From fossil fuels to renewable energy: Tracking Bulgaria's transition

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Abstract. The report examines Bulgaria's progress in transitioning from fossil fuels to renewable energy sources. It analyses the achievements and challenges faced by the country in this process. Recent changes in Bulgaria's energy mix, with a focus on the growth of renewable energy capacity, are discussed. The report outlines the achievements of Bulgaria's energy transition and emphasizes the importance of diversifying the energy mix. In addition, the challenges faced by the country in this transition are also addressed. The significance of factors such as policy and regulatory issues, economic and social considerations, technological and climate limitations is also highlighted. The research methods used include a review and analysis of relevant literature, examination of statistical data and reports from energy authorities, and interviews with experts in the field. This approach allows for a comprehensive understanding of Bulgaria's transition to renewable energy. The report draws conclusions on the performance of the sector and emphasizes the importance of different energy sources for the security and reliability of the electricity system and identifies key areas for further improvement.
Keywords: Bulgaria, electricity sector, renewable energy sources

I. INTRODUCTION

The energy transition is a global phenomenon that is a part of a broader transformation of the world economy towards climate neutrality. It involves a shift in the way society produces and consumes energy, with a key focus on replacing traditional fossil fuels with alternative renewable and low-carbon energy sources. This process of a fundamental change of the energy system is a complex and multifaceted task that brings a lot of challenges and opportunities. It involves various shareholders, different technologies and new infrastructure which require huge investment. In this process, finding the right balance between security, sustainability, and reliability of energy supply forces governments to take difficult decisions. The transition is also challenging for individual companies in the energy and resources industry as they face their own crises in the ongoing uncertainty of energy markets.

The purpose of this report is to examine the experience of Bulgaria in transitioning from fossil fuels to renewable energy sources. It focuses on the increasing integration of renewable energy sources into the country's energy mix. The key role of government measures in promoting the energy transition is also emphasized. The report evaluates the implementation of policies and measures related to low-carbon energy. Analysing the statistical data, it identifies and discusses the challenges and barriers faced by Bulgaria in its energy transition.

II. MATERIALS AND METHODS

Over the last ten years, advancements toward a new energy system have gained momentum. The growth in the renewable energy sector has stimulated significant research focus on this topic. A multitude of studies and reports have emerged, examining various dimensions of the shift to a low-carbon economy.

Researchers have been actively involved in constructing various models and making predictions about the future development of the renewable energy sector, providing insights into potential scenarios. Stefan Ćetković conducts comparisons of different energy transition models pursued by individual countries worldwide [1]. Authors such as Erik Gawel, Sebastian Strunz, and Paul Lehmann examine support policies for renewables from a public choice perspective [2], while Y. Yankov analyses energy transition from the perspective of geopolitics and diplomacy [3]. D. Stoilov develops model instruments for strategic planning of energy development in Bulgaria [4]. This research enables policymakers and stakeholders to develop strategies and improve energy planning.

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International organizations, including the International Energy Agency (IEA), the International Renewable Energy Agency (IRENA), as well as specialized supranational energy organizations like the Agency for the Cooperation of Energy Regulators (ACER) the European Network of Transmission System Operators for Electricity (ENTSO-E), the Federation of the European electricity industry (Eurelectric) have also contributed to the body of knowledge on the subject. Their publications examine various aspects and challenges of the transition, including preconditions, ongoing progress and results observed in different countries.

A. The World context

Renewable energy has become the fastest-growing energy source in most of the developed countries. China has emerged as major player in clean energy, accounting for around half of the global wind and solar additions and well over half of global EV sales in 2022 [5]. While oil and gas continue to play a role in the global economy, the transition towards renewable energy is expected to accelerate. The share of renewables in the global power mix is projected to approach 50 % by 2030 from around 30% today [5].

There are factors worldwide that collectively contribute to the shift towards a more low-carbon economy. Policies and regulations play a critical role in driving the transition. Regulations are becoming stricter, and capital is increasingly being directed towards renewable energy investments. Technological advancements are driving progress, with solar energy becoming the most cost-effective source of new electricity generation in many markets, even amidst inflation and price increases [6]. Furthermore consumer attitudes are also changing, with a growing interest in sustainability.

On the other hand, global geopolitical tensions, especially the war in Ukraine have underlined the importance of energy security. They have led to a renewed focus on renewable energy especially in countries that rely on energy imports. Instead of slowing down, investments in the energy transition have soared to unprecedented levels. In 2022 investments in low-carbon technologies surpassed $1 trillion for the first time, driven by strong clean energy policies in major economies [7]. Notably, the US Inflation Reduction Act allocated $369 billion for greentech initiatives, and the European Commission provided $270 billion for cleantech companies. China emerged as the dominant recipient of energy transition investments, attracting $546 billion, which accounted for nearly half of the global total [7]. In 2023, global investment in the low-carbon energy transition experienced a remarkable 17% surge, reaching a record-breaking $1.77 trillion [8].

B. The EU context

The European Union has implemented a number of strategies that set targets and deadlines for making the EU the world's first carbon-neutral economy by 2050. In 2019 the European Green Deal was introduced, followed by the adoption of the Climate Law. Additionally, the EU Fit for 55 legislative package was presented, outlining a plan to reduce emissions in the EU by at least 55% by 2030. To reduce energy dependence and accelerate the energy transition, the REPowerEU plan was published in 2022. The EU has also established ambitious goals for the share of energy from renewable sources in gross energy consumption. By 2030, the EU aims to achieve an average share of 42.5%, with a further target of 45% as each Member State determines its own national contributions towards this target [9].

In 2022, the energy mix in the EU mainly consisted of five different sources. Oil and petroleum products have the largest share in it (37%), followed by natural gas (21%), renewable energy (18%), solid fossil fuels (12%) and nuclear energy (11%). The shares of the different energy sources in the gross available energy vary significantly among Member States. In 2022, the share of petroleum products in the overall energy was highest in countries like Cyprus (86%), Malta (85%) and Luxembourg (61%). On the other hand, natural gas plays a significant role in Italy (38%), Hungary (31%), Ireland and the Netherlands (30%). Renewables hold the largest share in countries such as Sweden nearly 50%, Latvia 42%, Denmark and Finland (40%). Nuclear energy accounted for a significant portion of available energy in France (35%), Sweden and Slovakia (25%). The use of solid fossil fuels was most prominent in Poland (43%), the Czech Republic and Bulgaria (32%). Notably, the share of solid fossil fuels in Germany increased from 15% in 2020 to 20% in 2022 [10].

In 2022, renewable energy represented 23 % of gross energy consumed in the EU, up from 21.9% in 2021 with Sweden, Finland, and Latvia leading the way. However, the majority of Member States have shares below the EU average, with countries like Malta, Ireland, Belgium, and Luxembourg recording the lowest share of renewables, all below 15% [11].

C. Energy Landscape in Bulgaria

The EU's goal of becoming the first climate-neutral continent by 2050 poses a significant challenge for member states, which varies depending on their specific local economic conditions, climate, energy resources as well as opportunities for cooperation with countries in the region. Bulgaria has aligned its policies with the EU's priorities on renewable energy, setting national targets to contribute to the overall European objectives. These targets include reaching a 16% share of renewable energy in gross final energy consumption by 2020 and increasing it to 25% by 2030.

The development and implementation of the Bulgarian institutional and legal framework to promote the production and consumption of energy from renewable sources started in 2007, which is significantly later than in other EU Member States. Nonetheless, during the first programming period 2007-2013 the government did implement policies and set out incentives, which created a favorable business environment. Among the most attractive of the measures were: the mandatory purchase of electricity generated from renewable sources at feed-in tarrifs, priority connection of RES electricity producers to the power grid and the establishment of long-term contracts. Changes in the legislation at the end of 2008 increased the term of contracts for geothermal and solar power producers from 12 to 25 years and for wind and hydro power producers from 12 to 15 years respectively [12].

Undoubtedly, these measures significantly enhanced investor interest in the sector and gave a strong initial impetus to investments. Evidence of this is the statistics that shows a clear periodicity in the commissioning of renewable energy capacities in Bulgaria.

III. Results and Discussion

In the period 2007 - 2023, the installed capacity for electricity generation from renewable energy sources increased almost three times and reached 5896 MW. While hydroelectric capacity was mostly built before 2000, wind and photovoltaic capacities experienced two distinct periods of growth: a surge between 2008 and 2012, and a second significant increase in solar energy capacity 2020 - 2023.

Fig. 1 shows the RES capacity by type over the past twenty years. Two years stand out as peak with the highest levels of new renewable electricity generation capacity commissioned. These are 2012 and 2023 when 1 114 MW and 1 383 MW respectively were connected to the electricity grid [13]. The largest contributors to this increase are the new photovoltaic and wind power plants.

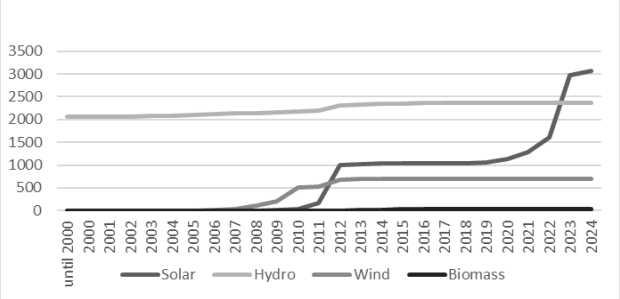

Fig. 1. RES capacity by type, 2000-February 2024, MW.

As a result of the incentives, Bulgaria has not only experienced a growth in renewable electricity generation, but also managed to reach its mandatory national target of a 16% share of energy from renewable sources in gross final energy consumption prematurely in 2012 instead of 2020. This early achievement of the target is a prerequisite for rethinking the policy by addressing some shortcomings, improving incentive mechanisms and discontinuing the implementation of some preferences for producers of electricity from renewable sources.

It should be noted that the main source of funding for the stimulus measures towards renewable energy producers is the demand side. It is through the feed-in tariffs paid by household and industrial consumers that the costs associated with the commissioning of new capacity, as well as the additional costs incurred by the energy system and grids for the construction of various facilities are subsidized. Additional financial support for renewable energy projects is provided from EU operational programmes and the European Regional Development Fund.

Regulatory changes have been made to address the negative impacts, as well as to align the support mechanism with the process of the electricity market liberalization and the gradual market integration of electricity from renewable sources on the free electricity market. The administrative procedures have been simplified and the deadlines for connecting facilities to the respective grid have been reduced. Furthermore, the support for the electricity produced from renewable sources through feed-in tarrifs is limited. Assistance is provided only for new energy facilities producing electricity from renewable sources with a total installed capacity of up to 30 kW, as well as for previously concluded contracts for the purchase of electricity from renewable sources produced by power plants with a total installed capacity of less than 1 MW. Since 2021 all electricity producers with an installed capacity of 500 kW and above, who have concluded long-term contracts for purchase at feed-in tarrifs, sell their electricity on the free market and receive premiums for the quantities of electricity up to the established net specific production. The premium is provided until the expiration of the respective contract for purchase at a preferential price [12].

Fig. 2 shows that Bulgaria has nearly tripled its installed solar capacity from a little over 1 GW in 2020 to almost 3 GW at the end of 2023. In 2023, 1,533 photovoltaic power generation assets with a total capacity of 1,381 MW have been commissioned [13]. Much of this boom is due to companies investing in solar to cover their own energy needs amid a sharp rise in the price of traditional fossil fuels triggered by the war in Ukraine.

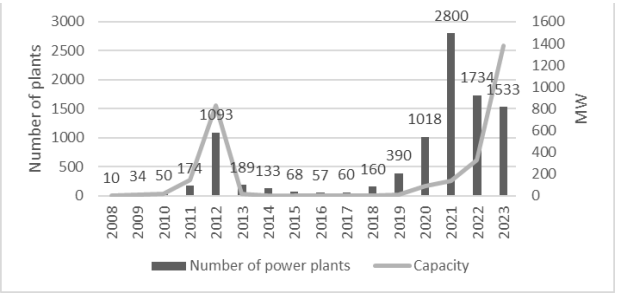

Fig. 2. Number and capacity of PV solar power plants

Concerning the country's origin of the investors in Bulgarian's renewable energy sector most of them are from Europe. Italian and German investors showed continued interest. Italy took the lead with 31 investment projects, while Germany held majority shares in 22 companies. The Czech Republic followed closely with investments in 16 Bulgarian entities. Luxembourg and Hungary were also noteworthy investors. Outside of Europe, notable investors included those from China, Republic of Korea, and Japan [14].

With the increase in 2023, the capacity of solar installations exceeded that of hydropower plants. It is noteworthy that no new wind farms were commissioned in 2022 or 2023. One of the main reasons is that the areas with wind power potential suffer from insufficient interconnections. Existing wind farms are exclusively onshore, and the country is taking steps to exploit its offshore potential in the Black Sea.

As a result of the changes, the structure of installed capacities for electricity generation from RES in 2023 is as follows: solar power plants have the largest share with 2782 MW (47%), followed by hydro power plants with 2365 MW (40%), wind power plants with 697 MW (12%), and biomass plants with 52.4 MW (0.9%) [13]. Fig. 3

represents that the increase in generation capacity has led to a near doubling of gross electricity generation from renewable energy sources over the period 2009-2023. In 2023, it increased by 3,635 GWh compared to 2009. The target for gross final energy consumption from RES was also achieved.

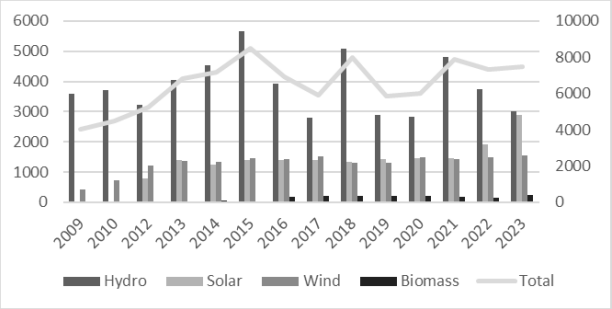

Fig. 3. Electricity generated from renewable sources, GWh

However, Fig. 4 shows that despite the significant growth in installed solar generation capacity, in 2023 hydropower generation remained the largest contributor, accounting for around 39.8% of gross electricity generation from RES. PV comes in second with a share of 37.8%, followed by electricity generation from wind at 20.4% and biomass 2.4% [13].

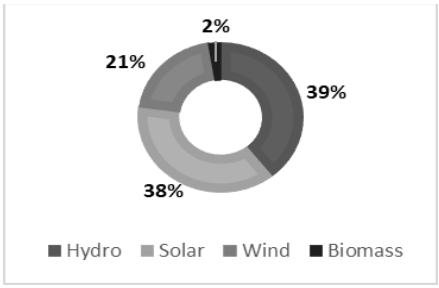

Fig. 4. Share of electricity generated from renewable energy sources in 2023

The commissioning of new renewable generation capacity has given rise to new problems that pose obstacles to the development of the sector. These obstacles include: the inability of the energy system to connect too many investment intentions for wind and solar farms, the construction of renewable energy projects in environmentally sensitive areas without proper environmental assessment procedures, the conversion of agricultural land for non-agricultural use resulting in the loss of fertile land, and the lack of serious investment intentions and readiness among potential investors [12]. These challenges bring attention to the work of transmission and distribution network operators. One particularly critical problem is the transmission of high capacities generated by photovoltaic and wind power plants. These types of power generation exhibit rapid fluctuations in output, necessitating the need for system balancing to ensure stability and reliability.

Despite the growth in installed capacity for renewable electricity generation, the share of renewable electricity generation in the country's total energy mix is still low at 14.5%. Even with this low percentage share in total generation, the summer months have seen record levels of green electricity generation, and there have already been times of negative prices. This trend highlights the need for investment in energy storage, balancing technologies and flexible tariffs to incentivise consumption during sunny periods.

In 2022 the energy mix of the country, shown in Fig. 5, was still dominated by thermal power plants and the Kozloduy nuclear power plant. The gross electricity generation reached 50 TWh, marking a 6% increase from the previous year. Domestic coal and nuclear power constitute the primary fuel inputs. Thermal power plants contributed the largest share at 52.3%. followed by nuclear power stations at 32.5%. Solar and wind sources combined made up 7%, while hydropower accounted for a 7.5% share [15].

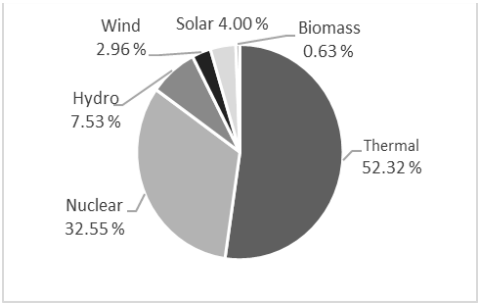

Fig. 5. Share of total gross electricity generation by plant type, 2022

It should be emphasized the significant growth in coal-based electricity generation in 2022, up by 22% compared to 2021. It can be attributed to the geopolitical dynamics and the war in Ukraine that changed the role of coal. The disruption in Russian gas supply has caused difficulties for major European energy facilities. The complex situation has had a positive impact on the operation of coal-fired power plants in Bulgaria. In the midst of the energy crisis, these plants have ensured the stability of the Bulgarian electricity system and have helped compensate for electricity shortages in the region. In 2022, Bulgaria's electricity exports reached 14 TWh, which is 28% higher than in 2021 and accounts for 27% of total generation. This has had significant financial benefits for the Bulgarian economy and society. However, with carbon allowance prices rising, it is unlikely that the spike in coal-fired power generation that was recorded in 2022 will be repeated.

On the other hand, low-emission baseload electricity generation capacities, such as nuclear power plants, will continue to be crucial for an extended period of time. In Bulgaria nuclear power has played a vital role in the country's energy security for more than 50 years, contributing to approximately one-third of its annual electricity generation. In 2022, nuclear power plants in Bulgaria produced 16,454 GWh of electricity, making them the second-largest electricity generation capacity in the country.

IV. CONCLUSIONS

In today's global system of international economic relations certain changes and trends are observed, determined both by purely economic, as well as by many other factors - social, political, security-related, etc [16]. In this context a global transition to renewable energy is also underway. Over the last two decades Bulgaria has made

tangible progress in increasing the share of RES in total energy production and consumption. The most notable growth has been in photovoltaic plants. This development so far has been directly influenced by an administrative approach that sets administrative targets for the share of renewables in gross electricity consumption and creates artificial incentives to promote renewable electricity generation. As a result, there has been a non-market-driven growth in the proportion of specific types of generation capacity while other types are neglected. This alters the functioning of the energy system, introduces additional costs and inefficiencies, and presents new challenges for the sector.

On the other hand, coal has demonstrated its importance in guaranteeing energy supplies as a domestic resource. In the future, its role may evolve from providing baseload capacity to serving as a strategic reserve. The leading role of nuclear power plants in driving the energy transition should be highlighted. They provide low-emission, predictable, and controllable electricity, which is crucial for ensuring energy security and facilitating the large-scale reform of the European energy sector towards an increased share of low-emission energy sources.

As the proportion of renewable electricity generation capacity grows, the need for system balancing becomes more urgent. Giving priority to the development and upgrading of the electricity grid is crucial for the transition to a low-carbon economy. To address this issue substantial investments in the development of the power grid are needed in order to avoid distortions in system operation.

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