CENTER FOR THE STUDY OF DEMOCRACY

Future Resilience

Building Bulgaria's Path to Clean Growth, Industrial Competitiveness and Economic Security

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DEMOCRACY

Bulgaria faces a convergence of global pressures that undermine its energy security, supply chain resilience, competitiveness and strategic autonomy. Yet these same dynamics also offer an opening for the country to reposition itself as a regional decarbonisation and innovation hub. By leveraging emerging technologies, strengthening institutional capacity, and accelerating the green transition, Bulgaria can enhance its economic growth and long-term energy and climate security.

To realise this potential, Bulgaria must better align its energy, innovation and security policies with the EU-US-G7 geoeconomics architecture; diversify its energy mix through a balanced and forward-looking low-carbon strategy; and scale-up investments in innovation, manufacturing, skills and strategic partnerships. Mobilising the full suite of available EU and national funding instruments will be essential to deliver on these strategic objectives.

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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
CBAM	Carbon Capture, Utilisation and Storage
CCUS	Carbon Capture and Storage
CfD	Contract for Difference
CRM	Critical Raw Materials
DSO	Distribution Systems Operator
ECSRI	Energy and Climate Security Risk Index
EED	Energy Efficiency Directive
EPBD	Energy Performance of Buildings Directive
ESO	Electricity System Operator
ETS	Emissions Trading Scheme
EU	European Union
GDP	Gross Domestic Product
GHG	Greenhouse Gas Emissions
GVA	Gross Value Added
HPP	Hydro Power Plant
IoT	Internet of Things
NECP	National Energy and Climate Plan
NPP	Nuclear Power Plant
NEK	National Electricity Company
NZIA	Net-Zero Industry Act
PPA	Power Purchasing Agreement
PV	Solar Photovoltaics
R&D	Research and Development
RES	Renewable Energy Sources
RRF	Recovery and Resilience Facility
SME	Small and Medium Enterprises
SMR	Small Modular Reactors
STEM	Science, Technology, Engineering, and Mathematics
TSO	Transmission Systems Operator

EXECUTIVE SUMMARY

Bulgaria is entering a decisive decade shaped by geopolitical realignment, technological competition, and the consolidation of global clean-energy value chains. Countries that successfully anchor innovation, industrial capacity, and energy security within a unified long-term strategy will emerge stronger and more resilient. Yet **Bulgaria continues to operate without such a strategic compass**. Fragmented governance, short political cycles, and institutional fragility have kept the country locked in a reactive, low-value economic model characterised by dependence on imported technologies, slow industrial modernisation, and chronic energy-system vulnerabilities.

Although Bulgaria benefits from the EU's extensive policy and funding architecture, it has struggled to leverage these tools effectively. Reforms have been piecemeal; major strategic documents are poorly coordinated; and administrative systems remain overloaded and under-resourced. Consequently, Bulgaria has repeatedly missed opportunities to modernise its energy system, strengthen its industrial base, and accelerate domestic innovation, even as neighbouring countries move decisively into clean-technology manufacturing, hydrogen development, and advanced infrastructure.

Over the past decade, the **shift toward low-carbon energy** has been driven mainly by market forces, especially the rapid and largely spontaneous expansion of solar PV. But this transition is incomplete and unbalanced. Wind energy development remains stalled; power grids and substations face growing congestion; digitalisation is insufficient; and the system lacks the flexibility required for high levels of variable generation. As a result, Bulgaria increasingly experiences negative electricity prices, curtailment risks, and underinvestment in essential technologies such as offshore wind, geothermal, and demand response. Transport emissions continue to rise, heating remains dominated by inefficient systems, and industrial decarbonisation has barely begun.

At the same time, Bulgaria possesses a suite of **strategic advantages** that remain largely untapped. It has excellent solar and wind resources, Europe-leading theoretical potential for geological CO_2 storage, high-temperature geothermal prospects, and growing capabilities in metals, electronics, digital technologies, and semiconductors. The country sits at a **pivotal geographical position** for regional energy, hydrogen, and CO_2 corridors, offering a foundation for new economic activity and regional influence. However, these strengths cannot generate competitive advantage without coordinated policies, predictable regulation, and long-term infrastructure planning.

Industrial capabilities tell a similar story. Bulgaria has assets in metals, mining, electronics, ICT, and mechanical engineering that could support competitive clean-tech value chains – from power electronics and battery components to offshore-wind structures and geothermal services. Yet the weak industrial strategy, the limited targeted support, and the insufficient integration into European industrial initiatives have left these opportunities largely unrealised.

Skills and innovation capacity remain among the country's most significant constraints. STEM shortages, low R&D spending, limited technology transfer, and continued emigration undermine Bulgaria's ability to build or absorb advanced low-carbon technologies. Strengthening education, research excellence, and industry–research collaboration is essential for the country to move up the value chain and retain high-skilled workers.

The success of any transformation depends on social acceptance and public trust. **Energy poverty** remains widespread, regional inequalities persist, and new technologies such as offshore wind, geothermal, hydrogen, and carbon management will require transparent engagement, predictable rules, and visible local benefits. Without rebuilding trust in institutions, Bulgaria will struggle to sustain long-term reforms.

Taken together, Bulgaria's position is clear: the country has the resources, capabilities, and geographic **advantages to become a competitive actor** in Europe's emerging clean tech industrial supply chains. But unlocking this potential requires a broader, long-term strategic vision that aligns energy, industry, innovation, infrastructure, and skills behind coherent national objectives. This report concludes that Bulgaria's future resilience depends on **eight priorities**:

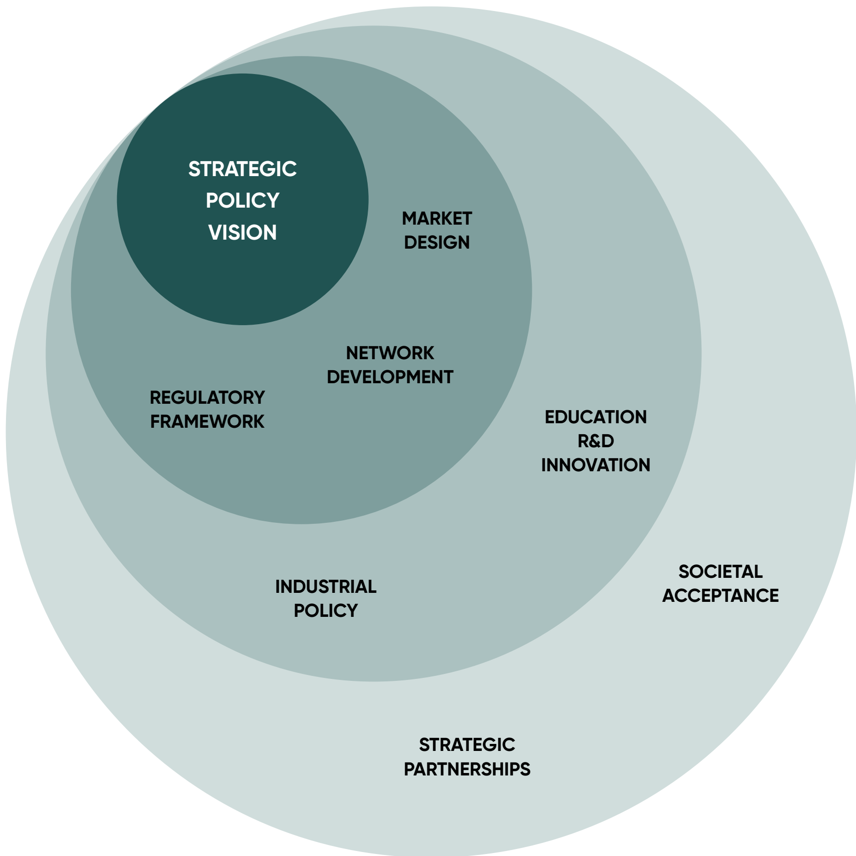
- Setting a unified **long-term vision** for economic and energy development.
- Creating a predictable, stable, and investment-friendly **regulatory environment**.
- Building a transparent, competitive, rules-based **energy market**.
- Modernising and **digitalising** energy, transport, and industrial infrastructure.
- Developing a vibrant local **clean-tech industrial base**.
- Strengthening **skills, research, and innovation** capacity.
- Ensuring societal benefits, **fairness, and public trust** in the transition.
- Forging **strategic partnerships** to anchor Bulgaria in global clean-tech ecosystems.

INTRODUCTION

Geopolitical competition, supply-chain fragmentation, and the accelerating technological race between major economies have transformed the energy transition from a primarily environmental and economic agenda into **a question of national security, strategic autonomy, and long-term economic resilience**. The countries that dominate clean-technology value chains, from photovoltaics and batteries to digital infrastructure, AI, and critical materials, will shape the next era of industrial and geopolitical leadership.

For over a decade, the Center for the Study of Democracy (CSD) has argued that Bulgaria must invest in sustainable innovation to turn environmental responsibility into an engine of competitiveness. That message has now become more urgent than ever. Bulgaria continues to rely heavily on imported technologies and fossil fuels, while domestic clean-technology development and advanced manufacturing remain limited. Instead of positioning itself at **the forefront of Europe's industrial renewal,** the country risks locking itself into **a low-value, low-productivity model** that leaves it vulnerable to external shocks and with a limited economic development potential**.**

Figure 1. System Redesign Matrix



Source: Center for the Study of Democracy.

The policy debate remains narrowly focused on electricity generation and building efficiency, instead of on industrial decarbonisation, clean manufacturing capacity, and innovation ecosystems. Most businesses continue to pursue incremental cost-saving measures rather than transformative technologies. At the same time, public support for low-carbon investment is inconsistent, and Bulgaria has yet to deploy the full power of public procurement, strategic state aid, or coordinated regional cooperation.

Yet, the stakes are far higher than simply meeting climate targets. Whether Bulgaria emerges from the coming decade as a secure, competitive, and technologically capable country will depend on its **ability to shape, not merely follow, the clean-economy transition.** It is no longer enough to deploy imported technologies; Bulgaria and Europe must increasingly be able to design and upscale them. This requires targeted investments in research and development, advanced manufacturing, modernised infrastructure, and a skilled workforce capable of supporting new industries.

At the same time, Bulgaria must anchor its own strategy within a broader European framework. No European Union (EU) Member State can achieve technological sovereignty alone. **Deeper integration with European partners, strategic alliances with like-minded countries, and participation in regional clean-technology value chains will be essential** to secure access to markets, knowledge, and supply chains.

This report argues that Bulgaria must seize the window created by multiple energy crises and global industrial shifts to articulate a clear, long-term vision linking energy security, innovation, and economic competitiveness. Without such a strategy, the country will continue to react to external pressures rather than shape its own future. With it, **Bulgaria can turn its natural advantages, human capital, and regional position into the foundations of a resilient, prosperous, and climate-neutral economy.**

THE POWER OF POLICY

Effective policy is the cornerstone of any successful energy and industrial transition. It sets the strategic direction, shapes investor expectations, and determines whether a country becomes a leader in the emerging clean economy or remains a passive recipient of external technologies and decisions. Bulgaria is in desperate need of a coherent long-term energy and economic security strategy that provides clarity, stability, and credible commitments. Recent history has shown how costly it can be when policy is reactive, fragmented, or captured by short-term interests. **While Europe managed to recover from the 2008 financial crisis, its policy response did not secure its long-term resilience**. Insufficient efforts to commercialise innovation, a fragmented energy market and decarbonisation policies, and high dependence on imported energy sources and low-carbon technologies, have all stifled Europe's competitiveness.[1] This has become increasingly apparent as the continent has faced cascading shocks since 2020 – from value chain disruptions during the pandemic and energy price shocks, to geopolitical rivalry and technological dependence. As the next decade will determine the winners and losers of the new industrial era, setting the right policy direction and ensuring its timely implementation is strategically indispensable.

The aftermath of the 2008 financial crisis, when the EU launched the **Europe 2020 strategy to drive innovation, sustainability and competitiveness**, highlighted structural weaknesses that continue to shape Bulgaria's transition today.[2] While the strategy provided Member States with a clear framework for modernising energy systems, boosting research and development and building resilient, low-carbon industries, Bulgaria failed to seize the opportunity. Long-standing governance deficits, political capture, and fragmented administration prevented the country from using EU funding and policy guidance to modernise its energy sector[3] or stimulate industrial innovation[4]. Instead, **successive governments prioritised short-term interests, maintaining dependence on carbon-intensive infrastructure and delaying diversification.** Weak coordination across institutions, limited analytical capacity, and the absence of strategic industrial policy further entrenched reactive, piecemeal decision-making-issues that continue to undermine Bulgaria's ability to align with Europe's current clean-growth agenda.

Bulgaria still lacks a unified vision linking energy security, economic competitiveness, and climate goals. As a result, the country entered the turbulent 2020s with fragile governance of the energy sector, outdated infrastructure, growing dependence on imported technologies, and no domestic industrial base capable of supporting the clean transition. The combined effects of bad

[1] Draghi, M., "The Future of European Competitiveness", September, 2024.

[2] European Commission, "EUROPE 2020: A European strategy for smart, sustainable and inclusive growth", 2010.

[3] Stefanov, R., et al., *Energy and Good Governance in Bulgaria: Trends and Policy Options*, Sofia: Center for the Study of Democracy, 2011.

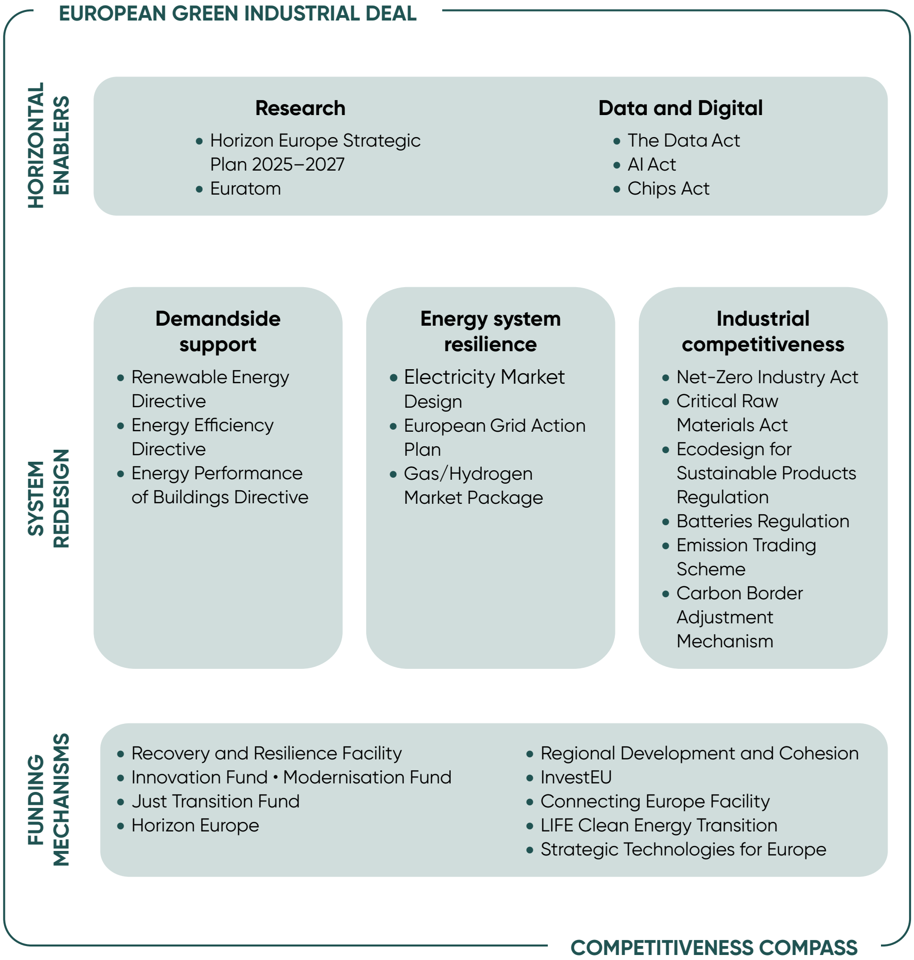
[4] Stefanov, R. et al., *Green Innovation.bg*, Sofia: Applied Research and Communications Fund, 2015.

governance, administrative stagnation, and the absence of forward-looking industrial policy meant that the country not only missed a historic opportunity for transformation but now faces the challenge of catching up under far more demanding global conditions. With the EU entering a new phase of geopolitical and economic transformation, **Bulgaria faces a critical choice: either continue reacting to events, weighed down by internal political rivalries, or finally design and follow through with a coherent, long-term strategy** for energy security, industrial competitiveness, and technological leadership.

EU Policy Framework

The EU has responded to the recent succession of crises with an **ambitious restructuring of its industrial, energy, and security policies that builds markets, reduces investment risks, and protects European industry in a world of geopolitical rivalry.** For Bulgaria, this amounts to an unprecedented opportunity to receive proper guidance, tools, and financing. If Bulgaria fails to mobilise the administrative capacity and political will to use these resources, it will widen the already growing energy transition gap between Bulgaria and with the rest of the Union.

Figure 2. EU Policy and Funding Framework for Energy Security, Industrial Competitiveness and Sustainability



Source: Center for the Study of Democracy.

The **Competitiveness Compass**[5] sets out an overarching framework based on three key priorities for the EU and its Member States for the 2025–2029 period**: closing the innovation gap, establishing a closer link between decarbonisation and competitiveness and increasing security, whilst reducing dependencies on external actors**. This framework then rests on three mutually reinforcing layers: demand-side rules that create stable markets for clean technologies; system and market reforms that make the energy system fit for high volumes of renewables; industrial, data and finance instruments that scale up and bring EU manufacturing and innovation up to speed with decarbonisation trends. At the same time, the framework is enhanced by horizontal enablers, complementary research priorities and multiple funding streams.

On the demand side, the **Renewable Energy Directive**[6], the **Energy Efficiency Directive**[7] and the **Energy Performance of Buildings Directive**[8], establish a long-term, legally anchored market for distributed renewables, electrification, and building renovation. They serve as market creation tools that provide European companies with predictable demand, crucial for investments in new products and services. The higher renewables generation and energy efficiency targets, coupled with faster permitting procedures, will not only help Europe meet its decarbonisation goals but also boost the competitiveness of European companies, while reducing the continent's dependence on imported energy sources. The countries with the lowest energy and climate security risk demonstrate a strong link between the improvement of sustainability indicators and the lowering of energy affordability risk. High shares of renewables in electricity generation and low energy and emissions intensities translate directly into lower CO_2 costs, electricity prices and energy expenditures. In addition, early investments in renewable energy sources lead to a decline in the geopolitical risk exposure associated with fossil fuel imports. The **policy-driven energy transition process means a more diversified power mix, and hence more reliable supply based on less volatile energy technologies**.[9]

In the current policy package, the fundamental shift in both supply and consumption is matched by specific measures accelerating system readiness and resilience. The **Electricity Market Design**[10], the **Gas/Hydrogen Market Package**[11] and the **European Grid Action Plan**[12] shift Europe's energy market

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5 European Commission, "Competitiveness Compass", Communication, 29 January 2025.

6 European Parliament and Council of the European Union, Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 on the promotion of the use of energy from renewable sources (RED III), 18 October 2023.

7 European Parliament and Council of the European Union, Directive (EU) 2023/1791 of the European Parliament and of the Council of 13 September 2023 on energy efficiency (recast).

8 European Parliament and Council of the European Union, Directive (EU) 2024/1275 of the European Parliament and of the Council of 24 April 2024 on the energy performance of buildings (recast).

9 Center for the Study of Democracy, Energy and Climate Security Risk Index, 2025.

10 European Parliament and Council of the European Union, Regulation (EU) 2024/1747 of the European Parliament and of the Council of 13 June 2024 amending Regulation (EU) 2019/943 on the internal market for electricity and other acts (Electricity Market Design – regulation pillar).

11 European Parliament and Council of the European Union, Directive (EU) 2024/1788 of the European Parliament and of the Council of 13 June 2024 on common rules for the internal markets for renewable gas, natural gas and hydrogen (recast).

12 European Commission, Communication "Grids, the missing link – An EU Action Plan for Grids", COM(2023) 757 final, 28 November 2023.

from short-term opportunism toward long-term investment stability, a direct response to the failures exposed by the 2021-2023 energy price surge. The power-market reform strengthens long-term contracting through the promotion of Power Purchasing Agreements (PPAs) and two-way Contracts for Difference (CfDs), improves consumer protections, and clarifies revenue frameworks in ways that stabilise renewables and storage returns on investment. The Gas/Hydrogen Package sets the internal-market framework for renewable and low-carbon gases, including access, tariffs and hydrogen network rules during the ramp-up phase. The **Grid Action Plan**, meanwhile, sets out short-term measures and guidance to expand and digitalise transmission and distribution networks and to integrate flexibility. All these combined measures will not only increase investment confidence and reduce energy price volatility, but also address the structural weaknesses exposed during the recent energy crisis.

On the industrial side, the **Net-Zero Industry Act** (NZIA)[13] and the **Critical Raw Materials Act** (CRMA)[14] aim to build domestic low-carbon manufacturing capacity, boosting competitiveness and strategic autonomy in critical materials – a direct response to the US and China's weaponisation of global supply chains. NZIA simplifies permitting for strategic net-zero technologies and encourages diversification in public tenders, while CRMA sets EU benchmarks across extraction, processing and recycling to reduce single-supplier dependencies. The **Ecodesign for Sustainable Products Regulation**[15] and the 2023 Batteries Regulation[16] add lifecycle, circularity and traceability obligations, raising global standards for products made or placed on the EU market, rewarding companies that design for durability, repairability and low embedded emissions. The trade and carbon-pricing layer of the EU policy framework reinforces this shift. The reformed **EU Emission Trading Scheme** (ETS)[17] will continue to tighten the emissions cap, while the **Carbon Border Adjustment Mechanism** (CBAM)[18] will be fully implemented from 2026, levelling the playing field for EU producers as free allowances for industry are gradually phased out.

Industrial and energy policy is supported by digital and research policy horizontal enablers. The **Horizon Europe Strategic Plan 2025–2027**[19] aligns calls

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[13] European Parliament and Council of the European Union, Regulation (EU) 2024/1735 of the European Parliament and of the Council of 13 June 2024 on measures to strengthen Europe's net-zero technology manufacturing ecosystem (Net-Zero Industry Act).

[14] European Parliament and Council of the European Union, Regulation (EU) 2024/1252 of the European Parliament and of the Council of 11 April 2024 establishing a framework for ensuring a secure and sustainable supply of critical raw materials (Critical Raw Materials Act).

[15] European Parliament and Council of the European Union, Regulation (EU) 2024/1781 of the European Parliament and of the Council of 13 June 2024 establishing a framework for setting ecodesign requirements for sustainable products (ESPR).

[16] European Parliament and Council of the European Union, Regulation (EU) 2023/1542 of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries.

[17] European Parliament and Council of the European Union, Directive (EU) 2023/959 of the European Parliament and of the Council of 10 May 2023 amending Directive 2003/87/EC (EU ETS reform) and Decision (EU) 2015/1814.

[18] European Parliament and Council of the European Union, Regulation (EU) 2023/956 of the European Parliament and of the Council of 10 May 2023 establishing a carbon border adjustment mechanism (CBAM).

[19] European Commission, Horizon Europe Strategic Plan 2025–2027, 20 March 2024.

and partnerships around the green and digital transitions and EU resilience. The **Data Act**[20] creates fair-use rules for Internet of Things and industrial data that enable new services, such as predictive maintenance and virtual power plants. At the same time the **AI Act**[21] establishes a risk-based regime with support for SMEs, while the **Chips Act**[22] complements these by anchoring semiconductor capacity, critical for power-electronics, inverters, chargers and smart metering within the EU.

Finally, the EU has put together a diverse range of funding streams, binding the EU policy framework to project implementation. The **Recovery and Resilience Facility**[23] and its **REPowerEU**[24] chapters, finance reforms and investments that accelerate clean energy uptake and digitalisation. The **Innovation Fund**[25] backs first-of-a-kind industrial decarbonisation and clean-energy projects, the **Modernisation Fund**[26] supports grids, renewables, storage and efficiency and the **Just Transition Fund**[27] supports the coal regions' economic transformation. **Horizon Europe** funds research and innovation from lab to pilot and **InvestEU**[28] supports guarantees that attract private capital. The **Connecting Europe Facility** (Energy)[29] co-finances cross-border and smart-grid infrastructure and the **LIFE Clean Energy Transition**[30] programme funds coordination and market-uptake actions.

Taken together, the EU's policy response represents a structural shift. **Europe is no longer treating the green transition as a gradual market correction but as a strategic re-industrialisation project.** The policy framework rewards countries capable of acting decisively and following the roadmap of clear regulatory direction, technological priorities, and investment incentives. For Bulgaria, this is an unprecedented opportunity to overcome long-standing struc-

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20 European Parliament and Council of the European Union, Regulation (EU) 2023/2854 of the European Parliament and of the Council of 13 December 2023 on harmonised rules on fair access to and use of data (Data Act).

21 European Parliament and Council of the European Union, Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 laying down harmonised rules on artificial intelligence (AI Act).

22 European Parliament and Council of the European Union, Regulation (EU) 2023/1781 of the European Parliament and of the Council of 13 September 2023 establishing a framework of measures for strengthening Europe's semiconductor ecosystem (Chips Act).

23 European Parliament and Council of the European Union, Regulation (EU) 2021/241 of the European Parliament and of the Council of 12 February 2021 establishing the Recovery and Resilience Facility (RRF).

24 European Parliament and Council of the European Union, Regulation (EU) 2023/435 of the European Parliament and of the Council of 27 February 2023 amending Regulation (EU) 2021/241, Council Regulation (EU) 2020/2094 and Regulations (EU) No 1303/2013, (EU) 2021/1060 and (EU) 2021/2115 (REPowerEU).

25 European Commission, Innovation Fund (EU ETS).

26 Modernisation Fund, Commission Implementing Regulation (EU) 2020/1001 of 9 July 2020.

27 European Parliament and Council of the European Union, Regulation (EU) 2021/1056 of the European Parliament and of the Council of 24 June 2021 establishing the Just Transition Fund (JTF).

28 European Parliament and Council of the European Union, Regulation (EU) 2021/523 of the European Parliament and of the Council of 24 March 2021 establishing the InvestEU Programme.

29 European Parliament and Council of the European Union, Regulation (EU) 2021/1153 of the European Parliament and of the Council of 7 July 2021 establishing the Connecting Europe Facility (CEF) 2021–2027.

30 European Parliament and Council of the European Union, Regulation (EU) 2021/783 of the European Parliament and of the Council of 29 April 2021 establishing a Programme for the Environment and Climate Action (LIFE).

tural barriers and build competitive advantages across the clean economy. Europe's strengthened demand for renewable energy, electrification, building renovation, circular industrial inputs and digital solutions creates predictable markets that allow companies to scale product development, from building automation and predictive-maintenance software to high-performance components and installation services. At the same time, the country's TSOs, DSOs and municipalities can invest confidently in grid modernisation, smart-meter deployment and local flexibility markets, opening procurement channels for Bulgarian hardware producers, power-electronics manufacturers, grid-software developers and AI innovators. Bulgaria's existing strengths in the processing of metals and minerals, electronics and mechanical engineering offer concrete localisation opportunities in balance-of-system equipment, power-electronics sub-assemblies, battery integration and recycling. Strengthened carbon-pricing and trade rules reward decarbonisation in Bulgaria's steel, cement, fertiliser and aluminium sectors while creating new markets for electrification technologies, waste-heat recovery and high-quality measurement and verification services.

The EU's policy direction is now unmistakably clear: Europe is restructuring its energy, industrial and security architecture around long-term resilience. This creates a uniquely advantageous moment for Bulgaria, but only if the country can overcome its long-standing structural barriers, above all the absence of a sustained strategic vision that rises above short-term political cycles. Accessing and fully leveraging the unprecedented EU funding streams for energy, innovation, and industrial transformation will require **Bulgaria to finally align its core policy instruments and commit to their consistent implementation**. Without this alignment, the country risks once again becoming a passive beneficiary of European policies rather than an active shaper of its own economic and energy future.

Decarbonisation, on Paper

Despite the clarity of the EU's new direction, Bulgaria's domestic policy landscape remains fragmented and often internally inconsistent. The country is struggling to navigate the transition away from a **traditional model of growth based on fossil fuels.** It is gradually replaced by a more sustainable and innovation-oriented paradigm, and remains firmly focused on the energy sector, with little attention paid to industry, mining and the digital space. Despite the overall convergence with European strategic goals, Bulgaria's overall system of policies, regulations, and institutions remains fragmented, resulting in uneven implementation and missed opportunities for technological transformation.

The recent actualisation of the **National Energy and Climate Plan** (NECP)[31], was an ideal opportunity for Bulgaria to realign its energy and climate security strategy, decarbonise its economy and complete the strategic decoupling from Russia's economic influence and fossil fuel lock-in. Instead, the NECP is based on opaque modelling and limited stakeholder engagement, resulting in **a technical box-ticking exercise, unlikely to yield significant results**. The Plan sets the national decarbonisation target for non-emissions trading sectors

[31] European Commission, Bulgaria – National Energy and Climate Plan 2021-2030, 15 January 2025.

(non-ETS) at 10% compared to 2005 levels, the minimum required by the EU in the 'Fit-for-55' policy framework, a clear sign of the lack of political will or the vision to extend the decarbonisation goals beyond the energy sector. Instead of streamlining policy measures to support the balanced development of the country's renewables capacity, the Plan preserves coal power plants in the power mix until at least 2038 and relies excessively on the construction of two new nuclear reactors at the Kozloduy Nuclear Power Plant (NPP).[32]

The pattern of bold promises not backed up by concrete measures, funding streams, accountability mechanisms and timelines, is evident in other strategic documents. The **Strategy for Sustainable Energy Development[33]** provides the overarching framework for Bulgaria's energy transition and articulates the long-term ambition of achieving climate neutrality by 2050. The strategy envisages a gradual reduction in coal-based electricity generation, the expansion of renewable energy capacity, and the introduction of innovative technologies, including battery storage, hydrogen and small modular reactors. However, the **only concrete step enacted by the government is the indefinite delay of the power market liberalisation**, which enables the continued operation of the country's coal power plants. On the other hand, the expansion of renewable energy capacity and storage has been almost entirely market-driven and still faces regulatory bottlenecks, while more innovative technologies, such as hydrogen, are completely neglected, despite Bulgaria having a National Roadmap for Hydrogen Technologies[34].

The **Innovation Strategy for Smart Specialisation 2021–2027[35]** introduces an essential innovation dimension to Bulgaria's transition. It identifies clean technologies and a low-carbon economy as one of the country's five priority areas, thus embedding climate action within the broader framework of research, development, and industrial policy. The strategy promotes stronger collaboration between academia, research centres, and businesses through the entrepreneurial discovery process, which allows stakeholders to co-create and continuously refine national priorities. However, these **ambitions are not matched by Bulgaria's true innovation landscape**. The country remains in the group of emerging innovators and has not met its national targets of achieving an research and development (R&D) expenditure level of 1.5% of GDP. In 2023, **R&D intensity amounted only to 0.79% of GDP** (EUR 750 million), a symptom of chronic underinvestment and policy focus on developing the country's research potential and supporting the leap from lab to market of solutions that underpin modern energy systems, productivity gains, and long-term industrial competitiveness.[36]

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[32] Center for the Study of Democracy, *Realigning Bulgaria's energy and climate strategy*, Policy Brief No. 154, March 2025.

[33] Ministry of Energy, "Draft Strategy for Sustainable Energy Development of the Republic of Bulgaria".

[34] Ministry of Innovation and Growth, "Bulgaria's Hydrogen Future: National Roadmap for Improving the Conditions for the Development of Hydrogen Technologies and Mechanisms for the Production and Delivery of Hydrogen".

[35] Ministry of Innovation and Growth, "Innovation Strategy for Smart Specialisation" 2021–2027.

[36] Georigieva, T. et al., *Innovation.bg 2024*, Sofia: Applied Research and Communications Fund, December 2024.

The **Recovery and Resilience Plan**[37] was designed to translate Bulgaria's strategic objectives into concrete, measurable commitments tied to EU funding, that would only be released once key reforms were completed. Its priorities centred on advancing the green transition through renewables, storage, interconnectivity and transport electrification, alongside the digitalisation of the economy and long-overdue institutional reforms, including anti-corruption measures. These governance reforms are particularly relevant for the energy sector, given its long history of state capture and entrenched vested interests. Yet Bulgaria has to date received only its first full payment (EUR 1.37 billion out of EUR 5.69 billion) and a significantly reduced second payment of just EUR 438.6 million, shrunk because of the country's refusal to establish an independent anti-corruption body. This outcome sends a clear signal: **the financial interests of a narrow group continue to outweigh the potential economic and societal benefits of fulfilling the required reforms**.

Bulgaria's slow and uneven energy transition is rooted not in technological or financial limitations, but in deep structural weaknesses in governance systems. Political dependency and resistance from entrenched networks remain the single greatest obstacle to Bulgaria's sustainable, long-term economic modernisation. **Over more than a decade, successive governments have avoided long-term planning, postponed strategic decisions,** and treated EU climate commitments as rhetorical, rather than operational. High energy poverty, low institutional trust, and electoral volatility made political actors reluctant to support reforms that could be framed as costly or imposed by the EU, a frequent scapegoat for local inaction. This governance avoidance was reinforced by sectoral capture, especially in the coal regions, where unions and local business interests gained disproportionate influence over national policy. Combined with years of political instability, this created a system where no actor had the incentive or the authority to initiate structural change. As a result, Bulgaria entered the 2020s without a coherent industrial policy, an innovation agenda, or the regulatory capacity needed to use the green transition as a driver of competitiveness and resilience.[38]

Reversing this trajectory requires confronting these structural obstacles. **Bulgaria must first rebuild strategic capacity: align all major policy instruments into a single long-term framework, establish binding sectoral pathways, strengthen regulatory independence, and depoliticise transition planning.** This should be paired with genuine social dialogue that moves beyond coal-centric narratives and prepares workers and regions for transformation, rather than preserving the illusion of indefinite lignite operation. To escape carbon lock-in, Bulgaria must shift from reactive crisis management to proactive industrial modernisation, using EU funding and market signals to drive diversification, clean manufacturing, digitalisation, and innovation. Without decisive action now, Bulgaria risks not only missing its climate targets but also forfeiting its future competitiveness and energy security as Europe moves ahead with its integrated green-industrial strategy.

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37 European Commission, "Bulgaria's National Recovery and Resilience Plan".

38 Bernaciak, M., "The politics of Bulgaria's uneven energy transition", *Energy Research & Social Science* 129, 2025.

DECARBONISATION WITHOUT DIRECTION

Bulgaria's decarbonisation pattern over the past decade reveals a fundamental problem: the absence of long-term, strategic policy direction. In a transition that requires predictable frameworks, clear milestones, and cross-sector coordination, Bulgaria has instead relied on short political cycles, ad-hoc decisions, and reactive measures driven by immediate pressures rather than long-term goals. This lack of sustained commitment is now fully visible in the country's uneven progress. Where EU rules and external pressure have been strongest, primarily in the electricity sector, emissions have fallen. However, in the absence of a coherent national vision, **the rest of the economy has remained effectively untouched**. Instead of using decarbonisation as a lever for modernising industries, upgrading infrastructure, and boosting competitiveness, Bulgaria has drifted toward a pattern of narrow, sector-specific adjustments that do not add up to a long-term economic transformation.

In 2014, CSD argued that the lack of targeted policy and financial support for Bulgaria's innovation ecosystem and the development and adoption of low-carbon technologies would "**reduce the chances of Bulgarian businesses of capitalising the potential of both innovations in general and green innovations in particular to improve their competitiveness and foster growth, while simultaneously decreasing environmental risks and reducing energy insecurity and energy poverty in the country**"[39]. A decade later, this warning remains strikingly accurate. Instead of enabling structural economic renewal, Bulgaria's decarbonisation process has reflected a pattern of crisis-driven reactions, one that has left the country with a transition that is partial, unbalanced, and increasingly misaligned with both Europe's strategic direction and Bulgaria's long-term economic interests.

Energy Security Risks

Despite Bulgaria's installed renewable energy capacity growing by over 3.6 GW since 2014, in large part driven by investments in solar photovoltaics (PV)[40], the lack of adequate and consistent economy-wide support for low-carbon technologies is now plainly evident. The country is **among the worst performers according to the Energy and Climate Security Risk Index** (ECSRI)[41], especially in terms of affordability and sustainability risks. The Index demonstrates that countries which invested early in low-carbon technologies are now reaping tangible security and economic benefits. For example, Denmark, Sweden, and the Netherlands have reduced their exposure to fuel-price volatility, maintained lower wholesale electricity costs, and strengthened their energy system resilience. Their diversified generation portfolios, which combine renewables, strong regional interconnections, battery storage, and flexible market design, limit their exposure to carbon price fluctuations, resulting in lower energy affordability risks and stronger competitiveness.

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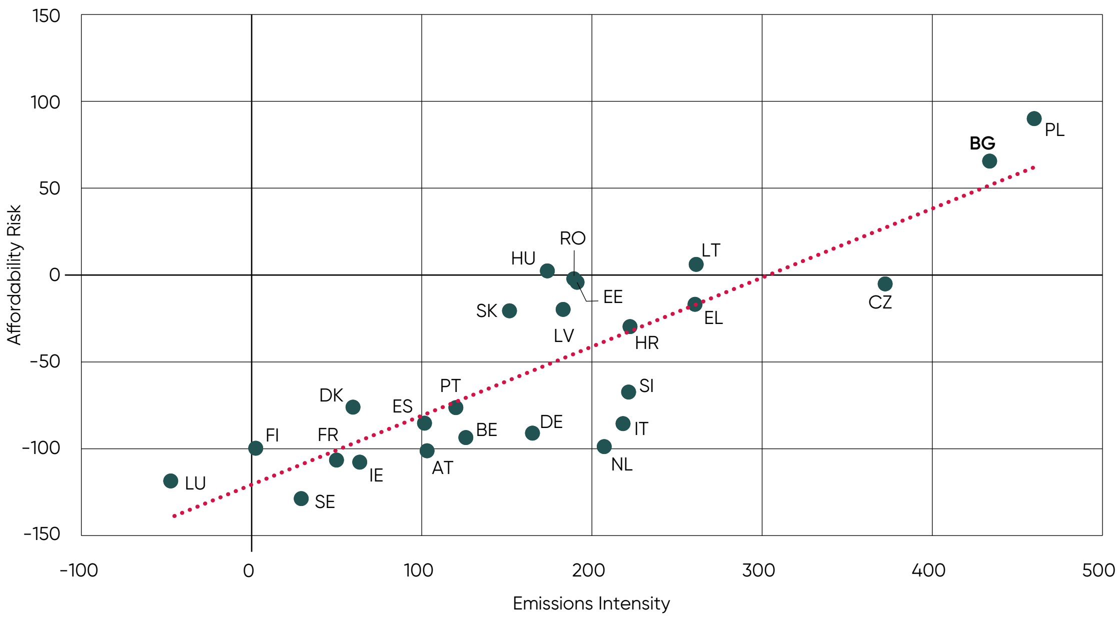
[39] Stefanov, R. et al., *Green Innovation.bg*, Sofia: Applied Research and Communications Fund, 2014.

[40] Electricity System Operator, Statistical yearbooks.

[41] Vladimirov, M., Köppen, M., and Rickles, M., *Energy and Climate Security in Europe: From Crisis Response to Structural Transformation*, Sofia: Center for the Study of Democracy, 2025.

By contrast, countries that delayed their low-carbon transition, including much of **Southeast Europe and Bulgaria, are now paying the price of inaction**. While renewables insulate economies from fossil-fuel price volatility once installed by providing domestically sourced electricity with stable, predictable marginal costs, fossil fuels have increased countries' vulnerability to the carbon price surges and the broader inflationary effects of the global energy crisis, kicked off by Russia's full-scale invasion of Ukraine. Postponing decarbonisation no longer shields consumers from higher energy costs, as was previously thought; it simply transfers the cost from fossil fuels to emission quotas, leading to lower competitiveness.

Figure 3. Energy and Climate Security Risk Index, Correlation between the Emissions Intensity of the Economy and Affordability Risk in 2023



Source: Center for the Study of Democracy.

Bulgaria's overall energy and climate risk is the second-highest in Europe, only trailing Poland. This is directly correlated to several structural features of its economy and energy sector in particular. The country **continues to rely on fossil fuels**, which made up 77% of its energy mix in 2022 (much of which was imported from Russia), including 25% coal[42]. Only 23.2% of the gross final energy consumption comes from renewables, with household firewood use for heating still accounting for 55% of RES consumption[43]. Bulgaria's energy price vulnerability worsened on the back of the influence of the EU Emissions Trading Scheme (ETS), which will be exacerbated further with the introduction of ETS2, as the **buildings and transport sectors are even further behind in the decarbonisation process** than the energy sector. Finally, as the heavy industry, which still benefits from ETS free emission allowances but has re-

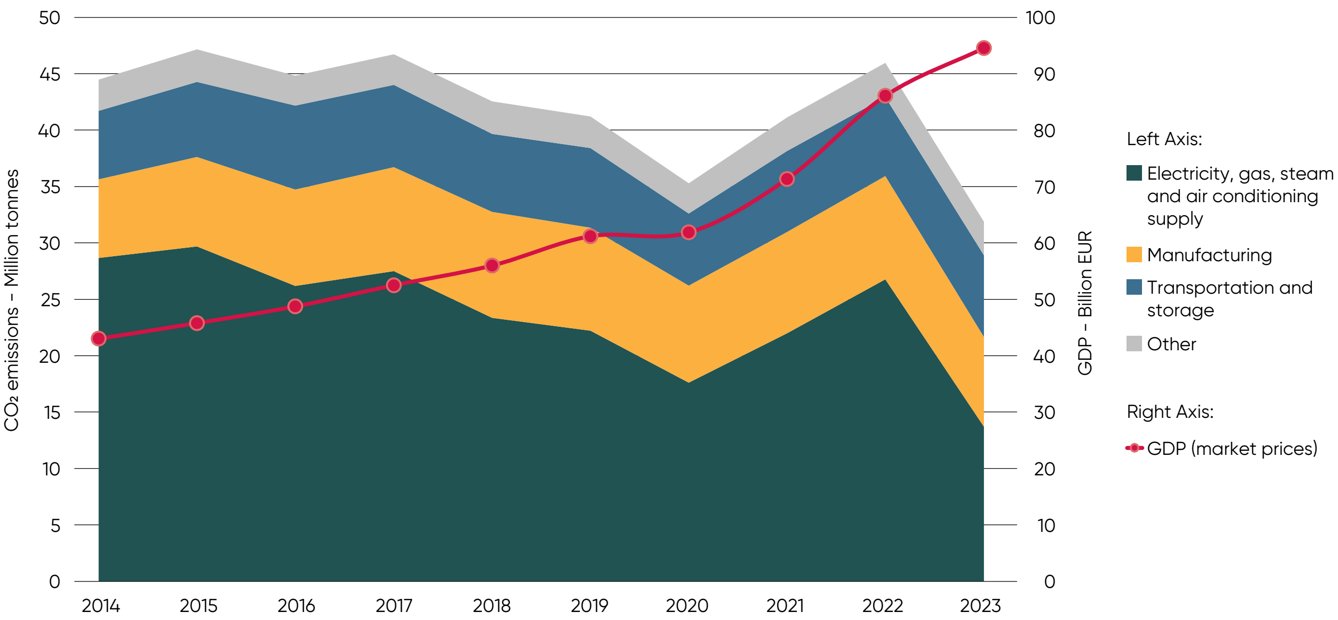
[42] Vladimirov, M. et al., *Decarbonising the Bulgarian Power Sector: Resolving the Coal Phase-Out – Security of Supply Conundrum*, Sofia: Center for the Study of Democracy, 2023.

[43] Eurostat, Share of energy from renewable sources.

ceived no government support to invest in low-carbon technologies, becomes subject to full quotas, Bulgaria's economy will bear the full cost of the delayed decarbonisation.

The close link between energy affordability and sustainability risks is mirrored in Bulgaria's GHG emissions profile over the past decade, which showcases the central role played by the energy sector, and the urgent need for decisive action to decarbonise in the remaining sectors of the economy. Although Bulgaria has made notable **progress in reducing greenhouse gas emissions while sustaining strong economic growth, the decline has been uneven across sectors**, revealing the absence of a systemic approach to decarbonisation. Most of the progress stems from changes within the energy sector, while other parts of the economy have seen limited transformation, underscoring that emission reductions have occurred despite, rather than because of, coordinated policy or technological innovation.

Figure 4. Total CO_2 Emissions and GDP Growth in Bulgaria (2014–2023)



Source: Eurostat.

Fragmented Decarbonisation

Between 2014 and 2023, GDP at market prices more than doubled from EUR 43 billion to EUR 94.5 billion, while total **CO_2 emissions fell from 44.5 million to 31.9 million tonnes**, a decline of roughly 30%. This was led almost entirely by the market-driven transformation of the energy sector, where emissions dropped by more than 50%, going from 28.7 million tonnes to just 13.7 million tonnes in 2023, as a result of the rapid introduction of renewables since 2022. This surge, supported by falling technology costs, demonstrates that economic expansion can now occur alongside lower fossil fuel use. In 2023, when PV deployment peaked, Bulgaria's GDP continued to grow, evidence that renewables can underpin, rather than hinder, economic growth.

On the other hand, **emissions from manufacturing rose modestly from 6.9 to 8.0 million tonnes** between 2014 and 2023, in line with industrial and export growth. With the exception of a few large manufacturers, often part of larger European multinational companies, Bulgaria's industry is yet to achieve substantial decarbonisation, because low-carbon process innovations, waste-heat recovery, and electrified heat systems remain rare[44]. This underlines the **urgent need to link Bulgaria's innovation policy more closely with its industrial strategy**, using instruments such as research and development tax incentives and technology demonstration funding to accelerate the adoption of cleaner production methods. Without accelerating industrial decarbonisation, Bulgarian manufacturers risk losing competitiveness under tightening EU carbon-pricing rules and the CBAM, which increasingly rewards low-emissions production and penalises high-carbon industrial inputs.

Despite the EU's policy ambition and growing electrification trends across the continent, **emissions in Bulgaria's transport sector increased by almost 20%**, reaching 7.25 million tonnes in 2023. Road transport dominates freight and passenger mobility, and the electrification of vehicles remains minimal. In 2023 **cars accounted for close to 89% of inland passenger travel**, while buses fell below 9% and rail barely exceeded 2%.[45] Out of a total of 3,762,267 registered vehicles in 2025 (up from just over 3 million in 2023), only 22,372 are fully electric, less than 0.6% of the national fleet.[46] Freight shows the same imbalance, **with roads carrying over 63% of goods and rail under 20%** despite repeated investments in the expansion and modernisation of the rail infrastructure.[47] Without a clear strategy for clean mobility, including incentives for the purchase of electric vehicles, charging infrastructure, and a systemic modal shift to rail and public transport, this **sector risks offsetting the gains achieved by the energy transition**. This gap is especially critical in light of the anticipated expansion of carbon pricing to road transport and EU-wide requirements for zero-emission vehicles and charging infrastructure, which will impose increasing compliance and **cost pressures on countries that fail to modernise their transport systems**.

Emissions in other sectors, including buildings and services, remained broadly stable at around 3 million tonnes. 24% of dwellings have been fully renovated, mainly on an ad-hoc basis in multi-family buildings, which does not maximise the potential of deep, full-building renovations.[48] The national renovation programmes only covered 4.2% of multi-storey residential buildings, leading to a minimal emission-reduction impact. While slowly declining, **widespread household energy poverty** continues to constrain progress. Between 2014 and 2024, the share of the Bulgarian population unable to keep their home adequately warm dropped from 39.2% to 20.9%, while those with utility bill arrears fell from 32% to 22.9%, still among the highest energy poverty rates in the EU.[49] Here too, innovation could play a transformative role

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44 Vladimirov, M. et al., *Exiting the Vicious Cycle: Long-term Vision for Decarbonisation and Transformation of the Bulgarian Economy*, Sofia: Center for the Study of Democracy, 2024.

45 Eurostat, Modal split of inland passenger transport.

46 Ministry of Interior, Open data portal.

47 Eurostat, Modal split of air, sea and inland freight transport.

48 National Statistical Institute, Housing Conditions as of September 7, 2021, Census 2021.

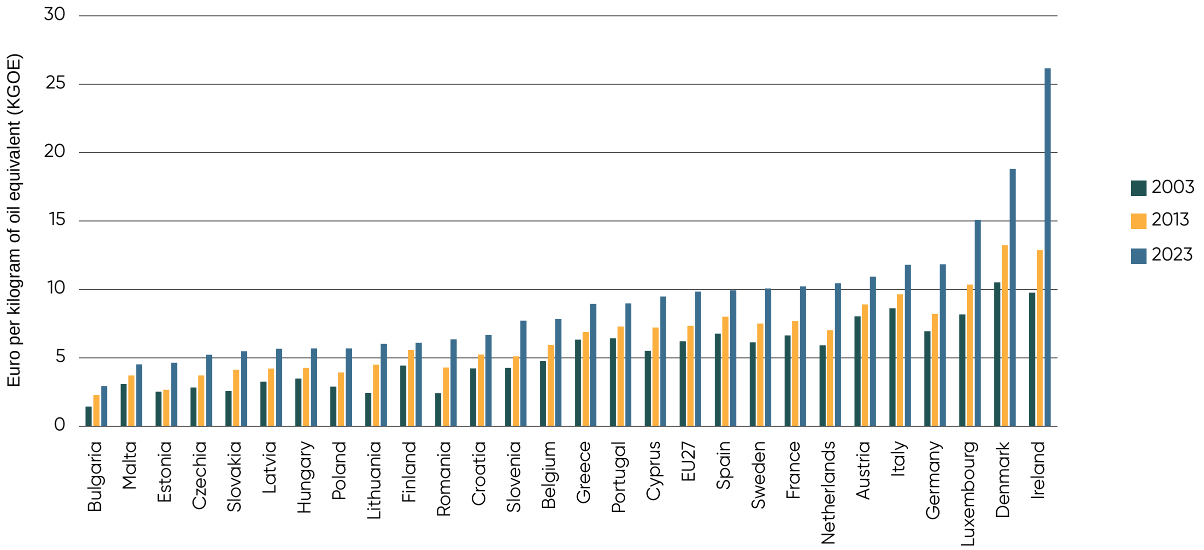
49 Eurostat, EU statistics on income and living conditions.

through smart-metering technologies, electrification of heating and cooling and cutting-edge retrofitting technologies that can reduce energy expenditures, improve temperature comfort and air quality and empower households to play a central role in the decarbonisation process. Yet without a long-term renovation strategy and a coherent approach to modernising heating systems, these opportunities remain fragmented, preventing the buildings sector from contributing meaningfully to Bulgaria's broader decarbonisation trajectory.

To sustain the overall positive emission trajectory and reduce Bulgaria's exposure to carbon pricing in the coming years, policymakers must extend the innovation dynamic of renewables into industry, transport, and the built environment. Aligning energy, innovation, and industrial policies will be crucial to **embedding low-carbon growth structurally into national strategies**, rather than sporadically. The challenge for the next decade is to turn the energy sector's success story into a whole-economy transformation, where **innovation becomes both the driver and the guarantor of Bulgaria's long-term sustainable economic development.**

Energy productivity, the economic value generated per unit of energy consumed, is one of the clearest indicators of whether an economy is decoupling growth from fossil energy. Over the past two decades, **Bulgaria's energy productivity has more than doubled**, rising from EUR 1.44 per kg of oil equivalent (kgoe) in 2003 to EUR 2.94 in 2023. Yet, it remains **the lowest in the EU**, and well below the levels of peer economies such as Romania (6.35) or Poland (5.69).

Figure 5. Energy Productivity in the EU (2003–2023)



Source: Eurostat.

Industry continues to consume about 22% of Bulgaria's final energy, and its productivity growth has stagnated amid low research and development intensity and ageing equipment. The modest convergence in productivity reflects Bulgaria's **incomplete structural shift away from heavy, energy-intensive industries** and the limited integration of innovation into production systems. While GDP has expanded rapidly since 2014, much of the improvement in energy productivity has come from closing inefficient industrial capacity and importing more efficient technologies, rather than developing domestic ones. In contrast, EU front-runners have embedded technological innovation in digitalised manufacturing, process electrification, and renewables as core drivers of productivity. This gap in energy productivity reflects the deeper **structural weakness of Bulgaria's transition, the limited technological upgrading and the inadequate innovation policy**, which now constrains both competitiveness and the ability to adapt to a low-carbon economic model.

Box 1. From Energy Intensity to Artificial Intelligence: Lessons from Ireland's Transition

Bulgaria aims to position itself as a strategic destination for high-tech investment, particularly in energy innovation and artificial intelligence (AI).[50] With more than 80,000 ICT specialists and growing institutional capacity through initiatives such as BRAIN++, one of the EU's six AI factories, and the Institute for Computer Science, Artificial Intelligence and Technology – INSAIT, **Bulgaria aspires to become a regional AI hub for Southeast Europe**. However, this ambition requires not only technological capacity but also massive volumes of clean, affordable electricity to power data centres, digital infrastructure, and industrial innovation. The country's future competitiveness will depend on how effectively it can combine its renewable potential, nuclear base, and innovation ecosystem into a coherent growth model. The country must move beyond traditional energy-saving measures and focus on **transforming the structure of its economy towards knowledge- and technology-intensive sectors**, supported by low-carbon industrial and energy strategies.

The European economies with the highest growth of energy productivity share two key characteristics: a shift towards knowledge-intensive activities, which reduce overall energy demand, and strict environmental and efficiency standards that stimulate innovation and technological upgrading. The Irish experience offers a particularly relevant model for Bulgaria. Over the past decade, **Ireland has combined rapid growth in ICT, pharmaceuticals, and AI-driven services with a decisive shift to renewable energy**, which now supplies over 40% of its electricity. The country's energy productivity surged to EUR 26/kgoe, the highest in the EU. Crucially, Ireland achieved this not by reducing energy use, but by decoupling growth from fossil fuels through innovation policy, grid modernisation, and coordinated investment in renewables and efficiency.[51]

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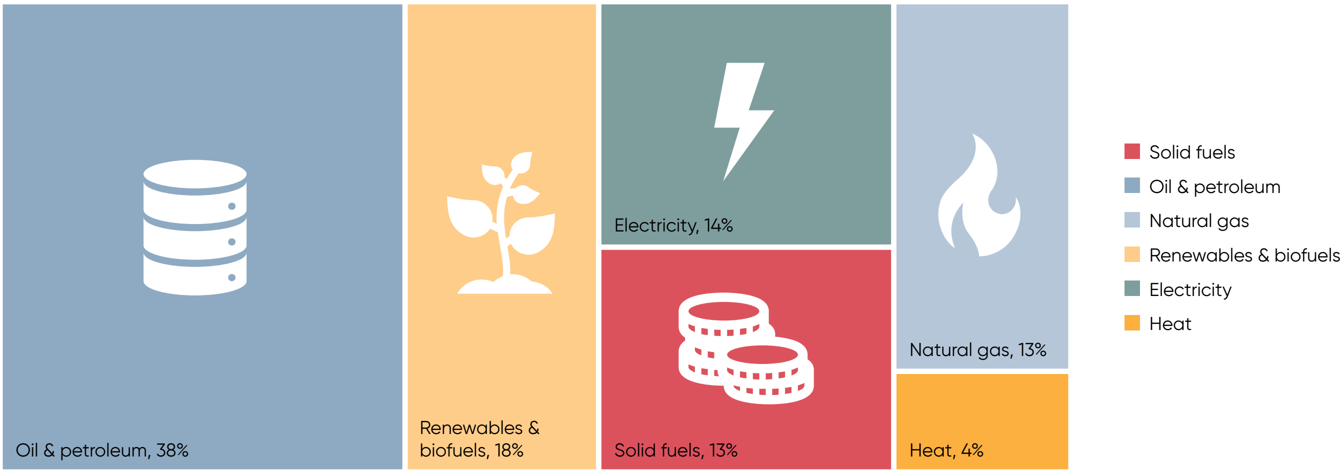
[50] Council of Ministers of the Republic of Bulgaria, "Prime Minister Rosen Zhelyazkov: Bulgaria is a strategic destination for high-tech investments in energy and artificial intelligence" [Премиерът Росен Желязков: България е стратегическа дестинация за високотехнологични инвестиции в енергетиката и изкуствения интелект], 25 September 2025.

[51] Environmental Protection Agency, "Ireland's State of the Environment Report 2024 – Chapter 12 – Environment and Energy", 2024.

Electricity Generation Leading the Way

Over the past decade, Bulgaria's energy system has undergone modest but important shifts, enough to show progress, but not yet the structural transformation needed for a resilient low-carbon economy. Between **2014 and 2023**, total final energy consumption fluctuated between **8.9 and 9.7 million tonnes of oil equivalent (toe)**, essentially remaining flat even as GDP more than doubled. The composition of Bulgaria's final energy use has changed only marginally in ten years. In 2014, Bulgaria's final energy consumption was composed of 3497 ktoe of oil and petroleum products (39%), 1422 ktoe of renewables and biofuels (16%), 1127 ktoe of natural gas (13%), 1199 ktoe of electricity (13%), and 1325 ktoe of solid fuels (15%). By 2023, both the quantity and shares of each product had shifted only slightly: the biggest changes were a 10% reduction in solid fuel use and a 15% increase in renewables.

Figure 6. Final Energy Consumption by Product in Bulgaria (2023) (in thousand tonnes of oil equivalent)



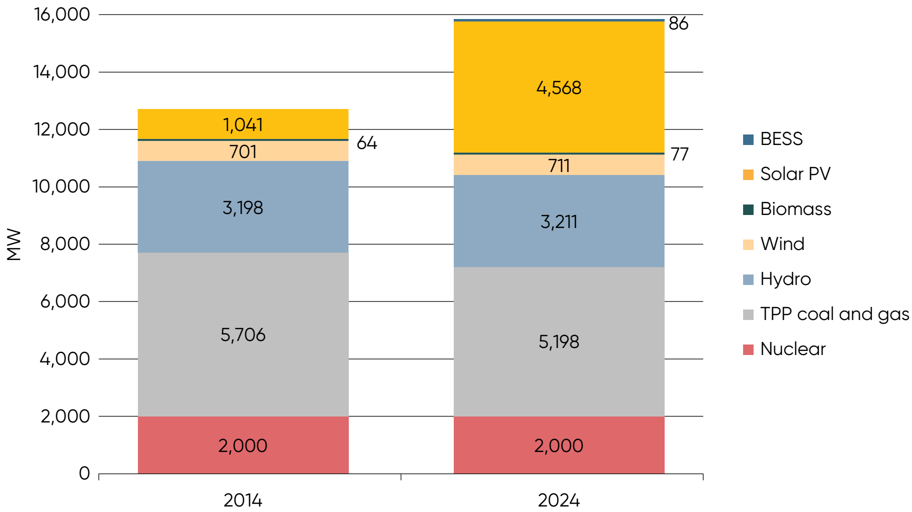
Source: Eurostat.

This static structure highlights a key limitation: while energy productivity and efficiency have improved, Bulgaria's **energy base remains heavily dependent on imported fossil fuels (51%)**. This exposes the economy to price volatility and supply risks, as seen during the 2021–2023 energy crisis. Given Bulgaria's high dependence on imports of crude oil, petroleum products and natural gas, reducing their share in the energy mix while increasing the share of domestic renewable sources that do not rely on imported raw materials represents a positive development towards energy security and low-carbon growth. **To achieve further independence while continuing to use domestic resources without increasing GHG emissions, policymakers must focus on further expanding RES-based generation** and introducing more efficient technologies, particularly in combined heat and power plants and district heating systems.

The distribution of energy consumption by sector has also remained virtually unchanged over the past decade. In 2023, the **transport, households, and industry** sectors together accounted for about **83%** of final energy demand, almost identical to 2014. This enduring pattern highlights Bulgaria's slow structural evolution.

Over the past decade, **renewables** have been the only area of Bulgaria's economy to experience substantial and sustained transformation. Installed capacity, particularly in **solar photovoltaics**, has expanded rapidly and renewables now provide nearly a **quarter of Bulgaria's electricity generation**. Much of this growth has been driven by market forces rather than strategic policy, as businesses and households responded to clear economic signals: **renewables are now cheaper than coal**, especially as ETS prices make fossil fuels increasingly uncompetitive.[52]

Figure 7. Installed Electricity Generation Capacity in Bulgaria (2014 and 2024)



Source: Electricity System Operator.

Despite this market-driven progress, Bulgaria's **regulatory framework remains opaque and distorted** by political interference. The state continues to sustain uncompetitive coal-fired power plants through a system of cross-subsidies, undermining fair competition and delaying full energy market liberalisation. In 2024, state-owned and private coal power plants received over **EUR 1.2 billion in indirect subsidies**, largely channelled through the **Electricity System Security Fund (ESSF)**, which redistributes revenues from carbon allowance sales to cover the price gap between coal generation costs and regulated household tariffs. This model not only violates EU competition principles but also diverts resources away from investment in modernisation, smart grids, and new low-carbon capacity.[53]

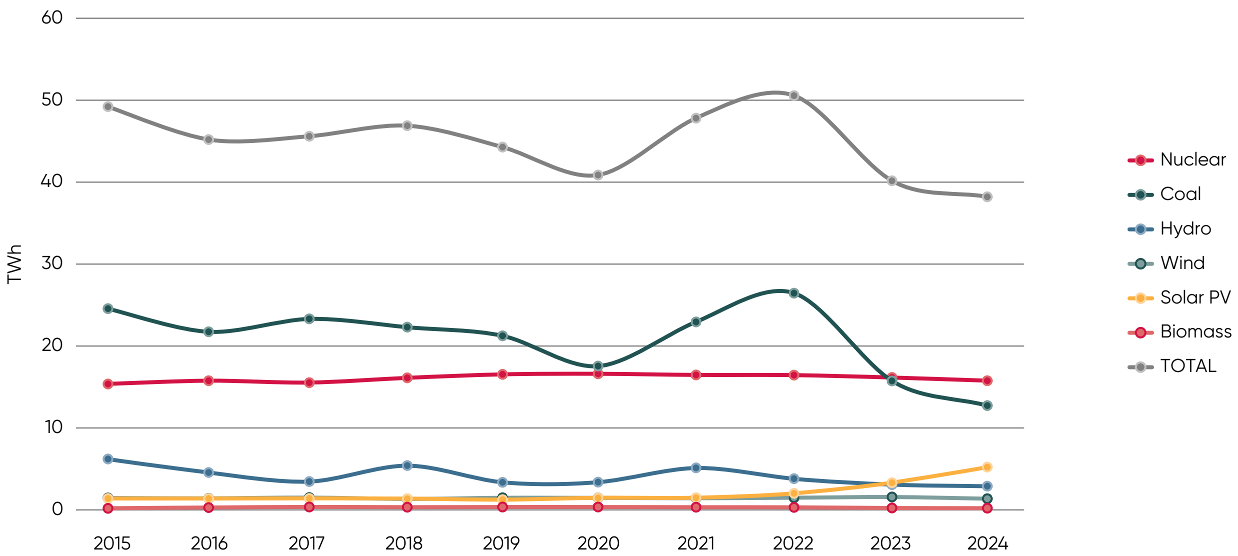
The result of the tension between market-driven renewables growth and the incumbent, fossil-fuel-based system is a **fragmented energy transition**. Renewables have already proven their strategic value. As the ECSRI reveals, the rising carbon costs and slow power market liberalisation after 2020 led to high energy-security risks, but affordability risk began to improve markedly in 2023 with the rapid uptake of solar PV installations, which sharply re-

[52] Electricity System Operator, Statistical Yearbook.

[53] Center for the Study of Democracy, *Ending the State Central Planning Model in the Electricity Sector*, Policy Brief, No. 158, October 2025.

duced wholesale electricity prices during peak production months and eased pressure on household tariffs. By offsetting expensive fossil-based generation with locally produced solar power, Bulgaria achieved short-term price relief and improved its sustainability profile.[54]

Figure 8. Electricity Generated in Bulgaria by Source (2014-2024)



Source: Electricity System Operator.

Taken together, these trends reveal a paradox: Bulgaria has **successfully decoupled economic growth from energy consumption and emissions**, but without achieving a corresponding **diversification or innovation-driven transformation** of its energy system. Gains have been achieved through efficiency and structural shifts rather than by embedding new technologies across the economy.

The energy system's resilience remains vulnerable to external shocks, as seen during the gas and electricity price crises. Bulgaria's reliance on fossil fuels in transport and industry continues to undermine competitiveness and expose consumers to volatility. Renewables, though growing, are concentrated in a few sectors and technologies, creating new imbalances even as they address old ones.

The lesson from the past decade is clear: **market forces alone will not deliver the structural transformation Bulgaria needs**. To move from ad-hoc improvements to sustained competitiveness, the country must anchor innovation, energy, and industrial policy within a single long-term vision and align public investment accordingly. The next decade offers a narrow window to turn Bulgaria's strong renewable potential, growing digital capabilities, and industrial base into a coherent strategy for resilience and growth that mirrors Europe's shift toward strategic autonomy and positions Bulgaria as a proactive, rather than reactive, participant in the green transition.

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[54] Vladimirov, Köppen, and Rickles, *Energy and Climate Security in Europe*, Sofia: CSD, 2025.

TECHNOLOGY IMBALANCES

The pattern of technological uptake in Bulgaria's electricity sector reflects the same structural weakness seen across the wider economy: **growth occurs where market signals are strong, but in the absence of policy direction, entire segments critical to a resilient and competitive energy system remain underdeveloped**. The result is a transition driven by opportunity rather than design, with a handful of technologies experiencing rapid growth while others stagnate or remain unexplored.

Bulgaria's progress over the past decade shows that economic growth and emissions reduction can indeed reinforce each other. The rapid expansion of renewables has significantly reduced greenhouse gas emissions and contributed to lower wholesale electricity prices during peak generation periods. Yet this progress has been achieved despite fragmented governance, short-term political decision-making, and the absence of an integrated technological roadmap. **External shocks such as the 2021–2022 energy crisis, combined with falling global technology costs, did more to accelerate the transition than any domestic planning effort.**

This uncoordinated trajectory has created **new structural imbalances that now pose risks to Bulgaria's long-term energy security, system flexibility, and technological sovereignty**. The country's decarbonisation progress is concentrated in a narrow set of technologies, primarily solar PV and, more recently, battery storage, while other essential pillars of a balanced, modern power system lag far behind. Wind power development has stalled for over a decade, grid digitalisation progresses slowly, flexibility services and advanced forecasting tools remain underutilised, and emerging low-carbon industrial and clean heat technologies struggle to move beyond pilot ideas. Although different technologies have grown at different paces, they all suffer from the same structural shortcoming: deployment accelerates when market incentives are strong, but progress stalls where policy vision, regulatory clarity, or institutional capacity are required. These cross-cutting weaknesses shape every technology area examined below.

This technology imbalance also leaves Bulgaria overly **dependent on imported components and foreign supply chains**, primarily from China, exposing the country to geopolitical uncertainty and price volatility. At the same time, insufficient investment in grid capacity, digital infrastructure, and sector coupling increases operational risks and limits the integration potential of additional renewable capacity. Without a system-wide strategic approach, **Bulgaria risks locking itself into a fragile, one-dimensional energy transition** that reduces emissions in the short term, but undermines resilience, competitiveness, and technological autonomy in the long run.

Front-runners

Solar Photovoltaics

Solar PV illustrates how Bulgaria's transition advances rapidly when market conditions are favourable, even in the absence of strategic coordination. Over the past decade, **solar PV have emerged as Bulgaria's undisputed front-runner in the low-carbon transition**. Installed PV capacity has increased from 0 in 2011 to **over 5 GW by mid-2025,** making solar the fastest-growing energy source in the country. While this represents a success story of decarbonisation, it also illustrates the **risks that short-sighted policy planning** can lead to long-term detrimental outcomes. The first wave of renewables in 2010-2012 was policy-induced through the Renewable and Alternative Energy Sources and Biofuels Act, which incentivised investments in renewables through subsidies and government commitment to purchase electricity from RES. This led to a sudden boom in investments, not only in solar, but also, to a lesser degree, wind and biomass, which the power grid was not yet equipped to handle and resulted in higher final electricity prices. This ultimately led to societal backlash towards renewables and to another ten years of stagnation in the renewables sector.[55]

The second wave of renewables investments has been decidedly market-led and decentralised, dominated by corporate PPAs, commercial self-consumption, and small- to medium-scale producers capitalising on falling technology costs. In 2024 alone, nearly 1.5 GW of solar capacity was added to the power mix, representing close to **90% of all new power generation capacity**.[56] The strongest expansion occurred in southern Bulgaria, where land availability, higher irradiation, and proximity to existing substations have enabled project clustering. Yet, this geographic and technological concentration exposes **new structural vulnerabilities**, grid congestion, curtailment risks, and a growing misalignment between production peaks and consumption profiles.[57]

The rise of solar PV has had a tangible impact on **energy affordability and macroeconomic stability**. During the 2021–2023 energy crisis triggered by Russia's war in Ukraine, Bulgaria's expanding solar fleet significantly **cushioned wholesale electricity prices**, particularly during peak daylight hours, and reduced exposure to volatile gas imports. This, in turn, eased inflationary pressures on households and businesses.[58]

The growth of solar generation has been so rapid and uneven compared to other low-carbon technologies that it has started to distort wholesale price formation, with **negative electricity prices** appearing increasingly often during midday hours, a phenomenon that was virtually absent before 2023.[59] In 2024 Bulgaria saw 138 hours of negative price, and by September 2025, the number had more than doubled to 285 hours. This trend reflects both **overgeneration during peak sunlight** and **insufficient grid flexibility or storage capacity to**

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[55] Stefanov, R. et al., *Green Innovation.bg*, Sofia: Applied Research and Communications Fund, 2014.

[56] Electricity System Operator, Statistical Yearbook.

[57] Center for the Study of Democracy, *Balancing Bulgaria's Energy Future*, Policy Brief, No. 160, October 2025.

[58] Vladimirov, Köppen, and Rickles, *Energy and Climate Security in Europe*, Sofia: CSD, 2025.

[59] Capital.bg, "Negative electricity prices in Bulgaria – a problem or a necessity? [Отрицателни цени на тока и в България – проблем или необходимост?], 25 September 2023.

absorb excess supply. As a result, producers are forced to curtail output or sell electricity below cost, undermining revenue stability. Industry representatives have highlighted that, while Bulgaria's solar expansion has strengthened short-term affordability, it now faces a "maturity bottleneck," where further capacity additions without grid reinforcement, demand-response mechanisms, or utility-scale storage could destabilise the power market.[60] These risks are already visible across Europe, particularly in countries with high shares of renewable power generation, where similar overproduction patterns have caused volatility, discouraging long-term investors and complicating financing conditions for new renewable projects. Unless Bulgaria accelerates **storage deployment, digital grid management, and cross-border trading integration**, it risks repeating the boom-and-bust cycles of its first renewables wave.

Battery Energy Storage Systems

The first puzzle piece – **battery energy storage systems** – is already emerging as a cornerstone of Bulgaria's clean energy transition and has grown dramatically in the past year. Batteries' rapid growth shows that Bulgaria can scale new technologies quickly, but also reveals how momentum depends on external funding and ad-hoc programmes rather than a long-term flexibility strategy. Since the first utility-scale facility became operational in June 2024, total installed capacity has reached 450 MW (around 1,500 MWh) within a year. The Transmission System Operator (ESO) projects that capacity could rise to **11 GW (32,000 MWh) by 2026**[61], equivalent to the full output of Kozloduy NPP for five hours, or Bulgaria's total daytime electricity consumption for about three hours.[62]

The rapid growth of BESS is largely driven by the EU-funded RESTORE project[63], which allocated Recovery and Resilience Facility (RRF) support for large-scale storage infrastructure, and a smaller tender for hybrid renewable energy facilities co-located with batteries launched in 2024.[64] The government aims to disburse approximately **EUR 770 million in RRF funding**. However, industry representatives warn that limited administrative capacity, insufficient technical expertise, and delays in equipment procurement may prevent timely implementation. Many developers had intentionally postponed orders until mid-2025 to benefit from the latest BESS technologies, further increasing the risk of project delays.

Despite implementation challenges, BESS offers Bulgaria a **faster, cheaper, and more flexible alternative** to large pumped-storage hydro power plant (HPP). Batteries require less space, can be deployed in months rather than

[60] Center for the Study of Democracy, based on interviews with industry representatives.

[61] Electricity System Operator, "ESO's projects for network development and expansion of interconnection capacity has set a target of 10,000 MW cross-border capacity", ESO, 17 June 2025.

[62] Capital.bg, "Battery-powered sun: Bulgaria can now store 1,300 MWh of energy from renewable sources", [Слънце на батерии: България вече може да съхранява по 1300 мВтч енергия от ВЕИ], 10 July 2025.

[63] Ministry of Energy, "National Infrastructure for Storage of Electricity from Renewable Sources (RESTORE)".

[64] Ministry of Energy, "Support for new capacities for electricity generation from renewable sources and electricity storage".

years, and have a smaller environmental footprint. They can also be strategically located near generation or demand centres, improving both grid stability and local resilience. This is particularly important, given the delays surrounding the repairs of the 800 MW Chaira pumped-storage HPP, and the uncertainty around the construction of two additional HPP plants at Batak and Dospat, each with around 800 MW of generation and 730 MW of storage capacity.[65]

Box 2. Strategic Foresight in Action: How Greece Balanced Its Renewable Boom

Greece's rapid progress in deploying large-scale energy storage demonstrates the importance of government foresight and policy coordination in managing the energy transition. The country did not leave the development of storage to market dynamics alone. Recognising early that renewable expansion without sufficient storage would destabilise the grid, the government created a dedicated **Energy Storage Task Force in 2021** to develop a national strategy and concrete regulatory recommendations. Within a year, the Task Force's proposals led to sweeping legal and institutional reforms, including measures to prevent double taxation of storage assets, streamlined permitting procedures, and priority grid access for hybrid renewable-storage projects.[66]

The Greek government then paired regulatory clarity with **targeted financial support**, launching three competitive tenders between 2023 and 2025 to allocate 900 MW of subsidised battery storage capacity. The tenders **combined capital expenditure grants of up to EUR 200,000/MW with CfDs** guaranteeing a fixed revenue stream for ten years, thereby reducing investor risk while maintaining cost efficiency. Together, these measures have laid the foundation for achieving Greece's National Energy and Climate Plan target of 8.1 GW of storage by 2030, ensuring that the country's 80% renewable electricity goal is underpinned by system flexibility and price stability.[67]

Greece's approach offers a useful blueprint for Bulgaria, which has so far lacked the same degree of planning, stakeholder involvement, and regulatory coherence. While Bulgaria has achieved rapid deployment of solar photovoltaics and launched the RESTORE battery programme, the process remains fragmented and vulnerable to administrative delays and market imbalances. The Greek experience underscores that **policy foresight, institutional coordination, and investor confidence are inseparable** from technological progress. Establishing a permanent national coordination mechanism which involves all relevant stakeholders, including policymakers, the regulator, system operators, and private investors, could help Bulgaria align renewable growth with storage, ensuring a balanced, secure, and competitive energy transition.

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[65] European Commission, Bulgaria – National Energy and Climate Plan 2021-2030, 15 January 2025.

[66] Papakonstantinou, A., "Electricity storage in Greece: State-of-play & near-term outlook", Electra-CIGRE, No 329.

[67] Ntemou, E., et al."Navigating Electricity Market Design of Greece: Challenges and Reform Initiatives", *Emerging Trends in Energy Economics*, 16 May 2025.

Since 2023, updated **market rules** have recognised BESS operators as a distinct category of participants in the wholesale and balancing markets. Storage operators can now provide frequency regulation, balancing reserves, and arbitrage between day-ahead and intraday markets under a "pay-as-clear" pricing model, which rewards efficient operation. They are also exempt from double network fees, enhancing profitability.[68] To unlock further investment, Bulgaria should enable **revenue stacking** through new market mechanisms, including a **capacity market** that allows BESS to secure long-term contracts for availability. Distribution operators could also procure local flexibility services to relieve grid congestion. If effectively implemented, these measures would consolidate Bulgaria's progress in renewable deployment, stabilise electricity prices, and transform BESS from a technical add-on into the **backbone of a flexible, resilient, and competitive low-carbon power system**.

Laggards

Electricity Grids

Battery storage and modern grids are two sides of the same coin. While batteries provide the short-term flexibility needed to balance intermittent generation, it is **the electricity grid that ultimately determines how efficiently and safely renewable energy can be transmitted, stored, and consumed**. It is in the delayed grid modernisation that the consequences of unbalanced technological progress become most visible, as the system struggles to absorb the very renewables it helped enable. Given that solar and battery installations in Bulgaria have expanded faster than anticipated, the power grid must now evolve to keep pace with the country's rapidly changing energy landscape. Bulgaria's electricity grid remains one of the most centralised in Europe, historically designed to transmit power from large baseload plants, primarily coal and nuclear, toward demand centres. As renewable installations multiply across the country, particularly in the Southern and North-eastern regions, this architecture is being tasked with integrating thousands of decentralised producers and managing more dynamic and bidirectional power flows.

To meet these challenges, several key grid modernisation and interconnection projects are already underway. The National Electricity Company (NEK) and the Electricity System Operator (ESO) have launched investment programmes to strengthen key transmission corridors and expand regional connectivity. Ongoing projects with **Greece[69] and Romania[70]** aim to increase Bulgaria's **net transfer capacity from 4,500 MW to nearly 10,000 MW by 2030**, including the new Maritsa–Nea Santa and Varna–Isaccea lines. These upgrades will enhance Bulgaria's ability to exchange renewable electricity across borders, stabilise the system during demand peaks, and reinforce regional resilience against supply disruptions. Domestically, the grid modernisation programme also includes the **replacement of ageing substations, new digital control centres, and upgrades to**

[68] Energy and Water Regulatory Commission, Rules for trading with electrical energy [Правила за търговия с електрическа енергия], last amended on 1 July 2025.

[69] ENTSO-E, project TR 142 – CSE4.

[70] ENTSO-E, project TR 138 – Black Sea Corridor.

medium-voltage infrastructure. If completed on schedule, these investments will form the backbone of Bulgaria's clean power system, allowing both utility-scale and distributed renewables to operate safely within a more flexible and decentralised grid.

The institutional and regulatory framework is still lagging behind the rapid technological change. The transmission and distribution system operators have struggled to keep pace with decentralised generation, often delaying or denying new grid connection requests. The lack of transparent data on available grid capacity, long permitting procedures, and unclear cost allocation for grid upgrades have all constrained the rollout of new RES projects. At the same time, **punitive measures** recently adopted by the government, including a fivefold increase in the fines for outages and mandatory reinvestment quotas for DSOs, risk creating financial uncertainty without addressing underlying governance issues.[71] Instead of penalties, the regulatory framework should link financial incentives to measurable outcomes, such as lower grid losses, improved reliability, and faster connection times for renewable producers.

The weakest link in Bulgaria's grid modernisation remains digitalisation. Smart grid solutions, which combine advanced metering, real-time data, and AI-based forecasting, are still in their infancy. **Officially, only 1% of consumers have smart meters[72]**, although DSOs claim that up to 34% of existing meters have remote functionality[73]. This discrepancy reflects a broader lack of strategic vision and regulatory coordination. Without real-time monitoring, Bulgaria's grid operators cannot accurately forecast demand patterns, manage distributed energy flows, or support flexibility services, which are all critical functions for a modern, renewable energy-based system.

The uptake of digitalisation technologies must therefore become a national priority. Introducing **mandatory smart meter deployment**, dynamic pricing schemes, and transparent **data-sharing frameworks** would not only empower consumers but also give DSOs and market participants the information needed to improve efficiency and reliability. The government should integrate these objectives into the **Energy Act** and the upcoming **Electricity Market Rules**, ensuring that every new grid investment includes digital infrastructure components. Digital grids would also enable Bulgaria to capitalise on its emerging expertise in ICT and artificial intelligence. By developing predictive maintenance tools, digital twins of grid operations, and AI-based load management systems, the country could transform the power grid from a reactive infrastructure into an innovation-driven ecosystem, aligning the goals of energy security, competitiveness, and sustainability.

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71 Amendment to the Energy Act, [Закон за изменение и допълнение на Закона за енергетиката], last amended on 11 August 2025.

72 European Union Agency for the Cooperation of Energy Regulators (ACER), *Energy Retail and Consumer Protection: 2023 Market Monitoring Report*, September 2023.

73 Eurelectric, Power Barometer 2023.

Box 3. Smarter Grids, Stronger Systems: Lessons from Europe's Smart Meter Pioneers

Smart metering is the foundation of a modern, flexible electricity system. By providing near real-time data on consumption and generation, smart meters enable consumers to actively manage their energy use, support demand-response schemes, and improve grid reliability. This limited rollout of smart meters in Bulgaria constrains energy efficiency efforts, prevents real-time visibility of distributed generation, and impedes the development of energy communities and demand-response markets, which require digital measurement and data exchange to function transparently.

Italy became Europe's smart meter pioneer after ENEL launched its *Telegestore* programme in 2001. Motivated by high electricity theft and costly manual meter readings, ENEL installed 30 million smart meters by 2006, cutting operating costs by over EUR 500 million annually. The rollout was accompanied by regulatory reforms, which mandated all distribution operators to complete the rollouts and to establish national standards and tariff-based remuneration for cost recovery. Today, Italy's second-generation rollout has achieved 99% coverage and continues to deliver consumer savings, reduced fraud, and better demand-side management. Italy's experience shows how regulatory mandates, backed by financial incentives and clear technical standards, can accelerate digitalisation while ensuring consistent national coverage.[74]

Germany's *Energy Savings Meter Programme* linked smart meter adoption with performance-based remuneration. By combining partial upfront funding with payments tied to verified energy savings, the programme encouraged innovation among start-ups and SMEs, improved data collection, and demonstrated measurable efficiency gains across sectors. Between 2016 and 2021, over 50 projects were funded, integrating AI-assisted "energy-saving assistants" and predictive analytical tools. Germany's approach underlines the power of linking smart meters to co-benefits like efficiency, emissions cuts, and innovation, rather than treating them purely as infrastructure upgrades.[75]

Sweden mandated smart metering in 2003 to improve grid management and consumer engagement. **More than 150 DSOs cooperated through pooled procurement, lowering deployment costs and sharing expertise**. The Swedish Energy Markets Inspectorate later introduced uniform functional requirements, including hourly readings, remote software updates, and outage tracking, ensuring equal service quality and data accessibility. Remote-upgrade features significantly cut field visits and operational costs, while enabling continuous functionality improvements.[76]

To rapidly and effectively catch up with its European peers, **Bulgaria should first mandate nationwide smart meter deployment** under a unified technical standard to prevent fragmentation and establish a dedicated task force to drive the process. Digitalisation should then be linked to measurable outcomes such as reduced losses or verified efficiency gains. Finally, to foster cooperation among DSOs, the government should encourage joint procurement or shared digital platforms.

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[74] Piti, A., et al, "The Role of Smart Meters in Enabling Real-Time Energy Services for Households: The Italian Case", *Smart Home Energy Management*, 10 February 2017.

[75] International Energy Agency, "Energy Efficiency Services: Germany's Energy Savings Meter Program", 19 June 2019.

[76] Huang, Y. et al., "Smart meters in Sweden – Lesson learned and new regulations", Conference Paper, December 2018.

Wind Power

Wind power represents the clearest example of how strategic neglect, rather than technical constraints, has stalled an otherwise highly competitive technology. Bulgaria possesses some of the strongest onshore and offshore wind resources in Southeast Europe, yet the sector has remained almost entirely stagnant for a decade. Installed capacity has been stuck at roughly 0.7 GW since 2015, despite wind power offering a mature, low-cost, and domestically available energy source that could significantly improve system balance, particularly during hours of low solar production. While the NECP's WAM scenario foresees 8.3 GW of wind by 2050[77], **Bulgaria could integrate up to 23 GW (10 GW onshore and 13 GW offshore)** by mid-century if regulatory and infrastructural barriers were addressed[78]. The discrepancy between Bulgaria's vast potential and its limited achievements reflects not a shortage of natural resources, but rather a long-term failure of strategic planning, regulatory clarity, and public communication.

A core reason for the sector's stagnation is the persistent absence of political commitment and long-term goal-setting. For more than a decade, **no government has articulated a clear vision for wind power, neither in terms of its role in energy security, competitiveness, nor industrial development**. The NECP provides numerical targets, but no practical roadmap to achieve them, and there are no designated development zones, forward-looking spatial planning exercises, or coordinated cross-ministerial processes to guide investors and public authorities. As a result, developers uncertain about future policy conditions often file speculative applications, further burdening an already overstretched permitting system and contributing to lengthy delays.[79]

This weak strategic foundation is compounded by a regulatory environment that continues to discourage investment**. Permitting remains slow, opaque, and bureaucratic, involving multiple layers of approval with unclear timelines, inconsistent methodologies for calculating grid-connection costs**, and frequent delays associated with environmental impact assessments.[80] The absence of transparent, unified rules across municipalities has led to further uncertainty for project development and implementation. In addition, Bulgaria's revenue cap for renewable energy producers, set at EUR 153.39/MWh, fundamentally distorts market signals.[81] Although intended to protect consumers, the measure bars producers from benefiting during periods of high prices, while exposing them fully to losses during low or negative price periods, now increasingly common as solar capacity grows. Combined with the 5% levy on revenues that needs to be paid into the Fund for the Security of the Electricity System, trading fees, and rising balancing costs, the cap sharply reduces prof-

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77 European Commission, Bulgaria – National Energy and Climate Plan 2021-2030, 15 January 2025.

78 Vladimirov et al., *Exiting the Vicious Cycle*, Sofia: CSD, 2024.

79 CSD, *Realigning Bulgaria's Energy and Climate Strategy*, 2025.

80 Center for the Study of Democracy, *The Lowest Hanging Fruit: Wind Energy Potential in Bulgaria*, Policy Brief No. 138, September, 2023.

81 Council of Ministers, Decision 340 from 28.05.2025 on For Determining the Values Used to Calculate the Revenue Cap for the Respective Type ff Electricity Producer [Решение 340 / 28.5.2025 г. За определяне на стойностите, които служат за изчисляване на тавана на приходите за съответния тип производител на електрическа енергия].

itability and disincentivises new investment, especially in capital-intensive wind projects that take nearly a decade to develop.[82]

Market design shortcomings further limit wind deployment. Wind power's ability to generate during hours when solar output is low is not rewarded within existing market structures. There are no long-term price stabilisation tools, such as contracts for difference or capacity mechanisms, no incentives for hybrid projects combining wind and storage, and limited access to demand-side flexibility solutions that could reduce balancing obligations. These gaps increase curtailment risks, especially in regions with constrained grid capacity, and weaken the business case for new projects. As a result, even though wind has a lower average LCOE in Europe than solar PV and offers higher annual operating hours, **investors perceive significantly higher risks in the Bulgarian market**.[83]

Infrastructure constraints represent another major barrier. The strongest wind resources are concentrated in Northeast Bulgaria, but **the transmission grid in this region lacks the capacity needed to integrate new projects**. While the TSO acknowledges the need for expansion, **current investment plans underestimate both the scale and urgency of upgrades, putting at risk many projects already in the pipeline**. High booking fees for grid capacity further discourage new entrants and tilt the market in favour of large incumbents. The situation is even more challenging for offshore wind, where Bulgaria has not yet upgraded the ports of Varna and Burgas to support turbine assembly and installation – an absolute prerequisite for any meaningful offshore development. Coastal grid infrastructure also requires reinforcement before it can absorb offshore-generated electricity.

This stagnation has prevented the emergence of a domestic wind industry, despite Bulgaria's favourable geographic position, engineering skills, and access to EU funding instruments for supply-chain development. With no predictable project pipeline, **suppliers have little incentive to establish operations in Bulgaria, limiting job creation, knowledge transfer, and potential export opportunities**. The missed industrial opportunity is substantial, given that offshore wind alone could unlock investments exceeding EUR 20 billion.[84]

Public acceptance has emerged as an equally important obstacle. **Local opposition, fuelled by misinformation and politically motivated campaigns**, has made municipal authorities increasingly reluctant to issue permits. Persistent myths about noise, health effects, impacts on tourism, and harm to biodiversity continue to circulate widely, despite being disproven by empirical evidence.[85] In reality, all RES projects combined occupy less than 0.1% of Bulgaria's arable land, far less than the footprint of coal mines and related infrastructure. For offshore wind, misinformation campaigns have been

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82 Official position of representatives of the renewable energy sector in relation to the proposed extension of the revenue cap applied to electricity producers, 24 June 2025.

83 International Renewable Energy Agency, Renewable Power Generation Costs In 2024, Abu Dhabi, 2025.

84 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.

85 Vladimirov, M. et al., *The Kremlin Playbook against Offshore Wind Energy in Bulgaria*, Sofia: Center for the Study of Democracy, 2025.

particularly damaging, practically blocking the adoption of the much-needed **Renewable Energy in Maritime Spaces Act**[86] and delaying the establishment of a comprehensive regulatory framework. Without structural reform, backed by political commitment, regulatory clarity, market modernisation, strategic infrastructure investment, supply-chain development, and systematic public engagement, **the country risks locking itself into an imbalanced and vulnerable energy transition**, missing out on the economic, social, and security benefits that wind power could provide.

Box 4. Denmark's Wind Power Playbook[87,88]

Denmark's rise to a global wind energy powerhouse did not happen overnight, nor did it follow a single policy blueprint. It reflects five decades of consistent political commitment, deliberate industrial strategy, community engagement, and system planning. While the country's experience cannot be quickly or easily replicated, it showcases how long-term vision, backed by adaptive regulation and public support, can deliver world-leading clean-energy industries, high-quality jobs, export competitiveness, deep decarbonisation and energy security.

Denmark's wind journey began in the wake of the 1970s oil crises, when energy security and public opposition to nuclear power converged to push policymakers toward alternative technologies. From the 1980s onward, **successive governments with different political leanings have maintained stable commitment to wind as a national strategic priority**. The Energy 2000 plan formally integrated wind into long-term energy planning, while later climate laws locked in ambitious targets, including a 70% emissions reduction by 2030 and climate neutrality by 2045. Public funding supported early research and development, test centres, certification schemes, and demonstration projects, creating a continuous pipeline of innovation. This consistency reduced investment risk and enabled Danish companies, universities, and municipalities to plan decades ahead, forming the backbone of the modern wind sector.

From the outset, Denmark established **clear, predictable rules for grid access, remuneration, and siting of wind turbines**. Early subsidies and tax exemptions stimulated private investment and accelerated adoption, but as technologies matured, support shifted to more market-based instruments such as competitive tenders and corporate PPAs. Crucially, the regulatory framework did not remain static: **rules were regularly updated to integrate new technologies, environmental standards, and market structures**. Offshore wind planning was centralised to reduce uncertainty, while permitting processes were streamlined and supported by robust environmental oversight. The result was an investment environment characterised by low regulatory risk, stable long-term earnings profiles, and clear trajectories for future expansion.

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86 Bulgarian National Assembly, Renewable Energy in Maritime Spaces Act, 2023.

87 van Est, R., "The Success of Danish Wind Energy Innovation Policy: Combining Visionary Politics and Pragmatic Policymaking", In: Successful Public Policy in the Nordic Countries, Edited by Caroline de la Porte et al., Oxford University Press, September 2022.

88 State of Green, "Wind energy – powering the future", April 2025.

Denmark redesigned its electricity market to accommodate increasing shares of variable renewables. It transitioned from a centralised, fossil-based system to a flexible, distributed, two-way grid capable of handling bi-directional flows and large fluctuations. Wind was guaranteed non-discriminatory access to the grid, while dispatchable combined heat and power plants, heat pumps, and district heating networks provided flexibility. **Integration into the Nordic and European markets** enhanced balancing capabilities and price stability. This combination of domestic flexibility and cross-border market coupling enabled wind to reach more than 50% of Denmark's electricity supply while maintaining exceptional reliability, averaging just 17 seconds of outages per consumer in 2024.

Wind in Denmark is part of a fully integrated energy system rather than a standalone technology. Ports such as Esbjerg, Aalborg, and Odense were transformed into **specialised industrial hubs for offshore wind construction**, servicing, and export logistics. These ports invested early in heavy-lift quays, deep-water berths, manufacturing facilities, and training centres, becoming Europe's main offshore wind staging areas. Grid infrastructure was upgraded continuously, with **strong transmission investments and modern digital tools enabling high wind shares and secure system operation**. Large-scale interconnectors, such as the Viking Link to the UK, provide additional balancing capacity. On the demand side, Denmark integrated wind with district heating, electrified industry, and transport, ensuring that excess production could be stored or consumed efficiently. These coordinated investments turned infrastructure into a strategic asset and reinforced Denmark's competitive advantage.

Denmark deliberately cultivated a world-class wind industry by aligning industrial policy, R&D, export finance, and standards. Early convergence on a common "Danish turbine concept" (three-bladed, horizontal-axis) enabled rapid scaling and standardisation. The country established testing and certification centres, export credit mechanisms, and public–private innovation clusters that supported manufacturers. As offshore wind expanded, **Denmark leveraged its first-mover advantage to become a global centre for turbine technology**, operations and maintenance, grid integration, and offshore engineering. Today, the sector directly or indirectly employs over 30,000 people and generates EUR 5.9 billion in high-value exports in 2023, demonstrating how clean energy can be a foundation for national industrial competitiveness.

Denmark's social model for wind has been as important as its technical and regulatory innovations. From the beginning, **local cooperatives and citizens have owned thousands of turbines, ensuring that financial benefits remained within communities**. Modern rules continue this tradition: at least 20% of shares in new onshore projects must be offered to local residents; municipalities receive dedicated payments per installed MW through a "green fund"; and neighbours receive annual renewable-energy bonuses and compensation for potential property devaluation. Transparent planning, early consultation, and local benefit-sharing have ensured that communities view wind projects as shared assets, not impositions, making Denmark one of the countries with the highest public acceptance of renewables globally.

Untapped Potential

Beyond its proven strengths in solar and wind, Bulgaria possesses substantial, but almost entirely undeveloped, potential in several other key low-carbon technologies. **Geothermal energy and carbon capture, utilisation and storage (CCUS)** in particular represent strategic opportunities that could elevate Bulgaria from a passive regional electricity exporter to a true regional energy and decarbonisation hub. Yet none of these technologies currently benefit from clear policy direction, deployment targets, or dedicated support mechanisms. Without long-term strategic planning, coordinated investment frameworks, and concrete implementation pathways, Bulgaria risks falling behind its neighbours and missing the chance to secure new industrial value chains, enhance energy independence, and anchor its economic competitiveness in the emerging European clean-tech landscape. The technologies that lag, grids, wind power, geothermal, and carbon management share the same set of structural barriers: fragmented governance, unclear long-term targets, underdeveloped permitting frameworks, and insufficient regulatory adaptation. These weaknesses explain why Bulgaria's energy transition is technologically narrow rather than balanced.

Geothermal Energy

Geothermal energy highlights a major missed opportunity: a domestic, low-carbon heat source with strong potential, limited not by geology but by the absence of policy direction. **Bulgaria is one of Europe's most naturally endowed countries when it comes to geothermal energy**, yet it remains one of the least developed markets on the continent. The country holds significant untapped potential across both deep and shallow geothermal applications. Decades of oil and gas drilling have already confirmed medium to high temperatures of 150–200°C at depths of 4–6 km in the areas North of the Balkan mountain range, suitable for electricity production and for large-scale district heating and industrial heat. The southern geological region shallow thermal aquifers and abundant hot springs signal deeper high-temperature reservoirs that remain unproven due to limited drilling beyond 1–2 km. In parallel, shallow geothermal heat pumps, usable everywhere in Bulgaria, can provide efficient heating and cooling for households, public buildings, and industry. This gap is particularly significant given Bulgaria's **heavy dependence on coal and firewood-based heating and the persistently high levels of energy poverty**. Geothermal energy could thus become the cornerstone of clean, affordable heat – an area where the transition has barely begun.[89]

In addition, recent technical assessments confirm that geothermal energy is cost-competitive across multiple sectors, including household heating, industry, and greenhouse agriculture, especially in the Sofia, Blagoevgrad, Pleven, Varna, Plovdiv, and Smolyan regions. Geothermal energy can compete directly with traditional fuels when drilling depth, water temperature, available distribution infrastructure, and technological options are properly matched. Despite this exceptional natural endowment, the **unlocking of the geothermal energy potential in Bulgaria has lagged behind for decades**. **Two structural gaps remain: incomplete mapping of deep geothermal re-**

[89] Bulgarian Association Geothermal Energy.

sources and the high upfront cost of exploratory drilling, which deters investors. [90]

Bulgaria has started developing a clear regulatory framework, but this legal effort is not matched by an overarching political commitment or strategic policy vision for geothermal energy. On the one hand, in line with Council Regulation (EU) 2022/2577[91], the **Amendments to the Renewable Energy Sources Act from 2023 shortened the permitting deadlines for geothermal heat pump installations** below 50 MW to a maximum of three months. On the other hand, the NECP suggests that geothermal installations will be granted preferential heat-network access and envision 400 MW of installed capacity for electricity generation by 2050, without proposing any specific measures or funding mechanisms to develop the sector.[92]

Some practical applications are already emerging. **Bulgaria's first new-generation geothermal district heating project** is under construction in the municipality of Zlatograd, near the Bulgaria-Greece border, where Minstroy Holding has chosen the region for a deep-geothermal heating installation. The project is still at an early stage and depends on external financing, but the preparatory work has started with the construction of the heat transmission pipeline from the Erma River to Zlatograd. The municipality has pursued geothermal development for more than 16 years, yet a lack of funding, estimated at around EUR 12 million, has delayed implementation.[93]

Carbon Management and Hydrogen

Bulgaria possesses a unique natural advantage in developing carbon capture and storage technologies. The country **stands out for its exceptionally large theoretical geological CO_2 storage potential**, estimated at between 3 and 450 gigatonnes (reflecting low- to high-scenario modelling), the highest range identified in Europe.[94] If even a fraction of this potential were confirmed and developed, Bulgaria could become ready not only to decarbonise its own industrial and energy sectors, but also to offer CO_2 storage services to neighbouring countries, creating a new strategic and commercial asset for regional cooperation.

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[90] Ministry of Energy, "Minister Stankov: Geothermal energy provides real energy diversification", [Министър Станков: Геотермалната енергия осигурява реална енергийна диверсификация], 25 February 2025.

[91] Council Regulation (EU) 2022/2577 of 22 December 2022 laying down a framework to accelerate the deployment of renewable energy.

[92] European Commission, Bulgaria – National Energy and Climate Plan 2021-2030, 15 January 2025.

[93] Bulgarian National Radio, "The first geothermal power plant in Bulgaria is being built in Zlatograd", [Строят първата геотермална електроцентрала в България], 2 October 2025.

[94] Clean Air Task Force, "Unlocking Europe's CO2 Storage Potential", 4 July 2023.

CCUS can be deployed most effectively in the industrial sector. In 2023, industry accounted for around 25% of Bulgaria's total greenhouse gas emissions.[95] The subsectors of chemicals, petroleum products, glass, cement, and non-metallic minerals have much higher carbon intensity levels in Bulgaria than the EU average. Petrochemicals release 12.5 kg CO_2e per euro of GVA on average in Bulgaria, which is one of the highest rates in Europe. These emissions already carry a significant financial burden: in 2024, Bulgarian industrial installations paid for 16% of their emissions, at an average ETS price of EUR 65/tCO_2, amounting to over EUR 70 million in carbon costs.[96]

However, limiting carbon management to industry alone would be a strategic mistake. Given Bulgaria's continued political commitment to maintaining coal-fired power generation despite the high costs on taxpayers, CCUS could prove essential to prevent the power sector from locking in structurally high emissions and vulnerability to rising ETS costs. While ETS prices are expected to continue rising[97], especially after 2030, the cost of carbon capture, like all other low-carbon technologies, is set to decline as a result of wider market penetration and technological advancements, making **carbon management technologies not only an important tool on the road to carbon neutrality but also a financially viable solution**[98]. Furthermore, while CCUS is not a complete decarbonisation solution for the power sector, it can play an important role in the energy transition process. Whilst Europe builds its electricity storage capacity, extending the life of coal and gas power plants through CCUS will enable them to continue providing baseload capacity and short and long-term system flexibility and compensating for seasonal variations of renewable generation.[99]

Carbon utilisation technologies offer an additional pathway within carbon management by converting captured CO_2 into valuable products such as synthetic fuels, green fertilizers, plastics and construction aggregates. Most CCUS pathways are technically viable at pilot scale, while some mature applications, such as urea and methanol production, have already reached commercial readiness.[100] Bulgaria has not yet explored carbon utilisation as an opportunity for industrial diversification, innovation, or value creation, even though it can provide emitters, particularly in chemicals, fertilisers, synthetic fuels, and construction materials, with new revenue streams that reduce the net cost of carbon capture while stimulating domestic demand for clean technologies.

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[95] Eurostat, Air emissions accounts by NACE Rev. 2 activity.

[96] European Environment Agency, "EU Emissions Trading System (ETS) data viewer", Accessed on 17 November 2025.

[97] Enerdata, "Carbon price forecasts under the EU ETS", 24 November 2023.

[98] International Energy Agency, "Driving down the cost of carbon removal: Why innovation matters", 17 February 2021.

[99] International Energy Agency, "How carbon capture technologies support the power transition", July 2020.

[100] European Commission, Joint Research Centre, "Carbon capture, utilisation and storage in the European Union", 2025.

Box 5. ANRAV – Bulgaria's CCUS Pilot[101,102]

The ANRAV project is Bulgaria's first attempt to build a complete, integrated carbon capture, transport and storage value chain and one of the most advanced CCUS initiatives in Eastern Europe. Led by Devnya Cement (owned by Heidelberg Materials) and funded by the EU Innovation Fund, ANRAV will capture CO_2 from clinker production in the Devnya industrial cluster and transport it via a dedicated pipeline to permanent offshore storage in the depleted Galata gas field in the Black Sea. The project will **capture around 0.8 Mt CO_2 per year**, equivalent to **95% of the plant's emissions,** resulting in 7.8 Mt CO_2eq avoided in the first decade of operation. ANRAV combines two complementary capture technologies, oxyfuel combustion and amine scrubbing, in a hybrid configuration that enables both highly efficient capture rates and the retrofitting of existing kiln lines without disrupting clinker quality. The project's pipeline is designed with **oversized transport capacity, allowing additional emitters in the Devnya cluster (chemicals, glass, soda ash, fertilizers) to connect over time**. On the storage side, the project uses the Galata depleted gas field for Phase I, with later phases expected to develop adjacent saline aquifers and additional depleted fields to increase storage capacity by an additional 10–20 Mt. This phased approach lays the engineering groundwork for a future national CO_2 storage network.

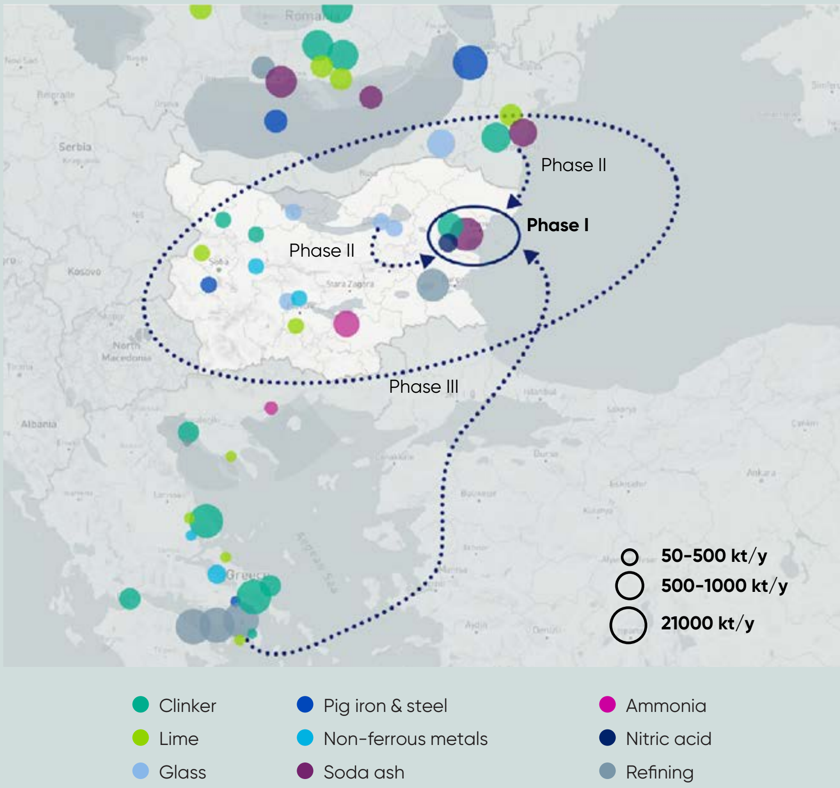
From a strategic standpoint, ANRAV is the first Bulgarian project aligned with the EU Industrial Carbon Management Strategy, the Net-Zero Industry Act, and the Innovation Fund's objective to scale up early CCUS deployment. Its EUR 190 million Innovation Fund award, the first for Bulgaria, signals **EU-level confidence in the country's geological potential** and in the project's bankability. Crucially, ANRAV exposes gaps in Bulgaria's implementation of the CO_2 Storage Directive, permitting procedures, transport regulation, and long-term liability rules. Successful delivery will therefore provide Bulgarian authorities with the administrative experience needed to establish a national carbon management framework, clarify permitting authorities, and define standards for monitoring, verification and risk management.

Beyond decarbonising a single cement plant, ANRAV is a system-building project. **It creates Bulgaria's first shared CO_2 transport infrastructure, demonstrates the viability of offshore storage in the Black Sea, and provides a replicable model for cluster-based decarbonisation**. By designing infrastructure with open-access potential, the project enables economies of scale that can later support other hard-to-abate sectors. Moreover, ANRAV strengthens Bulgaria's strategic position in regional carbon management, offering long-term potential for cross-border CO_2 transport and joint storage solutions with Romania and other Black Sea states.

101 Anrav project.

102 Clean Air Task Force, "Carbon Capture &Storage in Bulgaria: The Role of Carbon Capture and Storage in Decarbonising Bulgarian Industries", 2024.

Figure 9. ANRAV – Potential Stages of Development



Source: Clean Air Task Force, *Carbon Capture & Storage in Bulgaria*, 2023.

Despite the strategic value of a full CCUS value chain, carbon capture remains politically underexplored in Bulgaria. The country still lacks detailed geological data, clear public engagement strategies, and dedicated funding mechanisms. Crucially, **Bulgaria has not fully transposed the EU CO_2 Storage Directive** (2009/31/EC), leaving no rules for site exploration, licensing, monitoring, liability or closure. There is also no CO_2 transport network, no certified storage sites, and no national plan for cross-border CO_2 movement. Against this backdrop, ANRAV highlights the gap between Bulgaria's significant geological potential and the absence of an enabling policy framework.

To address these shortcomings, Bulgaria must establish a coherent legal and regulatory framework defining competent authorities, criteria for site selection and procedures for permitting, operation and monitoring. ANRAV's implementation can serve as a practical test case to identify regulatory bottlenecks, inform long-term liability rules and guide the drafting of secondary legislation for CO_2 transport, particularly relevant as Bulgaria expands hydrogen-ready pipelines and explores offshore storage options in the Black Sea. Institutionally, Bulgaria would benefit from **designating a national coordinating body to oversee geological mapping**, infrastructure planning and stakeholder engagement. Using ANRAV's open-access transport model as a template, Bulgaria can begin to **build a shared CO_2 infrastructure system** and set the foundations for a national carbon management strategy. This would enable the country to convert its natural geological advantage into a credible decarbonisation pathway and position itself as a future storage hub in the Black Sea region.

Hydrogen and CCUS are deeply interconnected in every major EU and global decarbonisation scenario. Today, most low-carbon hydrogen worldwide is expected to come not only from electrolysis but also from natural gas reforming and biomass gasification combined with carbon capture, which significantly reduces lifecycle emissions. **Hydrogen production is projected to become one of the largest applications of CO_2 capture globally by 2050**, following industrial process emissions and power generation. Countries aiming to scale hydrogen, especially for industrial feedstock, steelmaking, ammonia production, and heavy transport, will require parallel development of CO_2 transport and storage infrastructure. In practice, **hydrogen and CCUS evolve together**: without CO_2 storage, hydrogen production from non-electrolytic routes cannot be low-carbon; without hydrogen demand, CCUS deployment cannot reach scale or reduce costs through learning.[103]

Yet despite this tight coupling between hydrogen production and CCUS and the economic opportunities created when both develop together, Bulgaria has made little progress in either area. The potential development of CCUS transport systems is not considered in the Hydrogen Roadmap, creating a strategic misalignment between the two technologies. **Hydrogen's potential is formally recognised in the NECP as a key decarbonisation solution, yet the plan provides no concrete policies, timelines, or support mechanisms for its development**. The document assumes that industry will replace natural gas with hydrogen, projecting that hydrogen will account for 42% of renewable fuels in the sector by 2030, despite offering no roadmap for scaling production, building infrastructure, or reducing costs. Although the Plan hints at repurposing the gas transmission network for future hydrogen use, it does not outline the regulatory, technical, or investment steps required to achieve this shift. As a result, hydrogen's role in Bulgaria remains more aspirational than actionable, with no consistent policy framework to support industrial uptake or system integration.[104] Nevertheless, an EU Project of Common Interest to improve hydrogen interconnection with Greece, the planned "hydrogen valley" in the Stara Zagora region, and innovative EU companies already active in the European value chain are beginning to turn Bulgaria's hydrogen ambitions into reality.

Taken together, these technological trends reveal a transition process, driven by price signals rather than by strategic design. Solar and batteries have surged ahead, while grids, wind, geothermal and carbon management remain constrained by the same structural weaknesses: fragmented institutions, unstable regulation, and a lack of long-term targets. This imbalance reduces emissions today but creates new vulnerabilities related to market volatility, grid stress, overreliance on imported technologies, and growing exposure to the ETS and global competition. To secure Bulgaria's energy future, **technology deployment must be guided by a coherent strategy that integrates generation, flexibility, infrastructure, and industrial development**. Only then can the electricity sector's progress become the foundation of a resilient, competitive, and sovereign low-carbon economy.

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[103] EC, JRC, "Carbon capture, utilisation and storage in the European Union", 2025.

[104] CSD, *Realigning Bulgaria's Energy and Climate Strategy*, 2025.

TURNING RISKS INTO OPPORTUNITIES

To unlock its green innovation potential, Bulgaria must shift from crisis management to system redesign. It must take stock not only of its opportunities to upscale low-carbon-based power generation, but of all of its natural resources and decide how these can be utilised in an environmentally conscious, but also financially lucrative way, so that **Bulgaria can secure its place in global low-carbon value chains and secure a sustainable economic growth pathway.** Bulgaria's transition has so far been driven by narrow, energy-sector decarbonisation rather than a whole-economy strategy. The next step is to identify how the country can **turn its structural vulnerabilities into competitive advantages** by aligning its resources, industrial capabilities, and innovation potential with Europe's emerging clean-tech ecosystems.

Emerging Risks

Although Bulgaria's rapid decarbonisation has provided significant climate, affordability, and energy security benefits, it has also revealed a set of **structural vulnerabilities that stem from the country's reliance on imported low-carbon technologies** and critical raw materials.[105] The rapid deployment of solar PV and storage technologies has resulted in a surge in the country's import dependency. In 2024, **Bulgaria imported photovoltaic cells valued at EUR 272 million, 84% of which originated from a single source – China**[106]. When measured relative to GDP, this dependence places Bulgaria as the second most reliant country in the EU on solar panel imports, after Lithuania. This high supply concentration exposes Bulgaria to significant geopolitical risks. China's current dominance in the global PV value chain, controlling up to 95% of various manufacturing stages, means that any political or trade disruption could severely impact billions in low-carbon investments.

While the reliance on Chinese-made PV components poses a genuine geopolitical risk, it must be contextualised against the risks associated with continued fossil fuel dependence. Oil and gas are consumable resources that require a constant, massive flow of recurring imports, diverting billions of euros to often authoritarian regimes, such as Russia, and creating continuous exposure to price volatility. In contrast, **PV panels represent a one-time capital import with a long operational lifespan, expected to exceed 30 years** with minimal degradation and retain over 80% of their nominal power after three decades in the field, significantly lowering their long-term geopolitical risk.[107]

The energy storage revolution further complicates the material security landscape as the demand for battery components is set to surge. This growth directly translates into increased reliance on lithium-ion battery imports from

[105] Vladimirov, Köppen, and Rickles, *Energy and Climate Security in Europe*, Sofia: CSD, 2023.

[106] Based on expert assessments by the Institute of Baltic Studies.

[107] Özkalay et al., "Correlating long-term performance and aging behaviour of building integrated PV modules", Energy and Buildings, Volume 316, 1 August 2024.

China and high-risk materials[108], including lithium, cobalt, nickel, manganese, and graphite. The opening of IPS' BESS manufacturing plant in 2025 marks a significant milestone[109], as most components will be produced in Europe. However, the lithium-ion battery cells are still imported from China, demonstrating that **decoupling the supply chain of low-carbon technology from China is extremely difficult to achieve**, even with a special focus on 'Made in Europe' production. This reality necessitates strategic planning to mitigate volatility exposure, aligning with the EU's CRM Act targets for enhancing domestic processing and recycling capabilities. The challenges of supply dependence and raw material exposure open significant opportunities for Bulgaria to build systemic resilience and competitive advantage, primarily through the circular economy.

Carbon Border Adjustment Mechanism

The introduction of the EU's Carbon Border Adjustment Mechanism **will further exacerbate Bulgaria's vulnerabilities to carbon prices and high energy intensity**, and Bulgaria's competitiveness will depend not only on deploying clean technologies but on strengthening the resilience of its supply chains, industrial base, and domestic innovation ecosystem. CBAM will begin full implementation in January 2026 (following the introduction of an exemption for all companies importing less than 50 tonnes of goods subject to the Mechanism), and is designed to equalise the carbon cost borne out by EU producers under the ETS with that of foreign producers whose countries apply weaker or no carbon pricing. Importers of cement, iron and steel, aluminium, fertilisers, electricity, and hydrogen will be required to purchase CBAM certificates, corresponding to the embedded CO_2 emissions of these goods, priced weekly at the EU ETS rate. By ensuring that imported goods face the same carbon cost as domestic production, **CBAM aims to prevent carbon leakage, protect EU industrial competitiveness, and advance the EU's objective of climate neutrality** by mid-century.[110]

Third countries, particularly those with carbon-intensive export profiles or strong trade dependence on the EU, will feel CBAM's impact most acutely, unless they improve production efficiency or adopt domestic carbon pricing to offset CBAM liabilities.[111] At the same time, **CBAM can act as a technology-forcing mechanism**, incentivising cleaner production methods, improved monitoring systems, and the adoption of domestic climate policies that allow countries to capture carbon revenue rather than transfer it to the EU.[112] **EU Member States will also encounter challenges** during CBAM's implementation, including **higher input costs** in import-dependent sectors and **increased administrative burden** for national customs authorities, responsible for es-

[108] European Parliament and Council of the European Union, Regulation (EU) 2024/1252 of the European Parliament and of the Council of 11 April 2024 establishing a framework for ensuring a secure and sustainable supply of critical raw materials (Critical Raw Materials Act).

[109] Capital.bg, "The Bulgarian company IPS aims for 15% of the European battery market", [Българската IPS се цели в 15% от европейския пазар на батерии], 17 OCtober 2025.

[110] European Commission, Carbon Border Adjustment Mechanism, Taxation and Customs Union.

[111] Magacho, G., Espagne, E., and Godin, A., "Impacts of the CBAM on EU trade partners: consequences for developing countries", Climate Policy 24(2), 13 April 2023.

[112] Erdogdu, E., "The Carbon Border Adjustment Mechanism: Opportunities and Challenges for Non-EU Countries", WIREs Energy and Environment, 14(1), December 2025.

tablishing verification, monitoring, and enforcement systems. These pressures will be uneven across the EU, depending on the structure of national industries and the degree of reliance on carbon-intensive imports.[113]

For Bulgaria, the risks are concentrated in a handful of exposed sectors and arise from the broader carbon intensity of its economy. Cement and electricity imports are particularly vulnerable: Bulgarian cement imports may face cost increases of over 20% once CBAM is applied, while **electricity prices could rise by more than 7% as imports from carbon-intensive producers such as Serbia and Turkey become more expensive**[114]. Iron and steel, aluminium, and fertilisers will also see higher costs, albeit to a lesser extent. Bulgaria's domestic producers face their own pressures as free ETS allowances are phased out, with heavy industry already carrying substantial carbon-cost risks due to outdated production processes and low investment in low-carbon technologies. **Without adaptation, firms will find it harder to remain competitive within European value chains that are rapidly shifting toward low-carbon procurement standards.**

At the same time, **CBAM also presents a significant opportunity for Bulgaria to accelerate industrial innovation and strengthen its long-term competitiveness**. Expanding renewable energy generation and electrifying industrial processes can lower the carbon content of Bulgarian production, improve energy security, and reduce exposure to volatility in fossil fuel markets.[115] A more ambitious renewable energy deployment strategy would not only limit CBAM-related import costs but could restore Bulgaria's position as a competitive electricity exporter. Clean electricity would also lower emissions in CBAM-covered sectors such as aluminium, fertilisers, and steel. In harder-to-abate sectors like cement and primary steel, CBAM strengthens the business case for **investments in breakthrough technologies such as green hydrogen, advanced electrification, enhanced recycling, and carbon capture** and storage. By moving early, Bulgaria could attract investment, stimulate local supply chains, and position itself as a producer of low-carbon materials increasingly demanded across the EU.

Strategic Assets

Mining Potential

While Bulgaria's import profile reflects certain vulnerabilities, the country is also exceptionally well-positioned to leverage its geological endowment and industrial capacity to reduce risk and strengthen its strategic autonomy. **Several critical raw materials are already produced in Bulgaria or have strong production potential**. The country already lies within several emerging green-tech trade clusters, notably copper products, aluminium components, electric wiring harnesses, and solar glass inputs, suggesting a realistic opportunity to integrate into the fast-growing EU value chains if domestic bottlenecks are

113 Delgado-Téllez, M., Quintana, J., and Santabárbara, D., Carbon Pricing, Border Adjustment and Renewable Energy Investment: A Network Approach, European Central Bank Working Paper Series No 3020, 2025.

114 Dolphin, G., and Ferrucci, G., The EU's CBAM: Implications for Member States and Trading Partners, IMF (WP/25/125), June 2025.

115 Delgado-Téllez, Quintana, and Santabárbara, D., Carbon Pricing, Border Adjustment and Renewable Energy Investment: A Network Approach, ECB, 2025.

addressed.[116] Bulgaria is the EU's **third-largest copper producer**, contributing around 5% of EU copper extraction and 6% of processed copper production.[117] With some of the largest copper reserves in Europe, Bulgaria has developed a competitive downstream industry that produces cables, conductors, and automotive wiring systems. These are essential components for electric vehicles, renewable energy installations, and digital infrastructure, all key sectors in the low-carbon transition. This combination of strong geological endowment and existing downstream industrial capacity places Bulgaria in a uniquely advantageous position compared to many EU Member States that lack either domestic reserves or processing capabilities.

The continued expansion of these industries across Europe creates an opportunity for Bulgaria to consolidate its position as a key supplier of copper and copper-based products within the EU's clean technology value chains. Beyond copper, Bulgaria possesses several other critical or strategic materials. It accounts for **28% of EU gold extraction**, **8% of processed cadmium**, **3% of processed zinc**, and **11% of EU baryte production**. Bulgaria also contributes 15% of EU silica sand extraction stage imports and 3.3% of global silica sand production, materials essential for glass, semiconductors, and solar panels.[118] Although **manganese** production has declined sharply, Bulgaria retains geological potential that could be re-evaluated in light of its growing importance for steelmaking and battery applications. These materials align directly with the EU's Critical Raw Materials Act, which stipulates that by 2030 at least 10% of the EU critical raw materials be domestically extracted and 40% refined within the Union**. Bulgaria is one of the few countries that can simultaneously expand extraction and increase processing output**, giving it a realistic chance to capture new industrial investments redirected from third countries.

Nonetheless, the country's growing dependence on imported CRMs demands a coordinated approach that reduces exposure to external risks while unlocking the economic potential of its own resource base. To fully capitalise on these strengths and enhance its resilience to global supply chain disruptions and CRM shortages, **Bulgaria must shift from passive extraction to a coordinated strategy** that fosters domestic capacity for mining, processing, research, infrastructure development and regional cooperation. Furthermore, the **forthcoming rise in climate-related supply disruptions,** including heat stress on mining sites, water scarcity risks, and transport corridor vulnerabilities identified, **makes domestic production even more valuable**. Bulgaria's deposits are comparatively sheltered from many high-impact climate risks found in regions such as Latin America and Central Africa, strengthening the case for the strategic development of the CRM subsector.[119]

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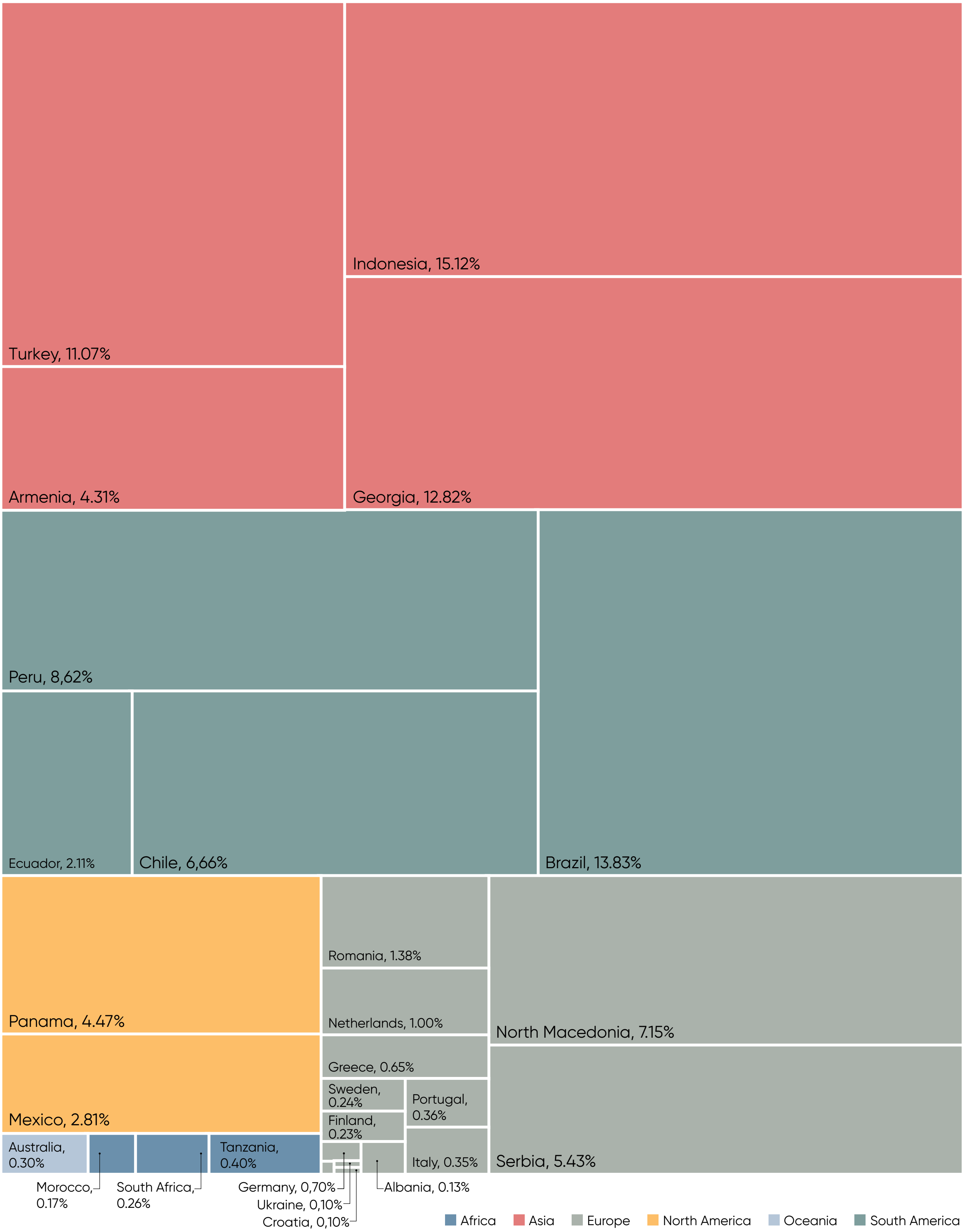
116 World Bank, "EU Regular Economic Report 10, Part 2, Clean Tech Value Chains: Using Trade Data to Guide a Complex Policy Space", 2024.

117 European Commission, "Study on the critical raw materials for the EU 2023 – Final report", 2023.

118 European Commission, "Study on the critical raw materials for the EU 2023 – Final report", 2023.

119 European Environment Agency, "European Climate Risk Assessment", EEA Report, January 2024.

Figure 10. Sources of Bulgarian Ores, Slags and Ashes Imports



Source: The Economic Complexity Observatory.

Turning Waste into Resource

The European Waste of Electrical and Electronic Equipment Directive mandates stringent targets for the recovery (85%) and reuse or recycling (80%) of collected PV panel waste[120]. Only eleven Member States have successfully met these targets – Bulgaria has not even submitted data about the status of its implementation.[121] The countries, which are able to establish **advanced recycling and remanufacturing capacity** will capture a disproportionate share of new industrial value, particularly in electronics, batteries, advanced materials, and solar technologies.[122] Bulgaria currently risks missing this opportunity due to gaps in collection systems, reporting infrastructure, and a lack of investment in high-value recycling technologies. By **investing in advanced recycling infrastructure and implementing an effective collection and reporting system**, Bulgaria could make significant progress towards these targets while minimising the environmental impact of solar panel waste and reducing the dependence on new imports. The same applies to battery energy storage systems.

Investing in advanced, high-efficiency recycling facilities for PV cells and battery components would enable Bulgaria to transform end-of-life products into a reliable domestic source of critical raw materials such as silicon, silver, rare earth elements, and lithium. By closing material loops through recycling and recovery, Bulgaria could substantially reduce the need for new imports and shield its economy from global price shocks and geopolitical disruptions.

At the same time, the development of domestic recycling and material refinement capacities represents a strategic industrial opportunity, closely aligned with the EU's long-term goal of building circular, low-dependency value chains capable of withstanding global shocks. Establishing local processing facilities would not only secure access to essential inputs for the green transition but also stimulate innovation, create high-value jobs, and foster a competitive national clean-tech ecosystem. Over time, such investments could **help Bulgaria evolve from a technology importer into a regional hub for circular economy practices and sustainable material management**. Moreover, recycling offers Bulgaria a chance to reduce its reliance on high-risk suppliers. By 2040, up to 30–40% of Europe's lithium, nickel, and cobalt demand could be met through recycling alone, provided that countries invest now in the collection, pre-processing, and advanced hydrometallurgical technologies.[123]

Equally important is the enhancement of system flexibility through **stronger waste collection, monitoring, and reporting systems**. Aligning with the requirements of the EU's Waste of Electrical and Electronic Equipment Direc-

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[120] European Parliament and Council of the European Union, Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE) (recast) Text with EEA relevance, 4 July 2012.

[121] Eurostat, Waste electrical and electronic equipment (WEEE) by waste management operations.

[122] World Economic Forum, "Climate Adaptation: Unlocking Value Chains with the Power of Technology", White Paper, January 2025.

[123] International Energy Agency, "World Energy Outlook 2025", 12 November 2025.

tive, Bulgaria can build robust data and feedback mechanisms that ensure environmentally sound waste management and inform future product design, procurement, and industrial policy. Improved transparency and traceability across the value chain would not only support compliance but also enable more responsive and adaptive policy intervention as global material markets evolve. Together, these measures would **reduce Bulgaria's exposure to external supply shocks, improve the sustainability of its green transition, and position the country to capture emerging industrial opportunities** within the EU's evolving framework for strategic autonomy and resource resilience. Developing these recycling and recovery capabilities would also complement Bulgaria's growing strengths in the digital and AI sectors, which can support predictive maintenance, real-time waste tracking, and optimisation of material flows, reinforcing the country's potential to enter high-value global clean-tech supply chains.

Beyond Energy Technologies

As Bulgaria accelerates its low-carbon transition, three strategic capability areas, **artificial intelligence, climate adaptation technologies, and defence-driven innovation, are emerging as decisive forces shaping global competitiveness**. These domains go far beyond the energy sector: they determine which countries can operate resilient digital grids, protect critical infrastructure, develop dual-use technologies, and integrate into next-generation European and global value chains. For Bulgaria, success will depend not only on adopting these technologies domestically, but on **embedding them within a coherent national strategy that aligns energy security, industrial modernisation, and innovation policy**.

AI as System Enabler

Artificial intelligence has rapidly emerged as both a driver and a disruptor of energy systems. Energy availability is now one of the top three determinants of future digital competitiveness and **AI models and data centres require vast and continuous electricity supply** projected to grow at least 10-fold by 2030, placing additional pressure on national grids.[124] Furthermore, countries lacking flexible, renewables-based grids will face progressive exclusion from the fast-growing digital and data-centre economy. At the same time, **AI offers powerful tools to improve energy efficiency, grid stability, and system forecasting**. As global technology companies seek locations with cheap, reliable, and low-carbon electricity, the geography of AI competitiveness is increasingly shaped by energy systems themselves. For Bulgaria, this intersection of AI and energy presents a dual challenge and an emerging opportunity. **Energy policy must now be digital policy too**.

Countries with abundant low-carbon energy resources and digital capabilities are best positioned to capture high-value segments of global clean-tech supply chains, including AI-enhanced grid technologies, energy-AI software, and predictive maintenance systems.[125] To attract AI-related infrastructure, Bulgaria must also **modernise and expand its grid, creating the conditions for decentralised solar and wind installations coupled with battery storage**.

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[124] World Economic Forum, "Chief Economists Outlook 2025", Insight Report, September 2025.

[125] WEF, "Climate Adaptation: Unlocking Value Chains with the Power of Technology", 2025.

This combination can deliver stable, low-cost, and low-emission power that meets the high load demands of large data centres while supporting overall grid flexibility.

The country's two planned nuclear reactors at the Kozloduy NPP, as well as the potential future deployment of small modular reactors (SMRs), will strengthen baseload capacity in the long term. However, due to the lengthy construction timelines and the current commercial immaturity of SMRs, **it is unlikely that new nuclear capacity will be operational before 2040**. In the meantime, accelerating the deployment of renewable energy sources and storage solutions remains the most viable and cost-effective way of meeting rising system demand, while the existing capacity at Kozloduy can be used to provide a stable power supply to data centres and industrial facilities. By way of comparison, the Meta data centre in Iowa, the largest in the United States, requires around 1.4 GW of electricity per hour, whereas Kozloduy can provide approximately 2 GW per hour. Iowa's appeal mainly lies in its electricity prices, which are around 17% cheaper than the US average. This is largely due to Iowa having the largest share of wind generation of any US state.[126] **Bulgaria could follow a similar model, leveraging its own abundant renewable energy potential to attract investments in digital infrastructure.**

While AI drives new demand for electricity, it also provides critical tools for managing complex, decentralised energy systems. **Machine learning algorithms can dramatically improve short-term forecasting of renewable energy generation and electricity demand**, integrating real-time weather and consumption data to enhance system reliability. This capability becomes increasingly valuable as the share of intermittent renewable sources rises. Bulgaria can harness the AI's potential not only for industrial digitalisation but also for smarter grid management. A key prerequisite is the nationwide roll-out of smart meters, which would generate the high-resolution consumption data needed to train predictive AI models. Accurate, time-specific information on household and industrial usage patterns would enable more precise load balancing, demand response, and energy efficiency optimisation. The need for digital grid management will be further exacerbated by climate and weather volatility. **AI-enabled forecasting and automated grid control are emerging as critical adaptation technologies**, essential for ensuring system stability under rising climate stress. This makes AI not only a competitiveness tool, but a resilience imperative.

Climate Adaptation as a Competitiveness Driver

As climate impacts intensify across Europe, **adaptation is becoming not only a resilience requirement but also a major industrial and technological opportunity**. Extreme weather, droughts, heatwaves, floods, and supply-chain disruptions are already placing growing pressure on energy infrastructure, water systems, agriculture, and critical manufacturing. Without rapid investment in adaptation technologies and protective infrastructure, climate impacts could exceed national coping capacity within the next decade, with energy systems, transport, and industry among the most exposed sectors.[127]

126 Why Altoona, Iowa is An Ideal Data Center Location – Altoona Now!

127 EEA, "European Climate Risk Assessment", 2024.

At the same time, **adaptation technologies represent a trillion-euro industrial opportunity**, spanning water efficiency technologies, precision agriculture, climate-resilient materials, early-warning systems, cooling technologies, and energy-system fortification. Countries that develop capabilities in these digital elements can secure high-value positions in emerging global value chains.[128] For **Bulgaria**, which is located in one of Europe's fastest-warming regions and **faces mounting risks to its hydropower, transmission infrastructure, water supply, and agriculture**, adaptation must therefore be viewed as a pillar of industrial competitiveness, not merely a defensive cost. Therefore, integrating adaptation into its industrial strategy can create new growth pathways while reducing climate-driven economic losses.

The country faces specific vulnerabilities that require targeted adaptation investment. Rising temperatures and more frequent heatwaves increase electricity demand for cooling while reducing efficiency in fossil, nuclear, and hydropower generation. Climate-related water stress threatens hydropower output and cooling water availability for thermal plants, **increasing system instability during peak demand periods**. Transmission and distribution networks also face heightened risk from storms, landslides, and extreme temperatures, underscoring the need for grid hardening, digitalisation, and climate-resilient infrastructure standards. These **vulnerabilities align closely with adaptation technologies where Bulgaria could build competitive specialisations**, including grid automation, remote sensing, early-warning systems, smart metering, demand-response, and AI-based forecasting.

Finally, adaptation technologies have direct energy-system benefits: improved forecasting, flexible demand, AI-assisted grid control, and automated emergency response systems increase resilience while reducing system costs. Bulgaria's digital transformation and climate preparedness must advance hand in hand. If approached strategically, climate adaptation can become a driver of innovation, investment, and national competitiveness**. Rather than treating adaptation as a financial burden, Bulgaria can turn it into an engine of industrial development**, one that strengthens resilience, anchors new value chains, and future-proofs the Bulgarian economy in a rapidly warming world.

Defence Innovation

Europe's increasing focus on **defence and security is transforming the landscape of innovation**, mirroring the same structural shifts seen in clean energy and AI technologies. The competitiveness of the Bulgarian economy increasingly depends on its ability to integrate into emerging industrial ecosystems where technological sophistication, low-carbon production, and secure supply chains reinforce one another. With EU defence expenditure surpassing EUR 2.5 trillion each year, there is high demand for cutting-edge technologies such as drones, artificial intelligence, robotics, advanced materials and cybersecurity systems. **For Bulgaria, aligning its research and industrial capabilities with the EU's defence agenda could strengthen its domestic industrial base**, enhance technological sovereignty and create high-value jobs in knowledge-intensive sectors.

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[128] WEF, "Climate Adaptation: Unlocking Value Chains with the Power of Technology", 2025.

Although defence innovation is primarily state-driven, its impact extends well beyond the military. **By fostering strong links between military and civilian applications, Bulgaria can ensure that investments in defence technologies generate spillover effects into critical civilian sectors, such as energy systems, manufacturing and green technologies.** These synergies are vital for building economic resilience, improving national infrastructure, and advancing the country's transition to a low-carbon economy.

The fabricated metal products sector is a prime example of this synergy. As a major producer of inputs for weapons and ammunition, **the sector contributed 12% to Bulgaria's total gross value added while maintaining a minimal carbon footprint**. Currently, 56% of its process heat is supplied by electricity, and its moderate temperature requirements mean that full electrification is achievable well before 2050. By fully decarbonising this sector, Bulgaria can support EU defence priorities and create a competitive, low-carbon industrial cluster that links defence-driven innovation to the broader goals of sustainable economic growth and energy resilience.

Therefore, strategic investment in defence-related research and development, stronger dual-use innovation pipelines, and modernisation of industrial processes will be central to Bulgaria's ability to leverage the EU's defence agenda as a driver of both national security and long-term economic competitiveness. **Progress depends on embedding defence innovation within a coherent national strategy that aligns energy, industrial, and technological policy.**

Given the emerging vulnerabilities, pressures, and opportunities, Bulgaria can no longer rely on incremental adaptation or isolated sectoral gains. Competing in a world shaped by net-zero industrial policy, secure supply chains, and rapid technological convergence requires a shift from reactive technology uptake to proactive strategic positioning. If the country aligns its resources, institutions, and investment priorities around a unified long-term vision, it can transform today's vulnerabilities into strategic assets. The choice ahead is clear: **Bulgaria can shape its role in the next generation of European industry, or risk being shaped by it.**

WHAT'S NEXT?

The past decade has demonstrated that fragmented, reactive policymaking, driven by short political cycles, institutional fragility, and entrenched interests, cannot deliver the competitiveness, resilience, or innovation capacity demanded by the new geopolitical and technological order. The next decade will determine whether Bulgaria joins Europe's clean-economy transformation as a competitive, resilient and innovative country, or remains trapped in a structural, industrial stagnation.

As global clean-technology value chains consolidate and the EU restructures its industrial, energy, and security architecture, **Bulgaria must finally define a clear long-term national objective encompassing economic, energy and climate security and align all major policy and financial instruments behind it. With such a direction, the country can shift from being an importer of technologies and policies to a regional clean-technology and innovation hub**. Without it, Bulgaria risks remaining locked in reactive crisis management and falling further behind its European peers. Shifting from reactive crisis response to long-term strategic statecraft will enable the country to build a modern, secure, and prosperous economy, but only if it urgently addresses its most pressing structural shortcomings.

- **Set a clear long-term objective and vision for Bulgaria's economic and energy future**

Bulgaria must articulate a unified national vision that positions the country not only as an energy corridor but as a **regional hub for clean technologies, advanced materials, low-carbon innovations, and digital infrastructure**. This requires integrating energy security, industrial competitiveness, and technological development into a coherent long-term strategy. A core step is to treat the NECP not as an administrative requirement, but as the foundational planning tool for Bulgaria's economic and climate direction, linking it to the Strategy for Sustainable Energy Development, the Innovation Strategy for Smart Specialisation, and the NRRP. Using the NECP to revisit long-term choices on coal, nuclear, renewables, hydrogen and CCUS would ensure that Bulgaria's transition strengthens economic resilience, supports domestic industry, and enhances strategic autonomy.

- **Align regulations to create a predictable investment environment**

Regulatory alignment must go beyond formal EU transposition and create long-term stability and clarity for investors. Bulgaria should **complete electricity-market liberalisation** and eliminate ad-hoc revenue caps for RES producers that undermine investment. Streamlining permitting, especially for onshore and offshore wind, must become a national priority, with clear deadlines and accountability. Regulatory frameworks should also tie incentives for the TSO and DSOs to measurable results such as reduced grid losses and shorter connection times.

- **Build a transparent and fair market**

A modern low-carbon economy requires competitive markets free from persistent distortions. Bulgaria must **phase out hidden subsidies that protect uncompetitive coal power plants** and delay market liberalisation. The introduction of fair long-term contracting tools, such as PPAs, two-way CfDs, and flexibility markets, will stabilise revenues for renewables, storage, and demand-side technologies. Strengthening the independence of the energy regulator is essential to enforce non-discriminatory grid access, transparent procurement, and a rules-based market that attracts new entrants and lowers costs for consumers.

- **Develop the networks that enable national and regional connectivity**

Bulgaria must **develop or modernise the infrastructure that underpins its economic competitiveness**: power grids, hydrogen networks, CO_2 transport systems, rail corridors, and digital infrastructure. Priority actions include upgrading key electricity transmission lines with Romania and Greece, reinforcing internal corridors, and unlocking RES potential in resource-rich regions such as Northeast Bulgaria. Achieving real system flexibility requires a nationwide smart-meter roll-out under a unified technical standard and deployment of digital grid management, AI-based forecasting, and data-sharing frameworks. Bulgaria should also plan hydrogen-ready pipelines in parallel with a CO_2 transport network, building on the ANRAV project as the nucleus of a future Black Sea carbon-storage system.

- **Develop a vibrant local industry based on Bulgaria's existing strengths**

Bulgaria's assets in metals, mining, electronics, semiconductors, ICT and mechanical engineering create the foundation for competitive clean-technology value chains. The country should **target higher-value segments such as power-electronics components, battery integration and recycling**, offshore wind assembly plants, grid-digitalisation technologies, and CCUS equipment and services. Industrial policy should connect these strengths to EU initiatives like the Net-Zero Industry Act and Critical Raw Materials Act, prioritising projects eligible for the Innovation Fund, Modernisation Fund, Just Transition Fund, and Horizon Europe. Bulgaria can also leverage dual-use capabilities by aligning defence-industrial strengths with civilian clean-tech innovation.

- **Invest in education, skills, and a strong domestic R&D system**

Bulgaria must **upgrade its human capital to compete in a technology-driven global economy**. This requires scaling STEM education, vocational reskilling, and research excellence across universities, applied institutes (e.g. INSAIT), and industry. National R&D investment must move decisively toward the 1.5% GDP target, supported by EU funds for cutting edge decarbonisation projects, clean-tech demonstration sites, and applied industrial research. Technology-transfer centres and public-private innovation hubs should focus on commercialising Bulgarian strengths: power electronics, AI-enabled grids, geothermal and CCUS exploration, and advanced battery materials.

- **Ensure societal benefits, build social acceptance, and strengthen trust**

A successful transition must deliver visible benefits to citizens and regions. Bulgaria should use the Social Climate Plan and Just Transition Fund resources to accelerate deep building renovation, heating electrification, and targeted energy-poverty reduction. **Coal regions must receive credible alternatives, industrial diversification, local clean-energy projects, and structured reskilling**, rather than promises of indefinite lignite operation. For emerging technologies such as wind, geothermal, hydrogen, or CCUS, Bulgaria needs early stakeholder engagement, transparent communication, local benefit-sharing mechanisms, and clear safety and monitoring rules. These steps are crucial to restoring public trust and enabling long-term reforms.

- **Build strategic partnerships with like-minded allies**

Bulgaria must **deepen cooperation with EU institutions, NATO partners, and global technological leaders** such as the United States, South Korea and Japan to secure access to finance, expertise, and advanced technologies. Partnerships should prioritise semiconductors, AI, hydrogen, nuclear technologies (including SMRs), critical raw materials, defence innovation, and clean-tech manufacturing. Regionally, Bulgaria should strengthen cross-border energy cooperation, joint RES development, offshore wind, grid interconnections, and CO_2 storage capacity in the Black Sea, anchoring Bulgaria in Europe's emerging clean-technology and industrial ecosystem.