacity of 99 GW, and lignite-fired power plants add a further 52 GW [10]. In the last few decades, in Europe's energy sector, the share of coal usage has been significantly reduced, mostly because of regulations for emission reductions, economic factors, and national policies [9]. Generally, the dependence of countries on the usage of coal is mostly related to the needs of the heat sector, electricity generation, industry and domestic mining, and related jobs [9].

The share of coal in the energy supply of the 27 EU Member States has more than halved in terms of absolute numbers (from 4900 TWh in 1990 to 2200 TWh in 2019). In 1990, 24% of the energy supply was relying on coal, while in 2019, coal was only responsible for 10% [9].

Although the data show that the share of coal for the needs of EU electricity generation is still being decreased, "even with the long-term decrease, CO_2 emissions from solid fossil fuels are still responsible for 20% of the total GHG emissions of the EU Member States" [9] (p. 32).

In general, the energy industry can be seen as a major contributor to climate change and also as the sector that will be disrupted by the consequences of climate change. Over the coming decades, the energy sector will be affected by global warming on multiple levels and by policy responses to climate change [12]. The climate policy, especially in the EU, targets climate neutrality of the economy by 2050. On that road, a phase-out of CFPPs is on the top of the agenda, since these facilities have the highest CO_2 emissions per unit of energy generated.

1.2. Towards Climate Neutrality

Although there is a scientific consensus at the international level that the primary cause of climate change is the increased concentration of anthropogenic GHGs, there is still controversy surrounding the issues of the type, extent, and way of reducing the impact that climate change will cause [13].

Certain initiatives and strategies have been launched globally to curb activities that could lead to further environmental degradation [2]. The requirements of the European Union (EU) in the area of the energy sector are contained in the establishment of the Energy Community (EC), where the emphasis is placed on the development of alternative routes of gas supply, environmental improvements, the implementation of energy efficiency (EE) measures, and renewable energy sources (RES). In 2020, about 194 countries that signed the Paris Agreement (Paris Climate Change Conference, COP21), together with the European Union, also committed to adopt and implement NDCs (Nationally Determined Contributions) with the targets for the reduction of total national GHG emissions]. The EU has managed by supporting different decarbonization policy measures to reduce GHG emissions by 22% and increase GDP by 58% over the period of 1990–2017 [3].

The EU, with the European Green Deal (EGD) and the aim to become the first climate-neutral region by 2050, has set "the ambitious climate and energy targets for 2030 to reduce GHG emissions by at least 40% compared to 1990, improve energy efficiency by approximately 32.5%, and provide that at least 32% of the consumed energy is generated from RES" [3,10,14]. In 2019, the target for GHG reduction increased from 40% to 55%. To meet its GHG emission reduction target, the EU must achieve the main goal of making its energy sector climate-neutral [9].

Many countries around the world are striving to achieve "net zero" emissions through participation in this optimistic zero-carbon transition race [2,4].

In order to participate, it is necessary to follow the fundamental aspects of climate neutrality, which are to reduce GHG emissions by 80–100% by 2050 or earlier, compared to the baseline year of 1990, or to achieve zero GHG emissions during a certain period in the future [2,5,14]. Future EU targets with GHG emissions for the period from 1990 to 2050 are shown in Figure 3.

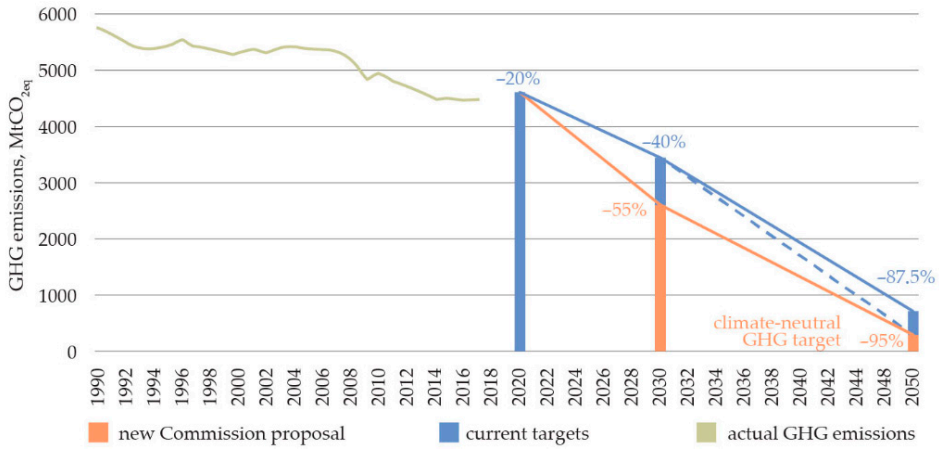


Figure 3. EU targets for the reduction of greenhouse gas emissions, 1990–2050 [15].

The motto of the UN Climate Change Conference of the Parties (COP26), organized in November 2021, was to "secure global net zero by mid-century and keep 1.5 degrees within reach, by constantly pursuing the goals of reducing greenhouse gases emission and gradual withdrawal from coal power so that by 2050 less carbon is produced than taken out of the atmosphere" [16]. Countries such as the EU, China, the United Kingdom, Japan, and more than 100 other countries "that account for more than 65% of the global CO_2 emissions, along with 70% of the world's economies", in 2011, made commitments to reduce carbon emissions and achieve climate neutrality by 2050 [4]. A significant reduction in the use of fossil fuels is the agreement of G7 countries and the EU (from 2021) to end the international financing of fossil fuel projects to ensure the meeting of the climate neutrality target. The parties agreed to stop government investment in coal-fired power plants totally [16].

In this regard, to fulfill this goal, it is necessary to eliminate dependence on the use of coal, increase investment in RESs, and achieve the overall optimization of energy

consumption, where the optimal energy mix is used to meet the energy needs without the risk of rising GHG emissions [7,16].

An awareness of the current situation of the energy landscape worldwide, the impact of climate change parameters, and the tendency toward sustainable development of the technologies that would provide necessary energy amounts and still be environmentally friendly have led many countries to focus on and turn to alternative uses of energy. Renewable energy sources (RES), as Yuan et al. state, "not only meet the demand for inexhaustible energy but are also capable of fulfilling the demand for the production of different forms of "clean" energy, those that especially do not emit GHGs" [3] (p. 3). In addition, the power loss of approximately 5–10% during energy transmission and distribution can be reduced to a negligible level through the system that contributes to energy resources' efficient and effective utilization while minimizing energy losses [9].

1.3. Decarbonization and Renewable Energy Development

In order to achieve sustainability in any kind of development, especially in terms of energy, environment, and climate, it is necessary to respect the limits that will not endanger, in any sense, the natural environment [17].

In recent years, energy transition, as a low-carbon pathway for achieving sustainability, has become one of the main pillars of the energy and climate policies of many countries worldwide whose energy production makes up a large part of the carbon emission share [18].

Low-carbon transition permeates through three different but mutually affecting approaches, including the process of the decarbonization of energy systems to achieve climate neutrality and ensuring the energy security of a certain area, which is causally related to the third approach. By ensuring a sufficient amount of energy, the energy needs of the public and residential sectors can be met. Considering the fact that it is unquestionably important to respect the consistency and implementation of the mentioned approaches, the energy policies of the countries need to have the main role in ensuring energy security without endangering environmental values [18].

In many studies that have researched different mitigation strategies and scenarios for the energy sector, the reduction "of the specific emissions from the generation of electricity is, in the long-term, almost entirely achieved by replacing emissions-intensive power from fossil fuels with electricity generated from RES nuclear power and power from plants equipped with carbon capture and storage technology" [19] (p. 2).

In order to establish a successful energy transition, a comprehensive strategy to achieve it is necessary, consisting of measures for the enhancement of energy efficiency and RESs, along with the use of low-carbon energy systems and technologies and respecting the energy principles, potentials, and possibilities of a certain country [14,18].

Regarding the decarbonization of the energy sector, it is considered one of the main topics of interest, especially for the countries of the European Union, through the introduction of a strategy for sustainable development known as the EU Green Deal [13]. However, decarbonization, as a measure alone, is not sufficient to achieve such clean emission targets, as is shown in the example in Figure 4 [13].

In addition to displaying CO_2 emissions depending on the region, Figure 4 also shows that countries with the highest share of renewables are also the major sources of CO_2 emissions. This means that the measure of the decarbonization of power generation is not sufficient to achieve the climate neutrality target, and it needs to be supplemented with other constructive measures [13].

Decarbonization should be accompanied by the implementation of EE measures by the renovation and enhancement of the existing buildings sector, and achieved benefits are reflected through lower energy demands for the needs of citizens, such as heating and cooling [20].

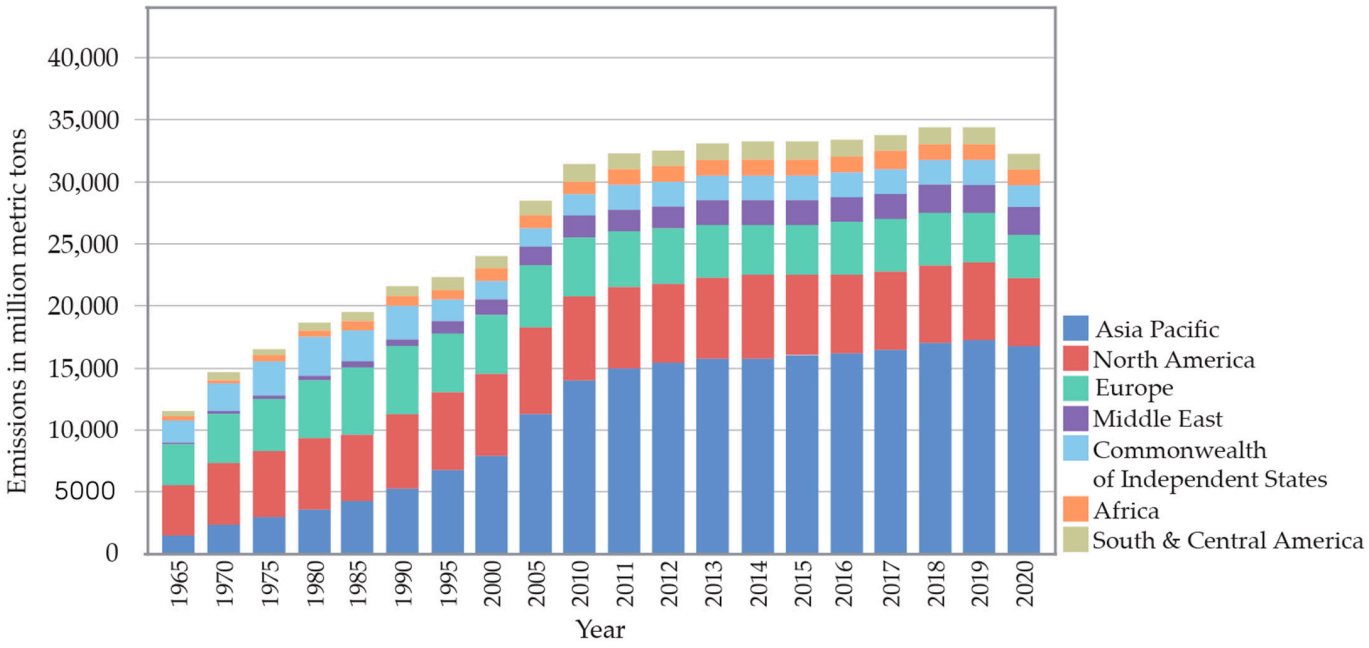


Figure 4. Emission of CO_2 per region [13].

Although researchers have developed decarbonization scenarios based on the various model approaches, there is still an agreement that the RES share has to be increased significantly [19]. Fischedic et al. conclude, based on a comparison of the decarbonization scenarios of the European power sector, that "all scenario studies, taken into account, whose scenarios run until 2050 indicate that the continent's electricity demand could be largely (at least by 80%) or even entirely be met by a mixture of renewable energy sources by the middle of the country" [19] (p. 2).

Renewable energy sources, as the next supporting component in the sustainable path of environmental development, have strategic importance in achieving net zero goals [3]. It represents an optimistic solution to establish a balance of increased energy consumption due to rapid economic growth and higher energy demands in the building and power generation sectors, as well as an alternative energy source for the transportation sector. Its role can be succinctly described "as an essential means to mitigate climate change, address energy security and improve environmental quality" [5] (p. 2).

To successfully contribute to lowering carbon emissions, RESs have to cover a significantly larger share of energy needs and demands. The potential in the use of RESs in recent years can be seen through the growth of the RES share in the world's electricity production—it was 29% of the share in 2020, compared to 27% of the share in 2019 [14]. Alabi et al. estimated that "in 2020, from 261 GW of RES that was commissioned, about 91% is shared between solar and wind plants, making the total global renewable capacity by 2799 GW" [13] (p. 1).

The advocates of RESs point out that when recalculating "the costs" of making the switch to renewable energy, positive environmental, health, and well-being benefits should be considered, unlike energy production from fossil fuels. The use of RESs has numerous potential benefits, such as reducing greenhouse gases, diversifying the energy supply, and limiting the dependence on fossil fuels (especially natural gas and oil). RES development may play a crucial role in stimulating employment in the RE sector across the EU. Furthermore, RESs offer the possibility of counteracting climate change and reducing dependence on energy imports. Instead of relying on large-scale power plants and high-voltage power grids, it allows for decentralized energy production.

According to the European Commission plan, with an average increase of approximately 2.3% per year, an overall target of 32% of the RES share can be reached by 2030. By complementing the use of RES potential with the implementation of energy-efficient

measures for the enhancement of the building sector, by 2040, the prediction is that about 50% of heating and cooling needs can be decarbonized, with the production of 155 Mtoe per year [21,22].

The diagram in Figure 5 shows that, in 2018, by using RESs (such as solar, biomass, wind, and geothermal energy), about 98 Mtoe were provided to cover energy needs. Additionally, the diagram includes two scenarios for final energy consumption until 2040; one has an aim to achieve a share of 50% of renewable energy for heating and cooling demands. Regarding the second scenario, with the prediction of a 100% renewables share for heating and cooling needs, non-RESs used for the same needs will be decreased to zero by 2040 [21,22].

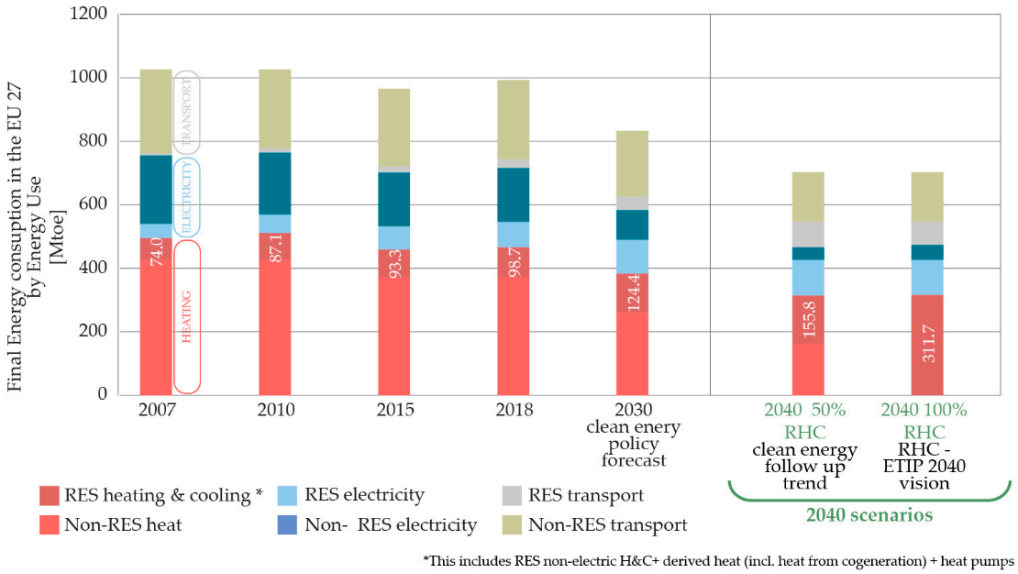


Figure 5. Scenarios of the Final Energy Consumption for the EU 27 Countries (2007–2040) [22].

The EU, with its strategy package "Fit for 55", increased the goal for the share of RESs in the total energy consumption to 40% by 2030, compared to the previously established target of 32% [6]. According to the Renewable Energy Directive, the Energy Efficiency Directive, and the Energy Performance of Buildings Directive, "approximately 40% of this is expected to come from the heating and cooling sectors" [21] (p. 10).

Many researchers are predicting a greater increase in the usage of RESs in electricity generation, which is in accordance with the fact that the future of humanity is directed towards securing a sufficient amount of energy, and "if the developments in the field of renewable energies continue, it would be advisable to adapt many parts of the electricity sector, taking into account all the factors that can influence on the investments into the rest of the power plant park, as well as the design of the transmission and distribution grids" [3,19] (p. 16).

This pathway can also bring many insecurities and questions about the sufficiency of the RES share to meet the high demand for energy and the ability to strengthen, not weaken, the energy supply chain by replacing fossil fuels without disrupting the economic growth of countries and the overall relation between energy, the environment, and the economy [3].

1.4. Countries' Pathways to Decarbonization

When considering the European path to decarbonization—specifically, the coal phase-out—it is necessary to end the use of coal in the energy sector in order to achieve a substantial reduction in GHG emissions, as the climate-neutral target. Many EU countries have set aspiring and prosperous plans to phase out coal from the energy sector and

achieve a significant reduction in GHG emissions by placing short-, medium-, and long-term options [9].

Although it is expected that, by 2030, most coal power plants could substantially be reduced to achieve the climate target, on the other side, the process of the decarbonization of the power system and the phase-out of coal "requires a major expansion of power generation capacities in all countries" [9] (p. 42). One of the short-term options for the replacement of the coal-fired capacities is an investment in natural gas-fired power plants, but on the other hand, this conflicts with the EU target to become climate-neutral by 2050. Such a point of view is supported by the fact that "replacing coal with natural gas is only a short-term option that risks leading to fossil path dependencies and stranded assets towards 2050 and should, therefore, better be avoided" [9] (p. 46).

EU countries have already started to deploy substantial renewable capacities, emphasizing that investments in RES power plants need to be increased compared to recent years. Countries that already have a substantial share of RESs in the power sector have the advantage of easily replacing coal-fired power plants with certain additional investments [9].

In Germany, for example, decarbonization strategies are based on the implementation of RES technologies, with an emphasis on the use of wind and solar energy, the use of biomass, and increasing the use of heat pump-installed capacities [20]. According to the Integrated National Plan for Energy and Climate for Italy, to achieve the accomplishment of targets for 2030, measures that need to be implemented include "energy efficiency, RES and CO_2 emissions reduction at the national level, as well as several objectives related to energy security, interconnections, the single market of energy and competitiveness, economic development and sustainable mobility" [3,6,7] (p. 2). It is also predicted that emissions can be decreased from 79 to 57%, compared to the levels of the referent year 1990, by increasing the share of RES use and by the "radical electrification of the energy" [20].

Countries such as Poland, whose electricity system depends on coal, require significant investments to be able to replace it, indicating that "Poland can reduce its share of coal in electricity generation to 13% by 2030 and phase out coal entirely by 2035. Short-term investments in gas-fired power plants are not profitable as they will be displaced economically by renewable energy sources in the 2030s" [9,23] (p. 42).

According to the low-carbon strategy of the United Kingdom, regarding the decarbonization of the heat supply system, a 70% reduction in industrial emissions needs to be achieved, and CO_2 emissions from the heating of the building sector need to reach near-zero levels by 2050 [20].

The low-carbon transition strategies of several Nordic countries were based on the greater commitment to decarbonization in energy sectors, the encouragement of the use of technologies based on alternative energy sources, and an incentive to increase emission reduction targets. A conceptual study [18,20] related to the energy sector of Denmark had an aim to achieve a carbon-neutrality goal by 2060, with a 100% renewable energy system. The optimistic scenario was based on the "reductions in space heating demands by 75% and various heating options, including district heating, individual heat pumps, and micro combined heat and power production". The Finnish government's strategy to move toward carbon neutrality by 2035 includes a "coal phase-out by 2029 and combining biomass, waste heat sources, heat pumps, and RES power for heat supply decarbonization" [18,20].

The transition period until 2050 will be marked by major changes in the world socio-economic scene due to the large increase in the number of inhabitants on Earth, the growing differences between rich and poor countries, the struggle for energy sources, the reduction in fossil fuel stocks, and the raising of social awareness about the meaning of energy and its rational use. This is supported by the fact that, by 2050, the expected growth of the world's population will be about 2.1 billion inhabitants, compared to 7.8 billion in 2020, which would consequently require significantly more energy—approximately 80%—to satisfy the increase in living standards and demands [1].

The transition from the conventional use of energy to renewable is not a simple and fast process that is to be achieved overnight [1]. The strategy for reducing GHG emissions and

quality action plans should ensure, through the available mechanisms, that decarbonization measures are implemented gradually, without a sudden loss of jobs in traditional energy, ensuring a fair transition. The production of electricity and thermal energy requires new expert analyses, the application of new technologies, increased investments in RES power plants and expanding capacities, and the building of trust and tolerance in the global economic scene [1,9].

1.5. Green Agenda—EU and Western Balkan

In 2019, by adopting the European Green Deal (EGD), the EU has committed to becoming a global leader in the transition process towards achieving the concept of zero emissions, striving to transform its resources, economy, and society in a sustainable way [23–25]. This general policy strategy defines aims and pretensions in different policy sectors, requiring that the existing regulations should be revised during the following years and that efforts should be put into the development and adoption of new laws and directives [24].

The EGD framework sets up 50 actions for enabling deeper decarbonization, and some of them include "increasing renewable energy share, decarbonization of the heat and transport sector, and technology development" [13] (p. 3). The elements of the EGD strategy are shown in Figure 6.

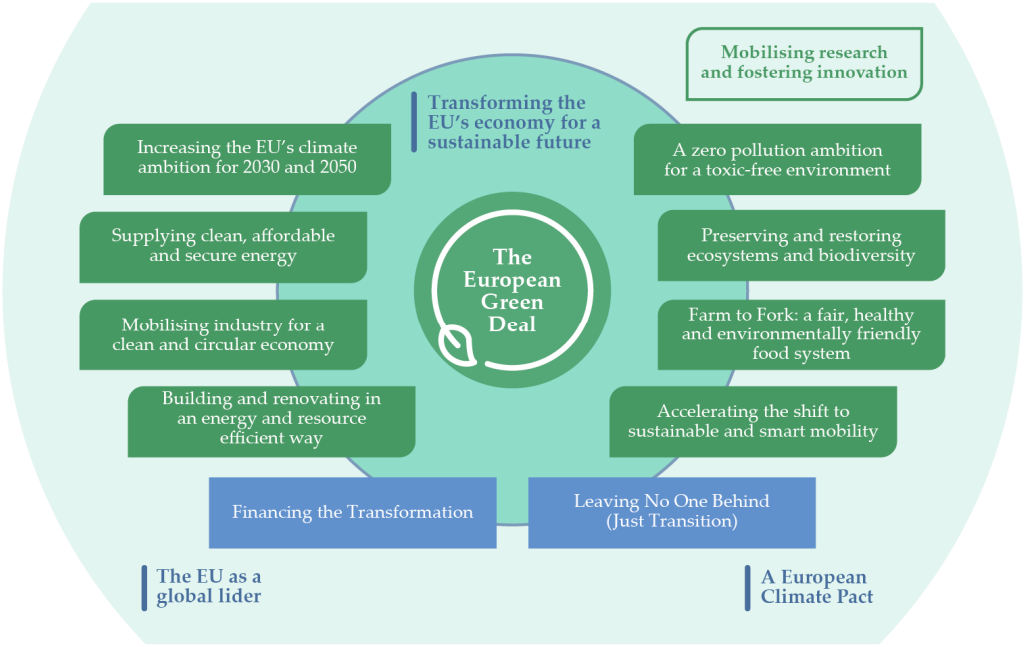


Figure 6. The European Green Deal and its key areas [26] (p. 24).

Furthermore, the Renewable Energy Directive and Energy Efficiency Directive are mechanisms proposed by the EU commission "to accelerate smart and highly efficient district heating and cooling systems" that are based on renewable energy [13] (p. 3). By proposing these directives, the EC tries to interconnect all relevant EU policies and legislative measures to prevent and control air pollution and environmental degradation [25].

For the EU, it practically represents a linkage of "a low-carbon future to sustainable and more equitable development for the EU" [27] (p. 1). The efficient use of energy based on the long-term vision of EU countries is the basis of low-emission development. Generally, the EGD is a development strategy focusing on the stimulation of a green transformation, comprising "a number of several initiatives, strategies and legislative acts that, together, are intended to enable a just, sustainable and inclusive transformation of European society and economy" [17] (p. 4).

Green Agenda for Western Balkan

By signing the Sofia Declaration, the Western Balkans joined the initiative of the European Green Plan by signing the Green Agenda for the Western Balkans (GAWB) [28]. This obligation highlights the need to make clear guidelines that will show what changes are required to achieve this ambitious target by 2050.

As stated in the Action Plan, one of the documents resulting from the Sofia Declaration on the (GAWB), "the absolute priority of the Western Balkan region is to adapt its climate policy without delay, formulate goals in the field of climate (and energy) in accordance with the more ambitious plans of the EU for the transition until 2030, and transpose the "Fit for 55" package and the EU Climate Law, align with the Strategy. The EU, on adaptation to climate change, more intensively develops natural and artificial carbon sinks and ensures a rapid green transformation of all economic sectors, primarily those with high carbon emissions" [23] (p. 12).

Developed guidelines of the Green Agenda propose activities and measures that the EU and Western Balkan countries should jointly adopt, such as harmonization with the EU climate law, the development, and implementation of National, Energy, and Climate Plans (NECP) with clear measures to reduce GHGs, the progressive increase of renewables in the energy sector and their implementation through the energy community, prioritizing energy efficiency and its improvement through all sectors, reducing and phasing out coal subsidies, etc.

The region of the Western Balkans is no exception in terms of the use of coal, as it is the framework of the economic development of society around the world, and a large share—about 70%—of the total electricity is produced in coal-fired power plants. However, abandoning the technologies on which the economies of the Western Balkans rely to a significant extent and switching from coal to renewable energy sources bring many socio-economic issues that the Western Balkan region must solve to avoid unwanted consequences such as unemployment, labor migration, the disruption of the economy and strength, and other possible unwanted effects. The significance of this transition is clearly explained as a necessity for the sake of human health, well-being, the environment, and the climate [23].

Being aware of this, Western Balkan economies need to develop long-term strategies, where the emphasis should be on the decarbonization of sectors with a high level of carbon emissions (energy and transport sectors). Additionally, strategies should establish emission reduction targets for all economies concerning all modes of transport, buildings, and the sectors of agriculture, industry, and waste [24]. Through the support program on sustainability, it is encouraged to increase the usage of a larger share of RESs in the total energy consumption, together with a systematic approach to the improvement of the building sector by implementing energy efficiency measures [24].

The reduction of emissions from large plants is still one of the region's biggest challenges. Therefore, the implementation of the Management Regulation, as well as the creation of NECPs, should be in full swing [23].

For the regional climate-neutral transition, it is necessary to update the relevant legal frameworks in a timely manner by transposing new provisions arising from the European Green Deal in accordance with the Energy Community Roadmap for decarbonization [23].

In order to achieve the goals contained in the Green Agenda for Western Balkan, Bosnia and Herzegovina (BiH) must further improve its approach to strategic planning, especially in areas related to decarbonization and the gradual reduction of the use of fossil fuels. It is clear how great a challenge this is for BiH, because the current goals of reducing GHG emissions are not enough to achieve climate neutrality, which is expected according to the commitment expressed by the signing of the Green Program. Therefore, continuously, in accordance with changes in relevant areas, it is necessary to constantly work on reviewing emission reduction targets.

BiH has defined strategic commitments to reduce GHG emissions through documents such as the Initial Determined National Contribution (INDC) for reducing emissions

by 2030, the National Determined Contribution (NDC) for the period 2020–2030, with projections until 2050, and the Strategy for Adaptation on Climate Change and Low-Carbon Development [29].

Additionally, BiH has defined an aim in the NDC to decrease the total GHG emissions by up to 17.5% by 2030, compared to 2014. The objectives stated in the NDC were assessed as satisfactory by the UNFCCC Secretariat. However, these goals are insufficient when it comes to the ambitions of the Member State of the Energy Community, and with this level of ambition to reduce emissions, no significant international assistance on decarburization can be expected. In addition, the NDC did not take into account the achievement of climate neutrality by 2050. Therefore, the 2030 emission reduction target needs to be significantly more ambitious in order to achieve climate neutrality by 2050 [21]. The NECP of BiH is being drafted, which will, among other things, define the goal of reducing GHG emissions by 2030 compared to the base year. Considering that the NECP is being worked on as an obligation under the Energy Community Treaty, the goal of reducing emissions by 2030 must be comparable to the EU goal. At the same time, the option of reducing emissions by 40% for BiH is being considered, and the EU is, in the meantime, working on the adoption of a more ambitious target for 2030—a 55% reduction compared to 2005. If it is not possible to achieve a reduction like the EU, it is necessary to give an explanation based on the modeling of the overall energy system [30].

2. Energy Transition of Bosnia and Herzegovina

2.1. Power Generation Sector and GHG Emissions in BiH

The concept of today's energy sector in the country is based on the economic paradigm of the 1970s, which is characterized by energy-intensive and inefficient energy consumption in the sectors of the production and consumption of electricity, heating, and transport. That is why energy has a dominant influence on emissions with the GHG emissions in BiH (with over 70% of total emissions), as well as emissions of pollutants that increase the level of pollution at the local/regional level, endangering the environment and human health.

BiH faces significant challenges in the context of the fight against climate change and energy transition. The energy sector (final total energy consumption) is currently dominantly based on fossil fuels, and there is no clear and agreed-upon vision of how to shape this sector in the future. Additional difficulties are caused by the complicated administrative structure of BiH, so there is no unified consensus at the state level (this primarily concerns natural gas). The key players in the electricity and gas market (producers and distributors) are publicly owned, and their strategic directions are mostly still based on the strong use of fossil fuels.

The EU strongly promotes energy from RESs in order to make such sources competitive and available in the future to most or even all citizens. BiH is recognized as a country with significant energy resources, both conventional and renewable. First of all, coal is imposed in parts of central Bosnia, as well as the northeastern part of Bosnia and eastern Herzegovina. Speaking of RESs, the water flows of large rivers, but also smaller flows throughout BiH, as well as solar and wind energy, mainly in Herzegovina, and biomass throughout the country, stand out. It is an indisputable fact that RES potentials exist in BiH, but the question arises of the possibility of their capitalization, i.e., exploiting and overcoming all the barriers, of which there are many.

Energy transition and environmental responsibility: cleaner energy and the reduction of negative environmental impacts are high on the agenda. BiH aims to reduce the emission of sulfur dioxide by 95%, nitrogen oxides by 62%, and solid particles by 88% compared to 2014 for large combustion plants by 2028. The goal was adopted that the share of RESs in gross final energy consumption should be 43.6% by 2030 [30].

2.1.1. Electricity Production and Consumption

According to the 2020 Performance Report of the State Regulatory Commission for Electricity (SRCE), the total installed capacity of power plants in Bosnia and Herzegovina

is 4530.64 MW, of which 2076.6 MW is in large hydroelectric power plants, 2065 MW is in CFPPs, and 92.85 MW was installed in industrial power plants (power plants installed in industrial facilities).

The total installed capacity of plants for the production of electricity from RESs (without large hydropower plants) amounts to 296.19 MW. About 58% of the power refers to small hydropower plants, followed by wind power plants, with a share of about 29%, and then solar power plants, with a share of about 12%. Biomass and biogas plants have the smallest share [31].

According to the data of the Agency for Statistics of Bosnia and Herzegovina, the gross production of electricity in 2020 was 16,874 GWh, of which 4,663 GWh or 27.6% was produced in hydroelectric power plants, 11,557 GWh or 68.5% was produced in CFPPs, and in industrial power plants and others (solar and wind power plants), 654 GWh was produced, i.e., 3.9%. Its own consumption in power plants is 1240 GWh, and in the rest of the energy sector, it is 304 GWh. In the final consumption of electricity in 2020, households participate with 48.3%, industry participates with 25.4%, and other consumers, including construction, transportation, and agronomy, participate with 26.3% [31].

Coal consumption in the energy sector (CFPPs and industrial power plants) amounted to about 13.4 million tons. Due to the large share of thermal power plants in production, the emission factor for carbon dioxide in 2018 was about 820 kg/MWh (in 2013 it was about 720 kg/MWh). In the structure of electricity generation in BiH for the period 2014–2018, CFPPs had the largest share in production, with a growing trend in their production, which resulted in a growing trend in GHG emissions [30].

When it comes to production from RES in 2020, the total production in that year was 661.25 GWh. Small hydropower plants have a dominant share with 341.02 GWh (497.99 GWh in 2019; 469.39 GWh in 2018), wind power plants produced 262 GWh (254 GWh in 2019), solar power plants produced 45.62 GWh (30.04 GWh in 2019; 20.65 GWh in 2018), biomass and biogas power plants produced 12.56 GWh (8.84 GWh in 2019; 8.15 GWh in 2018), and wind power plants connected to the distribution system produced 0.07 GWh (0.02 GWh in 2018) [31].

In 2018, BiH adopted the Framework Energy Strategy until 2035. In the power generation sector, four scenarios were analyzed. Out of four developed scenarios, only one leads to some emission reductions (called mildly renewable), which includes the construction of new units and the decommissioning of the existing units in thermal power plants, along with the intensification of building capacity that uses RESs. This scenario presents the largest share of renewable energy sources, and this refers primarily to hydropower plants and biomass power plants, followed by solar and wind power plants and wind farms. By 2021, three wind farms had been built in BiH, and several more wind farms are in the development phase.

As a consequence of the introduction of guaranteed incentive tariffs, a guaranteed period of purchase of electricity from RESs at the entity level, and the increasing competitiveness of RESs, the production of electricity from RESs in BiH is growing. However, the share of electricity from CFPPs is still very high and amounts to, depending on hydrological conditions, about 60% to 75%.

2.1.2. GHG Emissions in Bosnia and Herzegovina

BiH, as a member of UNFCC, is required to report on GHG emissions. Through the preparation of the first three national reports on climate change and two biennial emission reports, inventories of emissions from 1990 to 2014 were made using the IPCC 1996 methodology. The inventories for 2015 and 2016, according to the IPCC 2006 methodology, are being finalized, and domestic capacities to monitor them have been improved. In that way, it is possible to more reliably forecast emissions and, in that regard, define the goals arising from international agreements [21]. Figure 7 shows the annual GHG emissions in BiH, from which the trend of emissions from 1990 to 2016 can be seen.

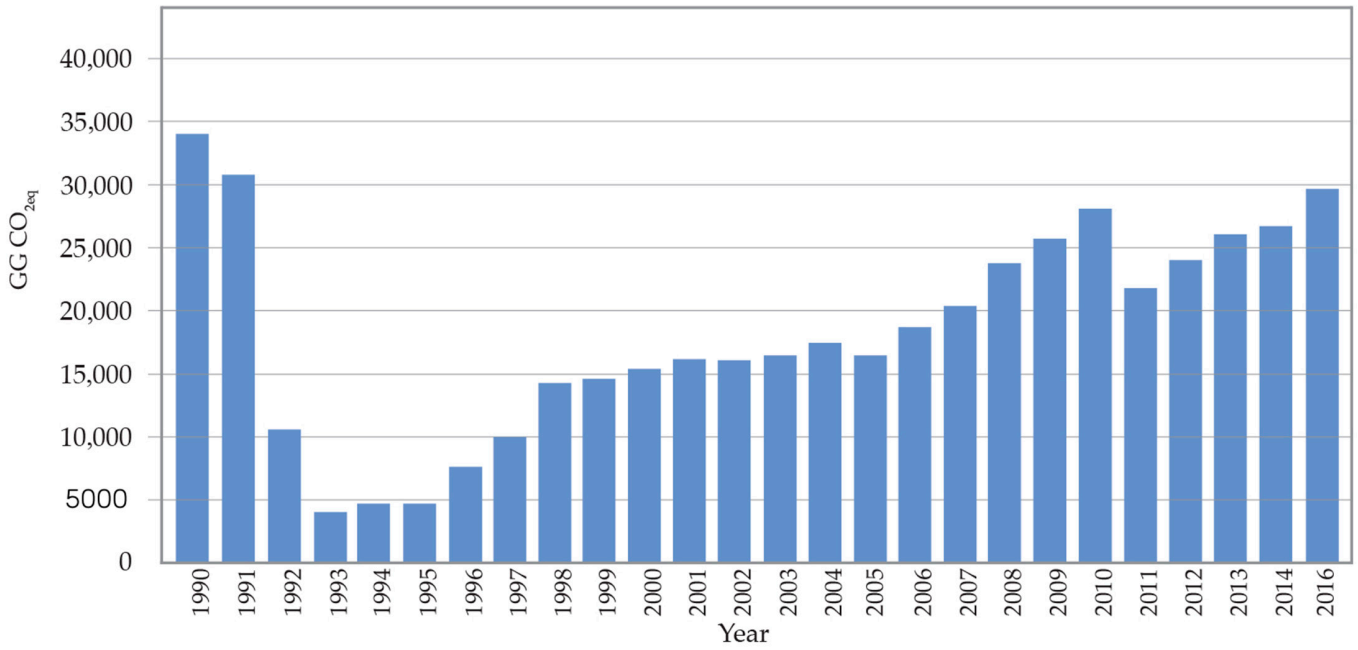


Figure 7. Annual GHG emissions in BiH (1990–2016) [30].

The highest emissions were in 1990 and amounted to 34.04 million tons of CO_2eq. Emissions were significantly reduced during the period of 1992–1995, after which they started to increase. After that, due to the increase in emissions in power generation, total emissions exceeded 20 million tons of CO_2eq in 2008. Emissions from other sectors were more than halved between 1990 and 2001 due to a reduction of more than 80% in industrial emissions and of 50% in the agricultural sector. Emissions in 2016 amounted to 29.67 million tons of CO_2eq, which is about 12.8% less than in 1990. Thus, it can be concluded that a trend of growth of total GHG emissions occurred and that the change in the number of emissions in a short period is relatively large. This can be explained by the relatively large share of GHG emissions from the power generation in total emissions.

The share of the type of energy sources in the production of electricity changes from year to year, which is also reflected in total emissions. In 2016, the thermal power plant Stanari was put into operation, which affected the growth of electricity production from CFPPs by about 19% compared to 2014. In addition to electricity, transport had a significant impact on increasing total emissions, where emissions increased by about 22% (in 2016 compared to 2014).

By analyzing emissions per capita, it can be seen that, in 2011, the levels of emissions per capita in 1990 were reached (although emissions are lower, the number of inhabitants has decreased), but they are still among the lowest values in Europe. In 2016, emissions amounted to about 8.4 tons of CO_2eq per capita, which is only 3.4% less than the average of EU countries in that year. However, concerning economic development, the emissions in BiH are about five times bigger than those in the EU. GHG emissions per unit of GDP for the country amounted to 1.94 kg CO_2eq per EUR 1 in 2014, while the EU average was 0.39 kg CO_2eq per EUR 1 [30].

The amount of emissions from 1990 has still not yet been reached. However, it is evident that emissions have a growing trend, primarily due to the increasing share of thermal power plants in power generation (which varies from year to year depending on the amount of precipitation) and the growth of emissions from transport. Taking into account the production of electricity in thermal power plants in 2017 and 2018, it can be concluded that, in those years, the emissions were slightly higher than they were in 2016, and it can be expected that they exceeded 30 million tons of CO_2eq. Therefore, it is necessary to urgently stop the further trend of emissions growth and actively work on emission reduction measures, considering that 2030 is very close.

The target of reducing emissions for 2050 is clear, and that is climate neutrality. In order to achieve climate neutrality, in addition to GHG emissions, it is important to increase GHG sinks. The sinks of GHGs are forests and land. According to the data from the inventory for the period of 1990–2016, they have a declining trend. In 1990, the sinks amounted to about 7.4 million tons of CO_2eq, and in 2016, they amounted to about 5.8 million tons of CO_2eq. There is a trend of declining sinks. In 2016, the sinks were reduced by about 1.6 million tons of CO_2eq compared to 1990. This amount is approximately equal to the emission of one thermal power plant in BiH.

2.2. Potential for Reducing Emissions in the Power Generation Sector

The greatest potential for reducing GHG emissions in the power sector and the use of that potential can go in the direction of a gradual closure of existing inefficient thermal power plants and the replacement of one part of existing ones with new, more efficient thermal power plants, taking into account that total emissions are reduced at the target rate or with the construction of RES plants, especially those that can play a role in the security of supply and the development of other sectors of the economy in Bosnia and Herzegovina (wood biomass power plants, biogas power plants, and storage hydropower plants, which will also enable the integration of larger capacities of wind power plants and solar power plants).

Replacing existing thermal power plants without limiting production does not mean much for an absolute reduction in emissions. No significant growth in the domestic demand for electricity is expected. Along with increased production from RESs, if the market limits exports, there will be a decrease in electricity production from thermal power plants. This process should be managed so that there is no sudden drop in demand for coal and, consequently, a sudden loss of jobs in the mines. New thermal power plants have an efficiency level of around 42%, while the existing ones are only slightly above 30%, on average. In proportion to the increase in efficiency, replacement/new thermal power plants have a lower specific carbon dioxide emission (below 1 tCO_2/MWh). The absolute amount of emission reduction from new thermal power plants depends on the volume of production [32].

Figure 8 shows the potential for reducing GHG emissions by building replacement thermal power plants, depending on electricity production, with the gradual closure of existing thermal power plants until 2035. It is emphasized that this is only a simulation of the potential for reducing emissions and not a plan for the production of electricity from CFPPs [24].

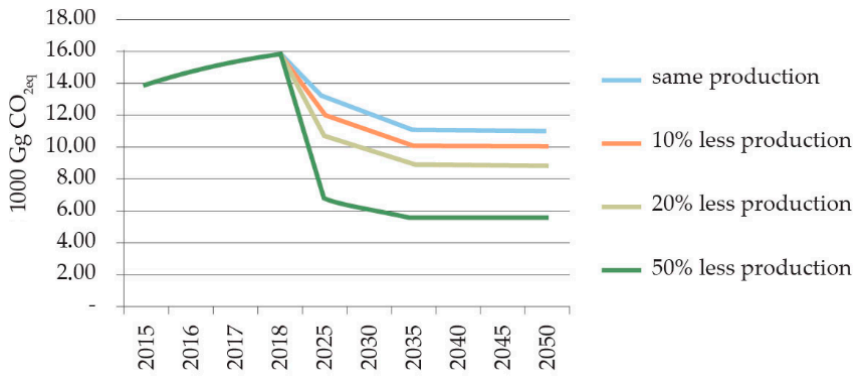


Figure 8. The potential for reducing GHG emissions by replacing thermal power plants in BiH until 2050 (simulation of the potential for reducing emissions) [32].

If production from CFPPs until 2050 is assumed to be in the amount of the average production in the period of 2015–2018 (about 11,110 GWh/year, which is slightly more than that in 2014), the emission in the power sector in 2030 is about 800 Gg CO_2eq or 6% lower

compared to the emission from 2014. The emission reduction in 2050 is about 2000 Gg CO_2eq or about 15% compared to the emissions from 2014.

This shows how important it is to gradually close the existing CFPPs and replace them with new ones. That is why Figure 8 presents the potential for emission reduction if production decreases by 10% (red line), 20% (green line), and 50% (purple line) [32].

Depending on the circumstances, beyond all the production from other sources, the production from CFPPs can drop significantly more than the stated percentages. A significant reduction of 25% is already achieved in 2030 with a 20% reduction in production, and for the same scenario, the reduction in 2050 is 32%. A reduction in the production of 20% amounts to about 2200 GWh/year. In order to compensate for this reduction from RESs, it is necessary to install about 750 MW of wind power plants.

Given that the largest share of emissions reduction is expected from the power industry, a 50% reduction in production from CFPPs, i.e., by about 5500 GWh/year, was also analyzed. In this case, the emission reduction in 2030 amounts to about 7000 $GgCO_2$eq. The emissions in 2050 are 58% lower than the emissions in 2014 [32].

It needs to be emphasized that this is only a simulation of the reduction potential. In accordance with the goal of the Green Program for the Western Balkans, BiH has committed to work on the achievement of the objective to make Europe climate-neutral by 2050. The action plan for the implementation of the Green Program will also define the operation of thermal power plants in this context, but it is certain that, after 2050, their operation will be reduced to a minimum or completely shut down [32].

There is significant potential for reducing emissions in the industry through increasing energy efficiency and the use of RESs, especially through on-site electricity production to cover part of one's own needs. The market will encourage the industry to decarbonize because it is a matter of competitiveness. In addition, there must be a system of incentives from the state (net metering or net calculation, education for energy efficiency, financing of measures, etc.). However, in the period up to 2030, no significant reduction in emissions from industry is expected because energy efficiency measures and the application of RESs will compensate for the increase in the volume of industrial production, which means that emissions will decrease compared to the base scenario (without the application of measures) [32].

By analyzing the targets for reducing GHG emissions, it should be taken into account that BiH has ratified the Paris Agreement and is a member of the Energy Community. Under the Paris Agreement, emission reduction targets are set on a voluntary basis. As a member of the Energy Community, BiH has an obligation to harmonize the energy sector with the EU and to base its climate goals on the climate goals of the European Union. This still does not mean accepting the same goals as the EU. BiH has the right to set its own goal with an adequate explanation of the ambition of that goal.

3. Scenario Analysis of a Coal Reduction Share in the Power Generation Sector until *2050—Bosnia and Herzegovina*

3.1. Methodology

Energy scenarios represent an important modeling tool to assess the country's energy stability and security through the evaluation of different energy paths and the observation of the effects of different scenario outcomes [4,32]. It can play a fundamental role in defining possible future alternatives in the field of energy planning, commonly dealing with the "long-term planning horizons, energy technologies with a useful life of several decades and variable implementation timelines" [4] (p. 2), [19].

According to the Intergovernmental Panel on Climate Change (IPCC), "a scenario is not a forecast; rather, each scenario is one alternative image of how the future can unfold. A projection may serve as the raw material for a scenario, but scenarios often require additional information (e.g., about baseline conditions). A range of scenarios is often adopted to reflect, as well as possible, the range of uncertainty in projections" [4] (p. 2), [20].

Although scenario analysis cannot truly predict the actual energy and climate situation for the specified target year and completely ensure the realization of the desired goal, its importance is reflected in the establishment of the visionary framework of possible optimal benefits that can be achieved and obstacles to be encountered [33]. Its outcomes depend on the modeling approach, addressed issues, established assumptions, preconditions, limitations, included sectors in the analysis, the availability of quality and reliable data that can be related, e.g., to the type and amount of RESs, as well as the influence of other parties, e.g., the interests of stakeholders and conflicting goals [33,34]. Therefore, any developed alternative future scenario can be defined by its main issues and targets, as well as the used methods necessary for the successful investigation [35].

Basically, to achieve "a goal of a complete energy transition, the integrated approach to scenarios, should include different influencing factors such as power, heat, transport, and industry" [34].

For scenario development purposes, in this paper, the projection of energy balance in BiH for the period of 2018–2050 was made using an integrated energy modeling software tool LEAP (Long-Range Energy Alternatives Planning).

The Long-Range Energy Alternatives Planning (LEAP) system, developed by the Stockholm Environment Institute, is widely used for energy policy analysis, power sector analysis, the monitoring of energy consumption and its production, as well as the assessment of climate change mitigation [36, 37]. It can also be used for monitoring and analyzing GHG emissions and sinks and air pollutants at the local and regional levels, representing a useful tool for research studies regarding air pollution reduction [33,36].

As a standard tool, it provides the possibility to create various models for a specific country or region from energy, economic, and environmental perspectives. Halkos et al., in their study, emphasize that LEAP is based "on the scenario approach in order for several paths of energy system evolution to be developed. The forecast of the energy demand is based on the effect of alternative market shares, whereas the supply side is based on a what-if analysis and possible development scenarios which LEAP integrates through simulation and accounting approaches" [37] (pp. 1–2).

For the scenario analysis in this article, the emission factor for domestic coal was inserted. Based on the BiH NDC, the specific emission factor is 105 tCO_2/TJ of energy in coal. Based on CFPPs' efficiency, predicted electricity generation, and emission factor, LEAP calculates CO_2 emissions from the power generation sector since CFPPs are the only source of CO_2 emission. The average efficiency of the existing CFPPs is 30%, while the efficiency of the new CFPP is 42% (used in the first scenario). The efficiency of the new CFPP is taken from its preliminary design. Historical energy data are taken from the energy balance of BiH (2018–2021), developed within NECP preparation.

The focus of the developed scenarios is on the gradual reduction of the use of coal for the production of electricity, keeping in mind the costs and requirements for the reduction of pollutant emissions for certain CFPPs in BiH. The main assumption is that power generation over time is on the same level as it is currently (net generation around 17–18 TWh annually), and there is a slight increase in domestic electricity demand (1% annually).

Two scenarios were analyzed;

- Low-carbon development of the power generation sector until 2050;
- Climate-neutral development.

For the scenario analysis, the fundamental approach is to "optimize the energy structure, local power structure, and the electricity generation structure", aiming at the reduction of GHG emissions [7] (p. 9).

3.2. Scenario 1—Low-Carbon Development of the Power Generation Sector until 2050

In Scenario 1 (S1), for the period from 2020 to 2035, the production of electricity in the existing CFPPs is gradually being reduced, and in 2035, they will completely phase out with operation. From 2020, according to the S1 scenario, the construction of the new CFPP (Public Enterprise Elektroprivreda plans to build a new CFPP and the plan is currently on

stand-by) will begin, whose electricity production will continuously increase until 2037 and then gradually decrease until 2050, when it reaches a value of 2.8 TWh per year. The new CFPPs have a higher efficiency rate (42%), and by 2035, they have completely replaced the existing CFPPs, whose efficiency rate is just 30%. At the same time, the data on the electricity production of RESs in S1 remain unchanged and are in accordance with the mitigation scenario of the development of the electricity sector from the energy strategy of BiH until 2035.

Although the production of peak CFPPs from 2011 to 2017, according to S1, was growing, after that, there is a continuous decline until 2030, when all peak CFPPs are being closed. Peak CFPPs are those which have limited working hours in accordance with the National Emission Reduction Plan for BiH (NERP).

Figure 9 describes the production of electricity according to S1, which shows that the production in 2050 of the new CFPPs, existing HPPs, new large HPPs, wind farms, and existing peak HPPs is balanced and ranges from 2.6 TWh to 3.4 TWh from each, except for new solar power plants, from which, according to this scenario, it amounts to 1.6 TWh. Taking into account that these are RESs, it is necessary to calculate how much capacity must be installed in RESs, taking into account that the annual number of working hours for wind farms is around 3000, around 1200 hours for photovoltaic, and around 4500 h for new hydropower plants. Therefore, to achieve the annual total production of BiH by 2030, the installed capacity in RESs will be about 550 MW for wind farms, 400 MW for solar power plants, and about 400 MW for new large hydropower plants. The conclusion is that it is necessary to anticipate a slightly higher installed capacity of new CFPPs (around 750 MW).

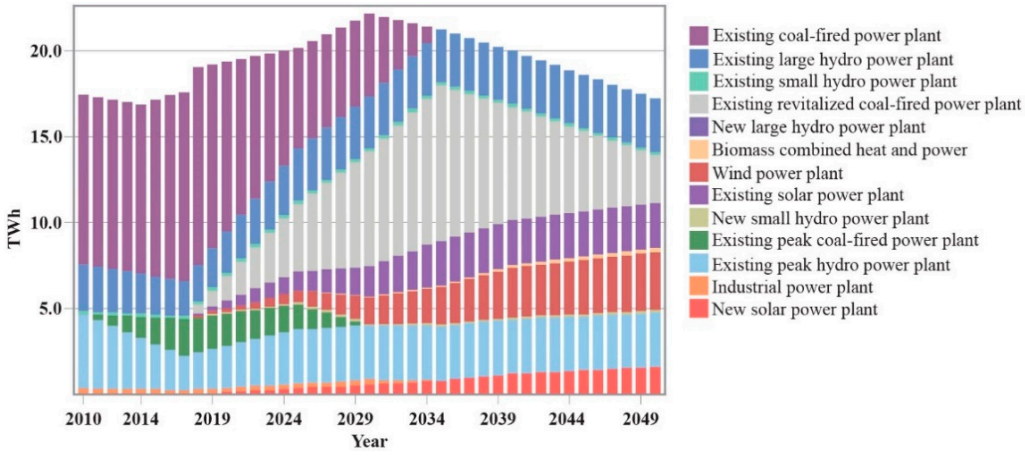


Figure 9. Share of different sources in power generation—Scenario 1.

Figure 10 shows that the total annual carbon dioxide emissions have been decreasing intensively from 2018, when total GHG emissions peaked at a value of 16.51 million tons, until 2025, when total emissions were 9.86 million tons. After that, from 2025 to 2035, emissions will decrease slightly, primarily because of the reduced production from existing CFPPs due to the environmental restrictions, the closure of some CFPPs (in accordance with the NERP (According to NERP, four units of CFPPs will be revitalized in order to reduce air pollution. In this article, these units are called existing revitalized coal-fired power plants.), and market conditions, and, in 2035, all existing CFPPs are being closed. With the phasing out of all existing CFPPs in 2035, an intense decline in GHG emissions will occur, and it will last until 2050. The new CFPPs will reach their maximum production in 2035 (9.05 TWh). GHG emissions in 2030 (9.61 million tons) are about 30% lower than they were in 2014 (13.3 million tons), and in 2050, the amount will be up to 2.2 million tons, which is about 83.5% less than that in 2014.

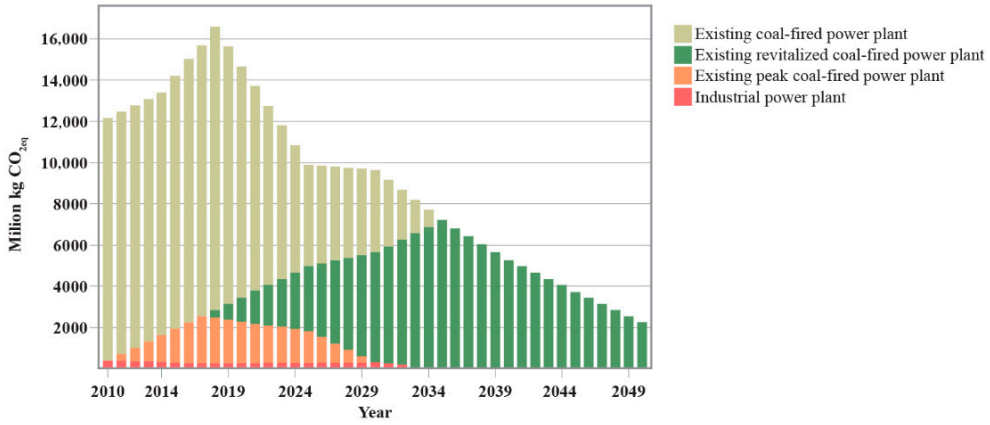


Figure 10. Share of GHG emissions from the power generation sector in BiH—Scenario 1.

3.3. Scenario 2—Achieving Climate Neutrality by 2050

In Scenario 2 (S2), the electricity production in existing CFPPs is the same as that in S1, where all existing CFPPs will be closed in 2035. Unlike S1, in S2, there is no construction of new CFPPs, and the difference in production due to the reduction in the production of existing CFPPs is compensated for by the production from renewable energy sources.

Because there is no construction of new CFPPs in S2 and the existing CFPPs are gradually shutting down, to maintain the level of annual electricity production, necessary amounts of electricity are compensated for by using renewable energy sources, when electricity production is increasing from new large hydropower plants, existing peak hydropower plants, biomass combined heat and power plants, wind farms, and new solar power plants. Production from existing large hydropower plants and existing small hydropower plants remains the same.

As can be seen in Figure 11, the production of electricity in S2 from coal will stop in 2035. According to S2, the largest production would be based on wind farms (5.2 TWh/a). In 2050, according to S2, in order to achieve the required total annual electricity production in BiH, the installed capacity needs to be a total capacity of about 3200 MW for solar plants, about 1800 MW for wind farms, and about 500 MW for new large hydropower plants.

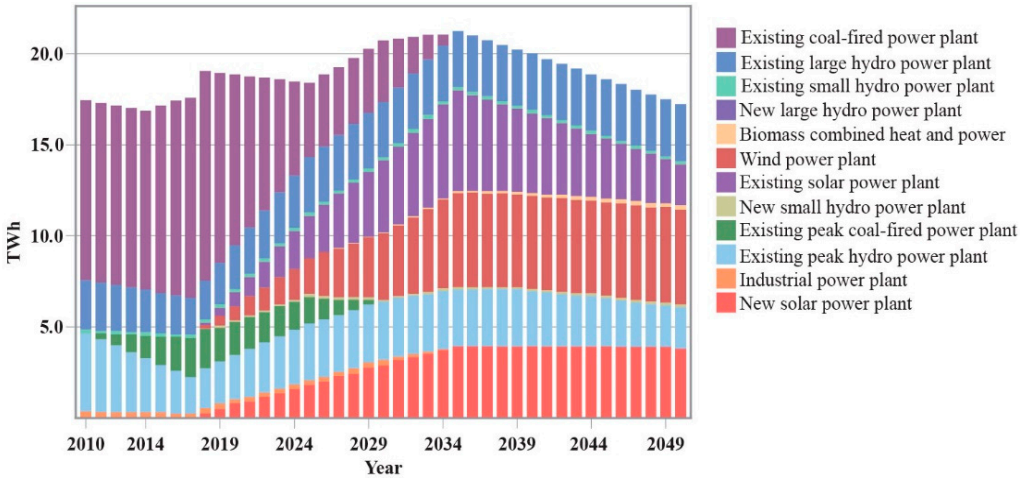


Figure 11. Share of electricity production in Scenario 2.

As shown graphically in Figure 12, carbon dioxide emissions from the electricity sector in 2025 amount to about 6.7 million tons, which is about 50% less than in 2014, when it amounted to 13.33 million tons. In 2030, according to this scenario, the emission of carbon dioxide is 4.3 million tons, which is about 36% less than in 2025. Carbon dioxide emissions

will decline until 2035, when, due to the complete closure of CFPPs and the complete switch to renewable energy sources, it amounts to zero.

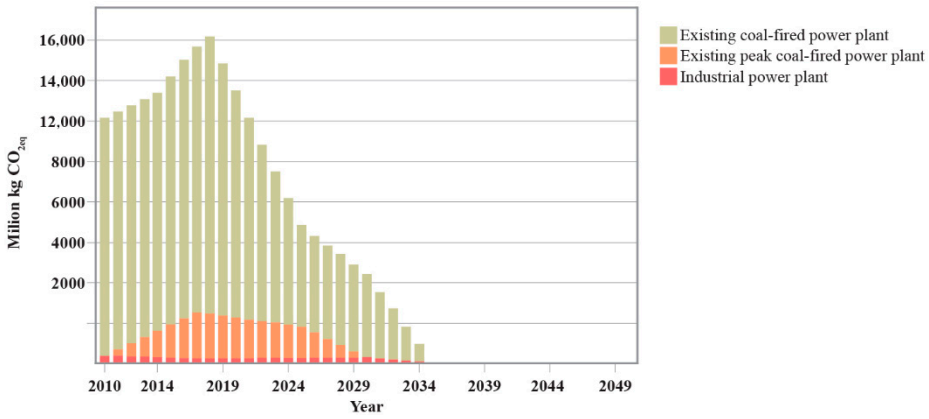


Figure 12. GHG emissions from the electricity sector in Scenario 2.

4. Discussion

In 2050, according to S1, there will be no production of electricity from the existing CFPPs, because, in 2035, they will stop working, and the optimization of coal use reduction will be compensated for by the construction of new renewable energy sources. The share of new CFPPs in total production in 2050 is just 16% (2.8 TWh), and the share of RESs has increased significantly, satisfying other energy demands.

According to S2, from 2035, there will be no production of electricity from coal, and the emphasis is strongly on the growth and promotion of RESs, which have significantly taken over the role of major producers of electricity, which is in line with the low-carbon development of BiH. Dominant sources of energy for electricity production are solar power plants (22%) and wind farms (30%), followed by existing large hydropower plants (18%), new large hydropower plants (13%), existing peak hydropower plants (13%), and other sources (4%), according to the total annual production in 2050. In 2050, according to S2, in order to achieve the required total annual electricity production capacity in BiH, the installed capacity needs to be a total capacity of about 3200 MW for solar power plants, about 1800 MW for wind farms, and about 500 MW for new large hydropower plants.

According to S1, the total production of electricity from RESs in 2050 in BiH would be 84%, and according to S2m, it would be 100%. Regarding the carbon dioxide emissions from the electricity sector in BiH, for S1 in 2050, it would amount to 2.2 million tons, and for S2, there would be no carbon dioxide emissions from the electricity sector in 2050.

Although the first scenario brings some improvements due to the higher efficiency of new CFPPs, the problem of carbon dioxide emissions still remains, because production still relies heavily on coal until 2035. The second scenario is the optimal scenario that would put Bosnia and Herzegovina on the list of countries with low-carbon development, but the other potential social and economic risks that the new orientation of the electricity sector "without coal" would bring about should not be forgotten. The construction of required RES plants to compensate for the electricity from CFPPs is a huge challenge for BiH. It is not a challenge from RESs' potential perspective but more from the social and environmental perspective, taking into account the space requirements for RESs and the loss of jobs in the coal sector.

5. Conclusions

This paper describes the energy system of BiH, which is currently predominantly based on coal. Given that almost 50% of GHG emissions come from the power sector of BiH and that, currently, about 70% of electricity is generated in CFPPs that have high specific carbon dioxide emissions (around 1.3 tCO_2/MWh), it can be concluded that the greatest potential for reducing emissions in BiH is from the power generation sector. Two scenarios

of the development of the power generation sector in BiH for the period until 2050 were developed.

In both scenarios, the current level of total power generation, along with a slight increase in domestic demand, have been assumed in the period until 2050. In the first scenario, the construction of new CFPPs to replace the part of the existing ones was assumed, while in the second scenario, there is no construction of new CFPPs. This means that all reductions in power generation from CFPPs due to the gradual shutting down of the existing plants will be compensated for by RESs.

The results of the scenario analysis show the required RES capacities needed for the achievement of climate-neutral power generation by 2050, with the current rate level of power generation. Based on the results, RES investment needs can be estimated. The article contributes to the application of modern modeling tools for scenario development, focusing on GHG emission development. The benefits of the contribution are reflected in a way that the results of the scenarios can be used for the strategic planning of the power generation sector in BiH until 2050. Additionally, this scenario analysis can be replicated in other countries, especially in neighboring countries, which have a similar baseline in the power sectors.

Future research related to the decarbonization of the power generation sector in Bosnia and Herzegovina should be aimed at optimizing the energy mix, considering the intermittency of solar and wind power plants. At the same time, a special focus should be given to sources that can balance the grid, such as storage and reverse-stable hydropower plants and biomass power plants, and, if necessary, analyze the role of green hydrogen.

In addition, climate neutrality has to be supported by investments in energy efficiency (e.g., EC Renovation Wave Strategy) as a supporting measure, along with decarbonization and RESs, for the improvement of the energy performance of the building sector in order to decrease energy demands.

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