CENTER FOR THE STUDY OF DEMOCRACY

Decarbonising the Bulgarian Power Sector

Resolving the Coal Phase-Out – Security of Supply Conundrum

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Compared to its peers in Central and Eastern Europe, Bulgaria has been hesitant and slow in utilising the opportunities to decarbonise its energy sector and economy through the ambitious policy and financial initiatives for climate neutrality of the European Union's (EU). The Bulgarian government has been among the last in the EU to adopt its National Recovery and Resilience Plan (NRRP), which commits billions of euro of EU funding for supporting government pledges for reforms and decarbonisation of the energy sector. A core commitment under the NRRP has been the establishment of the Energy Transition Commission (ETC). The ETC has been tasked to develop a detailed assessment of two scenarios for a coal phaseout until 2030 (early) and until 2038 (late) as a basis for the development of a climate neutrality roadmap until 2050. Yet, reaching a convincing consensual decision from the ETC's work has been elusive. This report aims to aid the development of the long-term decarbonisation framework by presenting the key policy findings from a comprehensive modelling assessment, conducted by the Regional Center for Energy Policy Research (REKK), of the Bulgarian power sector until 2050. The study can be seen as a sensitivity analysis that aims to validate and crosscheck the assumptions and conclusions of the final report, prepared by the Bulgarian Ministry of Energy unsuccessfully reflecting the discussions within the ETC. The analysis reveals that the Bulgarian economy is fully capable to achieve carbon neutrality until 2050 without considerable increase in electricity prices, increased gas capacity and/or coal power generation. Yet, the inability of managing conflicting vested interests in the Bulgarian energy sector might prevent the country from achieving this goal.

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CONTENTS

LIST OF FIGURES

LIST OF BOXES AND TABLES

LIST OF ABBREVIATIONS

CO_2	Carbon Dioxide
CfD	Contract for Difference
CL	Compass Lexecon
CSD	Center for the Study of Democracy
DSO	District System Operator
EPMM	European Power Market Model
ETC	Energy Transition Committee
ETS	Emission Trading Scheme
EU	European Union
GHG	Greenhouse gases
Kt	Kiloton
LCOE	Levelised Cost of Electricity
NRRP	National Recovery and Resilience Plan
PE	Pathways Explorer
PPA	Power Purchase Agreements
REKK	Regional Center for Energy Policy Research
RES	Renewable Energy Sources
SEE	Southeast Europe
TSO	Transmission System Operator

POLICY CONTEXT

The slow and hesitant approach of the Bulgarian government to implement its commitments under the NPRR might result in missing a crucial opportunity to transform its energy sector and align itself with the European Union's (EU) ambitious 2050 climate neutrality objectives[1]. Despite Bulgaria's formal commitment to the European Green Deal, powerful entrenched interests have repeatedly pushed the government to seek to delay the phasing out of (subsidized) coal power generation and to lock the electricity sector in large-scale energy projects that benefit incumbent highly concentrated economic interests at the expense of democratising the country's energy sector through the further diffusion of renewable energy sources and energy efficiency technologies.

Bulgaria's electricity generation mix is still dominated by coal although the high CO_2 prices have made lignite power plants economically unviable. Coal generation still makes up roughly 25-30% of the power demand in the country in 2023, on the back of hefty state support in the form of long-term power purchase agreements (PPAs), which are bound to expire in 2024 and 2026, and of the continuous provision of availability capacity.

The vocal opposition from miners and plant workers, misguided by entrenched political and economic interests, has effectively stalled the frail government efforts to transform the economic development of coal regions[2]. Bulgaria has so far failed to take advantage of the provided ample EU funding for the coal regions that can be effectively utilised towards the upscaling of renewables, the improvement of energy efficiency and the promotion of cutting-edge low-carbon innovations such as offshore wind, battery storage, green hydrogen, e-mobility, and synthetic fuels. Bulgaria is yet to develop a consistent long-term policy vision, which is based on widely accepted and tried in the EU data-based modelling[3].

The current report aims to close this governance gap by presenting the key policy findings from a comprehensive modelling assessment, conducted by the Regional Center for Energy Policy Research (REKK) using its European Electricity Market Model (EEMM), of the Bulgarian power sector development until 2050. The study can be seen as a sensitivity analysis that aims to validate and crosscheck the assumptions and conclusions of the report, pre-

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1 European Commission, Commission staff working document 2022 Country Report – Bulgaria. Recommendation for a council recommendation on the 2022 National Reform Programme of Bulgaria and delivering a Council opinion on the 2022 Convergence Programme of Bulgaria, COM 2022) 603.

2 Primova, R., Vladimirov, M. and Trifonova, M. *Towards a Just Transition in Bulgaria: Unlocking the Green Transformation Potential of Stara Zagora, Pernik and Kyustendil*, Sofia: Center for the Study of Democracy, 2022.

3 Vladimirov, M., Trifonova, M. and Tcolova, K. *Back to the Drawing Board: The Contours of Bulgaria's Climate Neutrality Roadmap*, Sofia: Center for the Study of Democracy, 2023

pared by the Energy Transition Committee (ETC)[4], as part of the Bulgarian Consultative Council on the European Green Deal at the Council of Ministers, which would underpin the country's Climate Neutrality Roadmap. The latter is one of the main energy sector reforms, part of Bulgaria's National Recovery and Resilience Roadmap (NRRP) and the backbone to the country's long-term decarbonisation strategy.

[4] The Roadmap is a public document endorsed by the ETC, the Consultative Council for the European Green Deal, the Council of Ministers, the Bulgarian Parliament, and agreed jointly with the European Commission. In a broader context, the ETC builds an analytical basis for decision-making. In the process of analysis and modelling, ETC members have the opportunity to contribute their expertise and exchange views in the framework of the broad discussions held.

MODELLING FRAMEWORK

The Climate Neutrality Roadmap should be based on two decarbonisation scenarios with a coal phaseout horizon, of respectively 1) 2030 and 2) 2038. Both scenarios share the same assumptions related to energy demand and the resulting projections from the Climact's Pathways Explorer modeling instrument.[5] They also share similar assumptions for the deployment of renewables and other non-fossil power generation sources. Hence, they differ mainly in their coal phase-out timeline assumptions and the need for including new large-scale baseload capacities such as two new nuclear reactors.

The ETC consultations and the materials provided, discussed and prepared by its members, including simulations and analytical reports, serve as a basis for defining the concrete policy steps and stages on the path to carbon neutrality, which will be detailed in the roadmap. In this sense, the role of the ETC in the creation of the roadmap is to outline (1) possible scenarios and pathways for the decarbonisation of the Bulgarian energy sector, as well as (2) possible measures for a just transition, to identify (3) financing needs, (4) environmental impact assessment, and (5) socio-economic impact of the transformation of the energy sector.

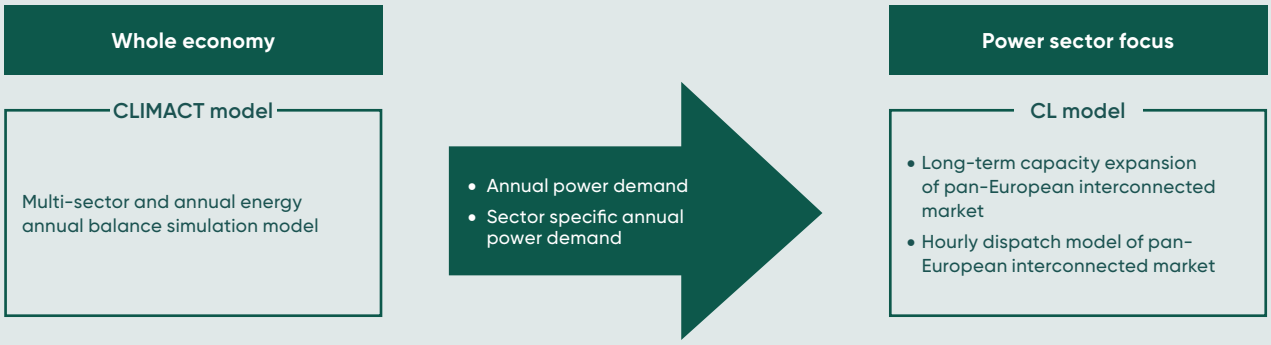
Box 1. Modelling Framework of the Energy Transition Committee

The ETC has decided to integrate two different modelling assessments including the models already constructed in the Pathways Explorer tool and the Compass Lexecon (CL) Energy European Model (Plexos-based platform). The joint implementation of the two tools aims to develop decarbonization pathways based on the assumptions adopted by the ETC members.

Common assumptions about technological pathways and installed capacity per technology	2030	2040
Onshore wind	3870 MW (PE) 4000 MW (CL)	6930 MW (PE) 7000 MW (CL)
Offshore wind	500 MW (CL Model assumes 1000 MW in an accelerated scenario)	2500 MW
Solar PV	6500 MW	10770 MW (PE) 10300 MW (CL)
Geothermal	60 MW	60 MW
Nuclear (*No new additions before 2040)*	2000 MW	2000 MW

[5] The Pathways Explorer is a socio-economic simulation model that integrates a wide range of environmental components. It is based on the Mackay calculators. It was developed as part of the EUCALC project, financed by the Horizon 2020 program of DG Research. EUCALC developed an open-source model as well as learning tools designed to engage and be used by European and national policymakers, businesses, NGOs, and other society actors. The model could serve as a key instrument for the Bulgarian government in preparing its different long-term scenarios and green recovery pathways. It constructs an economic model based on a bottom-up approach to project the main patterns of consumption that will influence decarbonisation trajectories and encompasses 5 main sectors: food production and land use (LULUCEF), transport, buildings, industry, and energy supply.

As the first step of the modelling, the energy consumption and carbon emissions levels are forecasted for all sectors of the Bulgarian economy, including energy, industry, transport, buildings, and agriculture and land use, using the online platform of the Pathways Explorer. Based on the results of this first stage, a cost-effective production mix of the Bulgarian energy sector up to 2050 is constructed following a real-time dispatch supply-side approach and pan-European modelling coverage. The modelling in the CL model also considers the security of supply and provides projections for the regional power demand.



The Center for the Study of Democracy (CSD) has taken a proactive approach in its contributions to the ETC, conducting an independent evidence-based modelling assessment of the impact of the two coal phaseout scenarios on the Bulgarian power sector based on the technical parameters agreed by the ETC and two modelling tools – Climact's Pathways Explorer and REKK's European Electricity Market Model (EEMM)[6]. CSD's assessment aims to pave the way for a well-informed fact-based discussion. It will ensure that the power sector analysis is an objective, evidence-based evaluation of the coal phaseout scenarios as to prevent political interference in the definition of the power sector outcomes.

[6] The European Power Market Model (EPMM) is a unit commitment and economic dispatch model. Electricity consumption is satisfied simultaneously in all modelled countries at a minimum system cost, considering spinning reserve requirements, capacity constraints of the available power plants and cross-border transmission capacities. EPMM endogenously models 41 electricity markets in 38 countries across the ENTSO-E network.

DISCUSSION OF THE RESULTS

The implementation of the proposed modelling framework, to a large extent, replicates the dispatch modelling performed by CL. Below are summarised the main results of the testing of the two scenarios (late coal phaseout until 2038 and early coal phaseout without addition of new natural gas capacity by 2030). However, both scenarios consider the national commitment in the NRRP of limiting the CO_2 emissions by 40% in the energy sector. The results of the EEMM model considers the CL modelling results and any other scenarios that might be published by the Ministry of Energy by the time of writing of the assessment. The main elements to be discussed below include:

- The evolution of the power mix until 2050
- The impact on electricity prices
- The potential for the reduction of CO_2 emissions
- Security of supply risks

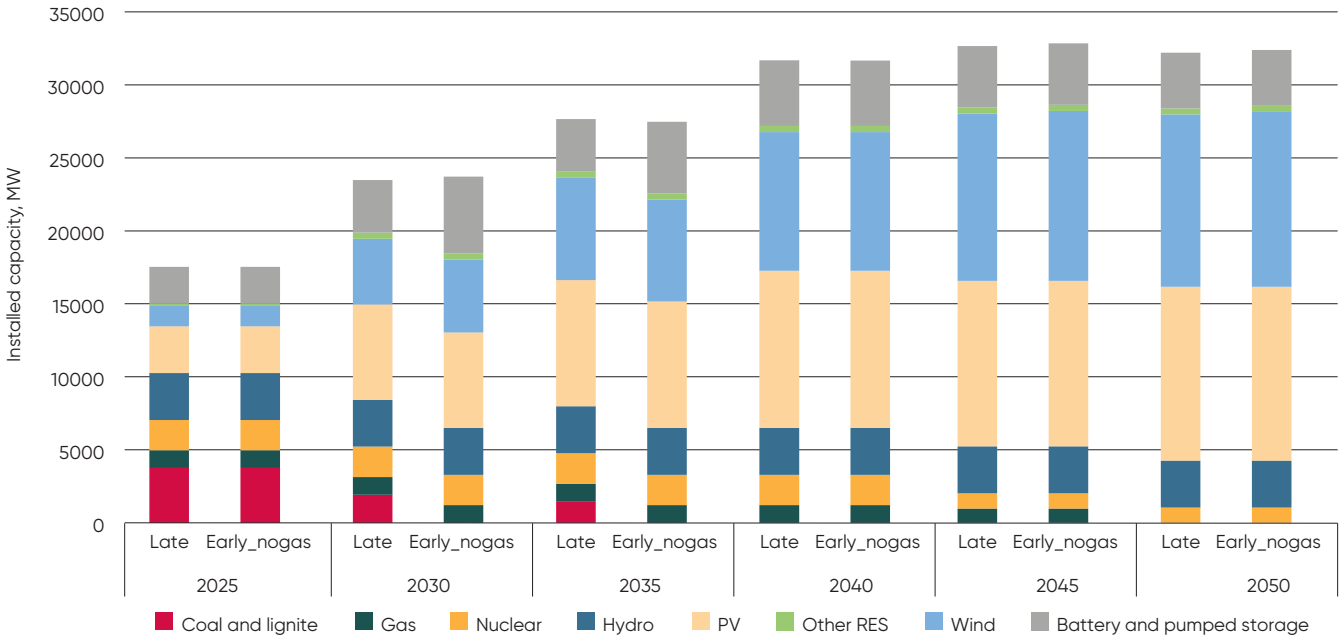
Table 1. Main Parameters of the Two Scenarios Analysed by the EEMM Model

Scenario	Accelerated coal phase out in 2025 (2 power plants closed)	Full coal phase out in 2030	New gas power plant in 2030
Late coal phaseout (40% CO_2 reduction target for 2026)	Yes	No	No
Coal phaseout by 2030 (40% target + no new gas capacity by 2030)	Yes	Yes	No

Electricity Mix Evolution

The results show that in both scenarios the lignite power plants will play an important role in the electricity mix until 2025. However, by 2030 they are only marginal players on the product market even if some coal capacity stays online until 2038. The reason for the faster shutdown of the coal capacity in the Bulgarian electricity system is the high CO_2 cost, which reaches EUR 100/ton in 2025 before climbing to EUR 116/ton in 2030 and EUR 250/ton in 2050. This means that the levelized cost of electricity (LCOE) of lignite power plants in Bulgaria will significantly exceed average power market prices. As a result, none of the lignite power plants will be commercially viable if there are no direct state support mechanisms in place. The latter will have to be phased out by 1 January, 2025 under the EU's Industrial Emissions Directive.

Figure 1. Bulgarian Power Mix by Installed Capacity (MW) until 2050



Source: European Electricity Market Model, REKK

In both scenarios, there is a massive increase in renewable energy-based capacity in the power system. Onshore wind capacity doubles until 2025 to 1.4 GW and expands to 4.5 GW in 2030 on the back of the first additions of offshore wind parks of at least 1 GW until the end of the decade. Total installed wind-based capacity reaches more than 11 GW by 2050. Similarly, both scenarios see a boom in photovoltaic investments over the next three decades, which has become very visible since the increase in average market power prices in late 2021. PV installed capacity rises from 3.2 GW in 2025 to 6.5 GW in 2030 before skyrocketing to 11 GW by mid-century.

Despite the political commitments to construct a new nuclear power reactor at the NPP Kozloduy by 2035, the two modelled scenarios do not show the need for such new large-scale baseload capacity in the power system. The reason is that power demand is not projected to increase significantly on the back of expected energy efficiency gains in the buildings and industrial sectors, the steep population decline and the overall transformation of the Bulgarian economy towards services and away from energy intensive business segments. Power demand is projected to rise by 11% between 2025 and 2030 and by around 40% until 2050, largely on the back of the gradual electrification of mobility and the uptake of heat pumps and AC use in residential buildings, previously burning firewood and coal for heating.

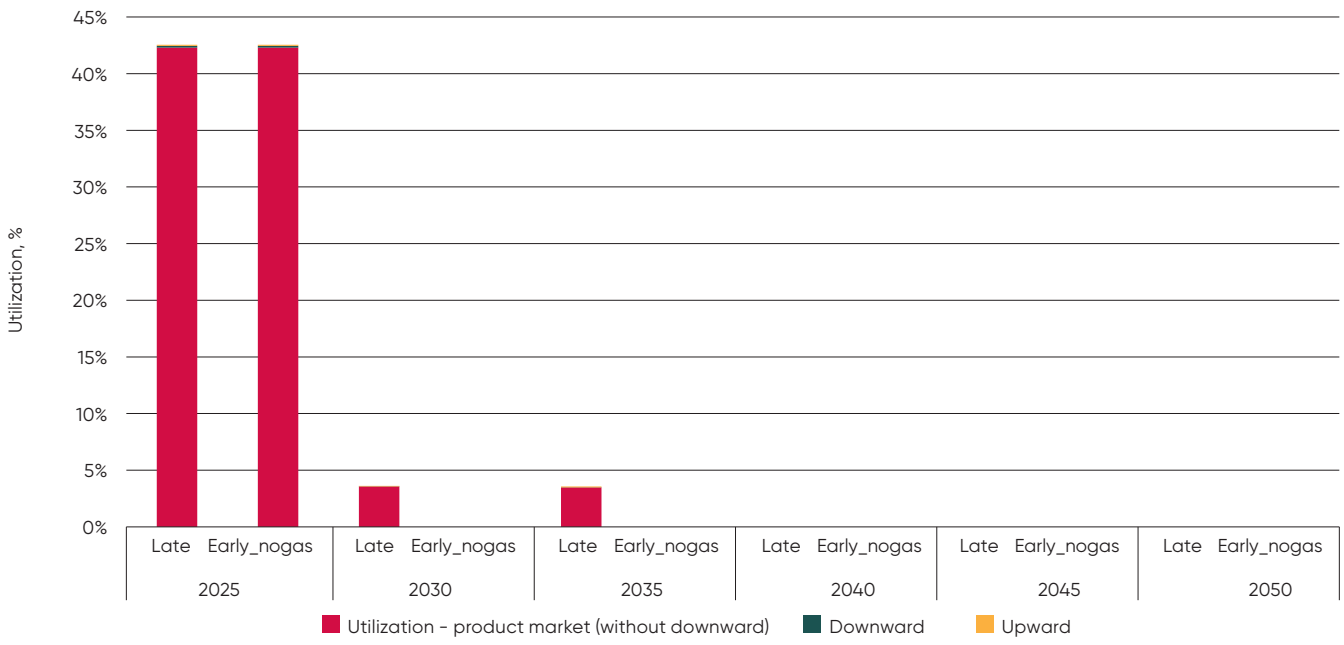
Previous modelling assessments of CSD depict that Bulgaria is not expected to closely follow the EU trend in terms of electrification. This is because it already has one of the highest electrification ratios among the EU-27 member states. With a ratio of 28%, Bulgaria ranks among the best performers, along with countries such as Spain (27%) and Finland (28%). This figure also exceeds the EU average of 22%. Previous ambitious decarbonisation scenarios

project a gradual and relatively moderate growth in power demand in the industrial sector and a similar pace of electricity savings in the buildings sector.

The rise in intermittent power generation from renewables will likely increase the system's storage needs.

However, the technical outage of much of the current installed pumped storage capacity after one of the Chaira plant exploded in 2022, and the expected delays in the 800 MW expansion of the Chaira hydro power cascade due to environmental concerns and governance bottlenecks in the sector, it is more likely that there will be 1 GW new battery storage and not pumped storage that will come online after 2030. A similar development is consistent with the organisation of 6 individual tenders as part of the NRRP list of projects for the addition of 1.4 GW of new RES-based plants with at least 30% battery storage attached to each facility until 2026. At the current slow speed of project implementation, the more likely deployment period is 2030 for these new capacities.

Figure 2. Utilization Rate of Lignite Power Plants (%)

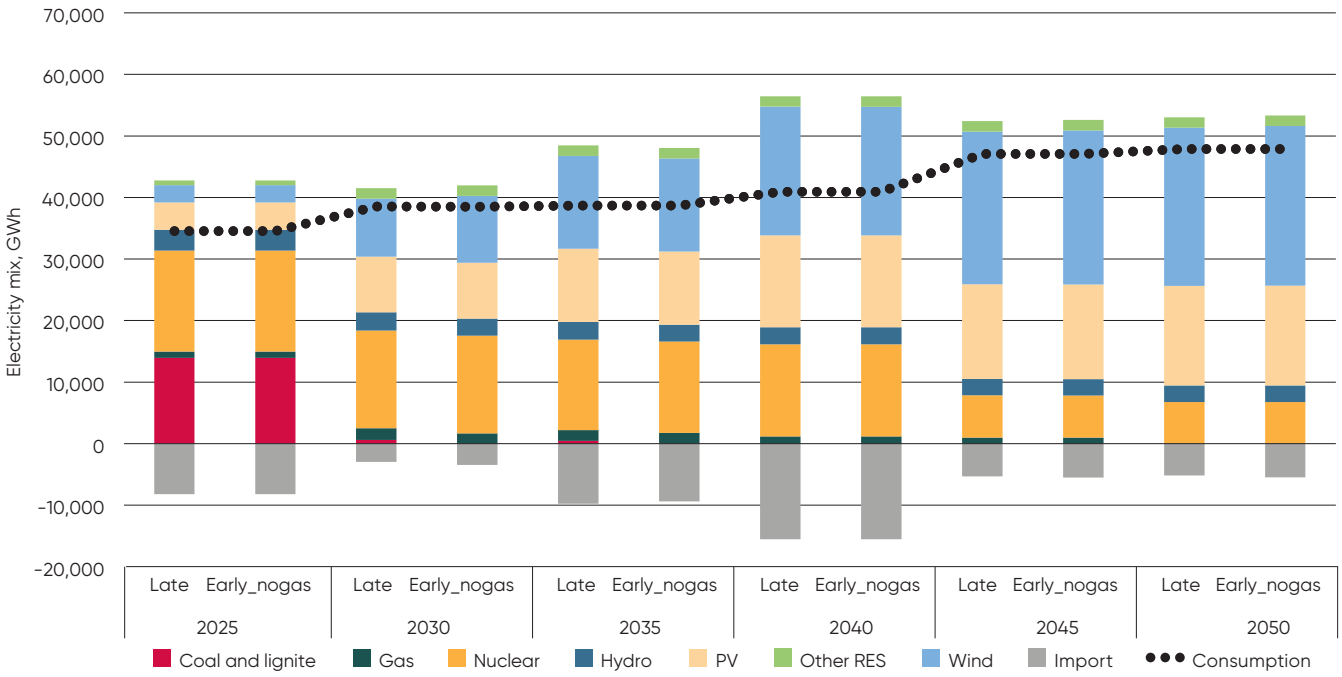


Source: European Electricity Market Model, REKK

Zooming in on the actual use of the different power plants in Bulgaria, it is important to note that the high costs of coal-fired power generation leads to a low utilisation of lignite plants. Nonetheless, due to the slow addition of new renewable energy-based power plants and storage capacity to the electricity system, the lignite power plant utilisation remains moderately significant at 40% in 2025. The power plants operate almost fully in the product market, while the associated reserve market utilisation is very low. In the late phaseout scenario, the utilisation of coal/lignite decreases to less than 5% in 2030 and 2035. In the more ambitious early scenario, the utilization drops to zero by 2030.

The natural gas price also remains at around EUR 45/MWh in 2025 before moderating down to EUR 27.5/MWh in 2030 and beyond. The positive clean spark spread (i.e. the preference to produce an extra MWh of gas-fired electricity versus coal-based one) means natural gas use in the electricity sector rises in both scenarios from around 1 TWh per year in 2025 to 1.9 TWh in the late phaseout and to 1.67 TWh in the early scenario. In the late phaseout scenario, although there is an economic logic to develop a new gas-fired power plant, which takes advantage of high hourly power prices in peak demand periods, such a new facility is not assumed by neither of the scenarios. The importance of a potential new gas power plant in the product market would also decrease over time although some gas-fired generation remains in the system until 2045.

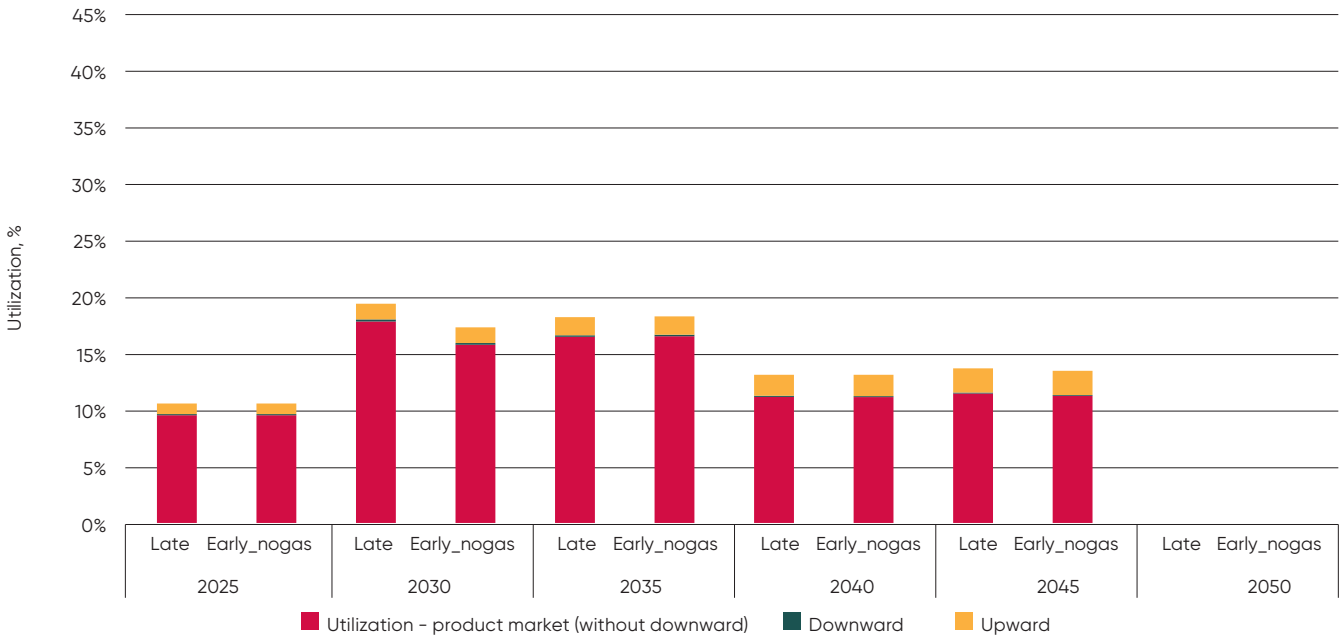
Figure 3. Bulgarian Power Generation Mix and Average Demand Projections (GWh)



Source: European Electricity Market Model, REKK

Natural gas utilisation is very low until 2025 as the long-term PPAs with lignite plants and the availability capacity, provided to Maritsa Istok 2, will make them the dominant suppliers of electricity in peak demand periods. However, depending on the year and the scenario, the gas capacity utilisation increases to 10-30%. The utilisation of gas is significantly higher in the early scenario as the new modern gas plant increases overall utilisation, but even in this setup average utilisation remains relatively low. The gas plant operation is mostly associated with the product market, but relevant upward reserve market participation is also present.

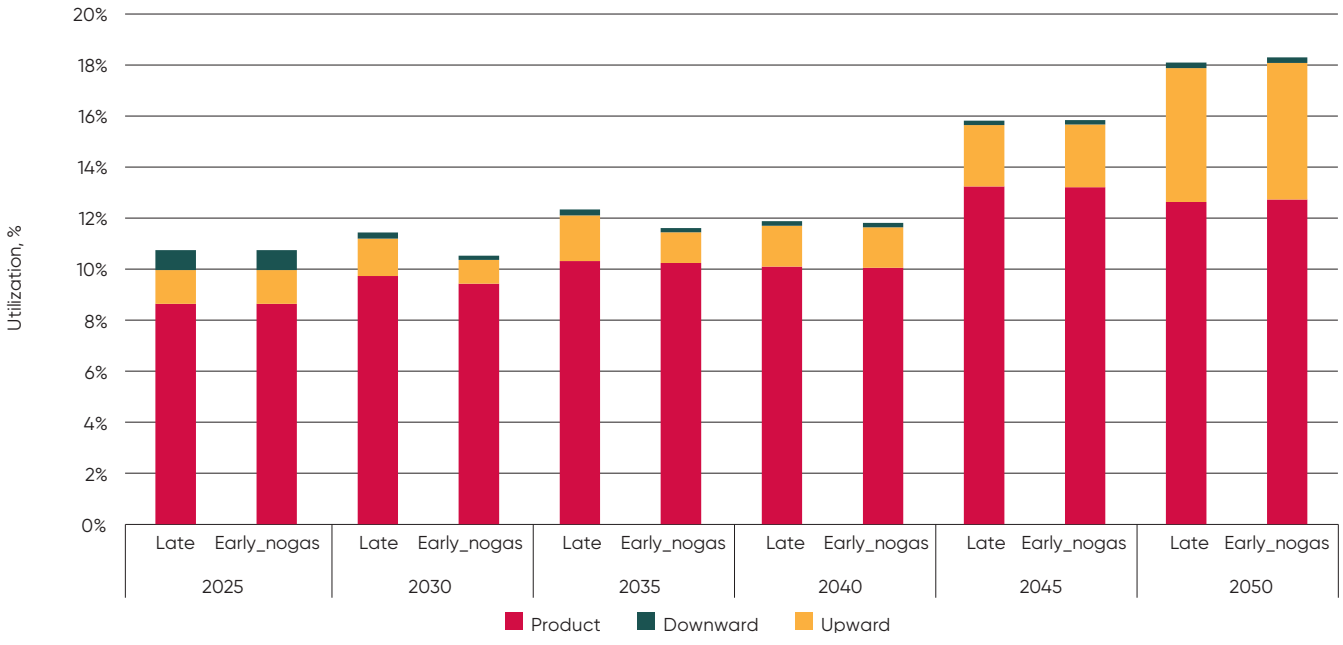
Figure 4. Natural Gas Utilisation in the Bulgarian Power System (%)



Source: European Electricity Market Model, REKK

Similar to the role of natural gas in the Bulgarian power market, the utilisation of the projected pumped and battery storage capacities remains relatively low. In both scenarios, the batteries are active in the product and upward reserve market, and there is little difference between the two pathways. The 10% average utilisation rate until 2035 reveals a one cycle/day operation mode.

Figure 5. Utilisation of the Installed Power Storage Capacities in the Bulgarian Power Market (%)



Source: European Electricity Market Model, REKK

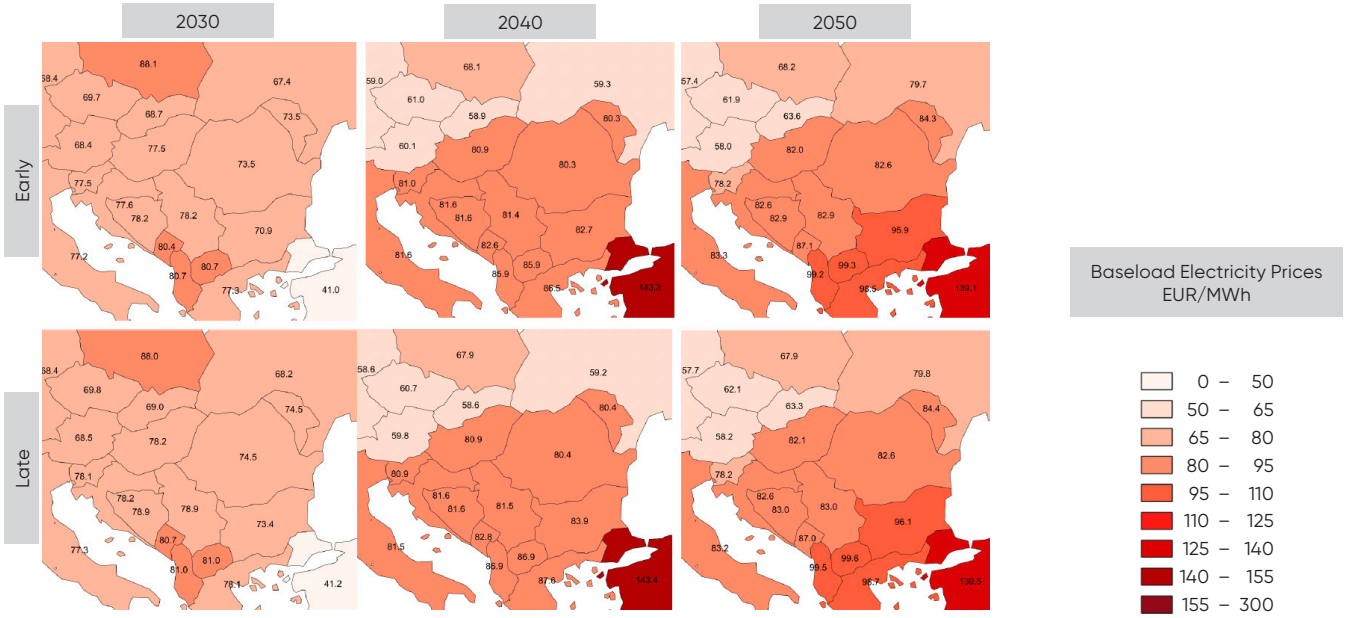
Batteries become much more active after 2040 reaching over 15% utilisation as in line with the expected concurrent phaseout of natural gas plants, storage technologies start playing much bigger role in the upward reserve market.

In the context of the EU transition to carbon-neutrality by 2050, for Bulgaria, a divergence from the pathways described above would mean higher energy and climate security risks, linked to a high exposure to the inherent volatility of fossil fuel prices as vividly revealed by the energy price crisis since August 2021, exacerbated by the Russian invasion in Ukraine. Going forward, the economic feasibility of operating coal- and gas-fired power plants will decline on the back of rising fossil fuel and ETS quota prices, to the point where they could become stranded assets. To avoid a fossil fuel lock-in, the Bulgarian government should develop a plausible and detailed strategy for the phase out of coal and gas-fired power plants as soon as possible, and ensure the uptake of renewable energy sources.

Impact on Prices

Despite the strong price volatility in the past two years, which has been linked to the geopolitical tensions and the associated rise in natural gas prices, it is likely that regional wholesale electricity prices will steady over the next three decades. Coal phase out does not have a significant impact on prices and market outcomes as even with the coal power plants present their utilisation is less than 5% from 2030 onwards. Baseload electricity prices are expected to increase to 122 EUR/MWh by 2025 before moderating to the range of 80-90 EUR/MWh in the 2030s. Price differences across the two scenarios are relatively low, largest in 2030, at 1.4 EUR/MWh.

Figure 6. Baseload Electricity Prices (EUR/MWh)



Source: European Electricity Market Model, REKK

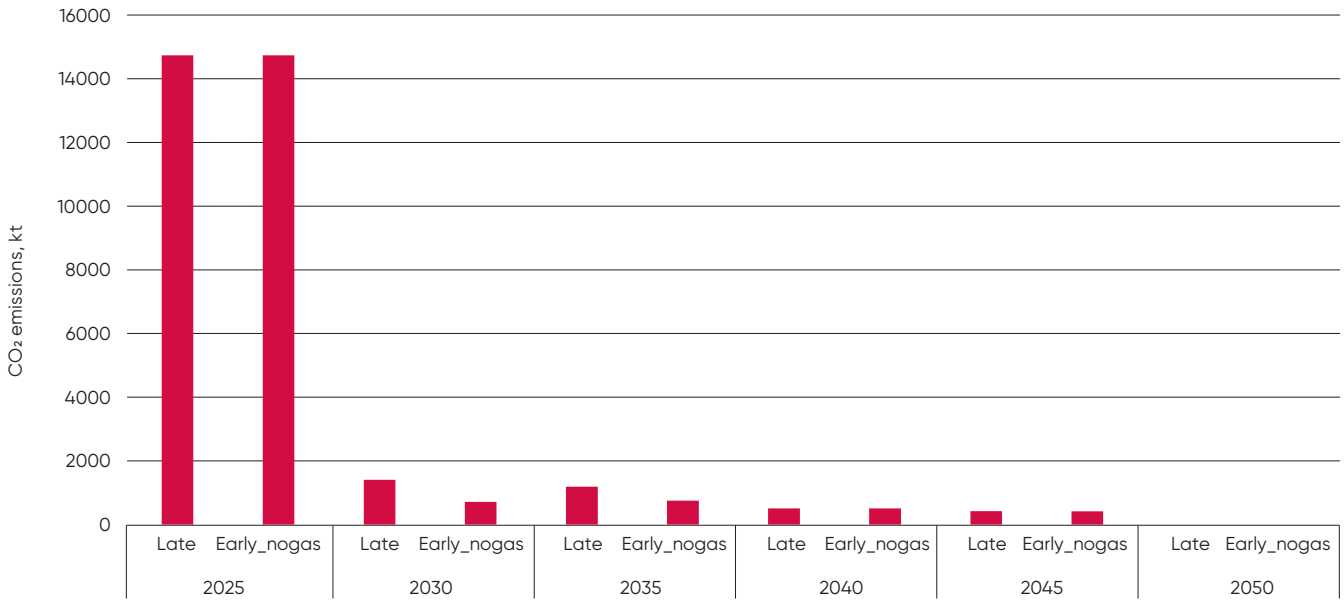
Prices in the early decarbonisation scenario tend to be generally lower based on two main factors. First, due to the low utilisation of coal and the associated CO_2 emisssions, there is lower production of lignite based electricity, and, hence, lower prices of the power mix. This is especially true for the late phase-out scenario where the coal power plants remain the longest in the system. Second, in the early scenario, there is higher penetration of renewables, which lowers prices.

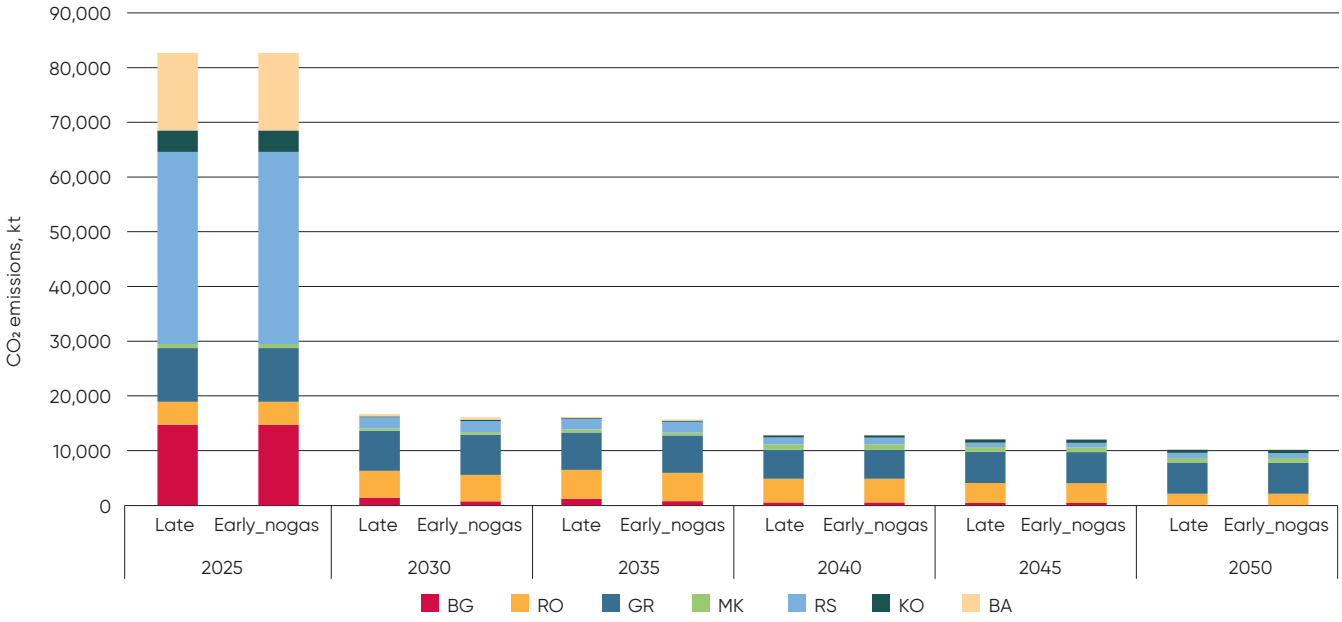
Decarbonisation Potential

The recent surge in power prices has increased the short-term profitability of lignite-based electricity, which has led Bulgarian policymakers to consider extending the lifetime of coal plants. This goes against the national target of reducing CO_2 emissions in the energy sector by 40% as outlined in the NRRP. Hence, not only was the 8% CO_2 reduction milestone for 2022 not achieved, but GHG emissions have actually increased by 15% year-on-year in 2022.

Carbon emissions remain very high at 14,000 kilotons (kt) in both scenarios in 2025 because of the still active participation of coal in power generation. After 2030, the CO_2 emission ranges between 500 and 2,000 kt depending on the year and the scenario. The late coal phaseout scenario is associated with higher emissions, relative to the scenario when coal is not present at all due to the low utilisation in the power system. The electricity sector of Bulgaria reaches zero CO_2 emissions in 2050 in both scenarios.

Figure 7. CO_2 Emissions in the Power Sector (kt) in Bulgaria and in the Region





Source: European Electricity Market Model, REKK

The overall CO_2 emissions in the region is again higher in the late scenario until 2035 with the difference being around 0.5-1 Mt. The drop in emissions is very similar in the whole SEE region as most coal power producers have committed to a phaseout timeline over the next decade. The carbon intensity of Greece remains slightly more elevated as the country remains locked-in gas-fired power generation, which, however, paradoxically, allows for a faster decarbonisation process in the rest of the region.

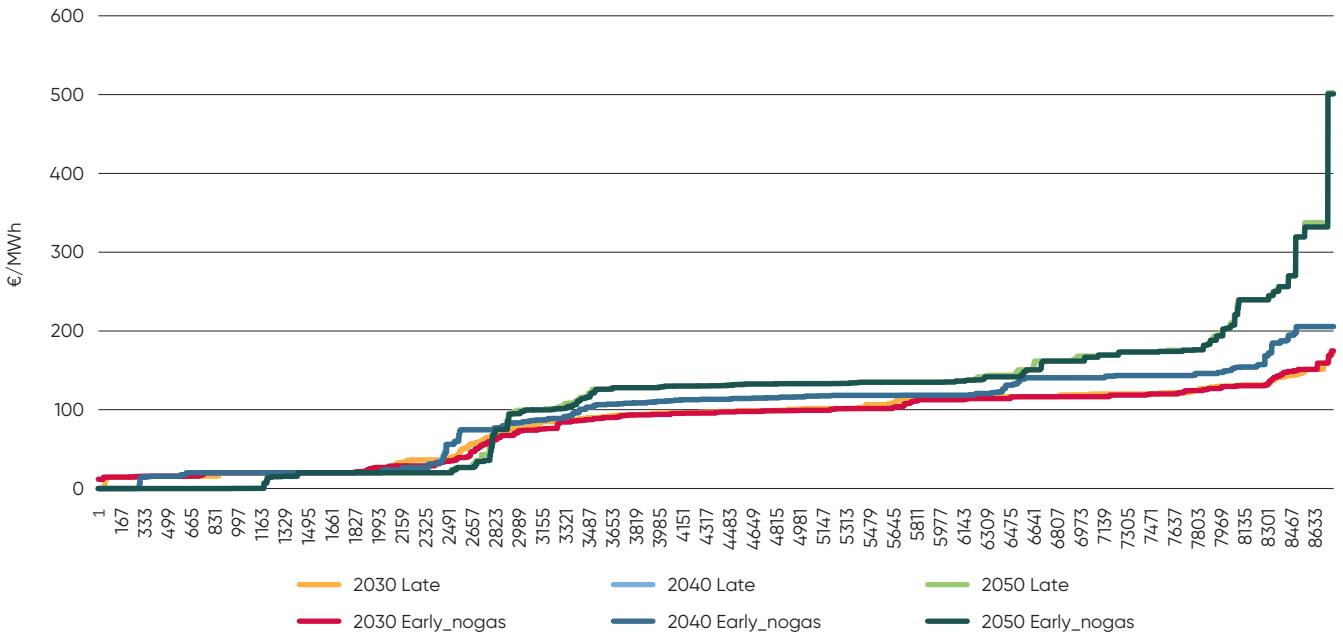
Security of Supply

In all of the modelled scenarios there is zero energy not served, no missing reserve capacity. The estimated reserve requires an increase but remains identical irrespective of the timing of coal phase-out**, as the role of coal is marginal from 2030 onwards.** There is also no occurrence of extremely high prices (indicator of a strained system), mainly because of the large storage capacities in place[7]. Yet, the number of hours with higher prices, increase from 2030 to 2040 and from 2040 to 2050. The changes in the price patterns within the different periods are similar in the two scenarios but, in general, the late phaseout scenario leads to slightly higher prices.

Meanwhile, the assessment of the different electricity flows in the region clearly shows that Bulgaria remains a net exporter of power throughout the whole period and in both scenarios. From an annual average point of view, there are large spare import capacities available in all years and scenarios. The Turkish demand is the leading determinant of Bulgarian imports and the Bulgarian-Turkish cross-border capacity is the most utilised until 2030. After that, the trade flows change but Turkey remains a critical determinant of the security of supply of the whole SEE region. In large part, Bulgaria will

[7] The highest hourly price is more than 250 EUR/MWh in 2050

Figure 8. Energy Not Served and Hourly Prices



Source: European Electricity Market Model, REKK

not observe rising security of supply risks despite the accelerated coal and gas phaseout because both Greece and Turkey have been increasing the capacity of the installed natural gas-fired power plants. In peak demand periods, these facilities will be able to cover any potential deficits on the Bulgarian market without any concerns about the adequacy of the electricity system.

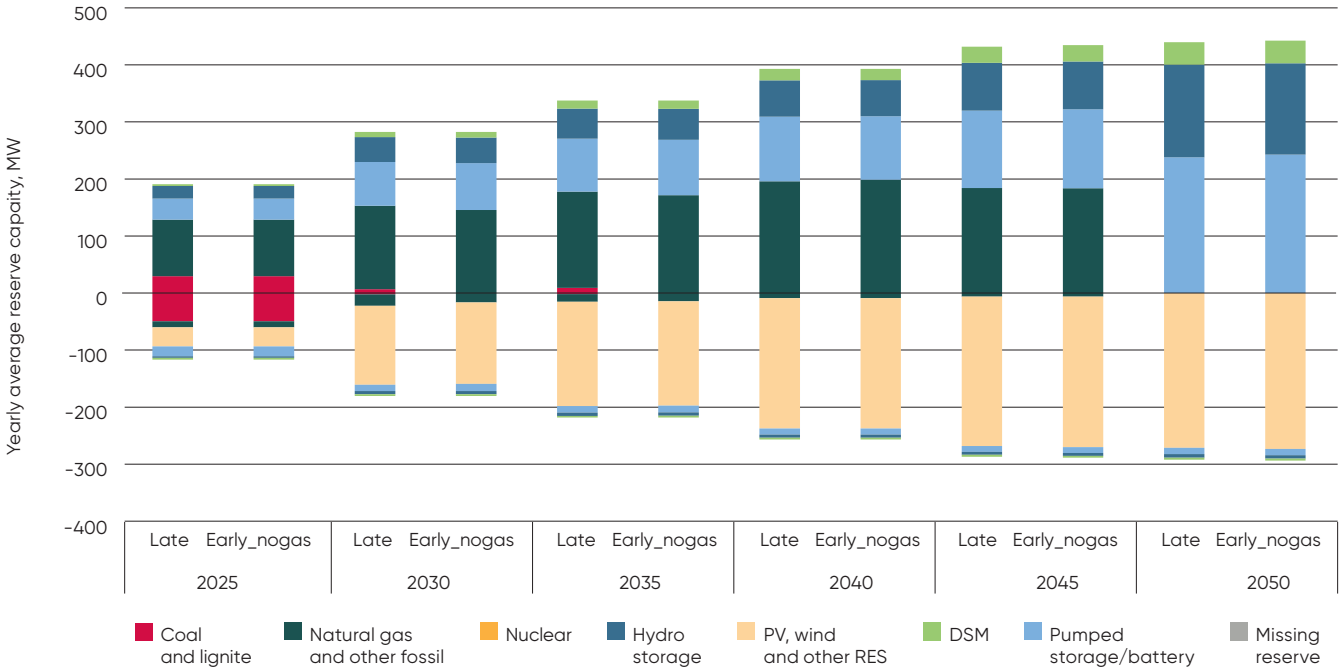
Table 2. Utilisation of the Cross-Border Power Transmission Capacity with the Different Countries Neighboring Bulgaria (% of Total Specific Cross-Border Capacity)

		2025		2030		2035		2040		2045		2050	
		Late	Early_ No Gas	Late	Early_ No Gas	Late	Early_ No Gas	Late	Early_ No Gas	Late	Early_ No Gas	Late	Early_ No Gas
Import	GR	8.7%	8.7%	30.6%	31.3%	21.4%	23.0%	17.1%	17.3%	36.9%	37.0%	33.9%	33.6%
	MK	2.1%	2.1%	5.9%	8.1%	4.9%	4.9%	14.8%	14.7%	25.0%	24.8%	16.8%	16.6%
	RO	34.4%	34.4%	52.5%	52.7%	55.0%	55.6%	66.5%	66.5%	74.1%	73.6%	73.0%	72.3%
	RS	23.5%	23.5%	22.0%	22.2%	41.4%	41.8%	52.6%	52.6%	61.7%	61.3%	56.4%	56.3%
	TR	85.8%	85.8%	71.3%	69.0%	0.2%	0.3%	0.2%	0.2%	2.7%	2.6%	7.1%	6.1%
Export	GR	57.4%	57.4%	39.9%	41.2%	44.7%	44.6%	45.2%	45.2%	27.8%	27.8%	32.6%	32.6%
	MK	65.5%	65.5%	66.3%	66.4%	50.3%	51.6%	39.5%	39.4%	30.8%	31.1%	36.6%	36.6%
	RO	21.0%	21.0%	22.9%	24.6%	16.3%	16.2%	12.0%	12.0%	8.7%	9.2%	9.3%	9.5%
	RS	42.1%	42.1%	50.0%	52.5%	28.6%	28.2%	22.4%	22.4%	17.0%	17.4%	18.4%	18.4%
	TR	9.4%	9.4%	24.2%	24.6%	42.7%	42.3%	92.5%	92.5%	80.5%	80.6%	69.9%	70.1%

Source: European Electricity Market Model, REKK

Although the fossil fuel phaseout does not have a negative impact on the overall adequacy of the power system, both the Transmission System Operator (TSO) and the District System Operators (DSOs) would need to strengthen their capacity to manage the system in a much more dynamic environment. The excess supply of renewables means that the estimated reserve need increases from almost 200 MW (upward) and 100 MW (downward) in 2025 to 400 MW (upward) and 300 MW (downward) until 2050, due to the increasing intermittent generation and growing consumption.

Figure 9. The Balancing Reserve Market in Terms of Yearly Average Reserve Capacity (MW)

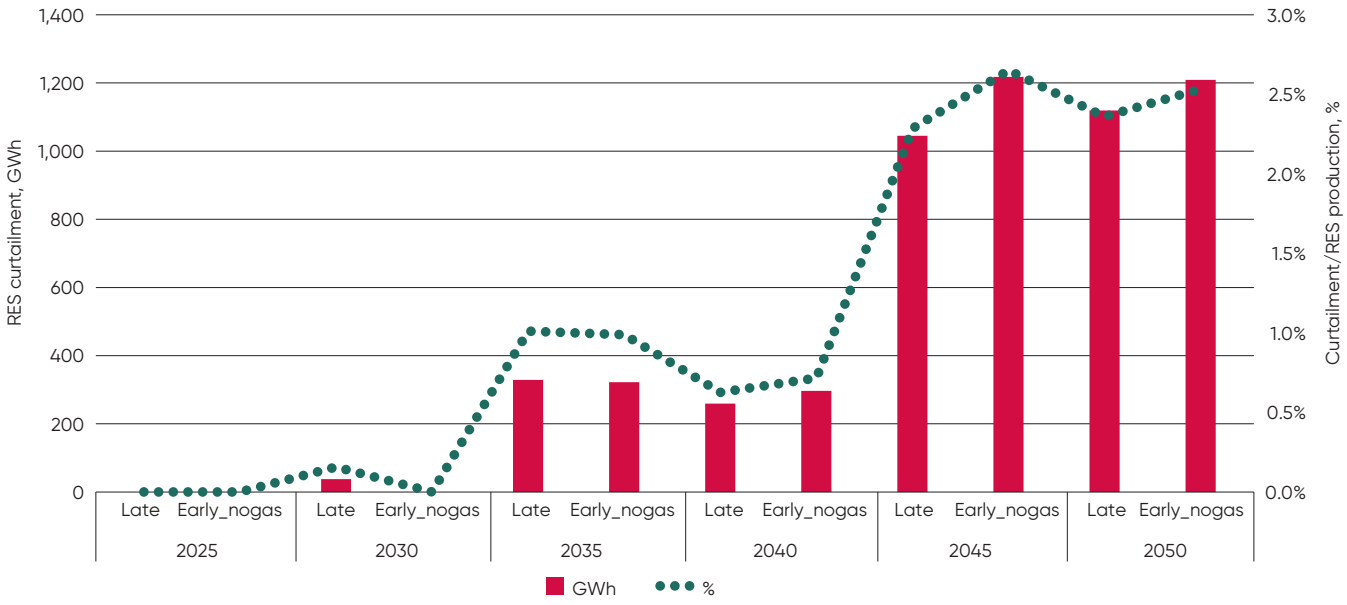


Source: European Electricity Market Model, REKK

The reserve market constitution is almost identical in the two scenarios. In 2025 the role of coal/lignite is large in both directions but their participation disappears after the expiration of state support mechanisms. The most important market participant is natural gas in upward direction and renewables in the downward direction. Although battery storage is installed in large quantities on the back of abundant EU public funding, natural gas remains the main upward reserve technology until its phase out in 2050.

One of the potential risks to the system comes from the need for partial curtailment of renewables as the massive investment of intermittent solar and wind could lead to unmanageable surpluses of electricity in certain times of the day. RES curtailment is not necessary until 2025 but it increases both in relative and absolute terms from 2025 to 2050 in both scenarios. In 2030, RES curtailment is less than 0.5%, in 2035-40 around 0.5-1%, while in 2045-50 it reaches 2.5% of total RES generation. Until 2035, the RES curtailment is

Figure 10. The Level of Curtailment of Renewables in GWh and as % of Total RES Production



Source: European Electricity Market Model, REKK

higher in the late scenario as coal and gas are blocking the full utilisation of the renewable capacity, but the trend changes and curtailment is more significant in the early scenario in the 2040s when even natural gas-fired power generation declines.

WHAT'S NEXT?

The modelling assessment, presented in this report, reveals that the Bulgarian economy is fully capable of achieving carbon neutrality until 2050 without a considerable increase in electricity prices, increased gas capacity and/or coal power generation. There are no security of supply risks identified in Bulgaria in any of the modelled scenarios, energy not supplied is 0 (zero) and extreme market prices are rarely present even in 2050. As a result, coal phase out does not have a significant impact on prices and market outcomes as even with the coal power plants present their utilisation is less than 5% from 2030 on.

Despite this overwhelming evidence about the feasibility of the decarbonisation process in the electricity sector, successive Bulgarian governments have failed to set a clear coal phaseout timeline risking Bulgaria and its region's continued and widening lagging behind its EU peers, a long-term and costly lock-in, stranded assets and human capital, and a delayed low-carbon technology deployment. In the proposed version of the ETC report, underpinning the carbon neutrality roadmap, the Ministry of Energy has exogenously included two new nuclear power reactors (most likely at the NPP Kozloduy) with combined installed capacity of 2 GW to be phased in 2035 and 2040. The addition of large-scale baseload power generation capacity is not justified by the assumptions in the cost-optimisation modelling exercise.

Consequently, the Ministry of Energy report has artificially and unrealistically lowered the expected additions of new RES capacity in the system despite the objections of most members of the ETC and the fact that the LCOE of new solar and wind power plants is much lower than those of new nuclear or fossil-fuel-based plants. The ETC report further steps on a pessimistic view about the private investment appetite in low-carbon technologies, an exaggerated need for 1 GW of surplus available capacity for peak demand period coverage, and the unrealistic vision that in case of extreme weather cross-border power trading would necessarily be fully banned. The latter argument stands in stark contrast with the EU energy competition rules, the multiple available studies by ENTSO-E about the regional-level power system adequacy, and the common objective and planned investments of all regional TSOs to increase cross-border power transmission capacity and, in general, security of supply cooperation.

The modelling based on the EEMM, conducted by REKK, does not validate the results of the Ministry of Energy-commissioned electricity dispatch assessment, which argues for a delayed coal phaseout, and insists that there would be a significant increase in gas-fired generation. The EEMM-based analysis, proposed here, reaches very similar conclusions in terms of power prices, expected changes in power trading flows in the SEE region and the deployment of renewables. However, it does not show the need for the preservation of any role for coal in neither the product, nor in the reserve market beyond 2030. The more realistic analysis of regional security of supply trends significantly moderates the need for additional gas-fired power generation and battery storage capacity.

Therefore, the current modelling analysis, confirms previous EU-backed conclusions that the Bulgarian government should set a clear timeline to decarbonise the power mix by focusing first and foremost on unlocking renewable energy investment and on strengthening the resilience of the power transmission and distribution systems. The following set of measures is a non-exhaustive list of short and long-term policy actions, which could enable the unlocking of Bulgaria's decarbonisation potential in the most contentious power supply segment:

- Accelerate the coal phaseout so that all coal power plants exit the power system by 2030. Bulgaria should renounce its plans to start negotiations on scrapping the commitments under the NRRP to reduce GHG emissions in the energy sector by 40% until 2026;

- Ensure that no state support (subsidies) mechanisms for coal and natural gas plants are in place after 1 January 2025;

- Establish a clear timeline for the transformation of coal-dependent regions by effectively utilising available technical assistance programs, the Just Transition Facility, the REPowerEU, and the Modernization Fund for economic restructuring, reskilling of workers, the smart specialisation of innovative industries, and the deployment of renewable energy and storage technologies;

- Shelve the construction plans for a new nuclear power plant until after 2040, while in the meantime launching a revaluation of the need for a new large-scale baseload capacity to cover the balancing needs left by intermittent renewable energy-based power supply.

- Avoid the overbuilding of expensive (in particular if centralised) battery storage capacity, which may not be necessary to balance the power system before the full phaseout of coal and the gradual decline of gas-fired power generation. The decision for power storage deployment should be based on case-by-case assessment of the balancing needs of individual RES power plants or (mainly) industrial consumers.

- Focus efforts on implementing comprehensive energy efficiency measures making savings one of the main priorities in the country's energy strategy. This would reduce security of supply concerns and would increase the resilience of the power and gas transmission networks;

- Develop a comprehensive policy and regulatory framework for RES deployment, which requires as an important milestone the establishment of a centralised model for planning and grid access allocation based on transparent criteria and publicly available information about grid connection costs;

- Introduce amendments to the RES regulatory framework in order to derisk renewable investments and enable RES investors access to low-interest capital;

- Adjust the power market design by introducing Contracts for Differences (CfDs), auctions, corporate Power Purchase Agreements (PPAs), a market for green certificates, green procurement requirements to attract private investment and to reduce the volatility of renewable energy business models.

- Unleash Bulgaria's enormous offshore wind energy potential by adopting an enabling regulatory framework and maritime spatial plans, coordinating with neighbouring Black Sea countries the exploration and site development activities for offshore parks. Launch competitive auctions to attract large-scale international investors[8].

- Prioritize in the design of funding instruments the development of smart grid capacity, which provides better integration of a large number of renewable energy-based power plants in the electricity system, and improved management of its balancing needs, and presents an important technical pre-condition for demand response management;

- Promote active energy citizenship by developing a new, comprehensive legal framework which transposes the EU's Renewable Energy Directive, and enables citizens to become energy prosumers. A key first step would be to remove all legal and administrative barriers for small-scale citizen- and community-driven RES projects, and to allow net-metering-based market participation for all RES producers, no matter the size of their plants.

- Develop a new evidence-based energy strategy, with in-built continuous regular (e.g. bi-annual) update cycle, which steps on the comprehensive stakeholder engagement process within the ETC, fosters expert knowledge exchange, improves policy coordination, and ensures transparency and legitimacy of the drafting and updating of other core strategic documents.

[8] Trifonova, M., Vladimirov, M., and Benov, V., *The Energy Security and Innovation Nexus: Towards a New Regulatory Framework for Offshore Wind Energy Development in Bulgaria*, Sofia: Center for the Study of Democracy, 2022.