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The Contours of Bulgaria's Climate Neutrality Roadmap

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DEMOCRACY

Russia's war in Ukraine has pushed the EU to step up its decarbonization plans, which have been temporarily disrupted by the Kremlin's weaponization of energy supplies in Europe. The EU has underpinned Europe's green transformation with the ambitious 'Fit-for-55 package', which has been reinforced by the REPowerEU initiative. Within this long-term framework, the energy and climate targets of individual member states should step on the use of a data-driven analysis of the potential decarbonisation pathways and of the array of measures at the governments' disposal. Bulgaria is yet to agree on a unifying strategy and faces numerous challenges in decarbonizing key sectors.

A comprehensive overhaul of the country's energy and climate policy framework is needed to unlock its potential for green economic transformation and energy diversification. This report is the outcome of CSD's work on designing decarbonisation trajectories for Bulgaria using scenario modelling. The analysis considers the feasibility of Bulgaria's current long term decarbonisation framework and zooms into the five key economic sectors: energy, buildings, transportation, industry, and agriculture and land use. For the first time, an assessment of Bulgaria's decarbonization strategy integrates effort sharing targets in the scenarios for Bulgaria as part of the EU's Effort Sharing Regulation.

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AFOLU	Agriculture, Forestry and Other Land Uses
BEMS	Building Energy Management Systems
BEV	Battery Electric Vehicle
BIM	Building Information Modelling
BMS	Building Management Systems
CAP	Common Agricultural Policy
CAPEX	Capital Expenditures
CCUS	Carbon Capture, Utilization and Storage
CH_4	Methane
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
CSD	Center for the Study of Democracy
CfD	Contract for Differences
DG	Directorate General
EEA	European Environmental Agency
EPBD	Energy Performance of Buildings Directive
ERAA	European Resource Adequacy Assessment
ESR	Effort Sharing Regulation
ETC	Energy Transition Commission
ETS	Emissions Trading System
EU	European Union
EV	Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
GHG	Greenhouse Gasses
GW	Gigawatt
Ha	Hectare (1 hectare = 10,000 square meters)
ICE	Internal Combustion Engine
IEA	International Energy Agency
KEP	Commission for Energy Transition
KPI	Key Performance Indicator
Kha	Kilo hectare (1 kilo hectare = 1,000 hectares = 10 million square meters)
LTS	Long Term Decarbonisation Strategy
LULUC(E)F	Land Use, Land-Use Change and Forestry
Mha	Million hectares (1 million hectares = 10 billion square meters)
MW	Megawatt
MWh	Megawatt-hour
$MtCO_2$	Metric tons of carbon dioxide

$MtCO_2e$	Metric tons of carbon dioxide equivalent
N_2O	Nitrous Oxide
NECP	National Energy and Climate Plan
NGO	Non-Governmental Organisation
NRRP	National Recovery and Resilience Plan
NVE	Norwegian Water Resources and Energy Directorate
OECD	Organisation for Economic Cooperation and Development
PHEV	Plug-in Hybrid Electric Vehicle
PM	Particulate Matter
PPA	Power Purchase Agreements
PV	Photovoltaics
RES	Renewable Energy Source
SEE	Southeast Europe
SO_2	Sulfur dioxide
TWh	Terawatt-hour
UNFCCC	United Nations Framework Convention on Climate Change
WEM	With Existing Measures

EXECUTIVE SUMMARY

In the aftermath of the Russian invasion in Ukraine, the EU has raised its overall decarbonisation ambitions via the REPowerEU initiative. The EU has defined a new energy and climate security strategy that aims to **decouple from the dependence on fossil fuel imports** on the basis of accelerating renewable energy investments, boosting energy savings and diversifying and **friendshoring** supply of energy and materials.[1] Yet, amid continuing political instability, Bulgaria has been reluctant to update its 2030 climate targets.[2] The country can utilize the EU funds at its disposal to create the necessary investment environment for ushering a **private sector and citizen-led switch to renewables** *en masse*. Instead Bulgarian policy-makers remain focused on a few unnecessary large infrastructure projects and the preservation of coal, beyond agreed deadlines. Without an effective and transparent spending plan with long-term objectives and indicators for success, the transition could cause a popular **backlash**.

The current analysis aims to draw the key policy lessons from the introduction of the ***Pathways Explorer-based*** decarbonisation scenarios for Bulgaria into the report of the national Energy Transition Commission (ETC), the body that will form the basis for the country's ***Climate Neutrality Roadmap by 2050*** (also a milestone of the National Recovery and Resilience Plan (NRRP)). These decarbonisation scenarios include:

- **WEM (With Existing Measures):** approximates the Bulgarian Reference scenario in line with the European Environmental Agency's (EEA) 2020 WEM scenario. It assumes a continuation of current trends and policies.

- **KEP:** steps on the vision jointly developed by the members of the ETC in cooperation with the Ministry of Energy and the European Commissions. The scenario envisions coal phaseout by 2030, i.e. the more ambitious scenario of the two constructed by the ETC. The other one sees coal phased out by 2038.

- **LTS:** presents a Long-Term Strategy for decarbonisation, which sets out more ambitious long-term decarbonisation targets leading to carbon neutrality by 2050. It assumes transformational behavioural changes that imply lifestyle changes and lead to a decentralised, citizen-oriented energy system with 100% renewable energy.

This assessment considers the feasibility of Bulgaria's current long term decarbonisation framework and zooms in on the five key economic sectors: energy, buildings, transportation, industry, and agriculture and land use (LULUCEF).

[1] Vladimirov, M., Rangelova, K., and Dimitrova. A., *The Great Energy and Climate Security Divide: Accelerated Green Transition vs. the Kremlin Playbook in Europe*, Sofia: Center for the Study of Democracy, 2022.

[2] Center for the Study of Democracy, *Tackling the Energy and Climate Security Conundrum in Southeast Europe*, Policy Brief No. 110, May 2022.

For the first time, the assessment **integrates effort sharing targets** in the scenarios for Bulgaria as part of the EU's Effort Sharing Regulation (ESR). None of the existing modelling assessments of the country's decarbonisation policy has so far included the 'Fit-for-55' policy framework, in which the European Commission (EC) has proposed new effort sharing targets in line with the 55% emission reduction goal for 2030. The assessment of the decarbonisation pathways in the current exercise will assist the Bulgarian government in developing adequate policy measures that raise the country's 2030 and 2050 climate ambitions.

Energy Supply

Decarbonising the Bulgarian economy requires a **deep transformation of the national energy mix** towards low-carbon sources. The decarbonization of power and heat production is crucial, as the latter accounts for about **two-thirds of all total national greenhouse gas** (GHG) emissions. Moreover, decarbonising electricity production is a key step in ensuring the electrification of final energy use, in particular in the buildings, transportation, and industry sectors.

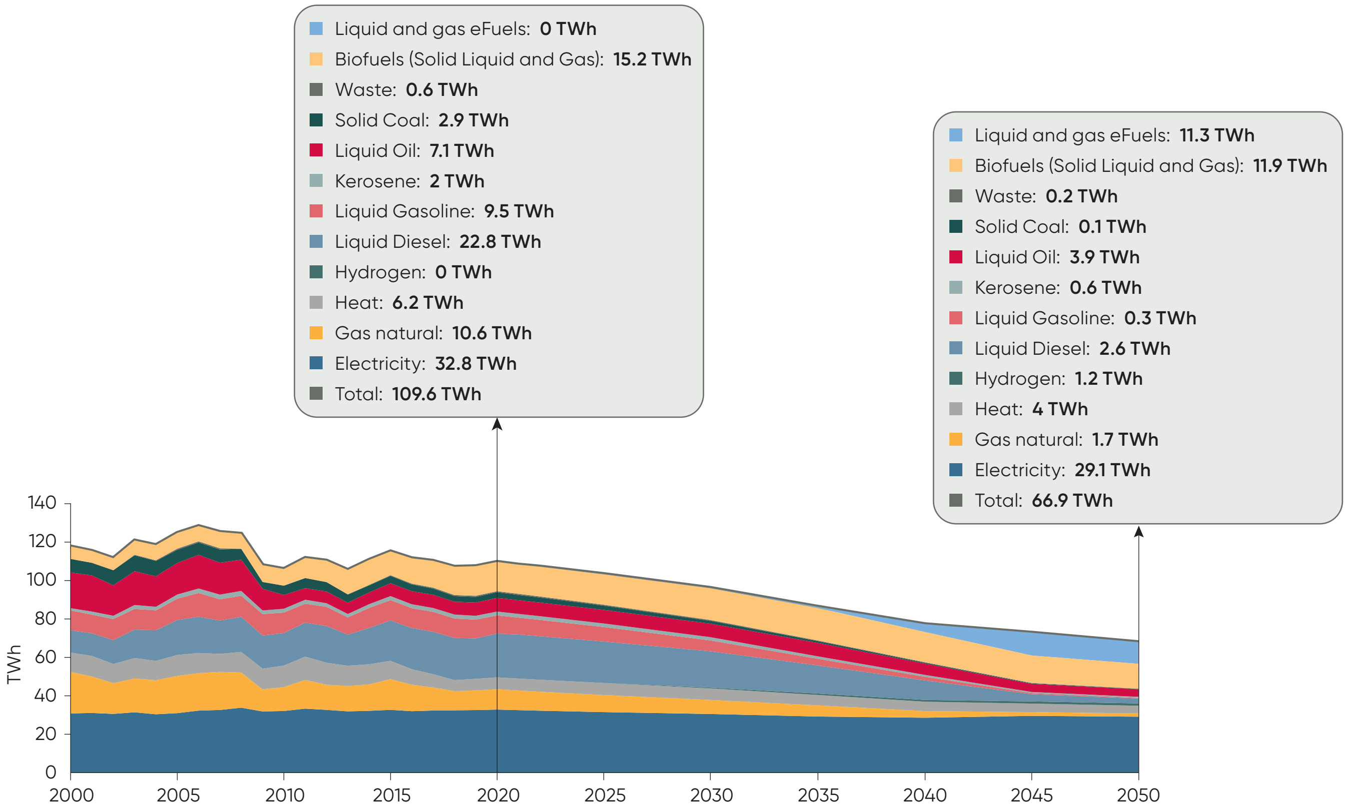
Any divergence from the path of the EU's transition to carbon-neutrality by 2050 would mean higher energy and climate security risks for Bulgaria, linked to a high exposure to the inherent volatility of fossil fuel prices. This has been vividly revealed by the energy price crisis, which started in August 2021, and was further 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 carbon prices (Emissions Trading System – ETS allowances), 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.

While the energy supply has the potential to transition to carbon-free energy sources, there is also significant scope for achieving large **energy efficiency** gains. Therefore, to achieve the EU's and national decarbonization targets, it is necessary to electrify all national economic sectors promptly and ensure carbon-free energy carriers.

Scenarios aimed at **achieving the net-zero emissions target** by 2050 can be achieved by using low-carbon fuels such as biogas, liquid biofuels, liquid and gas e-fuels, hydrogen, and renewables. Following global trends, in Bulgaria, solid coal will almost disappear as a vector in final energy consumption by 2050, compared to 2.9 TWh in 2020. The share of natural gas will shrink six-fold over the same 30-year period, while liquid oil's share will decrease by over 50%. Together, renewables and low-carbon fuels will account for more than half of the final energy in 2050.

Zooming in on the **electricity sector**, all three decarbonization pathways – the WEM, KEP, and LTS scenarios – predict a growth in power demand by 2050. In the WEM Scenario, power consumption increases by 42 % between

Final Energy Consumption in Bulgaria in the LTS Scenario by 2050



Source: CSD developed scenarios based on the Pathways Explorer.

2015 and 2050 or 1.4% per year on average. This trend is mainly driven by the electrification of the transport sector, particularly between 2025 and 2030. In contrast, demographic changes combined with modest energy savings in buildings are expected to decrease power demand in the residential sector by 0.7% per year or 20% for the period 2015-2050. The other two scenarios are expected to achieve more significant savings in the building sector – between 40% to 42% – through targeted and ambitious actions focused on improving energy efficiency and implementing deep renovations. These figures are in line with other European models.

The KEP and LTS pathways envision an **accelerated coal phaseout**, and lignite is substituted with a mix of PV and wind (onshore and offshore) in combination with battery storage already by 2030. Following the GHG emission reduction trajectories in the energy sector, the KEP scenario replaces 2/3 of the fossil-fuel based power generation with renewables by 2025 achieving 53% CO_2 emissions cuts.

The accelerated coal phaseout comes on the back of the **increasing costs for coal-based power generation** as the price of ETS allowances stays consistently around EUR 100/ton raising the marginal cost of the existing coal fleet in Bulgaria to levels above the expected wholesale power price. No new fossil gas plants are added to the system and gas-fired power generation remains online only in CHP mode as a by-product to heat generation in district heating plants.

The LTS scenario envisages Bulgaria to phase out coal and gas-fired power generation completely by 2030, with the largest power plants already shut down by 2025. This scenario achieves carbon neutrality in the entire economy and aims for 70% CO_2 savings by 2025. The LTS assumptions about renewables uptake are ambitious, and both coal and natural gas load factors decrease significantly after 2025. This suggests that new **investments in conventional technologies are not economically feasible** due to the oversaturated electricity market.

To keep pace with these ambitious targets, Bulgaria should **invest in the electricity transmission and distribution grids**, so that they could accommodate annual additions of 1 to 2 GW of renewable energy capacity in the system. The completion of these grid investments requires a comprehensive policy framework, risk-sharing instruments, transparency in terms of grid planning and capacity allocation, as well as improved coordination and cooperation among authorities managing the permitting process. **Innovation** is key to developing new clean energy technologies and advancing existing ones. Almost 50% of the emissions reductions needed for reaching climate neutrality depend on **technologies that are at the prototype or demonstration stage**, are not yet available on the market or are conditioned by specific infrastructure constraints.

To accommodate a higher proportion of intermittent renewable energy-based power plants, Bulgaria must invest significant public resources in **upgrading the national energy infrastructure**. Many transmission and distribution lines are outdated and not properly maintained, which can result in frequent power outages and blackouts. In order to maintain a secure power supply, dispatchable renewables, in combination with other low-carbon generation units, battery storage, and robust and well-interconnected electricity networks, are critical. Smart meters are also essential for the improved integration of decentralized power producers.

Buildings

A key factor for lowering GHG emissions in the buildings sector is the **reduction in overall energy demand** and the acceleration of the pace of **electrification**. The decline in emissions is driven by the phase out of coal, solid biofuel (firewood), natural gas, and liquid fuels in exchange for electrification, and the uptake of alternative fuels. The three scenarios examined in the buildings sector explore different indicators including the type of residential and service building construction technologies, heating and cooling behaviours, low-carbon heating solutions and buildings envelope renovation. All pathways show that **heating** will remain the most significant component of energy demand for the next 30 years. However, phasing out coal and solid biofuels in favour of electrification and improved ventilation could reduce consumption by more than 50%, as demonstrated in the *LTS Scenario*.

Energy consumption in buildings can be also significantly impacted by the daily behaviours and choices of their inhabitants. Individuals can make different choices to optimise their **energy consumption patterns**. Adjustments in daily routines may reduce household costs, carbon emissions, and relieve the pressure on the electrical grid during peak demand periods.

More structurally, to achieve carbon neutrality in buildings, it is crucial to reduce the per capita demand for additional residential surfaces. Currently, **more than 30% of dwellings in Bulgaria are not inhabited**, while around 40% of people live in crowded housing, which necessitates more efficient use of existing and new building stock

Instead of fuelling the new-building construction bubble, the government should rather focus on measures and support tools that incentivize the **renovation of empty, old buildings** – an approach that could be instrumental for lowering emissions in the buildings sector. The use of commercial buildings should also be optimized to reduce surface demand for businesses.

Transportation

Transportation is the second-largest contributor to greenhouse gas emissions in Bulgaria, with a continuous increase in its share of overall emissions, currently accounting for 19% of the total. **Mass transport electrification** is key to decarbonizing the sector in the future.

In the WEM scenario, emissions peak in 2025 at 10 $MtCO_2e$ and decrease to 6.1 $MtCO_2$ by 2050, with passenger emissions driving the majority of the decarbonization. The KEP scenario predicts emissions will decline by close to 60% in 2050, dropping from 9.8 $MtCO_2$ in 2025 to 4.2 $MtCO_2$, with a reduction in liquid oil consumption and a significant increase in the use of electricity. Meanwhile, the LTS scenario expects GHG emissions to decrease by 85% by 2050, with a considerable reduction in the use of liquid fuels and a decrease of over 50% in total energy consumption in the transport sector. However, none of the scenarios predict significant changes in behaviour that would incentivize **sustainable mobility**. Although the LTS scenario brings Bulgaria closer to meeting EU transport climate neutrality targets, the main obstacle to decarbonization is changing key behavioural drivers in the sector for both passengers and businesses.

The assessment recommends a two-step approach combining structural optimization with the current policy ambitions of the Bulgarian government directed towards the introduction of a **cleaner fuel mix** and a **new generation of vehicles** in the passenger segment of the market. The reliance on single technology-driven measures is not sufficient for a deep transformation of the transportation system towards a more sustainable future, and more ambitious policy approaches are necessary to achieve a significant reduction in energy use.

Industry

Bulgaria faces a significant challenge in decarbonizing its industry and lowering energy and carbon intensity. The country’s strategic framework focuses primarily on transforming the energy sector, leaving industrial decarbonization largely unaddressed. The WEM scenario, which continues current policies, sees stronger decarbonization due to the electrification of industrial demand and moderate phaseout of oil, coal, biomass, and gas. In contrast, the KEP scenario, reflecting Bulgaria's current economic development vision, almost doubles natural gas and coal consumption by 2050, driving up carbon intensity. The more ambitious LTS scenario shows a much greater potential for decarbonization in industry but **requires significant state support**, such as tax incentives, loan programs, and high manufacturing standards, to encourage circular economy supply chains with high material efficiency. This support is crucial for accelerating the transition to alternative processes using renewable energy and green hydrogen, or a combination of renewable energy and Carbon Capture, Utilization, and Storage (CCUS) technologies, especially in chemicals, iron, steelmaking, cement, and ceramics. Upgrading existing facilities to produce **synthetic fuels** on a sectoral level would require substantial initial capital investments, which can be covered through dedicated support. Without these measures, the LTS scenario remains unlikely.

Agriculture, Forestry and Other Land Uses (AFOLU)

Bulgaria **lacks well-defined policies** and measures for reducing greenhouse gas emissions from the Agriculture, Forestry and Other Land Use (AFOLU) sector, hindering the creation of specific scenarios for emissions reduction and carbon sequestration. The three elaborated scenarios are based on the EU's environmental, climate, and biodiversity protection commitments, but there is a lack of clarity on the extent of necessary measures and targets for emissions reduction in the draft national strategic plans in relation the Common Agricultural Policy. The scenarios predict emissions trajectories based on current forest management strategies, trends in the development of the agriculture sector, and the possible effect of less intensive agricultural practices. The LTS scenario is more ambitious and aims to reveal the potential evolution of emissions and carbon removals with more integrated actions. The land allocations and land-use changes, emissions and removals from forest lands, and emissions associated with agricultural soil management are the main drivers of emissions trends in all scenarios. The direct effects of behavioural changes on emissions reduction, such as meatless diets, limited consumption, and food waste management, are not considered, but they can contribute to changes in emissions through land allocation.

* * *

The **delayed debate** about the impact of the European Green Deal on a national, regional and local level has led to a limited progress on building a consensus around common decarbonisation strategies in Bulgaria. There is an urgent need for a **long-term national data-based energy transition policy** with consistent targets, concrete milestones and policy actions. Currently, Bulgaria lacks a coherent and up-to-date energy strategy and most key policy documents reveal no clear vision for long-term decarbonisation pathways.

To enable a deep decarbonisation of the economy, the modelling scenarios show that business-as-usual and even a moderately ambitious policy strategy would not deliver net-zero carbon emissions by 2050. The EC should work with the Bulgarian government to promote the **adoption of more ambitious climate transition measures**, such as:

- **Phase out coal** as early as possible and focus on sustainable energy infrastructure and renewable energy sources.

- **Invest in innovative technologies** like offshore wind, battery storage, and smart grids and remove legal and administrative barriers for citizen-driven projects.

- The country has **enormous offshore wind energy potential** that should be explored through the passing of a regulatory framework and development of maritime spatial plans.

- **Postpone the construction of new nuclear power plants** until after 2040 and focus on implementing comprehensive energy efficiency measures to reduce energy consumption.

- Prioritize the development of **smart grid capacity** and increase the rate and depth of renovations to reduce emissions and increase energy efficiency.

- Promote **sustainable transport** through the development of infrastructure for cycling and walking and the expansion of public transport systems.

- Implement policies to **reduce the overall demand for transport** and focus on the **electrification of production processes** in the industrial sector using renewable energy sources.

- Develop a **National Forestry Strategy** until 2030 to reduce climate change-related risks for the forest ecosystem and introduce carbon farming practices to sequester carbon in the soil and in vegetation.

- **Encourage sustainable livestock management practices** to reduce emissions and explore synergies with the energy sector, such as the production of biogas and electricity from biomass.

INTRODUCTION

For Bulgaria to integrate in the European and global green economy and society in line with the EU 2050 climate neutrality ambitions, there is an urgent need for a long-term national energy policy with clear, consistent targets and policy actions. The decarbonisation of the Bulgarian economy remains a **substantial challenge that successive governments have neglected** despite the overall commitment to the EU carbon neutrality goals. Coal and lignite still dominate the national electricity generation mix, whereas lignite power plants ensure about 40% of the power generation and employ more than 43,000 workers directly and indirectly.[3] The heavy **dependence on coal** and the vocal opposition of coal-dependent regions to any economic transformation have stalled the efforts of the Bulgarian government to promote a large-scale diffusion of renewables and energy efficiency projects. So far, the Bulgarian government has failed to envision and develop a **long-term data-driven national policy framework** in line with the European Union (EU) green priorities, thereby slowing down a much-needed reduction of carbon emissions in all sectors of the economy.[4] Modelling assessments have been conducted under heavy political pressure and without transparency or justification for the elaboration of scenarios.

On the eve of the COVID-19 outbreak, on 29 April, 2020, Bulgaria launched a special Consultative Council attached to the Council of Ministers to streamline the implementation of the European Green Deal. The initial goal of the Council was to prepare a detailed analysis of the impact of the Green Deal on the Bulgarian economy and to develop inter-institutional mechanisms for its implementation bringing together stakeholders from different relevant areas.[5]

In the summer of 2022, the Council set up an Energy Transition Commission (ETC) for the development of a Roadmap to Climate Neutrality, which is incorporated as one of the key reforms foreseen in the National Recovery and Resilience Plan (NRRP). The main objective of the Commission is to **prepare evidence-based scenarios and recommendations** for the decarbonization of the Bulgarian economy that shall include steps for completing the lignite coal phase-out as soon as possible and at the latest by 2038. The developed scenarios need to be described in a report made public and addressed to the Bulgarian government. In this framework, the Energy Transition Commission should prepare **two scenarios for a coal phase-out** in Bulgaria and a gradual low-carbon transition – a more ambitious one with an accelerated shutdown of coal power generation until 2030 and another one with a coal exit date no later than 2038. As required by the Annex to the Council Implementing Decision for the approval of the Bulgarian NRRP, the ETC should involve various stakeholders to ensure expertise, independence, and pluralism.

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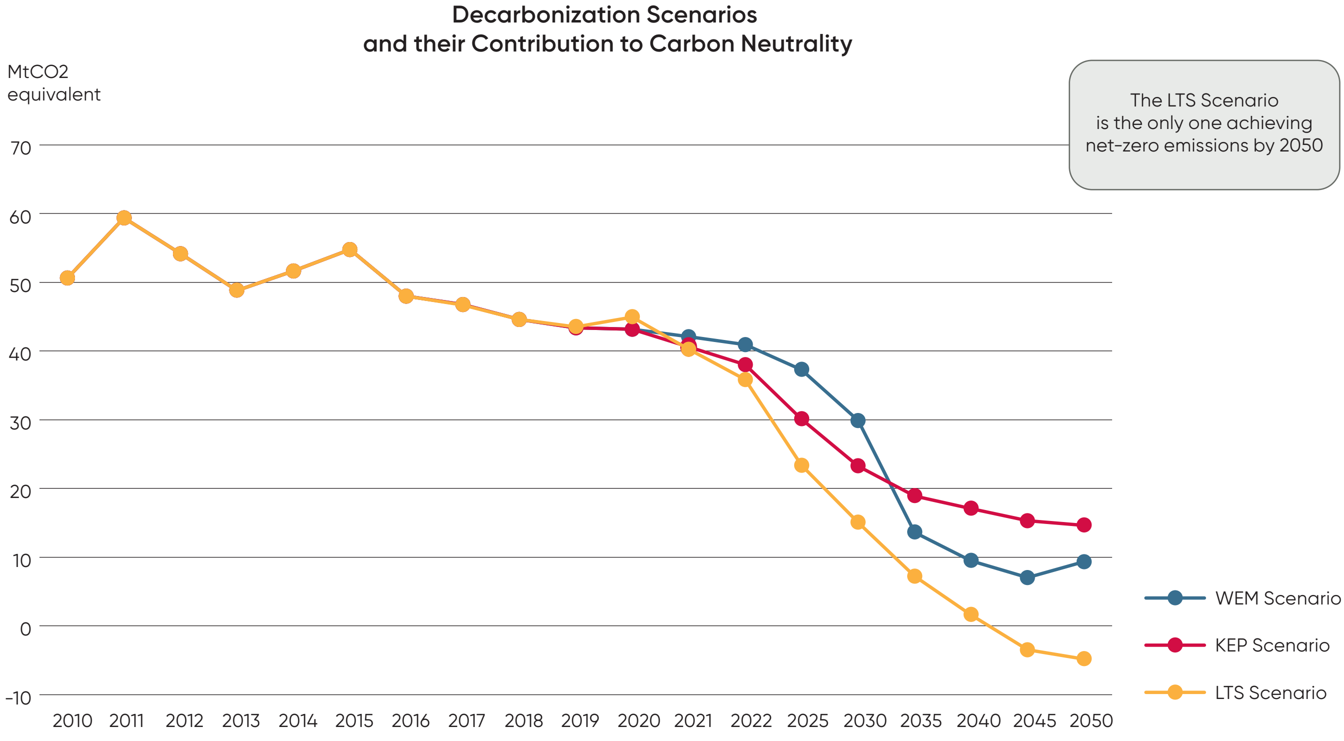
[3] László, S. et al., *Accelerated lignite exit in Bulgaria, Romania and Greece*, Joint Report by REKK, TU Wien, CSD, EPG, FACETS, 2020.

[4] Center for the Study of Democracy, *Technological and Policy Innovation Scenarios for the Low-Carbon Transition of the Bulgarian Energy Sector*, Policy Brief No. 109, April 2022.

[5] Center for the Study of Democracy, *Towards an Inclusive Green Recovery in Bulgaria*, Policy Brief No. 106, December 2021.

Applying an **interactive simulation tool**, this report compares and evaluates the more ambitious pathway to carbon-neutrality, designed by the ETC members with the outlook of accelerated coal-phaseout by 2030 (KEP) and two alternative scenarios: (i) one assessing the impact of the continuation of existing policies (WEM); and another drawing upon progressive long-term decarbonisation strategy (LTS), which includes behavioural change in addition to technological advancement. Although the KEP scenario constructed by the Energy Transition Commission leads to sharp CO_2 emissions reduction within the NRRP implementation framework, it slows down its pace after 2035 and misses the net zero target by 2050. The reason for this development lies primarily in the fact that the **KEP scenario focuses on investments and reforms in the energy sector** neglecting the potential for decarbonisation in the other economic sectors as well as possible behavioural impacts. Only the LTS pathway reaches Carbon Neutrality by mid-century.

Figure 1. Total GHG Emissions for All Economic Sectors: Buildings, Transport, Industry, Agriculture, Energy Supply, Land-Use, Waste and Others



Source: CSD developed scenarios based on the Pathways Explorer.

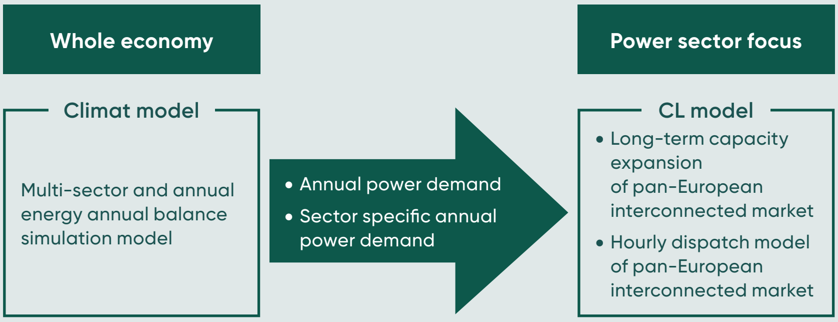
Box 1. The Approach of the Energy Transition Commission

The Energy Transition Commission (ETC) was created as a specialized sub-commission to the Consultative Council for the European Green Deal at the Council of Ministers. The ETC consists of 39 representatives of different institutional bodies, business organisations, NGOs and academic experts. Its sessions are also followed by 30 observers, members of national and international organizations. ETC's main objective is to create a Climate Neutrality Roadmap for the Economy of the Republic of Bulgaria, on the basis of two decarbonization scenarios, which include steps for a gradual coal phaseout by 2030 and beyond, but no later than 2038. The scenarios presented by the ETC should also feature policy recommendations for the enabling of the energy transition and the closing of coal power plants. The roadmap includes (1) possible pathways for decarbonizing the Bulgarian energy sector, as well as (2) possible measures for just transition, (3) financing needs, (4) environmental impact assessment, and (5) socio-economic impact. The Roadmap should be approved by the ETC, the Consultative Council for the European Green Deal, the Bulgarian Ministry of Energy, the Bulgarian Parliament, and should be agreed together with the European Commission.

The ETC has decided to integrate two different modelling assessments including the models already constructed in the Pathways Explorer tool and the 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

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 considers also the security of supply and provides projections for the regional power demand.



TOWARDS A CLIMATE NEUTRALITY ROADMAP: ASSESSMENT SCENARIOS

For Bulgaria to be in line with the **EU 2050 climate neutrality ambitions**, there is an urgent need for a long-term national energy policy with clear, consistent targets and policy actions. A **common methodology** for measuring progress towards climate neutrality is essential given the ongoing EU decision-making processes on important details of the EU Climate Law and Energy Union governance, the 8th Environment Action Programme, European Semester and Recovery process and European Green Deal Dashboard.

The current report aims to draw out the key policy takeaways from the introduction of two of the Pathways Explorer-based scenarios for Bulgaria into the report of the ETC that will be the basis for the country's ***Climate Neutrality Roadmap by 2050*** (also a NRRP milestone). These decarbonisation scenarios include:

- **WEM (With Existing Measures):** This scenario approximates the Bulgarian Reference scenario in line with the European Environmental Agency (EEA) 2020 WEM scenario. It assumes a continuation of current trends and policies.

- **KEP:** stepping on the vision jointly developed by the members of the ETC in cooperation with the Ministry of Energy and the European Commission. The scenario envisions coal phaseout by 2030, i.e. the more ambitious scenario of the two constructed by the ETC. The other one sees coal phased out by 2038.

- **LTS**: trajectory presenting a Long-Term Strategy for decarbonisation, which sets out more ambitious long-term decarbonisation targets leading to carbon neutrality by 2050. It assumes transformational behavioural changes that imply lifestyle changes and lead to a decentralised, citizen-oriented energy system with 100% renewable energy.

This assessment will consider the **feasibility of Bulgaria's current long term decarbonisation framework** and will zoom in on the **five key economic sectors**: energy, buildings, transportation, industry, and agriculture and land use (LULUCEF). For the first time, the assessment integrates effort sharing targets in the scenarios for Bulgaria as part of the EU's Effort Sharing Regulation (ESR). None of the existing modelling assessments of the country's decarbonisation policy has so far included the 'Fit-for-55' policy framework, in which the Commission has proposed new effort sharing targets in line with the 55% emission reduction goal for 2030. The ESR regulates emissions outside the EU emissions trading scheme – around 60% of total EU emissions – by setting binding national greenhouse gas (GHG) targets for each of the 27 EU Member States. The new package of measures also includes a revised version of the ETS that extends its scope to additional sectors such as maritime, as well as a new ETS for transport and buildings from 2026. The assessment of the decarbonisation pathways in the current exercise will assist the Bulgarian government in developing **adequate policy measures** that raise the country's 2030 and 2050 climate targets.

The assessment also integrates the Ecologic KPIs for measuring progress towards climate neutrality into the scenario-building for more ambitious strategic documents (NECP, LTS, Climate Neutrality Roadmap, etc.) and adapt them better to the Bulgarian energy policy landscape. The assessment uses the Pathways Explorer[6] modelling and planning instrument to estimate the increase in installed renewable energy capacity (in MW), the improvements of energy efficiency (saved MWh of electricity, heat, etc.), and the reduction of the use of fossil fuels in energy production, and in traditionally carbon-intensive industry segments (physical amounts of cement, steel, etc. produced) under different scenarios for the evolution of national climate and energy policies.

Key Assumptions per Scenario

- **Fossil fuel phaseout:** as coal-based power generation makes up more than 2/3 of GHG emissions in Bulgaria, the policy choice of a coal phaseout timeline and strategy is the most important element in the set of assumptions for each scenario (see the summary of the main assumptions in Figure 3).

In the WEM scenario, the coal phaseout begins only after 2030 and occurs gradually until 2035 when close to 4 GW of lignite capacity is shut down. Yet, in this baseline pathway, close to 0.5 GW of coal capacity remains online until 2050 as **lignite remains an important element of the electricity supply**. Meanwhile, fossil gas-installed capacity doubles to 1 GW by 2050 as it replaces the shutdown coal plants compensating for the lower integration of RES-based and storage plants in the system.

The KEP scenario follows the **framework of the NRRP** and considers all reforms and investments which the Bulgarian state committed to implement until 2026. Therefore, the scenario implies the annual caps on the carbon-intensive energy generation to ensure that CO_2 emissions reduction trajectories agreed by both the Bulgarian government and the European Commission are kept. The scenarios plan **a full coal phaseout by 2030**, which is the more ambitious of the two visions for coal phaseout that is being discussed by the ETC and should be the basis for the Climate Neutrality Roadmap as part of the NRRP implementation. No new fossil gas plants are added to the system and gas-fired power generation remains online only in CHP mode as a by-product to heat generation in district heating plants.

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[6] The Pathway Explorer 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 decarbonization trajectories and encompasses 5 main sectors: food production and land use (LULUCEF), transport, buildings, industry, and energy supply

In the LTS scenario foresees the retirement of the **largest coal power plants by 2025** and with stronger uptake of renewables, both coal and natural gas load factors increase noticeably until 2030.

Figure 2. Key Assumptions and Technical Parameters for the Three Assessed Scenarios

	ETS Split		
Key Assumptions for Decarbonisation Scenario	WEM	KEP	LTS
Coal Phaseout	After 2035	By 2030	Before 2030
RES Uptake	Based on EU Reference Scenario and NECP	Based on the NRRP	Accelerated RES Investments based on lower regulatory bottlenecks
Energy Demand	20% decline by 2050	10% decline by 2050	33% decline by 2050

Source: CSD.

- **Commodities price projections and CO_2 price:** are based on current futures market expectations of the underlying commodities. Long-term projections are derived from international energy scenario frameworks reflecting carbon mitigation ambitions in line with the present scenario set.

- **RES uptake:** the RES expansion pace is the key determined of the success of the power sector decarbonisation. The baseline WEM scenario envisions a very slow pace in RES capacity additions, and most of them come from solar PV and almost no onshore wind. Both the KEP and the LTS see **a surge in RES investments in both wind and solar power** plants as CAPEX for both technologies remain much lower than for all of the rest of available technologies and marginal costs are significantly below expected wholesale power prices. The key difference between the LTS and the KEP pathways is the speed and extent of the streamlining of regulatory and administrative frameworks for renewables investment to unlock the growth.

- **Nuclear capacity:** no new nuclear capacity is envisioned in the three scenarios. The life of the 2000-MW Kozloduy nuclear power plant is extended to 2050.

- **Energy demand:** energy consumption trajectories in all scenarios point to **a steep reduction until 2030-2035** followed by a gradual increase until 2050 but below 2020 levels. The driving forces assumed in the three pathways are improved energy efficiency and electrification of the non-ETS sectors. The different levels of energy demand reflect among other things the rate of buildings renovation, the electrification of heating and transportation and structural optimization of business processes.

- **Cutting-edge energy technologies:** a key determinant for the success of the different decarbonisation pathways is **the level of penetration of cutting-edge energy technologies, which could raise the capacity of RES electricity generation** (e.g. offshore wind), or that could replace carbon-intensive fuels in heating and industrial production (e.g. the uptake of hydrogen and synthetic fuels). Importantly, the current version of the Pathways Explorer does not model the uptake of storage technologies. However, the role of battery storage is assessed exogenously in the chapter on the energy sector below.

SECTORAL VISIONS FOR THE DECARBONISATION OF THE BULGARIAN ECONOMY

Decarbonising the Bulgarian economy requires **a deep transformation** of the national energy mix towards low-carbon sources. The decarbonization of power and heat production is crucial, as the latter accounts for about two-thirds of all total national greenhouse gas (GHG) emissions currently. Moreover, **decarbonising electricity production** is a key step in ensuring the electrification of final energy use, in particular in the Buildings, Transportation and Industry sectors.[7]

In the context of the EU transition to carbon-neutrality by 2050, for Bulgaria, a divergence from this path means higher energy and climate security risk, 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.

Energy

In Bulgaria, emissions from the energy sector are the primary source of greenhouse gases (GHG). Typically, energy generation and consumption are responsible for **over 80% of GHG emissions**, including land use, land-use change and forestry (LULUCF), with recent figures from 2020 indicating a share approaching 90%.[8] The primary source of emissions related to electricity generation, transportation fuels, and heating and cooling is the combustion of solid fuels. Public electricity and heat generation from coal is responsible for 90% of GHG emissions in the energy industry, highlighting the significant contribution that the sector can make to climate neutrality by switching from fossil fuels to low-carbon alternatives.

While the energy supply has the potential to transition to carbon-free energy sources, there is also significant scope for achieving large energy efficiency gains. Therefore, to achieve the EU's and national decarbonization targets, it is necessary to electrify all national economic sectors promptly and ensure carbon-free energy carriers.[9]

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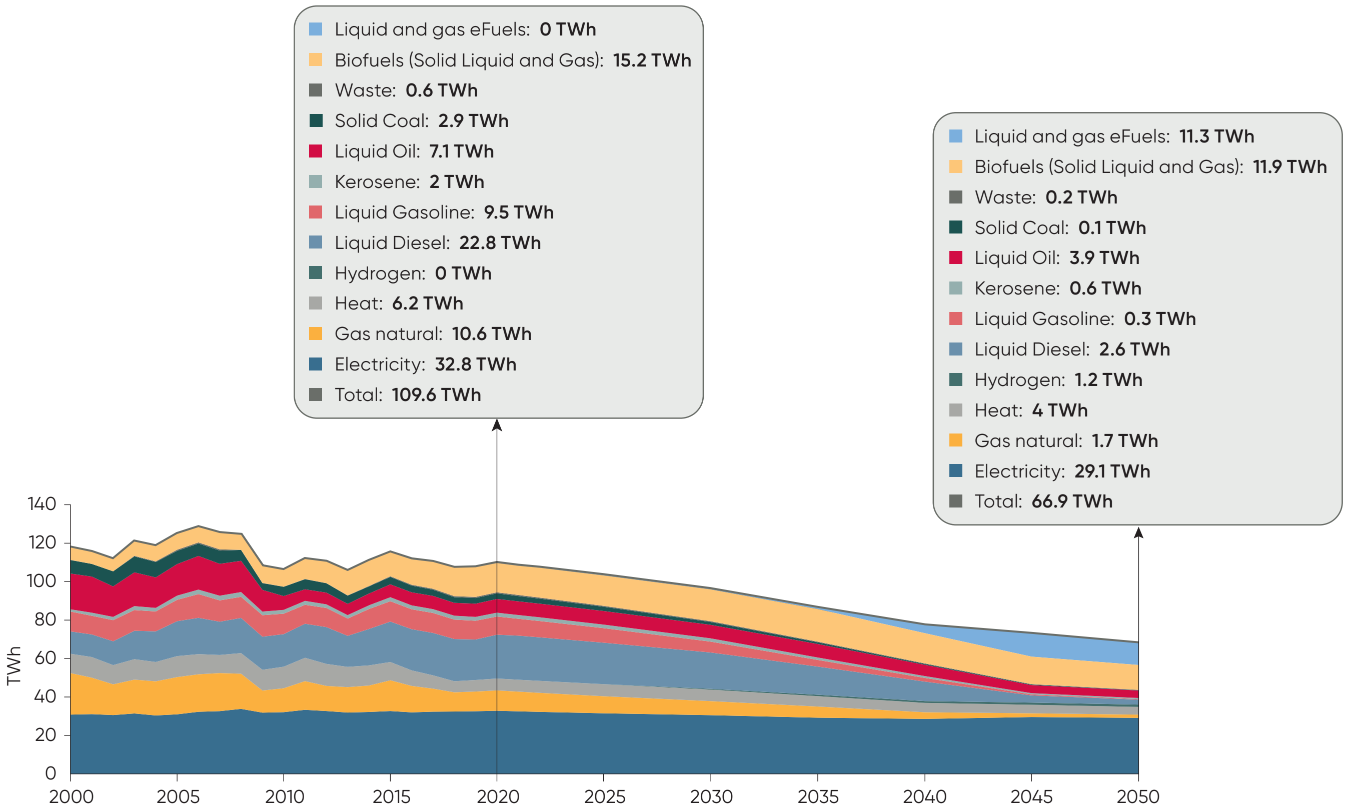
[7] Center for the Study of Democracy, *Technological and Policy Innovation Scenarios for the Low-Carbon Transition of the Bulgarian Energy Sector*, Policy Brief No. 109, April 2022.

[8] National inventory submission to UNFCCC (2022).

[9] Center for the Study of Democracy, *Technological and Policy Innovation Scenarios for the Low-Carbon Transition of the Bulgarian Energy Sector*, Policy Brief No. 109, April 2022.

Scenarios aimed at achieving the net-zero emissions target by 2050 can be achieved by using low-carbon fuels such as biogas, liquid biofuels, liquid and gas e-fuels, hydrogen, and renewables. Following global trends, in Bulgaria, **solid coal will almost disappear as a vector in final energy consumption by 2050**, compared to 2.9 TWh in 2020. The share of **natural gas will shrink six-fold over the same 30-year period**, while liquid oil's share will decrease by over 50%. Together, **renewables and low-carbon fuels** will account for **more than half of the final energy** in 2050.

Figure 3. Final Energy Consumption in Bulgaria in the LTS Scenario by 2050



Source: CSD developed scenarios based on the Pathways Explorer.

Power Demand Projections

To plan the future generation, mix and cost-efficient policy measures in the energy supply segment, it is essential to model power demand for each decarbonization scenario. This involves projecting electricity consumption by sector, considering potential energy efficiency improvements. Based on this information, three decarbonization scenarios are defined, along with two additional dimensions: the level of decarbonization ambition (including interim emission reduction targets and the timeline for coal-phase-out), and Bulgaria's technical capacity and targeted policies for utilizing various types of renewable energy sources.

By considering these factors, policymakers can create effective strategies for achieving the country's decarbonization goals. This approach ensures that the energy supply segment can meet the demand for power while reducing GHG emissions and moving towards carbon neutrality. With proper planning, Bulgaria can establish a sustainable and resilient energy sector that benefits the economy, society, and the environment.

All three decarbonization pathways – the WEM, KEP, and LTS scenarios – predict a growth in power demand by 2050, as illustrated in Figure 2. In the WEM Scenario, power demand increases by 42 % between 2015 and 2050 or 1.4% per year on average. This trend is mainly driven by the electrification of the transport sector, particularly between 2025 and 2030. In contrast, demographic changes combined with modest energy savings in buildings are expected to decrease power demand in the residential sector by 0.7% per year or 20% for the period 2015-2050. The other two scenarios are expected to achieve more significant savings in the building sector – between 40% to 42% – through targeted and ambitious actions focused on improving energy efficiency and implementing deep renovations. These figures are in line with other European models.[10]

It is important to note 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%.[11] The KEP and LTS 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 KEP scenario includes a significant electrification of the transport sector, resulting in a fivefold increase in power consumption for mobility needs. As a result, power demand is expected to grow by 25% according to the KEP vision. The LTS scenario assumes **behavioural changes that keep the total electricity demand** in the Bulgarian economy close to the reference year of 2015, allowing only a 4% increase in power consumption.

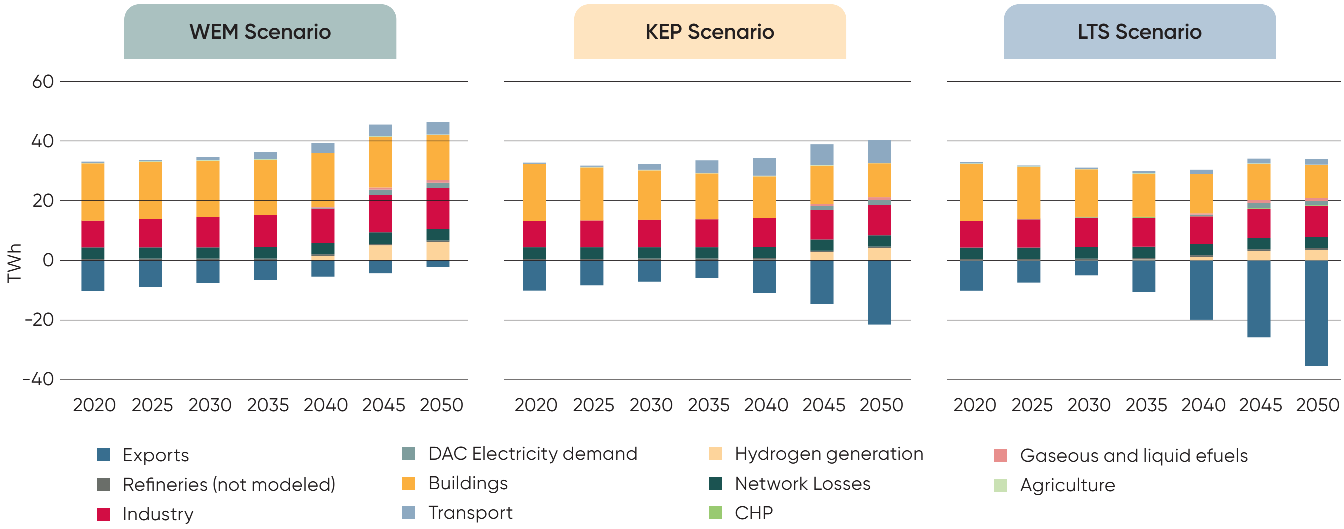
To achieve the decarbonization targets, **energy efficiency measures should be implemented proactively**, as they play a crucial role in reducing energy demand and emissions by 2030. Fuel switching, energy management services, and changes in consumer behaviour are key drivers of energy efficiency. Identifying incentives for demand response and more efficient heating in the residential sector is crucial, not only to reduce energy demand (which, in general, results in a 7% reduction in power generation for every 10% decrease in demand) but also to limit the need to maintain high margins of peak capacity, which can result in additional power system costs for consumers. For countries like Bulgaria, characterized by cold winters and high demand for power during the heating season, ensuring **capacity margins** can lead to significant costs for maintaining **underutilized power generation capacity**.

Expanding net electricity exports is an additional consequence of the power savings achieved in the residential sector, as shown in Figure 2. The detailed assumptions and parameters underlying the presented sectoral demand patterns are explained in more detail in the sections below. However, Bulgaria's

[10] Recent Eurelectric's analysis titles "Decarbonisation Speedways" suggest 45 % drop in the power demand of buildings between 2050 and 2015 and compares the results of the different studies.

[11] Source: Our world in data (2021).

Figure 4. Projected Electricity Demand and Net Exports in Bulgaria until 2050



Source: CSD developed scenarios based on the Pathways Explorer.

ability to reduce its high carbon intensity per unit of electricity generated and achieve climate neutrality by 2050 depends on **changes in the electricity generation mix** and the timely implementation of investments in new low-carbon technologies.

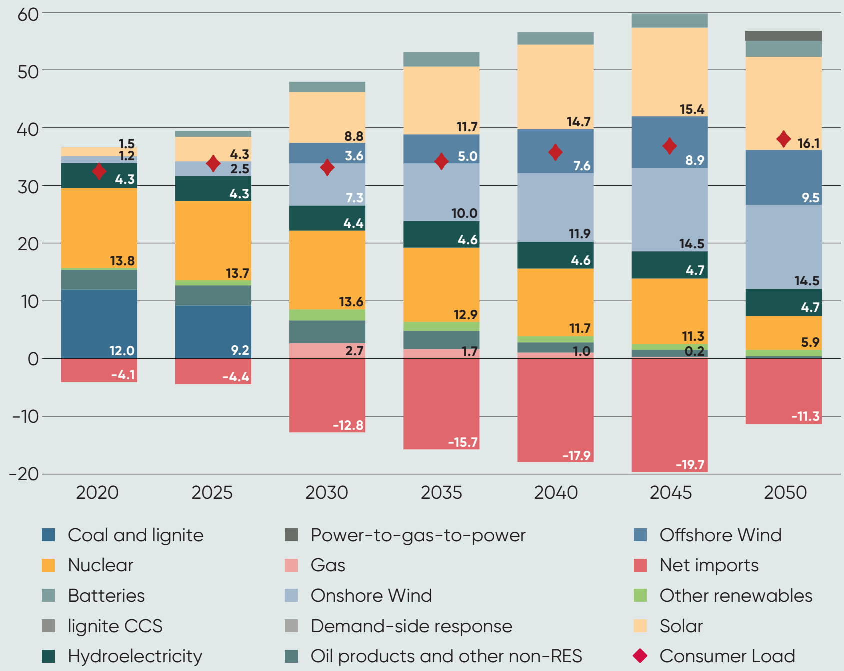
Box 2. Dispatch-Optimized Power Generation in the KEP Scenario

Although, the Pathways Explorer represents a set of trajectories on the demand side based on annual profiles, the model is not suited to simulate demand and supply developments in the electricity sector on an hourly base. In contrast, as a dispatch model Compass Lexecon assesses power supply and demand trajectories in real-time. As a result of the modeling optimization, and irrespective of the policy-determined coal exit timeline, the model shows the phaseout of 2.3 GW of coal power generation capacity before 2030 on the basis of low commercial viability at the current cost structure. This allows the remaining coal power plants to increase their utilization rate to 56% after 2030 (compared to 39% in 2020).

Despite the improved utilisation, the electricity produced from coal is cut in half compared to 2020 and between 2030 and 2035, the remaining assets serve only as a back-up capacity mechanims with a zero-utilization rate. Practically, after 2030 the new low-carbon sources should replace at least 8.5 TWh of generated electricity per annum in the period between 2025-2035.

In terms of capital investments, the scenario of phasing out coal-fired power plants by the later date of 2038 seems not to be economically more favorable, because the total system costs exceed the one of their accelerated retirement before 2030 by only 0.1%. The additional costs for emissions which occur in the scenario with gradual replacement by 2038 are not included in the calculation. Therefore, in the current analysis the *KEP scenario* mirrors the accelerated coal exit scenario of Compass Lexecon model.

Figure 5. Dispatch-Optimized Power Generation in the KEP Scenario in GWh



Source: ETC Analysis Based on Compass Lexecon Simulations

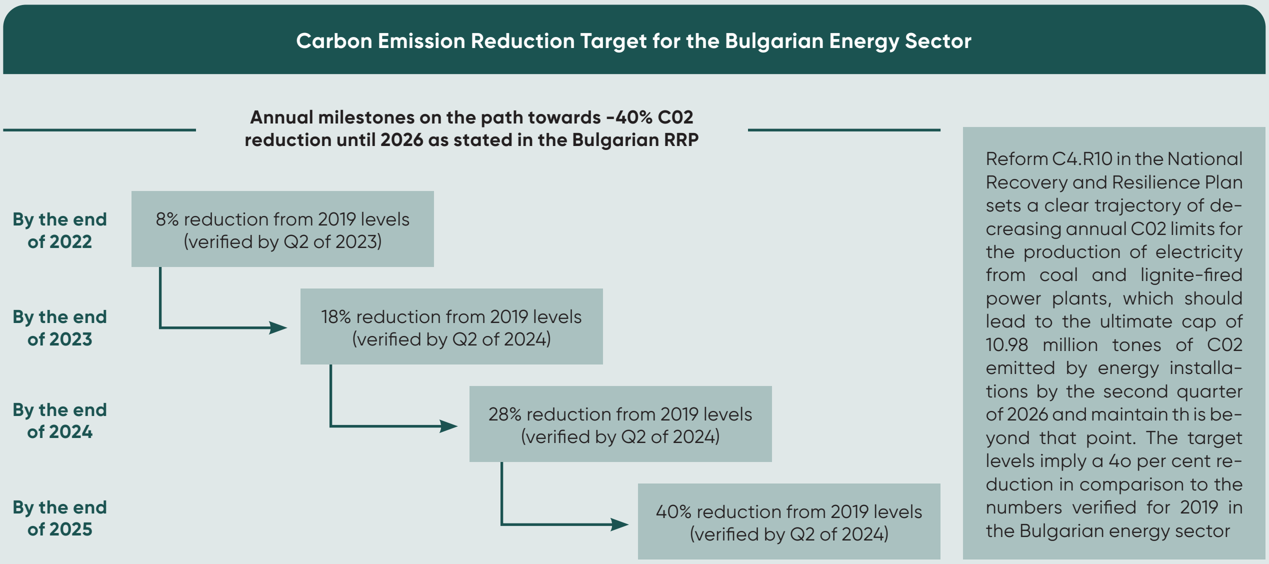
The main difference in the coal-based power generation timeline will be the volume of net power exports and Bulgaria's share in the Southeastern European market. If Bulgaria fails to deploy new RES-based generation capacities on time, the country's position of the biggest regional power exporter will be compromised. The commissioning of new power interconnectors with Greece and Romania triggers a shift in the regional power system, so that Bulgaria could turn from a 4 TWh/year net exporter in 2020 to a 6 TWh net import position with Greece by 2030.[12] Yet, in no scenario modelled by both the Pathways Explorer or Compass Lexecon is the level of system adequacy compromised as it remains positive, i.e. no physical power flow disruptions are observed.

Coal Phaseout

Coal-fired thermal power plants currently make up **45% of Bulgaria's power generation capacity** and produced nearly 50% of the national power output in 2022. The recent surge in energy prices has increased the short-term profitability of lignite-based electricity and has led policymakers to consider extending the lifetime of these plants, which goes against the national target of reducing CO_2 emissions in the energy sector by 40% as outlined in the National Recovery and Resilience Plan (NRRP). Unfortunately, not only was the 8% CO_2 reduction milestone for 2023 not achieved, but GHG emissions have even increased by 15% year-on-year in 2022.

[12] László, S. et al., *Accelerated lignite exit in Bulgaria, Romania and Greece*, Joint Report by REKK, TU Wien, CSD, EPG, FACETS, 2020.

Box 3. NRRP Carbon Emission Reduction Target Explained

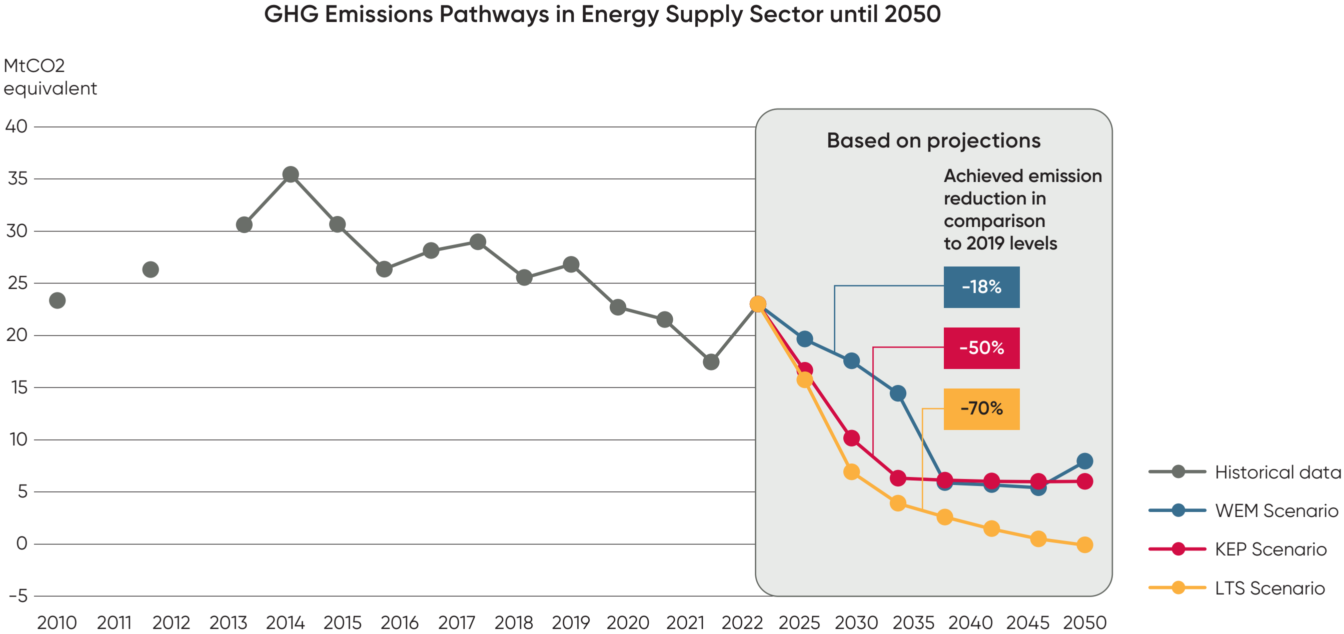


Source: CSD based on C4.R10 described in the Annex to Recovery and Resilience Facility. Operational arrangements between European Commission and Bulgaria

Based on the expert assessment carried out by the ETC and the scenarios developed by its members, the NRRP reform process plans to introduce legislation in the first quarter of 2023 adopting a coal and lignite phase-out schedule and implementing a CO_2 emissions cap. To ensure the sustainability of these measures, the national energy regulator will be required to **impose annual carbon emissions limits for individual installations beyond 2026**. Although no Bulgarian government has committed to a clear path for transforming the coal mining regions and setting an ultimate coal phaseout date, all three decarbonization scenarios assume a drastic reduction or suspension of coal use in power generation before 2035 due to economic reasons. The price of emission allowances reached €100 per ton at the beginning of 2023 and is projected to remain at €90 per ton by the end of the year. **This has led to additional costs for Bulgarian lignite power plants of approximately €120 per MWh**. The stabilization of the wholesale electricity price below €160 per MWh has already put the financial stability of the state-owned Maritsa Iztok 2 lignite plant, the largest plant in Southeast Europe with a 1.6 GW nameplate capacity, at risk.

The WEM scenario, which continues the current policy pathway, assumes that **coal phaseout will begin only after 2030, with 3.5 GW capacity gradually retiring by 2035**, while the remaining 850 MW will still be in the system until 2050. In addition, the installation of new renewable energy capacity underperforms, while the electricity demand keeps on rising until 2045. To meet the growing power consumption, the system utilizes 12% more nuclear power and biomass. Fossil gas-fired capacities double to 1 GW by 2050 as they replace lignite and compensate for the lower integration of renewable energy-based and storage plants in the system. As a result, the scenario achieves only 18% carbon emissions reductions by the end of 2025 and 33% by the end of 2030. The scenario also does not foresee Bulgaria to reach carbon neutrality by 2050.

Figure 6. Greenhouse Gas Emissions Trajectories in the Energy Supply Sector



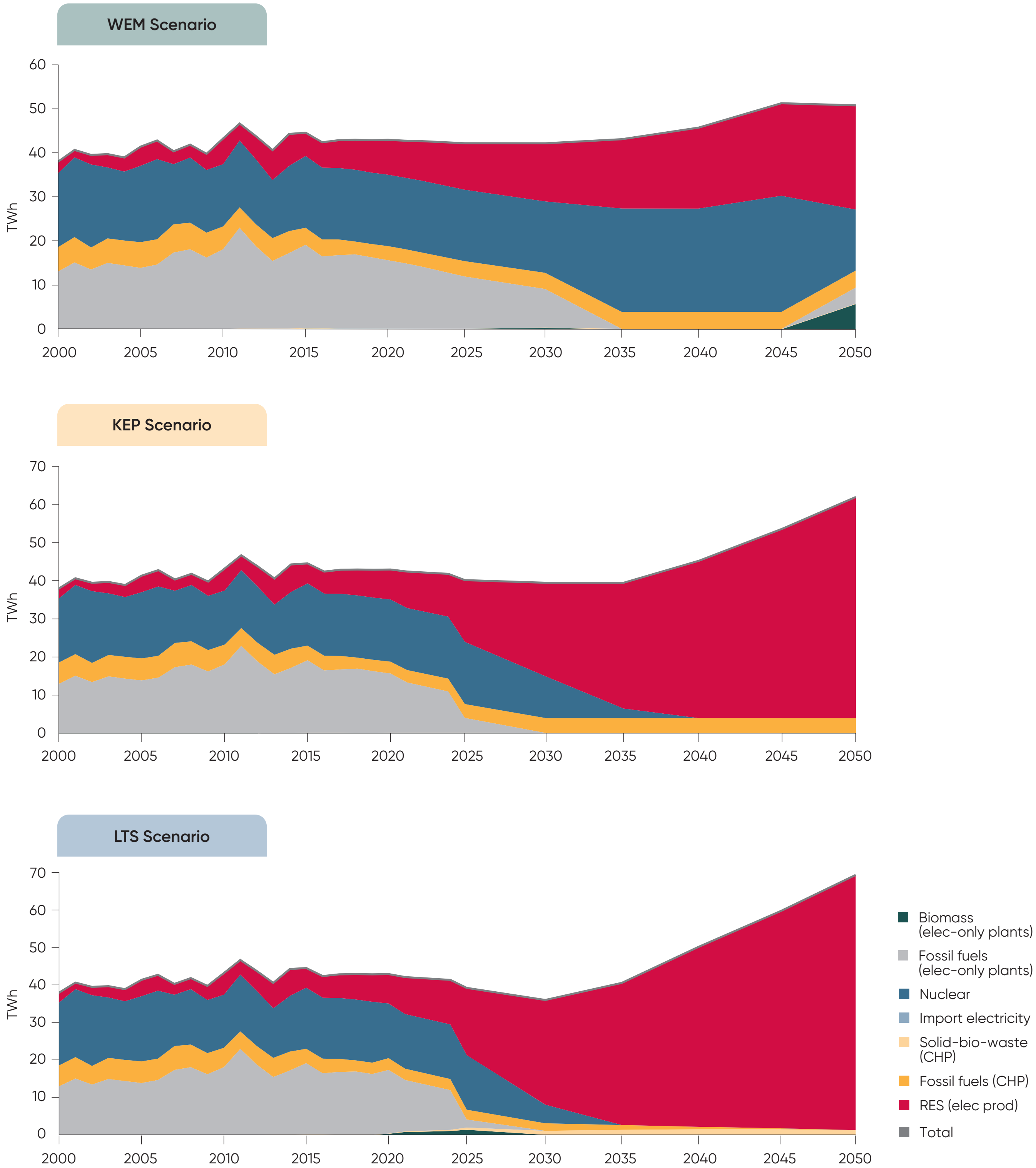
Source: CSD developed scenarios based on the Pathways Explorer.

The KEP and LTS pathways envision **an accelerated coal phaseout**, and lignite is substituted with **a mix of PV and wind (onshore and offshore) in combination with battery storage already by 2030**. Following the GHG emission reduction trajectories in the energy sector, the KEP scenario replaces 2/3 of the fossil-fuel-based power generation with renewables until 2025 achieving 53% CO_2 emissions cuts as visualized in Figure 3.

The accelerated coal phaseout comes on the back of the **increasing costs for coal-based power generation as the price of ETS allowances stays consistently around EUR 100/ton** raising the marginal cost of the existing coal fleet in Bulgaria to levels above the expected wholesale power price. Since no state support in the form of, for example, a capacity mechanism would be legal after 1 January, 2025, it will be unlikely that lignite plants will continue operating on commercial basis. No new fossil gas plants are added to the system and gas-fired power generation remains online only in CHP mode as a by-product to heat generation in district heating plants.

The LTS scenario envisages Bulgaria to **phase out coal and gas-fired power generation completely by 2030**, with the largest power plants already shut down by 2025. This scenario achieves **carbon neutrality** in the entire economy and aims for -70% CO_2 savings by 2025. The LTS assumptions about renewables uptake are ambitious, and both coal and natural gas load factors decrease significantly after 2025. This suggests that new investments in conventional technologies are not economically feasible due to the oversaturated electricity market. The shift to a more **competitive, liberalized market without subsidized generation** and state guarantees will put additional competitive pressure on coal-fired power plants and new investments in nuclear.

Figure 7. Electricity Production per Source and Net Imports until 2050



Source: CSD developed scenarios based on the Pathways Explorer.

Box 4. Cost and Gains from the Accelerated Lignite Coal Phaseout

Considering the external negative effects of fossil-intensive energy systems, such as health and environmental costs, can change the perceived benefits of accelerating the transformation of coal regions.[13] The Energy Transition Commission's analytical report must account for these "hidden" costs and benefits in the accelerated Lignite Coal Phaseout. By doing so, the phaseout can limit expenses associated with non-compliance with environmental norms and the cost of negatively affected health in local communities.

Bulgaria currently faces two legal cases for non-compliance with EU environmental legislation, with the case regarding pollution from fine particulate matter being more advanced than that for sulfur dioxide. The European Court of Justice recently ruled that Bulgaria violated European legislation by allowing the largest state-owned thermal power plant in the Stara Zagora region to pollute with sulfur dioxide without a deadline or plan to address harmful emissions. The European Commission has requested compensation of over €6.6 million by the end of 2022, with expectations for further accumulation. The amount for the second case exceeds €35 million by the end of 2022.

Air pollution from lignite- and hard coal-fired power plants in Bulgaria caused approximately 3,160 deaths between 2016-2020, including those attributed to exposure to PM2.5, ozone, NO_2, and mercury. Other estimated health impacts include 780,000 lost working days, 1,810 hospital admissions for cardiovascular and respiratory causes, 7,850 cases of acute bronchitis in children, 2,060 lost IQ-points due to babies' exposure to mercury in-utero, 1,550 new cases of chronic bronchitis in adults, and 76,800 days of asthma symptoms in asthmatic children. The economic cost associated with these health impacts is estimated to approach €11.9 billion.[14]

Unleashing the RES Potential

Figure 5 illustrates the significant deployment of PV and wind energy needed for a well-functioning and decarbonized electricity system by mid-century, as recognized by all scenarios. The left pie chart shows the existing capacities, including the 3.5 GW coal-based ones expected to exit the electricity system within different time horizons as per the three analysed cases.

The WEM scenario assumes **modest growth in new low-carbon installations**, relying heavily on PV solar and aiming for 3.5 GW renewable additions by 2030, which corresponds to the current tempo of RES market development (200-300 MW per year). However, this trajectory does not **mitigate energy security risks** or achieve the country's climate policy objectives, as focusing solely on the **large-scale deployment of renewables** with the same generation profile can trigger the process of **cannibalization** of the different renewable energy-based plants and ultimately depress wholesale electricity prices.

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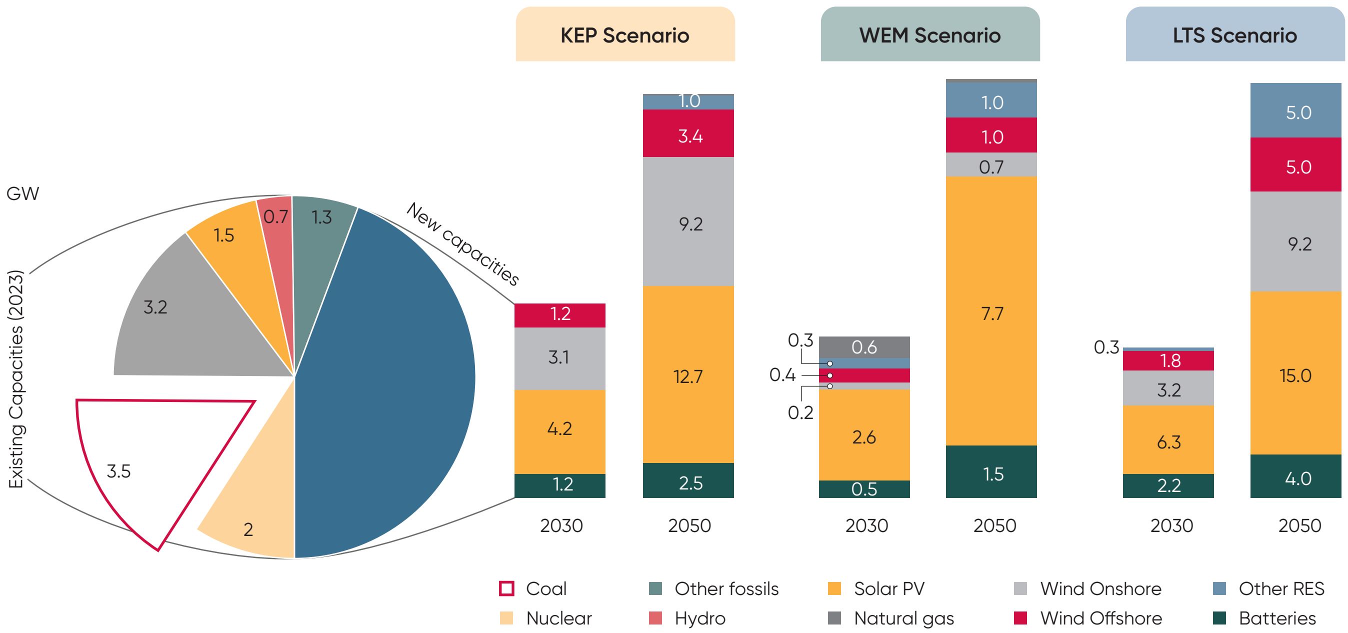
13 Primova, R., Vladimirov, M., and Trifonova, M., *Towards a Just Transition in Bulgaria: Unlocking the Green Transformation Potential of Stara Zagora, Pernik and Kyustendil*, Sofia: Center for the Study of Democracy, 2022.

14 Centre for Research on Energy and Clean Air (CREA)/Greenpeace

To replace the fossil fuel-based power supply, the share of electricity generated from different and well-balanced renewable sources is expected to **grow strongly**. The KEP scenario foresees **the tripling of the generated electricity from RES** to compensate for the decline of fossil fuels between 2020 and 2030. The total necessary aggregated wind onshore, wind offshore, PV, biomass, and hydro capacity is expected to increase by 8.8 GW until the end of the decade, backed up by 1.2 GW battery storage, in addition to other system flexibility options such as expanded power interconnection capacity, demand response management, and power-to-X technologies. **Renewable energy capacity is expected to triple by 2030**, reaching cumulatively 26 GW by 2050.

The LTS scenario's power mix follows the same diverse pattern as the KEP scenario, raising the predicted capacities of different energy sources even further. The new installations account cumulatively for 12 GW of wind, solar, biomass, and hydro by 2030 and 39 GW by 2050. The LTS scenario **represents a transformative shift** as it requires significant flows of private capital in various complex projects for the **exploitation and deployment of new clean technologies** such as offshore wind, geothermal, hydrogen, storage, floating solar, as well as hybrid concepts.

Figure 8. New Renewable Energy Additions until 2050



Source: CSD developed scenarios based on the Pathways Explorer.

To keep pace with these ambitious targets, Bulgaria **should invest in the electricity transmission and distribution grids**, so that they could accommodate annual additions of 1 to 2 GW of renewable energy capacity in the system. The completion of these grid investments with requires **a comprehensive policy framework**, **risk-sharing instruments**, **transparency in terms of grid planning and capacity allocation**, as well as improved coordination and cooperation among authorities in the permitting process. Innovation is key to developing new clean energy technologies and advancing existing ones. Almost 50% of the emissions reductions needed for reaching climate neutrality depend on technologies that are at the prototype or demonstration stage, are not yet available on the market or are conditioned by **specific infrastructure constraints**.[15]

Offshore wind energy is one of the most promising power generation technologies manufactured and designed in the EU, mainly due to its intrinsic characteristics such as more predictable renewable energy-based power supply, cost efficiency, expansion possibilities, cutting-edge technological developments, and limited environmental impact. Offshore wind also carries **long-term economic benefits for coastal communities** and a potential for leap-frogging in a niche technology. Because of its high capacity factors (45-50%),[16] the potential for generating large volumes of low carbon energy and developing synergies with a number of other related industries, the offshore wind segment offers excellent opportunities for the permanent replacement of coal and natural gas in the power system. The technology for offshore wind farms has largely focused on bottom-fixed platforms, which are less suitable for Bulgaria due to the high water depth in the areas with the biggest wind potential.[17] However, even with bottom-fixed technologies, the more conservative WEM and KEP scenarios show the feasibility of adding 1 and 3 GW, respectively, of offshore wind capacity in the system by 2050. Yet, the likely acceleration of **the commercialization of floating offshore wind technologies before 2030**, also visible in the ambitious plans of Portugal, Greece and Poland, would provide the necessary technological basis for the implementation of the LTS pathway for the development of offshore wind in Bulgaria.

The expansion of offshore wind could create a number of synergies with local **green hydrogen production**. In the short run, the production and use of hydrogen according to the scenarios is primarily related to the conversion of existing uses of fossil energy in industry or refineries to low-carbon hydrogen in ways that do not immediately require new transmission and distribution infrastructure. Hydrogen and ammonia start to emerge as fuel inputs to electricity production only by around 2030. They provide excellent opportunities for ensuring electricity system adequacy and reduction of the overall electricity transformation costs. All three scenarios consider the first production and demand for hydrogen starting from 2030. The WEM scenario predicts the highest growth (2.2 TWh for sectoral demand until 2050), followed by the LTS (1.2 TWh).

The lowest hanging fruit in terms of cutting-edge low-carbon technologies concerns advanced batteries, hydrogen electrolysers, and direct air capture and storage. Globally, these three technology areas could potentially be vital contributions to the reductions in CO_2 emissions between 2030 and 2050.[18] Pairing battery storage systems with solar PV and wind to improve power system flexibility and maintain electricity security becomes commonplace in

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15 International Energy Agency, *Net zero by 2050: A Roadmap for the Global Energy Sector*, Paris: IEA, 2021.

16 Trifonova, M., and Vladimirov, M., *Wind Power Generation in Bulgaria: Assessment of the Black Sea Offshore Potential*, Sofia: Center for the Study of Democracy, 2021.

17 Ibid.

18 International Energy Agency, *Net zero by 2050: A Roadmap for the Global Energy Sector*, Paris: IEA, 2021.

the late 2020s, complemented by demand response for short duration flexibility and hydropower or hydrogen for flexibility across days or even seasons. In implementation of the NRRP, the Bulgarian energy system is expected to secure new power storage of 1 500 MW in terms of both grid-scale and batteries attached to the development of RES-based plants behind the meter.

In addition, hydropower, bioenergy and geothermal technologies are well established, mature and flexible renewable energy technologies, which are commercially viable dispatchable power generating options, improving security of power supply in tandem with battery storage, whose costs have gone down sharply and, which have proven to provide high-value grid services and can be deployed quickly in many locations at the same time.

Security of Supply Concerns

Bulgaria ranks among the EU member states in the SEE region, **exposed to the highest energy and climate security risks,**[19] which became very visible on the eve of the Russian invasion of Ukraine. Bulgaria is highly dependent on the imports of natural gas and crude oil coming from Russia, and after Gazprom cut the gas supply to the country in April 2022, has scrambled to find alternative gas imports resorting to importing Russian gas from Greece for at least 1/3 of its natural gas demand. In addition to the structural fossil fuel dependence, Bulgaria faces **severe reliability risks linked to the aging power grid infrastructure, the limited gas storage capacity, the excessive reliance on coal for baseload power generation** and the limited investments in the modernization of the energy sector, especially when it comes to the implementation of cutting-edge technologies.

Both the WEM and KEP scenarios reveal little progress in the reduction of oil and gas imports. In the WEM scenario, imports do not change until 2030, and only decline slightly to 15.8 TWh until 2050. In the KEP scenario, natural gas imports expand significantly reaching 27.1 TWh in 20250. It is only in the LTS where natural gas imports are phased out almost completely by 2050.

Although Bulgaria has a diverse power generation mix, **the security of electricity supply has been negatively impacted by Bulgaria's excessive reliance on coal-fired power generation**, which would need to be curtailed in the future due to the lignite plants' lack of profitability at the current wholesale power prices and due to the severe environmental restrictions in place.[20] Modelling assessments conducted by the Bulgarian Transmission System Operator (TSO)[21] in October 2022, assessing the power supply and demand trajectories of the whole SEE region, reveal that the Bulgarian **power system remains adequate** even after full coal phaseout. Furthermore, an analysis conducted

[19] Vladimirov, Ranglova, and Dimitrova, *The Great Energy and Climate Security Divide: Accelerated Green Transition vs. the Kremlin Playbook in Europe*, Sofia: CSD, 2022.

[20] The European Commission accused Bulgaria before the Court of Justice of the European Union of "persisting non-compliance" with hourly and daily limits values of SO_2 and harmful air pollution when coal is burned. This is the second procedure in Brussels against the country since Bulgaria was referred to the court over poor air quality for breaching limit values for particulate matter PM10.

[21] Chavdarov, N., and Sulakov, S., *Bulgarian Resource Adequacy Assessment*, Sofia: ESO, 2022.

at the European level using the same methodology (ERAA 2021) reveals that both the entire Southeast European region and individual countries within it can maintain a secure power supply, even when considering the decommissioning of fossil fuel-based generation units in other SEE countries. This resilience is due in part to the coupling of day-ahead and intraday markets, as well as the expansion of power interconnections with neighbouring countries. These measures help to mitigate risks in the electricity sector, including unexpected shutdowns of large domestic generation units in Bulgaria.

The capacity for power interconnections with neighbouring EU member states is set to increase by at least 2.500 MW by 2026, thanks to **a complete flow-based market coupling**. However, if no new low-carbon capacity is brought online in Bulgaria, the country may become **a net importer of electricity**. This situation could create additional risks to the security of electricity supply.

To accommodate a higher proportion of intermittent renewable energy-based power plants, Bulgaria must invest significant public resources in **upgrading its national energy infrastructure**. Many transmission and distribution lines are outdated and not properly maintained, which can result in frequent power outages and blackouts. In order to maintain a secure power supply, dispatchable renewables, in combination with other low-carbon generation units, battery storage, and robust and well-interconnected electricity networks, are critical. Smart meters are also essential for the improved integration of decentralized power producers. Most of the current energy sector investments in Bulgaria are directed towards the maintenance and repair of electricity generation units, transmission and distribution infrastructure, with less emphasis on innovative technical solutions and the integration of new generation technologies. The energy investment index in Bulgaria was 0.58 in 2019, which is relatively low compared to other European countries and falls below the averages for both EU and OECD countries. For instance, in Romania, the index value is 0.71, in Greece it's 0.86, while countries such as Poland, Turkey, and Germany have indices over 1. Denmark is among the leaders with an index of 2.31 in 2019.[22]

Buildings

Reducing Energy Demand

A key factor for lowering GHG emissions in the buildings sector **is the reduction in overall energy demand and the acceleration of the pace of electrification**. The decline in emissions is driven by the phase out of coal, solid biofuel (firewood), natural gas, and liquid fuels in exchange for **electrification**, and the uptake of alternative fuels.

In 2020, buildings consumed more than 42% of all final energy used in the EU, resulting in significant greenhouse gas emissions.[23] Household energy consumption alone constituted 67% of the total energy consumed in buildings, with 78% of that spent in space and water heating. The majority of this energy, 57%, came from fossil fuels such as natural gas, oil, and coal, while only

22 International Energy Agency, *World Energy Investment 2022*, Paris: IEA, 2022.

23 European Environmental Agency, *Briefing no. 27/2022: Decarbonising heating and cooling — a climate imperative*, Copenhagen: EEA, 2023.

24% came from renewable energy sources such as solid biomass. Therefore, **decarbonizing heating in households is critical** to the low-carbon transition of the buildings sector.

In Bulgaria, over 90% of the year-round occupied residential buildings are single-family houses, with multi-family dwellings comprising less than 5% of the total number of such buildings.[24] Despite having a useful floor area of approximately equal size to that of single-family houses, multi-family dwellings have been severely neglected in terms of energy renovation, as only 4.2% of the multi-family building stock was renovated under previous national programs between 2007 and 2021.

Currently, 95.8% of the remaining multi-family buildings have poor energy performance, with 91% of them falling into classes E, F, and G. Despite the inadequacy of the slow renovation rates, the ongoing national program "Support for sustainable energy renovation of residential building stock" is only expected to cover an additional 1000 buildings, raising doubts about the ability to reach **long-term targets for energy demand reduction**.

The three scenarios examined in the buildings sector explore different indicators including the type of residential and service building construction technologies, heating and cooling behaviours, low-carbon heating solutions and buildings envelope renovation.[25] All pathways clearly show that **heating will remain the most significant component of energy demand** for the next 30 years. However, phasing out coal and solid biofuels in favour of electrification and improved ventilation could reduce consumption by more than 50%, as demonstrated in the *LTS Scenario*.

The *WEM Scenario* demonstrates the **major role that different consumer behaviour plays** in the overall energy consumption. Extrapolating the current trends like the increase of the living space per person with over 50% and maintaining average indoor temperature above 22°C over the next 30 years should lead to only 20% reduction in the energy demand for heating. Additionally, the scenario plans gradual electrification of the domestic heating systems as a replacement of solid biomass and fossil fuels with heat pumps and solar thermal. Interestingly, the yearly renovation rate of 0,9% shows a slight decrease in comparison to 2015 (1,4%). The combination of these factors indicates that the total energy reduction for 2050 is not expected to exceed 19% versus 2020, which means that **carbon neutrality in this scenario would be impossible**.

In contrast to the *WEM*, the *KEP Scenario* envisions a more prevalent use and ownership of electric appliances. It also combines gradual electrification of the domestic heating systems through the replacement of solid biomass and fossil fuels with heat pumps and solar thermal, together with an increase of the share of district heating in the heating energy demand by 30%. In addition, the *KEP scenario* envisions the acceleration of the annual residential buildings renovation rate to 2,8% by 2025 and 2,5% for service buildings. By

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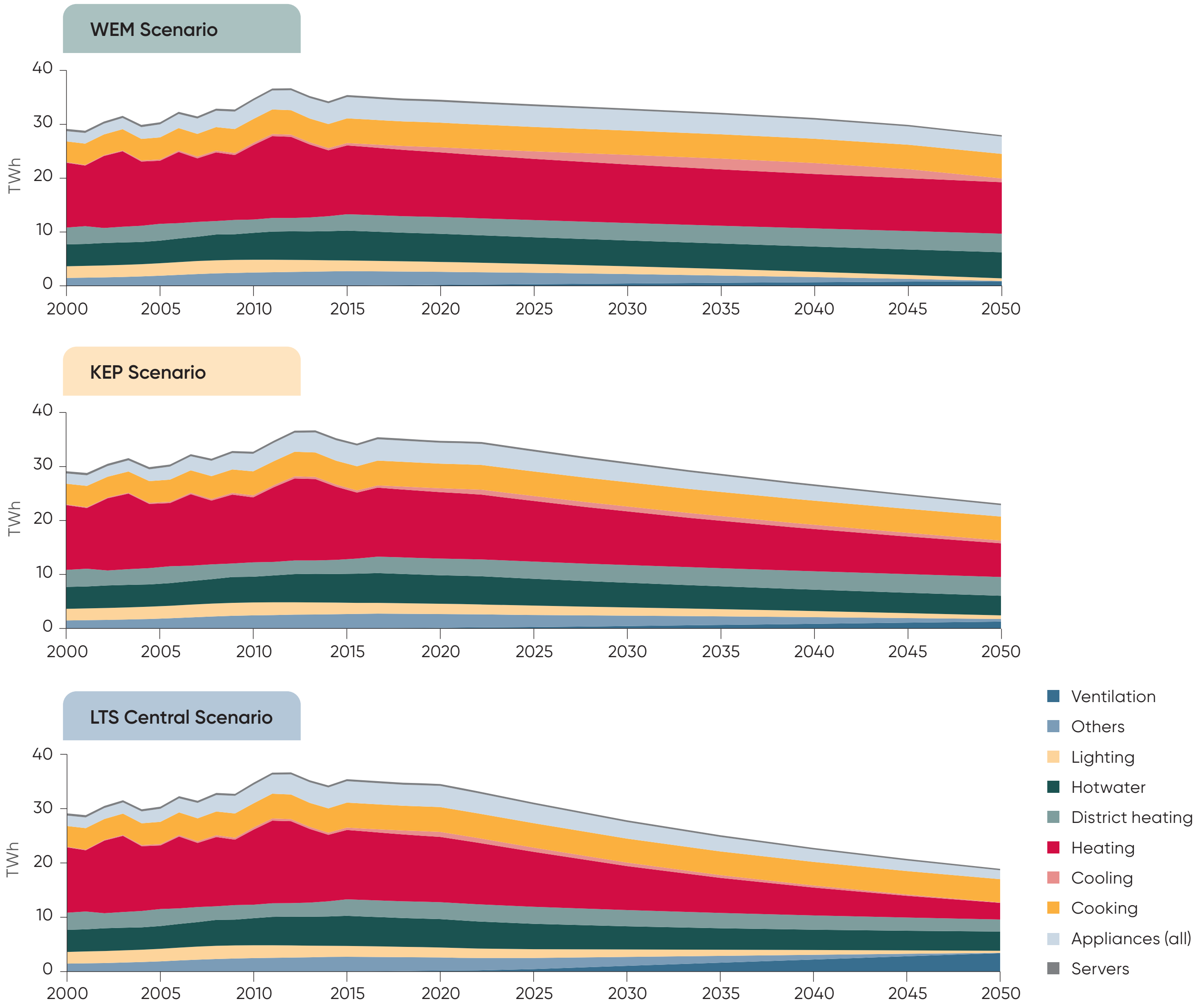
[24] Bulgaria, Ministry of Energy, Дългосрочна национална стратегия за подпомагане обновяването на националния сграден фонд от жилищни и нежилищни сгради до 2050 г. [Long Term Renovation Strategy], 2021.

[25] The energy use for 'district heating' should be allocated to the 'heating' and 'hot water' segments.

Figure 9. Energy Demand per End-Use in Buildings

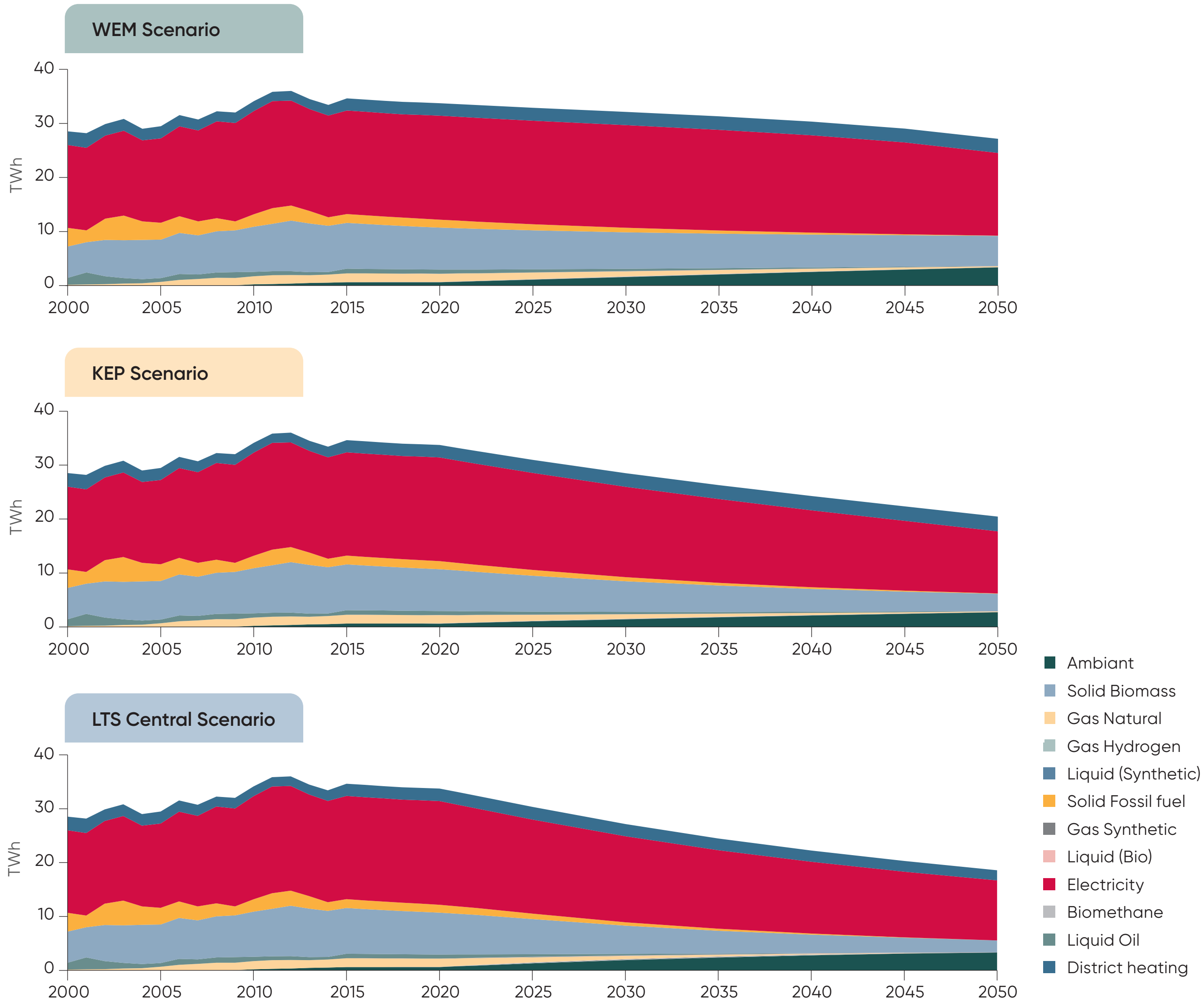


Source: CSD developed scenarios based on the Pathways Explorer.

reducing the heating temperature by 4 degrees and changing behavioural patterns towards energy conservation, the heating consumption can fall by 55% to 5.5 TWh.

In comparison to these more conservative scenarios, the most ambitious renovation rate and the level of electrification of heating are observed in the *LTS Scenario*. Overall demand is estimated to decline by 50% down to 18,9 TWh by 2050. The renovation rate accelerates to 3,7% for residential and 3,5% for service buildings on a yearly basis starting from 2025. The use of solid fuels for heating use falls to 3% in non-residential buildings and is fully phased out in residential ones by 2050, while space heating via heat pumps and solar thermal solutions increases by 90% and 10% respectively. As a result, energy consumption in heating shrinks by a factor of four to just 3 TWh. Ventilation as an additional retrofitting measure is prioritized for achieving higher energy efficiency in buildings and ensuring healthier indoor environment.

Figure 10. Energy Demand per Energy Vector in Buildings



Source: CSD developed scenarios based on the Pathways Explorer.

New Technology Mix

The environmental impact of buildings goes beyond the emissions generated during their operational phase. As much as 20-25% of the life cycle emissions of the current EU building stock are due to the embodied carbon in building materials.[26] Given that more than 85% of today's buildings are likely to still be in use in 2050, it is crucial to focus on **improving the sustainability of existing buildings** throughout their lifecycle.

As new construction consumes more materials than renovating existing buildings, by extending the lifespan of the latter and **optimizing residential surfaces and available living space per person**, greenhouse gasses emissions

[26] European Environment Agency, *Briefing no. 12/2022: Linking circular economy and climate change mitigation in building renovation*, Copenhagen: EEA, 2022.

can be reduced effectively. The retrofitting and refurbishment of existing buildings provides opportunities for reducing embodied carbon emissions, by replacing or upgrading materials and buildings systems with innovative sustainable alternatives, thus improving indoor comfort and air quality, reducing maintenance costs, and increasing property values. Deep building renovation should be prioritized and executed in line with the objectives of the EU Energy Performance of Buildings Directive (EPBD).

Considering the substantial energy consumption associated with heating and cooling, the significance and adoption of Building Energy Management Systems (BEMS) to promote energy efficiency and sustainability in residential and commercial buildings have been increasingly recognized. By utilizing sensors and advanced algorithms in an integral way, these systems **optimize building performance and reduce energy consumption** by controlling heating, ventilation, air conditioning, lighting, security systems, and other building systems based on factors such as current occupancy and weather conditions. The implementation of these technologies in existing and new buildings **ensures optimal operational efficiency**, making them a critical element of the overall energy management strategy of buildings.

Additionally, Building Information Modelling (BIM) technology has emerged as a major tool for achieving long-term sustainable construction. With the ability to provide contractors and designers with a comprehensive visualization of the construction project throughout its entire lifecycle, **BIM has the potential to significantly reduce the carbon footprint of buildings** and optimize their energy consumption. Using BIM, engineers can identify potential energy inefficiencies and make necessary design changes before construction begins. This not only reduces energy consumption and associated costs over the building's lifetime, but also minimizes the environmental impact of the building's construction and operation. Related to this and the creation of community energy systems, new technical solutions such as digital twins, digital building logbooks and novel heat pump technologies will play a significant role for the decarbonation of the sector in the coming years.

Behavioural and Policy Implications

Energy consumption in buildings can be significantly impacted by **the daily behaviours and energy choices of their inhabitants**. Individuals can optimise their energy consumption patterns by adjusting their daily routines, which would reduce household costs, carbon emissions, and relieve the pressure on the power grid during peak demand periods.[27]

An effective communication campaign would be crucial to ensure the success of policy interventions and government programmes. This is especially important when it comes to the delivery of **data-driven information on energy consumption patterns**, such as monthly bills, appliance efficiency labels, and energy audit reports. Feedback mechanisms are useful in showing consumers how their energy demand changes throughout the day and seasons, increas-

[27] International Energy Agency, *The Potential of Behavioural Interventions for Optimising Energy Use at Home*, Paris: IEA, 2021.

ing their awareness of how their **daily use of appliances, heating, and air conditioning affects energy costs**. These feedback mechanisms can be provided in real-time through various digital instruments such as mobile applications or in-home displays, which are fed with data from smart metering systems.

Comparing one's energy consumption to that of peers in the same area can also leverage **social norms and competition effects, motivating users to reduce their consumption**. Energy dashboards and smart meters can enable users to monitor their energy use and identify opportunities for energy savings. Providing incentives, such as reduced energy bills or other rewards by energy providers, can also promote energy-efficient behavior and create a social norm that reinforces these actions, making them more likely to be adopted by others.

More structurally, to achieve carbon neutrality in buildings, it is crucial to reduce **the per capita demand for additional residential surfaces** and the available living space per person. Currently, more than 30% of dwellings in Bulgaria are not inhabited, while around 40% of people live in crowded housing, which necessitates more efficient use of existing and new building stock.[28] Instead of easing the expansion of the new-building construction bubble, the government should rather focus on measures and support tools that **incentivize the renovation of empty, old buildings** – an approach that could be instrumental for lowering emissions in the building sector. The use of commercial buildings should be also optimized to reduce surface demand for businesses.

Meanwhile, the uptake of alternative heating technologies would require initial investments by Bulgarian consumers, the predominant part of whom would not be able to afford them without additional **support schemes and targeted credit facilitates**. Despite the subsidization of electricity and natural gas prices for residential consumers, a growing share of the population has experienced difficulties in covering their bills. Over a third of Bulgarian households are unable to afford to adequately heat their homes, with roughly 50% using wood and coal as the major heating source.[29] Low household energy efficiency has also contributed to increasing energy consumption levels. The lack of full access of the population to energy infrastructure has maintained the reliance of 50% of households on biomass (mainly firewood and coal, burned in inefficient stoves). Energy subsidies do not **incentivize a shift of consumption patterns** towards more electrification and the process is not sustainable considering the planned full liberalisation of the electricity market by 2025.

To reduce the cost burden of energy efficiency enhancements on the most vulnerable societal groups and to incentivise their active transformation into energy producers, the development of an energy poverty strategy is key for addressing the socio-economic aspects of decarbonisation. The inclusion of an energy poverty dimension in the NRRP is a milestone but there is a need for

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[28] Eurostat, Housing in Europe, Statistics Visualized, 2020 Edition. See also Eurostat 2018, File: Unoccupied dwellings, by NUTS level 3 region, 2011 (% share of all conventional dwellings).

[29] Eurostat, *Can you afford to heat your home?* 2016 Survey; Vladimirov, M., and Özenc, B., *Towards a Stronger EU-Turkey Energy Dialogue: Energy Security Perspectives and Risks*, CSD and Economic Policy Research Foundation of Turkey, 2017.

a more **comprehensive overhaul of state support schemes** so that only the most vulnerable consumers are targeted. In addition, the government should **phase out the artificially-low regulated energy prices** that are contributing to market distortions, and disincentivise the middle-class from investing in energy efficiency improvements or to switching to less energy-intensive consumption patterns.

The energy poverty reform set out in the NRRP should outline a strategy about how energy-poor households are to be supported as the special target group of vulnerable consumers, and in particular what kind of specific incentives for energy savings and the use of small-scale PV installations will be introduced to make these households direct participants in the energy transition. In the process of transposing the new EU Directive on Renewable Energy Sources, the Bulgarian government must adopt a regulatory framework to ensure that all consumers (including low-income households) can participate in renewable energy communities. The strategy should also identify financial mechanisms for supporting their creation and the integration of **socially vulnerable consumers**. The latter would also encourage the replacement of polluting fuels and technologies with more environmentally friendly alternatives.

Revolving funds linked to grants and soft-loan schemes, could be mobilized for this purpose. Financial support schemes could take the form of an eco-/super-bonus that would allow domestic residential users to benefit from tax deductions on the total energy efficiency investment projects. In view of the EU strategy for a renovation wave as part of the European Green Deal, national governments shall propose specific measures to promote the role of energy communities in the implementation of energy efficiency measures. Member-states governments should consider designing electricity sharing schemes tailored to the needs of households to facilitate joint household renewable energy projects. The introduction of the possibility for virtual net metering has been successfully applied in Greece for the needs of vulnerable consumers. It allows householders to share the electricity output from a joint facility that is not physically connected to their property or meters. The most significant advantage of this scheme is that the bill credits could be assigned to the electricity generated in one location but at the same time these could be bought, sold and/or transferred to the bill of an electricity customer at another location. Virtual net-metering is particular attractive for tackling energy poverty in Bulgaria, since around 60% of citizens live in multi-family, apartment-based residential buildings.

The decarbonisation of the heating and cooling sector, which is a major pillar in the EU RW strategy, is not explicitly covered by the proposed measures in the NRRP. Since it has a major impact on emission levels from the building sector and also the energy efficiency measures in the buildings, the plan needs to be better aligned with promoting renewable energy heating and considering other alternative RES sources beyond biomass, such as heat pumps, solar collectors and geothermal energy. The plan could also include district renovation projects with the long-term goal of developing smart neighbourhoods. The promotion of **sustainable construction materials** should also be imperative. This ought to be the next measure to fulfil the objectives of the Construction Products Regulations revision and design a long-term strategy for making the construction ecosystem fit for sustainable renovation.

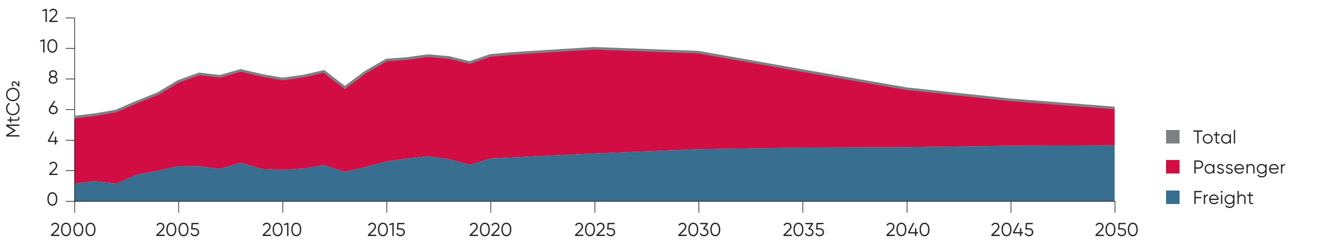
Transportation

Transportation is Bulgaria's second-largest GHG emitter, and its share of overall emissions is continuously growing (19% of the total). Transportation also has a 24% share in final energy consumption with no visible trend for its decline. The carbon intensity of the transport sector in Bulgaria is 3.5 times higher than the EU average, reaching 2.8 kg of GHG for every euro gross value added in 2019. With more than 3.6 million vehicles on Bulgaria's roads, passengers' mobility accounted for 77% of the total sectoral emissions (9.57 $MtCO_2e$) in 2020. Not surprisingly, gasoline and diesel are the two primary sources of energy used in transportation, while the current level of electrification barely reaches 1% of the total. The capacity for **mass transport electrification would be key for the sector's future decarbonization potential.**

Breaking the Trend of Rising Emissions and Demand

In the **WEM scenario**, the overall reduction of transport emissions start after 2025 when they peak at 10 $MtCO_2e$ then go down by 40% until 2050 to 6.1 $MtCO_2$. In terms of breakdown of emissions (see Figure 10), passenger emissions drive most of the decarbonisation in the transport sector (60% reduction by 2050), while emissions in freight actually increase by 20% to 3.7 $MtCO_2$ in 2050.

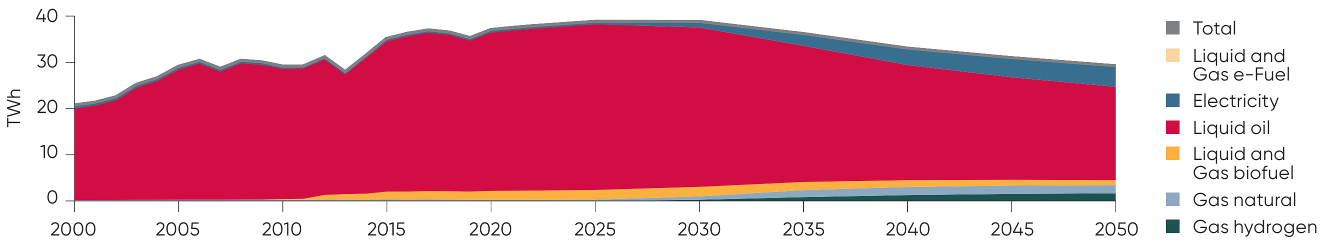
Figure 11. Passenger and Freight GHG Emissions Reduction in the WEM Scenario



Source: CSD developed scenarios based on the Pathways Explorer.

Meanwhile, total energy consumption in the transport sector will peak in 2025 at 38.6 TWh and decrease to 29 TWh in 2050, according to the WEM scenario. The energy demand by vector (fuel source) in transportation shows that liquid oil will peak at 35.8 TWh in 2025 and remain the primary energy source in

Figure 12. Energy Demand by Vector in the Transport Sector by TWh in the WEM Scenario



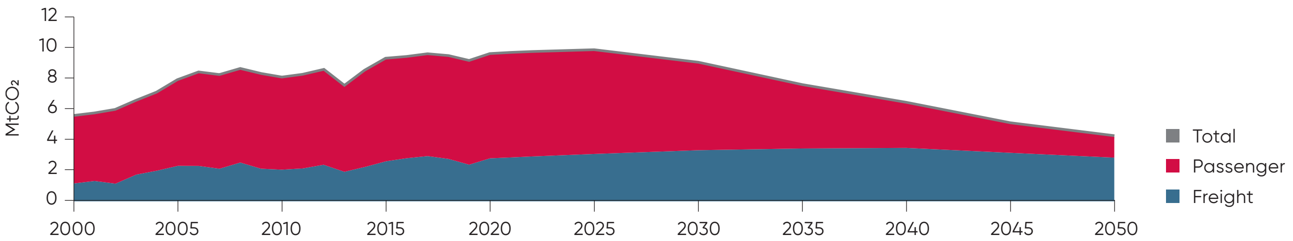
Source: CSD developed scenarios based on the Pathways Explorer.

transport, declining to 20.2 TWh in 2050. Electricity will make only a marginal contribution of 0.4 TWh to the overall energy mix in 2025, reaching 1 TWh in 2030 and slowly increasing after 2035, jumping tenfold by 2050, reaching 4.3 TWh. The natural gas use will also **increase fivefold** between 2025 and 2050, and hydrogen will also slowly enter the mix after 2040, but even in 2050 its share will be negligible at 1.7 TWh.

According to the WEM scenario, by 2035, transport will become the largest sector of CO_2 emissions in Bulgaria, reaching 8.5 $MtCO_2$. The main obstacle to the decarbonisation of the sector is the **difficulty in changing the key behavioural drivers** in the sector for both passengers and businesses. All this will make achieving the common European climate ambition in Bulgaria challenging although the transport sector will play the most important role in achieving carbon neutrality following the decarbonisation of the electricity sector.

In the **KEP Scenario**, GHG emissions reduction in the transportation sector starts slowly in 2025, and by 2030 have already declined by 10%. Overall, in this scenario, GHG emissions decline by close to 60% in 2050 dropping from 9.8 $MtCO_2$ in 2025 to 4.2 $MtCO_2$. However, as in the *WEM scenario,* the emissions from the freight segment keep rising until 2035 (by almost 15% although even they decline by 10% in 2050. Emissions in the passenger segment shrink fivefold reaching a low of 1.3 $MtCO_2e$ by 2050.

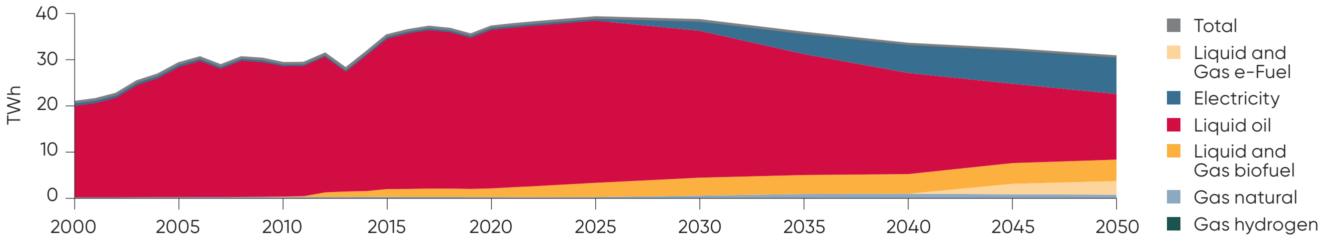
Figure 13. Breakdown of Passenger and Freight GHG Emissions Pathways in the KEP Scenario



Source: CSD developed scenarios based on the Pathways Explorer.

In the *KEP scenario,* total energy consumption in the transport sector will peak in 2025 at 38.8 TWh and decrease to 30,4 TWh in 2050, more than 1,5 TWh above the achievement of the WEM scenario. The energy demand by a vector (fuel source) in transportation shows that liquid oil consumption will peak at 35 TWh in 2025 and start dropping dramatically after 2030 reaching a low of 14.2 TWh in 2050. The use of electricity in vehicles increase ten times from 0.4 TWh in 2025 to 4,3 TWh in 2035 and reach 7,8 TWh by 2050, a nearly twenty-fold rise from 2025 but is still only half of the level of liquid oil consumption. There will be a substantial **increase in the number of electric cars after 2030**, reaching 2.4 million in 2050. Meanwhile, the energy consumption of freight transport will increase by 20% from 2025 to 2050 without decarbonising in the process. Although the use of natural gas is tripling by 2050, it will remain at only 0,8 TWh in 2050. Hydrogen is practically missing from this scenario.

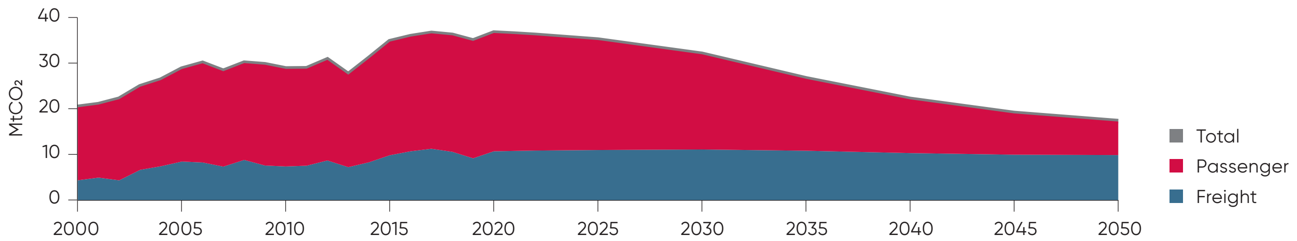
Figure 14. Energy Demand by a Vector in the Transport Sector by TWh in the KEP Scenario



Source: CSD developed scenarios based on the Pathways Explorer.

In the ***LTS Scenario***, the GHG emissions peak at 9,5 $MtCO_2$ in 2020, and by 2030 and 2050 would already fall by 10% and 85%, respectively, down to 1,6 $MtCO_2$, **the most significant cut in GHG emissions from the 3 scenarios**. As visible from Figure 14, this is the only scenario, in which freight emissions do not grow after 2020 but remain stable at 2.8 $MtCO_2e$ until 2035 when they start to decline dropping to 1.1 $MtCO_2$ by 2050. Passenger emissions will decrease tenfold, from 6.7 $MtCO_2$ in 2020 to 0.5 $MtCO_2$ in 2050.

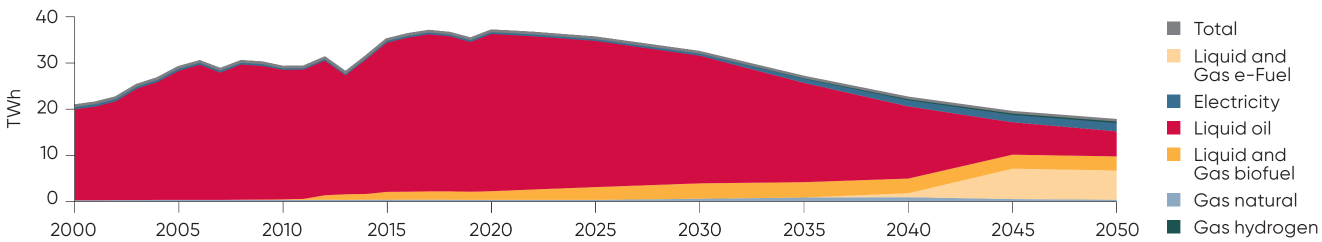
Figure 15. LTS Central Passenger and Freight GHG Emissions Trajectories



Source: CSD developed scenarios based on the Pathways Explorer.

The total energy consumption in the transport sector reached its peak in 2020 at 36.6 TWh, but it is projected to decrease by over 50% to 17.2 TWh by 2050. This reduction is the only scenario that could significantly decrease energy transport demand, resulting in a sharp drop in greenhouse gas emissions. The energy demand by a vector in transportation indicates that liquid oil consumption reached its peak at 34.3 TWh in 2020. However, after 2030, a considerable reduction in the use of liquid fuels is expected, with a consumption

Figure 16. Energy Demand by Vector in the Transport Sector in the LTS Scenario



Source: CSD developed scenarios based on the Pathways Explorer.

of 5.5 TWh in 2050. The scenario does not foresee any significant growth in electricity consumption until 2030. Nevertheless, by 2050, it is expected to triple from 0.4 TWh to 1.8 TWh.

According to the LTS Scenario, the transport sector will become Bulgaria's highest CO_2 emitting sector in 2025 with 8,9 $MtCO_2$, five years earlier than the expectation in the KEP Scenario. The pathway in the *LTS Scenario* brings Bulgaria closest to meeting the EU transport climate neutrality targets although fossil fuels remain the dominant energy source in transport due to the insignificant changes in behaviour that would incentivise sustainable mobility including the higher use of public transport (mostly rail), biking and e-vehicles penetration.

As the more conservative scenarios reveal, the **reliance on single technology-driven measures is not sufficient for a deep transformation** of the transportation system towards a more sustainable future. More ambitious policy approaches should address **behavioural changes and a redesign of the predominant models in mobility**, which are necessary to achieve a significant reduction in energy use, in addition to the replacement of the current vehicle fleet with safe, environmentally friendly and affordable alternatives. Hence, in the more ambitious LTS scenario, the assessment introduces **a two-step approach combining structural optimization with the current policy ambitions** of the Bulgarian government directed towards the introduction of a cleaner fuel mix and new generation vehicles in the passenger segment of the market.

All three scenarios foresee **the number of electric vehicles to increase significantly** – from 6,000 in 2025 to 1.4 million in the WEM Scenario, from 30,000 to 2.4 million in the KEP Scenario. Only in the LTS scenario is the main driver of the transport sector decarbonisation the large drop in the total number of vehicles on Bulgarian roads from almost 3 million in 2020 to 712,000 in 2050, of which low-carbon vehicles would make up around half of the total. The sharp reduction in the overall vehicle fleet comes on the back of the strong state support for public transportation and the introduction of wide reaching behavioural changes.

The role of electric vehicles should be further stressed because electric cars transform more than 77% of the electrical energy sourced from the grid into driving power.[30] In contrast, internal combustion engine (ICE) vehicles can only convert approximately 12-30% of the energy contained in gasoline. This clearly indicates the EVs' higher level of efficiency. A study by the Norwegian Water Resources and Energy Directorate (NVE) shows that a typical registered EV in Norway consumes roughly 11 MWh per year. This means that the projections for a highly expanded power demand in the *KEP Scenario* due to the penetration of e-vehicles are highly exaggerated. Even at the highly optimistic vision for the uptake of e-vehicles, i.e. 550,000 electric cars on the Bulgarian roads by 2030, power demand would jump by 6 TWh only or around 15% above today's levels.[31] **The expansion of the e-vehicles fleet**

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[30] Lovell, J., "EVs: Are they really more efficient?", Australian Energy Council, January 30, 2020.

[31] Norwegian Water Resources and Energy Directorate, *Energy Use in Road Transport 2020*, NVE, 2020.

can be sustainable only in tandem with the decarbonisation of the grid or if charging is based on decentralised locally-generated wind and solar energy by households or businesses themselves. At the level of the low-voltage grids, e-vehicles can be used as a form of distributed power storage to balance the grid and reduce the need for peak-time baseload generation. This means that EVs can store electricity when demand is low and supply it back to the grid when demand is high, reducing the overall energy consumption and increasing the efficiency of the electricity grid.

Structural Optimisation and Behavioural Changes

To decarbonise the transport sector, Bulgaria needs to **take up advanced processes of automatization and digitalization**, improved infrastructure and logistics, revitalization of electric public transportation modes, **the expansion of share-economy models** in the travelling and delivery segments and shifts in work-life modes (for instance the provision of distance working conditions). The modelling assessment suggests that keeping all the other parameters constant, **structural optimization might contribute to a 2/3 reduction** of the overall GHG emissions by 2050. In particular, the envisioned policies strive to optimize **occupancy rates in passenger transport**, measured as the number of people in vehicles on the road, as well as to double the passenger transport kilometres with the available vehicle fleet through incentivizing car sharing practices.

Transition to various alternatives of traditional oil-based fuels could have an additional impact on GHG emissions in the sector. However, the radical shift to new technology solutions such as battery electric vehicles, new generation biofuels, and hydrogen face significant barriers. Due to the current low penetration level and nascent charging infrastructure, conventional liquid fuels powering combustion engines would remain the main fuel of choice even until 2040. Therefore, practical approaches for decreasing fuel consumption of large duty vehicle (LDVs), such as engine and conventional power train developments, hybridisation and light-weighting, as well as different techniques for the control of exhaust emissions (particulates, NOx, CO and HC) are also considered and their effects measured in respective energy efficiency improvements.[32]

Promoting sustainable behaviour change is crucial to decarbonize Bulgaria's transport sector and to achieve the EU's climate goals. **Challenges include policy and regulation, financial incentives and disincentives, education and awareness-raising, social norms and networks, and technology and innovation**. Positive examples of successful initiatives and critical lessons learned should be explored. Policymakers, practitioners, and researchers can benefit from the behavioural change recommendations below to implement sustainable mobility.

Bulgaria should embrace consistent and extensive measures to incentivize people to adopt alternative mobility options and to improve urban planning

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32 Leach, F. et al., *The scope for improving the efficiency and environmental impact of internal combustion engines*, Transportation Engineering, Volume 1, 2020.

that favours pedestrians and bikers, which, thus, reduces the overall car and van fleet in cities. Electrification of the transport sector depends on consumer choices. Yet, infrastructural pre-conditions such as charging station networks, incentive programs for EV adoption, or zero emission vehicle standards could accelerate its deployment *en masse*. The government should also support a fleet conversion in freight although the currently available technologies are still not mature enough to make them a cost-competitive alternative before 2025. Policies directed at research and development in vehicle development and new generation of fuels, digitalization as well as routes and load optimization could improve the efficiency of logistics.

Industry

The most difficult decarbonisation challenge for Bulgaria lies in the **lowering of energy and carbon intensity, as well as the fostering of green innovations in industry**. Fuel mix and the efficiency of materials are among the key drivers for reducing GHG emissions and the energy demand of industrial processes. The country's current **strategic framework does not adequately address the challenges of industrial decarbonisation** as most measures and investments are concentrated in the transformation of the energy sector. In 2020, industry made up approximately 15% of Bulgaria's total GHG emissions. With the decline of fossil-fuel-based energy production, industry will become the second biggest GHG emitter in the country after transport, while facing also some of the biggest carbon-pricing-related costs as per the 'Fit-for-55' policy framework.

A Herculean Challenge

Despite the enormous challenges representing the decarbonisation of the Bulgarian industry, there is little to no attention paid to the three key elements of reducing industrial emissions including:

- Lowering energy demand: Bulgaria's industry remains around **2.5 times more energy intensive** than the EU average
- The electrification of energy consumption in combination with the massive uptake of **decentralized renewable energy-based power plants** and the introduction of synthetic fuels and hydrogen.
- **Optimizing material use towards a circular-based production process:**[33] by 2050, 20% of steel in car manufacturing has to be replaced by chemical products and 50% by aluminium; In new buildings: 20% of steel has to be replaced by wood, 40% of cement by wood, and 10% of chemical products by paper fibres; in building renovations: 20% of chemical products have to be replaced by paper fibres, and 20% by wood.

The surge in energy prices since 2021 has put even greater pressure on industrial energy consumers to cut demand and decarbonise. The market signals have pushed business owners to rethink their energy supply mix and

[33] In 2019, the productivity of the resource use is EUR 0,3288 per kg while the EU average is EUR 2.1 euros per kg; National Recovery and Resilience Plan for Bulgaria, October 2021.

to invest in replacing expensive natural gas with electricity (where this is technologically possible) and with propane (which does not actually reduce GHG emissions but has become more cost effective). Industrial gas demand fell by 17% year-on-year in 2022 and is likely to fall further in 2023 as large energy consumers are accelerating investments in decentralized power supply systems and energy efficiency. Importantly, the fall in consumption did not undermine the country's overall industrial output. In fact, Bulgaria was one of the member states with the highest growth rates in the EU in terms of industrial output in 2022.

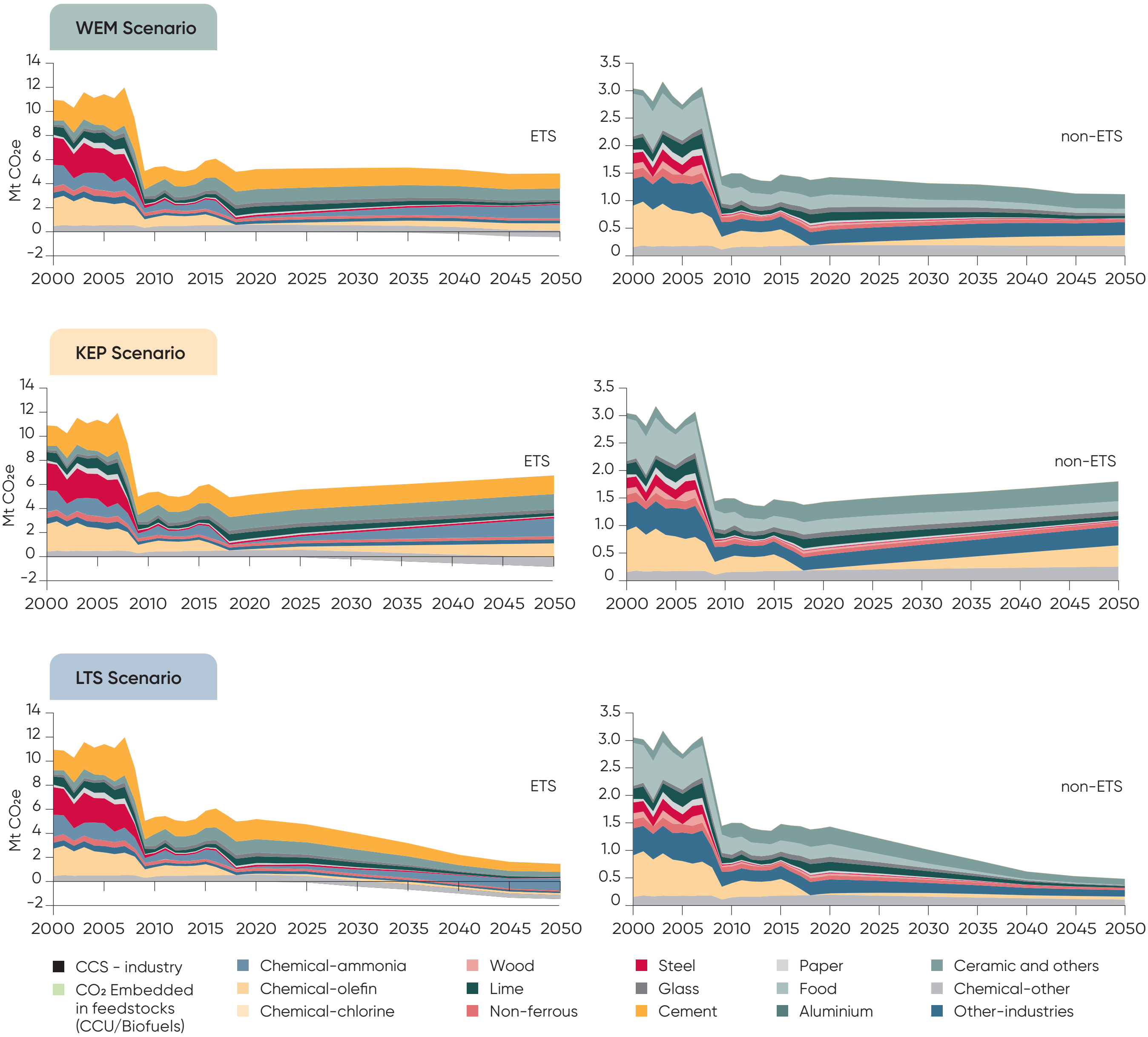
The most carbon and energy-intensive industrial subsectors including metals extraction, refining, petrochemicals, cement, ceramics and glassworks are highly concentrated in the hands of a few large-scale businesses that are also often part of multi-national European groups that have already initiated investment plans for industrial transformation and decarbonisation. However, there is no one-size-fits-all approach and solution for all and **the transition of industry will be much harder than the one in the energy sector**. Although electrification is the long-term objective, high-temperature processes would still require the replacement of natural gas with hydrogen or synthetic fuels, technologies that are yet to become commercially viable on a large scale.

The findings from the modeling assessment confirm the notion that improving energy and material efficiency, accelerating the circularity of production and switching to low-carbon fuels and technologies remains a significant challenge. Considering the expected long-term growth of the Bulgarian economy, and the gradual convergence with the rest of the EU economies, the analysis of the GHG emissions trajectories show that in none of the observed scenarios carbon neutrality is possible.

In fact, in the KEP scenario emissions increase in both the ETS and the non-ETS sectors, by 30% and 26%, respectively from 2020 to 2050, driven by the expansion of the chemical industries including of ammonia and olefin production. In the baseline WEM scenario, GHG emissions fall marginally by 7% in the ETS segment and more sharply in the non-ETS sectors (by a fifth by 2050) of paper, wood, steel, glass, food and other light industries despite the rise in **emissions in the chemical sector, which proves to be the major driver of industrial manufacturing growth (40% of total industrial emissions)**. Most of the rest of the emissions are based on the cement and ceramic industries, which both remain largely stagnant in terms of total emissions, due to the expected continued growth in construction. Only in the LTS scenario do emissions drop sharply (by around 2/3 from 2020 to 2050) for both ETS and non-ETS sectors as with the exception of petrochemicals, all other industrial segments almost fully decarbonise in the next three decades. The main driver of the transition process is the natural gas phaseout in these subsectors and the extensive use of low-carbon electricity and hydrogen (See Figure 17 below for detailed breakdown).

The development of the energy demand trajectories is similar in the different scenarios. Consumption rises in both the WEM and the KEP scenarios by 29% and 51%, respectively, following the expected economic growth trend. The paradox is that the **baseline WEM scenario**, which envisions a continuation of the current policies, **sees stronger decarbonisation on the back of the electrification of industrial demand** (up by 55%) and moderate oil, coal, biomass

Figure 17. GHG Emissions Pathways in the Industrial Sector

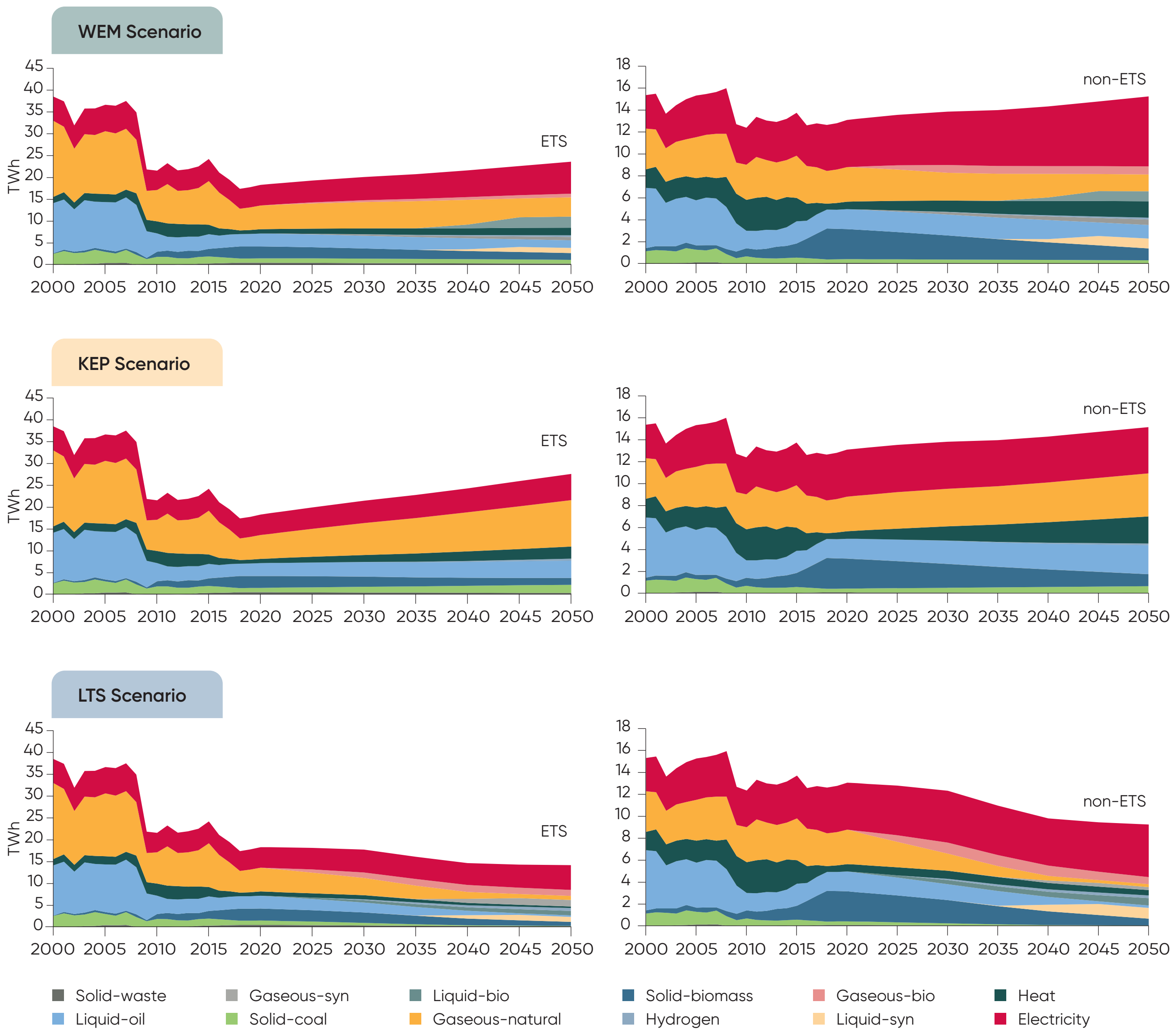


Source: CSD developed scenarios based on the Pathways Explorer.

and gas phaseout (by between -19% and -40%). Meanwhile and most worryingly, in the KEP scenario, which reflects the current vision for the development of the Bulgarian economy, natural gas and coal consumption almost double in the energy mix by 2050. Electrification is not as pronounced (a rise in 27%) despite the increase in the demand from light industries and services, which depend less on heat generation and on high-temperature production processes. The production of petrochemicals, cement and ceramics drive the rise in carbon intensity in such a way that the share of natural gas in the fuel mix expands from 30% to 40% over the next three decades in the KEP scenario. In the WEM scenario, electricity gradually replaces natural gas as the main source of energy consumption, while businesses also deploy hydrogen technologies, as well as bio- and synthetic fuels in their production processes.

However, it is only the more ambitious *LTS scenario* that reveals a much bigger decarbonisation for the industry. Overall, energy consumption drops by a quarter from 2020 to 2050 to 14,17 TWh in the ETS segment and by 29% in the non-ETS one down to 9,26 TWh, although the scenario sees a significant expansion of the petrochemical industry, which makes up a third of energy demand in 2050. Despite the rise in the petrochemical output, **the share of natural gas falls from 30% to 7%** in the observed period, while 40% of consumptions is taken up by electricity. **The reorientation of the economy away from heavy industry such as steel, aluminium and cement, towards lighter industries with higher added-value predisposes their growing share in the structure of energy demand over the next three decades**. As with other economic sectors such as buildings and transportation, electricity becomes the dominant fuel of choice (around 44% of the total) in energy, replacing natural

Figure 18. Energy Demand by Vector and by Scenario (ETS Split) in Industry



Source: CSD developed scenarios based on the Pathways Explorer.

gas, whose consumption declines by around 85% by 2050 between the ETS and non-ETS segments.

Supporting an Industrial Transformation

In line with the expected energy demand growth in the industrial sector, the Bulgarian government would need to provide strong state support in terms of incentives to businesses aiming to meet their decarbonisation goals. These could include tax incentives, loan programs, and high manufacturing standards for business projects optimizing internal manufacturing processes in line with the recommendations of the EU Industrial Strategy. Industry and manufacturing are likely to be among the biggest beneficiaries of the funding streams from the Bulgarian Operation Programs (2021-2027) for improving competitiveness and energy efficiency on top of the dedicated program in the NRRP for the uptake of decentralised RES-based power generation and storage capacity, and it is likely that the Just Transition Mechanism in combination with some of the EU horizontal programs such as InvestEU could be leveraged to achieve this transformation. However, without a major push from the government to incentivise big businesses to develop circular economy supply chains with high material efficiency starting already in the 2020s, the ***LTS scenario*** **for the industry remains an unlikely decarbonisation pathway for Bulgaria**.

Reaching the targets set by the *LTS* requires a structural shift in all industrial production processes, but especially in chemicals, iron, steelmaking, cement and ceramics. This could be achieved through switching to alternative manufacturing processes, using renewable energy and green hydrogen, or a combination between the utilization of renewable energy and the capturing of CO_2 emissions from existing processes with Carbon Capture, Utilization, and Storage (CCUS) technologies.

The current policy framework would not make **the uptake of an ambitious decarbonisation pathway possible**. While electrification of the production processes in combination with independent RES-based power generation systems would enable GHG emission reduction, the chemical sector would require a much faster integration of synthetic fuels. Pilot systems for their production are already available in some manufacturing facilities but upgrading them on a sectoral level would be difficult without dedicated support for covering the initial capital costs, especially related to electrolysis in hydrogen and synthetic methane production.

Agriculture and Land Use

AFOLU, which stands for Agriculture, Forestry and Other Land Uses, accounts globally for 20-24% of the net greenhouse gas emissions, mainly due to agricultural activities and deforestation. In Bulgaria, the sector is a net sink of emissions due to the lower level of deforestation, as well as the significant reduction in agricultural production capacity since the collapse of the Communist regime after 1989.

According to data from the National Greenhouse Gas Inventory of Bulgaria (2022), the Agricultural sector contributes to almost 13% of the total GHG emissions in the country, without counting the emissions and removals from Land use, Land-use change and the Forestry sector (LULUCF). The main sources of emissions in the sector are CH4 (Methane) emissions from enteric fermentation and N2O (Nitrous Oxide) emissions, associated with manure management and with direct and indirect emissions from agricultural soils. Although a steady trend in falling emissions can be observed since the 1990's, in the past decade, **there has been a slight increase in agricultural emissions** due to the overall development of the sector linked to increased investments on the back of lavish subsidies and the intensification of the cultivation of agricultural lands. Thus, there has been an increase in the rate of emissions from agricultural soils, which is also a by-product of the jump in the application of synthetic nitrogenous fertilizers and urea application.

The land-use and forestry sector has become a net sink of GHG emissions. Ye, the level of the net removals of CO_2 (Carbon Dioxide) from the atmosphere has gone down because of a jump in the harvesting of forests and the observed increase in their average age. Although harvesting is on the rise, the forest stock in Bulgaria is on an upward trajectory and is set to expand further in the next 20-30 years.

The share of carbon sequestration from the total GHG emissions in the country is remarkable – almost 20%, which could be also explained by the drop of emissions in all other economic sectors since the 1990s, as the Bulgarian economy has restructured away from the heavy industry and into services-led growth. However, to maintain the ratio between carbon sinks and other sectoral emissions, Bulgaria needs to take up specific actions with a focus on conservation, restoration, and improved land management e.g. the stimulation of forest ecosystems, grassland biomass, agricultural lands etc. In addition, the Bulgarian government needs to incentivise behavioural changes of food consumption patterns, the diet, and waste management.

Bulgaria does not have clearly defined sectoral policies and measures towards the fulfilment of its emissions reduction commitment in the AFOLU sector. In addition, the government has lagged behind on delivering its national strategic plans and programmes in the field of Agriculture and Forestry, which further poses ambiguity on the concrete priorities in sectoral policy development and innovation. This complicates the definition of specific scenarios for GHG emissions reductions in Agriculture or the enhancement of the carbon stock and sequestration potential of forests.

A Transition Without Specific National Policy Framework

As there is no elaborated national policy framework for the sector in Bulgaria, the assumptions in the three elaborated scenarios follow the general policy visions in the EU's environmental, climate, and biodiversity protection commitments set in the European Green Deal and the associated EU strategic documents such as the EU Common Agricultural Policy (CAP), the Farm to Fork strategy, the EU Biodiversity strategy and the EU Forest strategy, among others.

For example, farmers are rewarded for making extra steps in the implementation of sustainable agricultural practices under the so called ‘eco-schemes’, introduced by CAP. Such practices can include agroecology, organic farming and agroforestry, as well as other environmentally friendly production systems. Farmers are also compensated under the rural development framework and its environmental and climate management commitments for voluntarily committing themselves to the implementation of sustainable practices.

These policies are to be addressed in national strategies and programmes, which are still under preparation. However, in the draft national CAP’s strategic plan, there is a **lack of clarity on the extent of the necessary measures**, as well as the particular targets for the reduction of emissions from the sector. This hinders the definition of realistic decarbonisation visions based on the current policies and, as a result, makes the creation of elaborate visions for the evolution of GHG emissions from the Agriculture and Land sector difficult.

Hence, the *KEP and WEM scenarios* both define the GHG emissions trajectory based on 1) the expected continuation of the current forest management strategy in the country, and 2) the extrapolation of the current trends in the development of the agriculture sector. However, the scenario considers the possible effect of implementing less intensive agricultural practices (such as reducing the application of inorganic fertilizers and pesticides), which are implicitly included in the EU CAP’s objectives.

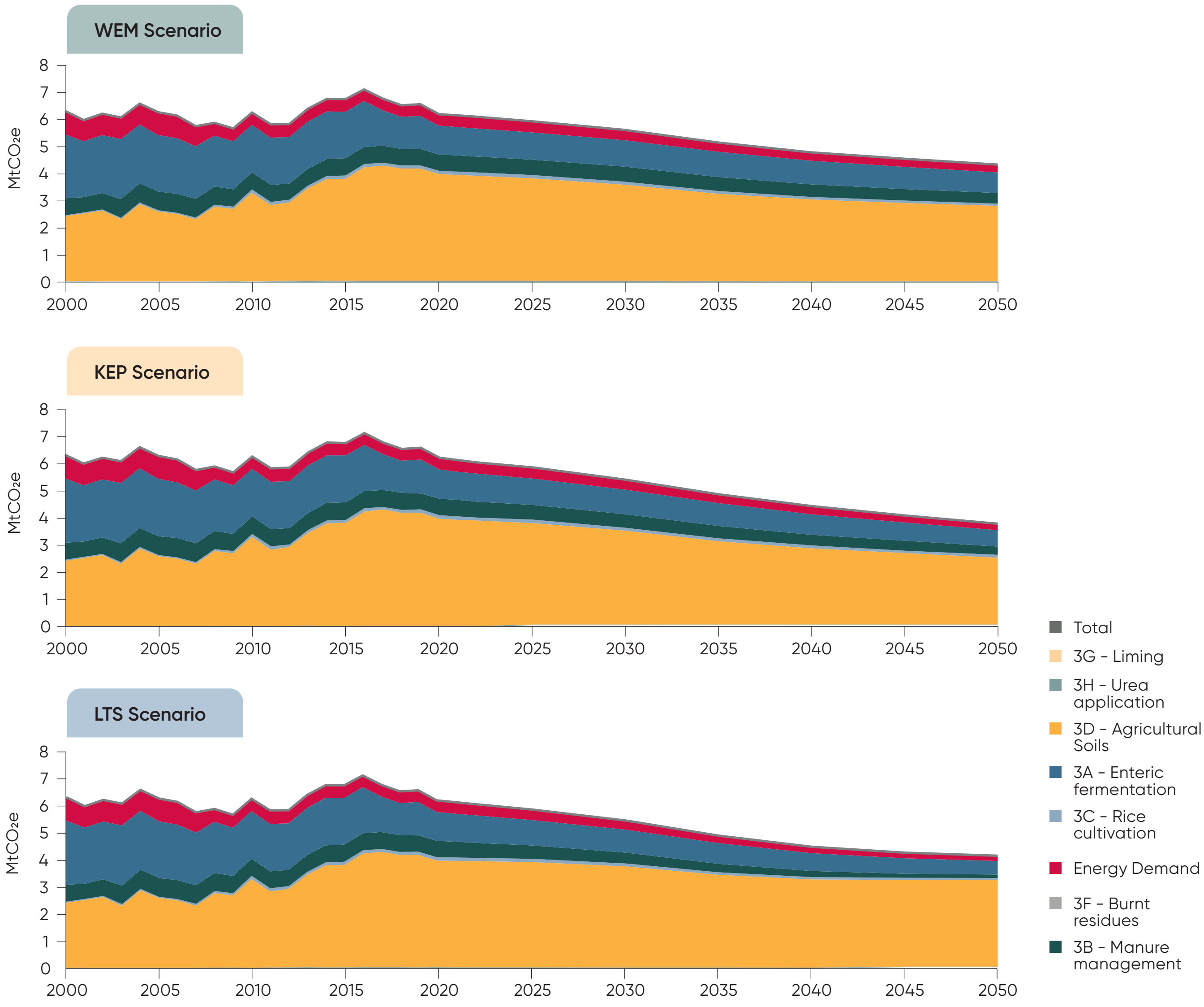
The LTS scenario is more ambitious than the other two visions and aims to reveal what would be the evolution of the GHG emissions in the agricultural sector and the carbon removals trend if more integrated actions towards emissions reduction are undertaken.

The main drivers for the trajectory of the emissions trend in all scenarios are **the land allocations and the related land-use changes**, the emissions and removals from forest lands, as well as the emissions associated with agricultural soil management. The direct effects of some behavioural changes such as meatless diet, limited consumption, food waste management etc. on the overall emissions reduction are not considered. However, these changes have an important impact on the land allocation as they can trigger increase and/or decrease in agricultural lands and thus contribute to the change in the GHG emissions in the atmosphere.

In the *KEP scenario*, agricultural emissions would fall by 40% from 6.19 in 2020 to 3.74 Mt CO_2e (Figure 18) by 2050. In contrast, the *LTS scenario* sees additional 15% reduction in the total emissions from the sector down to 3.19 Mt CO_2e. The reduction is mainly due to changes in the agricultural practices with focus on applied entrants to the soils such as fertilizers, pesticides, promotion of green manure and organic fertilization, and others.

Although there has been an increase in the inputs of N fertilizers in Bulgaria since 2015, this trend is expected to be reversed because of the general provisions of the EU’s CAP, the Green Deal, and the Farm to Fork strategy. The trend in the *KEP scenario* is for a 20% reduction in applied fertilizers (N, K, P) and pesticides over the next 30 years. This assumption is in line with the draft of the Bulgarian CAP’s Strategic plan, which envisages supporting schemes for organic farming, maintenance of soil organic matter through appropriate practices, and responsible use of inputs such as fertilizers and pesticides. Meanwhile, the more ambitious *LTS scenario* projects a decrease in fertilizers' and pesticides' application by 60% until 2050 in comparison with the 2015 levels.

Figure 19. GHG Emissions per Agricultural Sector



Source: CSD based on the Pathways Explorer.

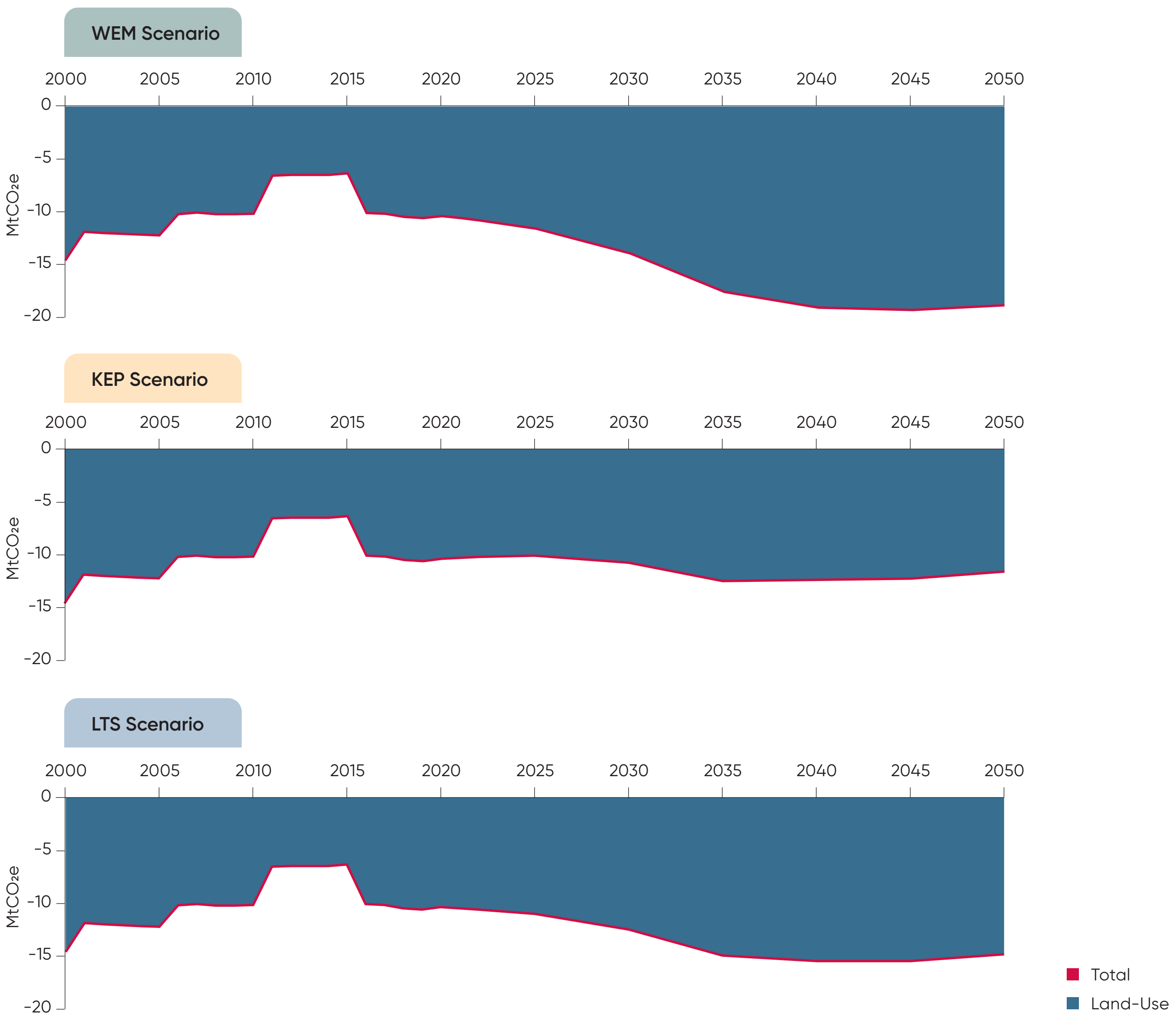
The *KEP scenario* also envisions a cut in non-CO_2 emissions from livestock. The projections reveal a fall in methane emissions from Enteric fermentation by 43% by 2050. The non-CO_2 emissions from Manure management will decrease by 50% during the same period. The main driver of this trend is expected to come on the back of **improved manure management**, while there is no further intensification of livestock production is likely until 2050, which is also consistent with general trends for the decline in the Bulgarian population, and hence, of total food consumption. The more ambitious scenario also predicts **a decrease in methane emissions from Enteric fermentation by 65%**

in comparison and a decrease in non-CO_2 emissions from Manure management by 85%.

Meanwhile, the energy demand in the Agricultural sector is expected to decrease between 37% and 42%, according to the LTS and the KEP scenarios, respectively, due to improved energy efficiency (25% decline in energy demand by 2050 in both scenarios) on the back of innovation in the maintenance of equipment. **Energy efficiency improvements come hand in hand with a massive shift to renewable energy sources** such as biogas and agrivoltaics.

Decarbonisation does not concern only the agricultural sector but would also depend on higher carbon removals by 11% from -10.39 $MtCO_2e$ in 2020 to -11.58 $MtCO_2e$ in 2050, according to the *KEP scenario* (See Figure 19). The main driver for this positive change is the land allocation and more specifically the

Figure 20. GHG Emissions in the Land Use Segment



Source: CSD based on the Pathways Explorer.

evolution of the scope of the so-called ‘other territories’ (shrubs, secondary grasslands, marginal lands, other disturbed terrains, wetlands, rock, barren areas etc.).

The *LTS scenario* is even more ambitious as it projects an increase in the net removals by 38% to -14.41 MtCO_2e in 2050 compared to the 2020 levels. The main difference between the two scenarios is the projected evolution of the category of “Other” lands. In the *KEP scenario* it is projected that the “Other” category will decrease by only 6%, whereas in the more ambitious *LTS scenario*, a 22% decline is to be expected.

Expanding the Carbon Sink

The ***KEP Scenario*** **sees the forestry area expanding by 9% until 2050 up to 4.26 million hectares (mha)** due to land-use changes from grasslands and other lands such as shrubby areas. This assumption is in line with the historical trend of land-use shifts to wooded lands, which in most cases are driven by the natural regrowth on abandoned agricultural lands. The expected change is similar to what is already observed in the past 30 years, and despite the absence of particular policies for afforestation.

The *LTS scenario* envisages a bigger increase in the total area taken up by forests up to 4.32 mha in 2050. This will contribute to an increase of carbon sequestration, which would require dedicated actions towards afforestation as well as legislative steps strengthening the protection regimes for forests and the reconversion of arable land to forests. Although **the LTS scenario predicts a bigger increase in wooded lands, it is worth mentioning that the potential for the increase in forest lands** is even larger taking into consideration the large extent of shrubby and marginal lands referred to in this study under the “Other” category.

Two scenarios have been projected for Bulgaria’s agricultural area, including arable lands and grasslands. According to the KEP scenario, the total agricultural area is projected to decrease slightly by 5%, while the LTS scenario predicts that it will remain the same as 2020 levels. However, the allocation between the different categories of the agricultural area will change more substantially.

The area of non-food cropland is expected to increase from 41 ha in 2020 to 460 thousand hectares (kha) until 2050 in response to the growing demand for biomass for renewable energy production like bioliquids. The LTS scenario predicts an even bigger increase to 542 kha until 2050. The increase in non-food cropland area would affect the size of arable lands, which are expected to decrease by 17% from 3.6 m ha in 2020 to around 3 mha in 2050 in both scenarios. The projected decline in croplands is in line with the expected changes in the food market demand in relation to the projected demographic structure and the lifestyle diet changes associated with **an overall decrease in calories intake per capita**. Thus, the increase in non-food croplands is not considered detrimental to the country’s food security.

According to the KEP scenario, the area of pastures (permanent and temporary) is set to decrease by 20% due to the expected changes in livestock production and management. However, the total grassland area is expected to remain within the limits from 2020 due to newly developed secondary grasslands from other land categories. The LTS scenario predicts a bigger increase in newly developed grasslands, thus the total area of the grassland is expected to increase by as little as 5%.

The settlement area, which refers to urban infrastructure, is expected to increase by 1.5% until 2050 according to the KEP scenario, representing the historical trend of change. All areas related to transportation systems such as railway routes, highways, etc., or other areas with artificial surfaces, are expected to increase more intensively and are considered part of the "Other" category. In comparison, the **LTS scenario predicts a lower increase in the buildout of urban infrastructure of 1% until 2050**.

Another important aspect of the overall emissions and removals from the land-use and forestry sector is **the carbon balance and sequestration potential of the wooded lands**. In Bulgaria, the forestry sector is expected to continue to follow the principles of sustainable forest management practices. The harvest intensity is set to increase by 10-15% but will remain below the expected amount of the mean annual increment. The **share of the firewood use is expected to decrease** due to the adoption and implementation of various programs and measures towards energy efficiency improvement in the building sector and the increasing share of wood pellet use. The sequestration potential of the forest biomass depends on the dynamic of the age-dependent forest's characteristics. Thus, the application of proper silvicultural practices is encouraged with measures such as regular thinning, **successful conversion of coppice forests into seed forests**, applying cuttings with prolonged regeneration period, etc.

WHAT'S NEXT?

In the aftermaths of the Russian invasion in Ukraine, the EU has raised its overall decarbonisation ambitions via the REPowerEU initiative. The EU has defined a new energy and climate security strategy that aims to **decouple from the dependence on fossil fuel imports** on the basis of accelerating renewable energy investments, boosting energy savings and diversifying and friendshoring supply of energy and materials. More than a year after the conflict in Ukraine began, Bulgaria has been reluctant to up its 2030 climate targets. The EC should work with the Bulgarian government to promote the adoption of **more ambitious climate transition measures**, such as:

- an as early as possible coal phase out;
- the building of sustainable energy infrastructure and RES expansion;
- promoting investments in innovative technologies including offshore wind, battery storage and smart grids;
- the removal of legal and administrative barriers for small-scale citizen-led projects.

Choosing to decarbonize the energy system, with long term emission reduction targets in mind, would require **massive investment in renewable energy**. This in turn necessitates sophisticated economic transition planning on all governance levels so as to not leave a gap in the security of supply. Bulgaria needs to utilize the EU funds at its disposal to create the necessary investment environment for ushering a private sector and citizen-led switch to renewables **en masse**, instead of the current focus on a few unnecessary large infrastructure projects. Without an effective and transparent spending plan with long-term objectives and indicators for success, the transition could cause a popular backlash.

The modelling scenarios clearly reveal that the main difference between a moderate emission reduction and a full decarbonisation in the economy comes down to **the transformation of individual and collective lifestyle choices**. To enable these profound lifestyle changes, the government should introduce a coherent framework for a sustainable consumption policy that is a mix of fiscal incentives which raise the cost of wasteful consumption, vehicle/property ownership, and considerable investment in public transportation and power charging infrastructure, as well as the introduction of high efficiency standards for construction.

The following set of measures is a non-exhaustive list of sector by sector short and long-term policy actions, which could enable the **unlocking of Bulgaria's decarbonisation potential**.

Energy

- 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 utilizing available technical assistance programs, the Just Transition Facility, the REPowerEU and the Modernization Fund for economic restructuring, reskilling of workers, the smart specialization of innovative industries and the deployment of renewable energy and storage technologies;

- Gradually **phase out natural gas** from the buildings and industry by 2035. In the short term, however, the Bulgarian government should secure two to five-year LNG supply contracts with non-Russian suppliers via the LNG regasification terminals in Greece and Turkey;

- Shelve the construction plans for **new nuclear power plants** until after 2040 when long-term decarbonisation scenarios show nuclear might actually be needed.

- Focus efforts on implementing comprehensive **energy efficiency** measures making savings one of the main priorities in the country's energy strategy. Lowering energy consumption will reduce security of supply concerns and will 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;

- 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 to the Black Sea market;[34]

- 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, which presents an important technical pre-condition for demand response management;

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[34] 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.

- Introduce amendments to the RES regulatory framework and financial schemes in order to **de-risk renewable investments** and guarantee 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, which could undermine the development of the electricity system in the medium run.

- 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 kye first step would be to remove all legal and administrative barriers for **small-scale citizen-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**, which steps on the comprehensive stakeholder engagement process within the Energy Transition Committee, which fosters expert knowledge exchange, improves policy coordination and ensures transparency and legitimacy of the drafting and updating of core strategic documents.

Buildings

- Increase the **rate and depth of renovations** by setting the target annual renovation rate at 3-4% over the 2021-2027 period compared to less than 1% currently. Shallow energy efficiency measures such as wall insulation must be superseded by deeper renovations that transition buildings to near-zero energy consumption through the integration of renewable energy for heating and power production. Prioritizing the worst-performing buildings and households struggling with energy poverty would also be essential to strengthen the social acceptance of large-scale energy efficiency programs.

- Introduce **deep renovation standards** in the Energy Performance of Buildings Directive (EPBD) due to be passed in 2023 so that deep renovation is considered the norm in energy efficiency measures on the basis of clear and well-targeted renovation requirements.

- **Smarten buildings** by introducing buildings monitoring systems that can help reduce energy demand and optimise heating, cooling, lighting, and ventilation systems based on occupancy and weather conditions.

- Ease the **access to renewable energy technologies** of citizens and small businesses to achieve near-zero energy consumption in residential buildings. This requires the provision of incentives for households to invest in RES alongside the building renovation process.

- Introduce a combination of **grant financing with ESCO schemes** to incentivise household investment in energy efficiency that is not depending on 100% state financing.

- Encourage **conscious consumption patterns** among households, which could, thus, reduce energy demand and emissions. This would require changes in behavioural habits, such as using the existing and new building stock more efficiently and decreasing the per capita demand for additional residential space. Rather than contributing to the construction of new buildings, the government should prioritize measures and support tools for accelerating renovation and incentivising the take-up of more efficient or less-carbon-intensive heating technologies such as heat pumps and solar collectors.

- Address **state capture practices in the construction sector** as a matter of priority. Without strict regulations, stronger rule of law and monitoring tools in the buildings sector, there is a serious risk that the funds under the NRRP allocated for the large-scale renovation program might be misused and open the door for corrupt practices.

Transport

- **Increase public awareness and education** about the impact of transport emissions on the environment and public health**,** and encourage individuals and businesses to make sustainable choices by providing incentives, such as tax credits or subsidies for low-emission vehicles and sustainable transportation options.

- Invest in **research and development** of new technologies and solutions to improve transportation sustainability. This could include the development of new fuel technologies, the improvement of public transport systems, and the development of intelligent transportation systems.

- Focus on **sustainable and active transport** such as public transport, cycling, and walking. This could be achieved through the development of infrastructure for cycling and walking, as well as the expansion of public transport systems;

- Implement policies to reduce the overall **demand for transport,** such as encouraging telecommuting and remote work, promoting urbanization and mixed-use development, and incentivizing the use of shared transportation options like carpooling and ride-sharing services.

- Strengthen regulations to limit **emissions from vehicles**, including emissions standards for new vehicles and mandatory vehicle inspections to ensure that older vehicles meet emissions standards.

- Unlocking the decarbonization potential of Bulgaria's transportation sector by implementation of **low emissions zones** in major cities. This policy could be complemented by offering incentives for the purchase of low-emission vehicles, such as tax rebates or subsidies. By improving air quality and reducing emissions in major cities, Bulgaria can improve public health and contribute to its overall decarbonization goals.

- Incentivize the use of **low-carbon vehicles** through instruments**,** such as tax rebates, subsidies, and reduced tolls for low-carbon vehicles could be implemented to encourage the uptake of electric vehicles.

- Improve the efficiency of **freight transport** through encouraging the use of more efficient trucks, trains, and ships, as well as implementing logistics strategies to optimize transport routes and reduce empty runs, can help reduce emissions.

- Increase investment in **low-carbon infrastructure**, such as charging stations and renewable energy sources, to facilitate the uptake of low-carbon vehicles.

- Introducing **low-carbon fuels** (biofuels, hydrogen, and others) to replace fossil fuels in transportation, and, thus, reduce emissions. The government can encourage the production and the adoption of these fuels through subsidies and other incentives.

- Implementing **congestion pricing** for busy roads and areas to reduce the number of cars on the road and encourage the use of public transportation or active transportation.

- Support **fleet renewal** to reduce road transport-related emissions and improve city air quality. Consumers can prioritize the use of new-generation low-carbon vehicles, and governments can incentivize the utilization of such vehicles through tax exemptions, subsidies, or flexible financing schemes.

Industry

- The fastest and cheapest way to decarbonise the Bulgarian industry is through the **electrification of production processes** where this is technically feasible.

- Electrification should go hand in hand with the **uptake of renewable energy** as only a decarbonised grid could reduce emissions in the industrial sector.

- In the **chemical industry**, which contributes to around 40% of all GHG emissions and energy demand in industry, the use of natural gas should be replaced by the gradual introduction of synthetic fuels and hydrogen. Government support should be prioritized for pilot projects dealing with the integration of these alternative fuels into the supply chains of fertilizer and basic chemical manufacturers.

- The government should further ease the conclusion of corporate power purchase agreements (PPAs) where businesses can invest in the development of renewable energy-based power **generation units for own consumption**. This would require both the removal of administrative burdens for the installation of new plants and close coordination with the transmission system operator (ESO) and the distribution system operators (DSO) who can better streamline capacity addition approval processes and improve long-term planning for infrastructure upgrades to allow faster integration of business-linked RES plants.

- The planned investments in the low-carbon transition of businesses in the NRRP via the integration of RES plants focus excessively on the introduction of power storage technologies which is currently the most expensive technological solution. This limits the total coverage of the program to very few companies, hence providing for only a marginal uptake of renewables among SMEs. Instead of prioritising investments in renewable energy self-consumption only, the government should work with the DSOs to enable **effective net-metering systems**, in which businesses could become active power market players on par with electricity plants only.

- Overall, there is a need for economic restructuring towards increased production of goods with higher value-added instead of dependence on mineral extraction. A key will be to increase the use of **higher recycling rates** for plastics, metals and other carbon-intensive products. Bulgaria could become a regional secondary market for recycled materials and industrial products with the ambition of kick-starting the circular economy.

Agriculture and Land Use

- Ensure more consistency between the national policy framework and the goals of the European Green Deal with focus on accelerating **ecosystem restoration** and improving **soil health**. Long-term national strategies in agriculture and land use need to step on a solid scientific basis and on close policy coordination across different government actors.

- Develop a National Forestry Strategy until 2030, which recognises the **role of the forest** in the climate mitigation process by introducing measures to reduce climate change-related risks for the forest ecosystem and to stress out the need for adaptation. A special implementation plan attached to the Strategy needs to set clear goals and measures for enhancing the potential for carbon removals by aging forest stocks.

- Change the regulations related to the **forest inventory and planning** with the goal of implementing the National Forest Inventory in Bulgaria which will improve the quantitative and qualitative data about the forest ecosystem in the country encompassing all the carbon pools – biomass, dead wood, litter and soil.

- Implement a comprehensive strategic programme for **afforestation** that aims to expand the forest stock and to promote sustainable land management practices through targeted financial and policy incentives.

- Elaborate and adopt a National Soil Strategy, which aims to ensure **sustainable soil management and restoration** on the back of the gradual decline of the use of pesticides that are some of the main sources of agricultural emissions.

- Develop a 2030 National Programme for the implementation of the Farm to Fork strategy of the EU that encourage **sustainable farming** practices such as crop rotation, agroforestry, and conservation tillage can help reduce carbon emissions in the agricultural sector. These practices improve soil health, increase biodiversity, and reduce the need for synthetic fertilizers and pesticides.

- Introduce **carbon farming** that involves using agricultural practices to sequester carbon in the soil and vegetation. This can include practices such as no-till farming, cover cropping, and agroforestry. Providing financial incentives and support for carbon farming practices can help farmers to reduce their carbon footprint and earn income from carbon credits.

- Ensure more **sustainable livestock management** by encouraging sustainable livestock management practices such as improved feed management, pasture management, and manure management can help to reduce these emissions. Synergies with the energy sector should be explored especially in the production of biogas to be fed in the gas transmission system or the generation of electricity from biomass.