ORIGINAL SCIENTIFIC PAPER
UDK: 339.972:620.9(497.11)
502.131.1:620.9(497.11)
DOI: 10.5937/EKOPRE2502001D
Date of Receipt: December 20, 2024

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NAVIGATING THE POLYCRISIS: A RESPONSIBLE ROADMAP FOR SERBIA'S GREEN ENERGY TRANSITION

Kroz izazove polikrize – odgovorna mapa puta za zelenu energetsku tranziciju u Srbiji

Abstract

The global economy is in an age of astonishing change driven by a polycrisis, full of conflicting signals and contradictions. The post-COVID recovery in Serbia in the period 2022-2024 was characterized by slow-to-moderate growth. However, the country's future growth faces significant challenges from deeply rooted external and internal disruptors. One of them certainly is the 30% energy output gap. The structure of energy output is the related challenge. Defining a solution for energy security, in terms of the volume and structure of energy production, as a key limitation to sustainable growth, has been influenced by the green energy transition. Persistent issues, such as a widening energy output gap, a high carbon footprint, the dominance of energy-intensive and hard-to-abate industries in economic structure (mining, steel, copper, cement, construction, transportation, ICT, etc.), as well as the low efficiency of end-use sectors, pose serious macroeconomic risks. The policy mix implemented in 2024 successfully curbed inflation, bringing it within the target tolerance band of 3% ± 1.5%, and reduced simultaneously the share of the fiscal deficit and public debt relative to GDP. Consequently, Standard & Poor's has classified Serbia as an economy with an investment-grade credit rating (BBB-). In parallel, the dangerous nexus of key disruptors continues to fuel inflationary pressures and challenge the country's macroeconomic fundamentals. To make matters worse, (geo) political malaise erupted in Q4 2024. The escalating costs of concerted mediation efforts to counteract these negative consequences have further squeezed the fiscal space available for investment. In this deteriorating context, the current energy output gap could soar to an uncontrollable level, exacerbating the energy security issue. In the meantime, a new external asymmetric shock has emerged, the US sanctions to NIS (Naftna industrija Srbije), a Russian-Serbian joint venture and a leader from the energy sector. The sanctions on NIS could exacerbate an already severe energy output crunch. An additional factor of concern is the structure of Serbia's energy production, which is heavily reliant on lignite, accounting for 68% of electricity generation. There is a growing urgency to address this issue, not only to ensure energy security in Serbia but also to align with global climate change mitigation goals. To achieve and sustain energy security in Serbia, three critical goals provide the solution: energy output expansion, supply diversification, and the shift from fossil fuels to renewable energy sources. The Green Energy Transition Action Plan serves as the framework for achieving these goals. In the energy sector, the EU tends to be more explicit, elevated, and sophisticated in its requirements regarding compatibility with candidate countries. By meeting a net-zero future, Serbia will increase its chances of joining the EU. We want Serbia to be integrated into the EU as sustainably and inclusively as possible. A responsible roadmap should be not only feasible and effective but also based on local renewable energy sources, fiscal space, and the credit potential of relevant stakeholders, making it affordable for the capital blending needed for green finance. Our view is that biomass will be a key renewable energy source in the medium term. Other elements of the plan include the regulatory framework for the carbon marks, the issuance of thematic securities (green bonds, green credits, etc.), and green fiscal subsidies, along with measures to prevent non-complying behavior. Following the previous line of reasoning, the paper is organized around four fundamental issues. Part 1 is dedicated to explaining the polycrisis as the context that demands a polytransition, colloquially referred to as the green transition. In Part 2, we focus on a strategic audit of Serbia's macroeconomic fundamentals as a zero step in defining feasible solutions. Part 3 discusses two growth scenarios: the "as-is" scenario and the "to-be" scenario. Part 4, the most important section, provides the key explanatory details regarding the deployment

of biomass technology as the center of Serbia's green energy transition in the medium term, along with aggregate financial projections. The paper concludes with a *Nota Bene*.

Keywords: *Serbia, market fundamentalism, structural imbalances, polycrisis, climate change, energy security, green energy transition, macroeconomic fundamentals, biomass, green financing, carbon tax*

Sažetak

Globalna ekonomija prolazi kroz period spektakularnih promena na koje utiče polikriza obeležena konfliktnim signalima i kontradiktornostima. Oporavak u Srbiji u post-Covid periodu 2022-24 obeležen je sporim do umerenim rastom. Ipak, budući rast izložen je brojnim izazovima pod dejstvom duboko ukorenjenih eksternih i internih uzroka problema. Jedan od takvih faktora svakako je energetski autput gep od 30%. Povezani izazov je struktura energetskog autputa. Rešenje za pitanje energetske sigurnosti, definisane preko količine i strukture proizvodnje energije kao ključnog ograničenja za održiv ekonomski razvoj, pod uticajem je zelene energetske tranzicije. Uvreženi problemi kao što su povećanje energetskog autput gepa, visok ugljenični otisak, dominacija energetski intenzivnih sektora čija se potrošnja energije teško smanjuje u strukturi industrije (rudarenje, proizvodnja čelika, bakra i cementa, građevinarstvo, transport, IKT), kao i niska efikasnost u potrošnji energije, utiču na ozbiljan makroekonomski rizik. Kombinacija ekonomskih politika primenjena u 2024. godini uspešno je smanjila inflaciju uvodeći je u ciljani koridor 3% ± 1.5%, a simultano smanjujući učešće fiskalnog deficita i duga u BDP. Posledično, Standard & Poor's klasifikovao je Srbiju među ekonomije sa investicionim kreditnim rejtingom (BBB-). Paralelno, opasna grupa faktora rizika povećava inflatorni pritisak i kvari makroekonomske fundamente sistema. (Geo)politička kriza koja je eruptirala u četvrtom kvartalu 2024. godine značajno je pogoršala situaciju. Rastući troškovi sveobuhvatnih napora za medijacijom, kako bi se suzbile negativne posledice, smanjuju fiskalni prostor za investicije. U kontekstu koji je izložen pogoršanju postojeći energetski autput gep mogao bi se povećati do nekontrolisanih granica, još više zaoštravajući problem energetske sigurnosti. U međuvremenu, pojavio se novi eksterni asimetrični šok, sankcije SAD uvedene NIS (Naftna industrija Srbije) rusko-srpskom zajedničkom ulaganju i lideru energetskog sektora. Sankcije mogu pojačati problem nedovoljne energetske proizvodnje. Faktor koji zahteva dopunsku pažnju je struktura energetske proizvodnje koja je visoko zavisna od lignita koji učestvuje sa oko 68% u proizvodnji električne energije. Postoji visoka urgentnost rešavanja tog problema, ne samo u svetlu energetske sigurnosti Srbije, već i poštovanja globalnih ciljeva koji doprinose rešavaju problema klimatskih promena. Rešenje pitanja postizanja i održavanja energetske sigurnosti u Srbiji zavisi od tri cilja: povećanje proizvodnje, diversifikacija snabdevanja i prelaska sa fosilnih na obnovljive izvore energije. Akcioni plan zelene energetske tranzicije predstavlja okvir za ostvarivanje ovih ciljeva. Kada je reč o usklađivanju zemalja kandidata u energetskom sektoru, EU nastoji da bude potpuno eksplicitna i sofisticirana u svojim zahtevima. Ostvarivanjem nulte emisije u budućnosti, Srbija se približava integraciji u EU. Želimo da Srbija bude integrisana u EU na što održiviji i inkluzivniji način. Odgovarajuća mapa puta nije samo izvodljiva i efektivna, već i zasnovana na lokalnim obnovljivim izvorima, fiskalnom prostoru i kreditnom potencijalu relevantnih interesnih grupa sposobnih da stvore kombinaciju izvora kapitala potrebnu za zeleno finansiranje. Naša ideja je da će biomasa biti ključni obnovljivi izvor energije u srednjem roku. Drugi elementi plana uključuju regulatorni okvir karbonskog tržišta, kao i emisiju tematskih hartija od vrednosti (zelene obveznice, zeleni krediti) kao i zelenih subvencija, zajedno sa merama prevencije njihove zloupotrebe. Sledeći prethodni način razmišljanja, rad je organizovan oko četiri bitna pitanja. Prvi deo je posvećen objašnjenju polikrize kao konteksta koji zahteva politranziciju, poznatu po kolokvijalnom nazivu „zelena tranzicija". U drugom delu fokusiraćemo se na strategijsku reviziju makroekonomskih fundamenata u Srbiji kao nultom koraku u definisanju izvodljivog rešenja. Treći deo razmatra dva scenarija rasta: „as-is" scenario i „to-be" scenario. U četvrtom delu, kao najvažnijem segmentu rada, navodimo ključne činjenice u vezi sa uvođenjem tehnologije zasnovane na biomasi kao centralne tehnologije u sprovođenju zelene tranzicije u Srbiji u srednjem roku, uz agregirane finansijske projekcijei. Članak završava sa završnim napomenama.

Ključne reči: *Srbija, tržišni fundamentalizam, strukturne neravnoteže, polikriza, klimatske promene, energetska sigurnost, zelena energetska tranzicija, makroekonomski fundamenti, biomasa, zeleno finansiranje, karbonske takse*

A Growing Need for the Green Transition

For nearly two and a half centuries, the economy and society have prospered within the liberal capitalism framework, fueled primarily by the cumulative impact of four industrial revolutions. The related socio-economic context was shaped by three key vectors: private property, market economy, and democracy (both political and economic). By the end of the last millennium, the same mix of forces redirected evolution toward the most extreme variant of capitalism, the neoliberal capitalism. Such a radical change brought capitalism into a long and deep crisis. This crisis is the consequence of inbuilt fault lines, such as financialization, deindustrialization, soft budget constraints, etc. Climate change stands as the most severe physical structural imbalance in the system, while income (and wealth) inequality serves as the most impactful social structural imbalance of neoliberal capitalism.

In the Anthropocene age[1], climate change and its multiple negative effects on the socio-economic system are

1 The period of humankind evolution with a dominant impact of humans on nature, physical system and biosphere.

evident to all, along with their detrimental impact on the physical subsystem and the biosphere as components of the planet, or the so-called "system dynamics," as defined by J. Forrester [15]. Anomalies within system dynamics interact with one another, disrupting the "sustained sustainability" across the planet's subsystems. Additionally, the physical system and biosphere upon which humankind critically depends have been deeply reconfigured, indeed destroyed. The planet does not need the economy and society (or people). In contrast, people, society, and the economy depend on the planet.

These days, the prevailing economic narrative has changed, as facts have dictated this change. Neoliberalism, rooted in the ideology of market fundamentalism, has exacerbated the inbuilt imbalances of the economic system. A nexus of rules, such as liberalization, deregulation, privatization, and globalization, forms the ideological foundation of neoliberalism. The problem with this nexus is its disregard for the limits of nature, the laws of nature, and the negative externalities of economic transactions on the planet. First and foremost, these propositions are not in line with common sense, simply because the planet has finite natural resources. Moreover, since the rise of neoliberalism, the situation that existed at the beginning of capitalism has fundamentally changed. The overuse of resources driven by egoism and profit maximization, along with the uncontrolled expansion of industrial production (and consumption), urbanization, and massive transport, has pushed the planet to the brink of upheaval. On the other hand, the globalization rule has been exclusive, benefiting some while discriminating against others. Namely, it has created opportunities for some but has not been inclusive of all.

Moreover, neoliberal policies (monetary and fiscal, primarily) are in direct conflict with planetary boundaries and the laws of nature, particularly the reversibility of the physical system and the evolution of the biosphere. Despite systemic overconsumption and the depletion of natural resources, supply has become a much more serious problem than demand. Furthermore, trade and investment in rare earth metals/minerals, energy resources, and food are becoming casualties of the geopolitical game. As investment expectations decline under such circumstances, the economy is heading toward low or even negative growth. In the end, after the socio-economic system becomes trapped in a polycrisis, the planet shifts from a "Green Planet" to a "Ponzi Planet."

In this new context, non-linear systems dominate over linear ones. Non-linear systems are filled with unknowns, whether they are labeled as "risk" or simply as "uncertainty." Planetary (or strictly external) unknowns, e.g., climate change or microbe pandemic, dominate other types of unknowns (those related to individuals, companies, financial institutions, national economies, etc.). Planetary unknowns, often referred to as "external asymmetric shocks," have a universal but asymmetric impact, which is impossible to mitigate through individual reactions because they consist of interlinked, non-linear components.

At tipping points, unknown factors, characterized by multiple correlations, holistic by nature, can trigger external asymmetric shocks. The "black swan"[2] phenomenon belongs to this class of system anomalies. Multiple interactions of unknowns further cement existing imbalances, deepening them and creating new mega-imbalances. In such a context, the number of asymmetric external shocks and black swan events grows exponentially, generating global headwinds that obscure the prospects of addressing the root causes of crises and navigating through them.

After experiencing unconventional, experimental, and mostly ineffective policy responses based on neoliberal theory, in the prevailing economic narrative mega imbalances have been institutionalized as the "new normal" (or "non-normality"). Without corrective mechanisms in place, the economy is destined to be crisis-prone, which is also part of a new narrative.

The current conjuncture could be described as a "permacrisis"[3], a "rolling crisis," a "crisis in a system of crises" or a "crisis of crisis." However, the construct of "polycrisis" may be the best way to depict the explanatory element of the new crisis, in which separate crises (climate,

2 The correlation of multiple non-linear feedback loops, which have a low probability but extremely high impact.

3 After the word "permacrisis" was announced as the Word of the Year by Webster's Dictionary in 2023, three economic luminaries wrote a book with the same title [6].

economic, biotic, etc.) have emerged, interacted, and amplified one another.

Climate change is the most significant disruptors of the modern socio-economic context, maybe. For a long time, business and political elites around the world have not taken climate change seriously enough, or at most, viewed it as a non-normality. The scientific understanding, however, has been much stronger. At the beginning of the last century, Nobel Prize laureate S. Arrhenius [1] used principles of physical chemistry to explain how an increase in carbon dioxide (CO_2) in the atmosphere impacts the so-called "greenhouse effect" and contributes to temperature increases on the planet's surface. In the 1960s, Ch. Keeling [23] further elaborated on the impact of CO_2 on global warming and climate change. Later, the Kyoto Protocol [44], by defining seven greenhouse gases (GHGs), including CO_2, recognized this phenomenon as a root cause of global warming.

The impact of GHG emissions on global warming and related climate change is scientifically verified through thousands of research papers across various fields of science. Since the start of industrialization in the late 1800s, the world economy has emitted more than 30 trillion metric tonnes of CO_2 equivalent. There is no doubt that the top ten hottest years on record, including 2024, have occurred, driving real-time climate breakdown. The planet is heating up rapidly, approaching the "boiling point." Glaciers are melting at an alarming rate, triggering a negative chain reaction, with a variety of extreme weather events. Agriculture, transport and casualty insurance have been hit hardest by extreme weather events, such as wildfires, droughts, flooding, and water shortages, particularly affecting crop and livestock production. All these events are becoming more intense and frequent.

Climate change is predominantly driven by human behavior. Energy production based on fossil fuels is a key negative externality of industrialization, urbanization, and transportation expansion. Even today, fossil fuels account for majority of primary energy production. The second major contributor to global GHG emissions is agriculture. The third is the indirect effect of deforestation, as the biosphere is incapable of offsetting GHG emissions.

Focusing on maximizing GDP (macro level) and shareholder value (micro level) is highly unhygienic and contradicts the sustainability proposition. In a world with physical limits and competition for scarce resources, development that ignores the natural boundaries is unsustainable. To simplify to the extreme, the planet is not enough for the development ambitions of all economic agents (supranational institutions, fast-growing national economies, incumbent companies, startups, or anyone else). Moreover, humanity's ecological and, particularly, carbon footprint exceeds the planet's biogeochemical capacity to regenerate used natural resources and absorb and reuse the related waste. Plastic is a prime example. When we factor in ultimate but rare earth materials such as fossil fuels and precious metals, resources that are not only limited but also non-recoverable on one hand, and contribute significantly to various forms of pollution on the other, it becomes clear that "maximization" is a fundamental fault line in neoliberal economic reasoning.

Let us illustrate the problem of resource regeneration and waste management by using "Earth Overshoot Day"[4] According to Global Footprint Network [17], the overconsumption of natural resources is causing earth overshoot day to arrive sooner and sooner each year, leading to the conclusion that the economy, society and the planet are on an unsustainable path. Specifically, the planet's biogeochemical capacity to regenerate already used natural resources and absorb the waste resulting from anthropogenic activities has been significantly diminished. On Earth Overshoot Day, humanity will have already consumed all the renewable resources the planet can replenish in a given year. For example, in 2024, earth overshoot day was marked on August 1. By applying some formula, it means that after August 1, humanity would require 1.75 planets to meet the demands of the global population.

Figure 1 illustrates how quickly selected countries were depleting natural resources in 2024, alongside their relationship with the global average of earth overshoot day. In the same year, Serbia entered its overshoot day on May 23. The United States experienced its overshoot

4 It marks the date when the demand for resources in a given year exceeds what the planet can regenerate during that year.

day on March 14, meaning that the U.S. has an ecological footprint roughly five times higher than the global average. Also, it means that if the entire world lived like the average American, we would need about five Earths to sustain that level of consumption.

One of the key consequences of overshooting is pollution. Global warming is the most dangerous form of pollution. Global warming will continue to escalate in a non-linear manner because there is no Planet B. Recent reports from the Intergovernmental Panel on Climate Change (IPCC) highlight an alarming reality [19], [20], [21]. At the beginning of 2025, the planet is 1.55°C warmer than it was in the late 1800s, and it is warmer than at any point in the past two thousand years. In other words, the planet is already facing a climate emergency.

Climate scientists from the IPCC, UNESCO and other relevant institutions are concerned that, before 2050, the average global temperature will rise by more than 2.0°C above pre-industrial levels. Despite efforts of the Paris Agreement [45] to mitigate climate change, the planet is not on track to avoid surpassing the 1.5°C red flag by 2050.

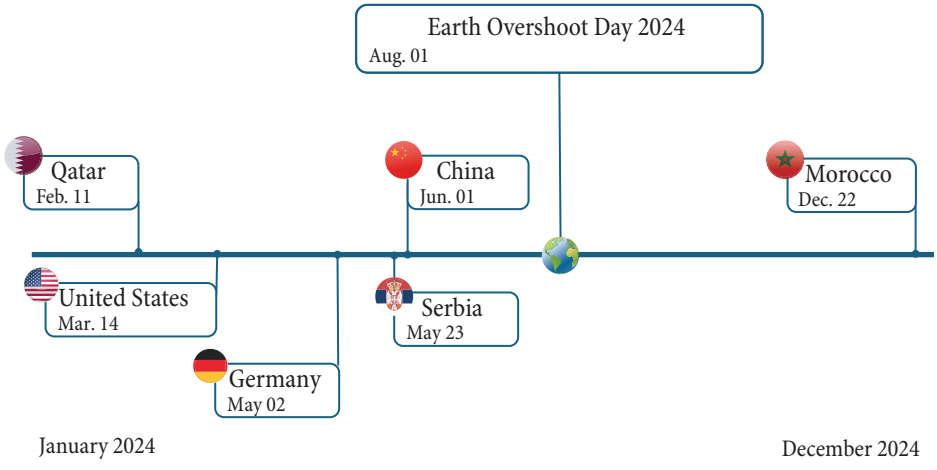
Moreover, uncontrolled global warming increases the likelihood of more frequent biotic feedback loops, a higher emergence of microbial pandemics, and the rapid extinction of living organisms. The extinction rate of living organisms in the Anthropocene, with the exception of the human race, is accelerating faster than in any previous period of the planet's geological history. Over the past 50 years, biodiversity loss has amounted to around 50%.

Paradoxically, the current socio-economic context does not allow for the massive diffusion of groundbreaking innovations, such as converging and super-intelligent technologies that combine innovations from various fields enhanced by AI solutions. In fact, the commercialization of these breakthroughs is neither as frequent as expected, nor does it possess the capacity to significantly boost productivity and/or living standard. Although new technologies have the potential to propel the economy and society from crisis to prosperity, socio-economic frictions can prevent them from fulfilling this potential.

In the latest crisis, the dominance habit, deeply rooted in human nature, is amplified. When humanity wages war on both nature and human nature itself, the interactions within the nexus of conflicts lead to the emergence of new dimensions of conflicting interests. To navigate the road ahead with less risk, economic challenges will likely require a more intensive approach to geopolitics. As a result, geo-economic policy measures become significant macroeconomic variables.

The treatment of geopolitics as a part of macroeconomic equation represents the final push toward the degradation of neoliberal capitalism. Under the influence of geopolitics, certain resources such as oil, gas, uranium, rare metals, even food are being weaponized. As these resources move out of the market, their trade incurs higher transaction costs. Consequently, geopolitics leads to massive supply shocks in the global economy and asymmetric inflationary pressures at the local economic level. As imported inflation

Figure 1: Global average of earth overshoot day and overshoot days for selected countries in 2024



Source: Earth Overshoot Day, 2024

expectations become unanchored from economic logic, this external asymmetric shock not only exacerbates inflation but also diminishes the growth potential of the local economy.

Geo-economic policy measures are expanding in various forms, including economic sanctions, trade wars (import and export tariffs), currency wars, FX wars, hybrid wars, and even world war. Geopolitics poses a major threat to deglobalization. After deglobalization, the next stage is re-globalization. However, since re-globalization is based on geopolitical criteria, it will likely lead to the fragmentation of the global market.

Import tariffs (trade levies and sliding scale fees) are the most frequently used tools in the geopolitical game. Within the biggest economies, import tariffs exacerbate existing structural imbalances and create new ones. When sanctions are imposed, the benefits of outsourcing, such as cheap labor, and the effects of diversification are undermined. Also, import sanctions on energy, critical commodities, and essential food accelerate the inflation spiral. In doing so, the biggest economies, formerly leaders of the free market economy, further exacerbate protectionism, de-globalization, and global market fragmentation. In this process, counter tariffs also have the role to play. The side effects of import tariffs include export counter tariffs from smaller, open, and landlocked economies, which act as self-defeating measures.

Such a game, based on geo-economic measures, is a zero-sum game. The planet operates as a closed system rather than an open one. In a closed system, a zero-sum game is possible but inherently unsustainable. In this game, toxic stressors interact and amplify one another, creating a downward spiral. These dynamics trap the planet, along with the economy and society, in a conundrum, a lose-lose game. The lose-lose game makes the freefall of the global economy very real. Consequently, all subsystems of the system dynamics and the planet as a whole are dying slowly but surely.

The dominance of geopolitics over economics signals that the socio-economic system is heading toward the final stage of crisis, militarization. When "soft power" fails to function effectively, "hard power" takes over. Any activism in this regard becomes counterproductive, as militarization serves to entrench inbuilt imbalances while exacerbating or creating new ones. Furthermore, geo-economic measures and countermeasures contribute to the further militarization of both the economy and society, emphasizing the unlimited use of cutting-edge technological solutions to develop so-called "weapons of mass destruction" (WMD).

Militarization misuses leading edge technologies and consumes valuable fiscal space that could otherwise be allocated to productive investments, making them counterproductive in addressing profound climate, economic, financial, and ecological imbalances. As a result, going green ambitions could fade, transforming the current climate situation from bad to worse. Namely, from climate change to a full-blown climate emergency.

Without significant investment in decarbonization, the average global temperature could rise by more than 2 degrees Celsius, potentially even before 2050. This trajectory would transform conventional weather patterns into what can be described as "weather of mass destruction" (WMD).

Weapons of mass destruction and weather of mass destruction, intertwined in "2WMD," potentially lead to apocalyptic consequences. Echoing the spirit of the appeal by I. Šlaus and J. Zidanšek [37], the Doomsday Clock[5] inches ever closer to midnight.

From an economic perspective, the epilogue of the inability to resolve the current polycrisis would be the entry of the global economy into a technical "stagflationary recession," as predicted by N. Roubini [34].

It is uncertain how long the current 2WMD and related stagflationary recession will last. Finding systemic solutions, namely a way to escape from the "new normal" toward a "better normal" in all economies, whether developed or developing, small or large, fast-growing or stagnant, is the imperative of our time. Confronting the reality of the "new normal," alongside the potential of the "better normal," calls for a radical change in the structure and functioning of the economic system through polytransitions (climate, economic, biotic, and geopolitical). This non-evolutionary

5 The Doomsday Clock measures how close the planet is to annihilation. If the clock strikes midnight, it signals catastrophic consequences, such as the irreversible effects of climate change or the exchange of weapons of mass destruction, which would devastate the economy, society, and the planet itself.

shift is often referred to as the "green transition," with the intention to remind how the planet was before the era of market fundamentalism. The green transition is a gateway to a new model of growth, which should be circular and regenerative. This growth model should be based on the decarbonization of current industries and the deployment of climate-neutral technologies, primarily in the power sector. Following the Paris Agreement [45] and the UN's 17 SDGs, by 2050, the economy, society, and planet could reach a climate-neutral inflection point, known as "net-zero," which serves as the linchpin of the green transition.

Serbia can explore different views on how to meet its climate-neutral commitments. One group of climate thinkers argues that carbon pricing[6] and the marketization of thematic securities are key drivers in advancing the green transition, primarily contributing to "going green" approach. Another group advocates for state impact investments in high-capacity power generation and green energy infrastructure, along with related financing models. The solar boom is particularly evident in China, while both wind and solar are hallmarks of the EU's energy strategy. Energy experts agree that nuclear energy[7], especially nuclear fusion, as well as green hydrogen and biomass-based technologies, represent the most potent and sustainable solutions.

Both sides of the argument present strong points, and everyone has their own individual preferences. However, whether one likes it or not, the momentum for a new economy based on climate-neutral reindustrialization is steadily increasing worldwide. The specific choice depends on local circumstances, including the nexus and critical mass of renewable resources, fiscal capacity, and the credit potential for capital blending to finance green initiatives. High-potential decarbonization technologies are unlikely to be financeable in the visible future without a significant combination of funding sources, including multilateral development credit institutions as anchor investor, and additional sources of financing based on carbon taxes, public incentives for thematic securities (green bonds and green credits), and green surcharges.

6 Current carbon tax of USD 53 per ton is too low to avoid Paris 2C limit. More than USD 90 is required.

7 COP28 advises a threefold increase in nuclear energy capacity by 2050.

Many empirical studies, e.g. [10], [28], have confirmed that there is still a limited shift in the attitudes of Serbia's private capital towards the green transition and sustainability-based disclosures (SDGs/ESG metrics). Therefore, it is essential to understand what the green transition is and what it is not. The catalytic role of the state in impact investments and industrial policies for tradable sectors is crucial.

To survive, recover, and prosper, Serbia's economy in 2025 and beyond must be powered by, and extremely agile in, the green energy transition. In the first stage, coal-based electricity production and heating systems should be significantly reduced. Other fossil fuels must follow. In the medium term, many sectors dependent on oil and gas will need to implement net-zero targets. Serbia should outcompete fossil fuels primarily by using its hydro potential and implementing nature-based solutions, such as planting trees for biomass production. Simultaneously, Serbia should begin serious preparations for the deployment of nuclear energy.

Serbia has biomass as a significant local renewable energy resource. Also, the country possesses substantial deposits of lithium and copper. The demand for precious metals and minerals essential for green technologies, such as lithium, cobalt, and copper, has surged dramatically. As a result, mining, metallurgy, and new materials management are poised to benefit from the green transition.

Before delving into the specifics of implementing biomass technology as a key renewable energy source for a quantum leap in the energy sector in the middle run, we will first analyze the macroeconomic fundamentals that are essential prerequisites for financing related investment.

Serbia's Macroeconomics: The Scale and Nature of Challenges

Growth, fiscal balance, debt, investments, (un)employment, payrolls, pensions, and participation rates are always in the spotlight for policymakers, particularly during the recovery stage of the business cycle. Relevant data indicates that the policy mix in Serbia during the post-Covid period (2022-2024) has been working well. Favorable

developments over the past two years suggest that Serbia's economy has strengthened significantly.

After the successful fiscal consolidation 2015-2018, Serbia's economy made a U-turn, driven by state impact investment in infrastructure and a strategic restructuring of its portfolio of industries. Unfortunately, the COVID-19 lockdown 2020-2022 slowed down this recovery. The state's support for companies facing liquidity problems and its solidarity with people in credit distress during the pandemic placed a significant financial burden on the country's economy. Interestingly, during the post-COVID period, the economic contraction was less severe than in the EU and less than initially expected. The growth rate of 3.9% in 2024 vividly illustrates the previous point.

As for inflation, the data is encouraging, confirming that the NBS is on track to meet its target tolerance band of 3.0% ± 1.5%. Headline inflation has been slowing since April 2023 and has continued to decline thereafter. By May 2024, headline inflation returned to the target tolerance band. In November 2024, headline inflation stood at 4.6% YoY. Unfortunately, core inflation remained above headline inflation, amounting to 5.3% YoY in December 2024 [32].

Debt as a share of GDP is on a declining path, dropping from 51.0% in 2023 to 47.1% at the end of November 2024. The share of fixed investments in GDP has been consistently increasing, hitting a historic high of 24.3% at the end of 2024. In Q3 2024, employment reached a historic maximum of 51.9%, while unemployment fell to a historic low of 8.1%. Employment growth was driven by a participation rate of 73.1% and an activity rate of 56.4%. The growth in formal employment was accompanied by double-digit real growth in wages and pensions throughout the year.

The current account deficit in the analyzed period amounted to around 5% of GDP, which does not comply with fiscal rules, but it is within the bounds of external sustainability. The current account deficit is fully covered by FDIs. By the end of 2024, the budget slipped into a deficit of around 2.7%, which remains within the Maastricht criteria. The budget deficit is stable despite an increase in expenses, largely due to the expansion of FDIs by 7.9%, reaching roughly EUR 5.1 billion, and an export growth of 4.5% YoY. General government debt at the end of 2024 was below 50% of GDP.

During the last year, the stability of the financial sector has been preserved. The NPL ratio was at a historical minimum of 2.7% at the end of 2024. The benchmark interest rate has remained steady at 575 bps, after a 75 bps cut in June 2024.

Macroeconomic indicators at the beginning of 2025 fuel cautious optimism, despite the global polycrisis and evident local weaknesses, such as core inflation being higher than headline inflation, signaling inflationary pressures and a negative impact of (geo)politics. Low-to-moderate growth, which could, under certain circumstances, be transformed into moderate-to-strong growth, is a predominant factor impacting the overall viability of the economy. The NBS's headline inflation expectations, as well as those of the financial sector, remain within the target tolerance band. Based on state impact investments and industrial policies for tradable sectors, the government anticipates an acceleration of the growth rate over the next two years, in the range of 4.0% to 5.0%.

The aforementioned macroeconomic fundamentals have been aligned with an improvement in credit ratings. Specifically, in October 2024, Standard & Poor's upgraded Serbia's rating to BBB-, placing it in the investment-grade category. Serbia received this credit rating because the economic conditions are expected to remain favorable, in line with capital market expectations.

Unfortunately, risk stressors remain strong and active. The industrial malaise in the EU, Serbia's main export market, is taking hold, particularly affecting the tradable sector in Serbia, most notably manufacturing and ICT. For instance, Germany accounts for approximately 15% of Serbia's total exports, making it Serbia's largest single export destination. However, in November 2024, German industrial orders dropped by 5.4% MoM, fueling fears of an impending recession [14].

Why is this so important? Because the EU, and Germany particularly, as Serbia's immediate environment, are experiencing a long-term stagflationary recession. The combination of inflation, economic slowdown, and a "fear of fear" mindset in the investment community are the consequences of deeply rooted structural imbalances of economic neoliberalism and impact of geopolitics. The

fractures of the socio-economic context have been further deepened and exacerbated by reaction policies (often unconventional, inconsistent, and experimental) as well as external asymmetric shocks, such as climate change, microbe pandemics, geopolitical disputes, etc.

In addressing the negative effects of the stagflationary recession from its key export markets, Serbia, as a small, open, and developing economy on the path to catching up with the mainstream EU, faces two policy choices. The first option is to rely on market forces following a currency adjustment to purchasing power parity (PPP), which would initially involve a depreciation of the national currency and maintaining a flexible FX rate after that. The second option is to keep FX rate stable while hiking key policy rates in line with the global shift from hawkish to dovish monetary policies. Simultaneously, Serbia could leverage FDI inflow to compensate for insufficient money supply (M2) through fiscal stimulus. Supporters of the first option overlooked the elephant in the room, the output gap. Policymakers in the recent period have chosen and consistently applied the second option for years. A key weakness of this policy mix is high inflationary pressures, which continuously undermine price stability, increase the cost of capital, and exacerbate recession fears. So, to make this policy mix effective, the NBS must focus on controlling inflation, while the Treasury Department should prioritize controlling the budget deficit and providing sufficient liquidity by attracting FDI.

In recent history, Serbia has had a respectable track record in combating inflation. In the period 2014-2020, headline inflation in Serbia averaged around 2%, which was one of the key factors contributing to the country's attractiveness for investors. However, the COVID-19 lockdown and subsequent geopolitical headwinds have slowed this trend. Inflation surged dramatically in the post-COVID period, particularly during 2022-2023.

In the past two years, the NBS has been relatively successful in its fight against inflation. After peaking at 15.1% YoY in March 2023, headline inflation reached an inflection point in July 2023, declining to 13.6% YoY. Inflation cooling gained momentum in the second half of 2023. Specifically, in October 2023, headline inflation had dropped to 9.5% YoY, continuing to decline at an accelerated pace in the following months, plateauing within the target tolerance band by the end of the first half of 2024.

To bring inflation down, the NBS has consistently avoided FX interventions, maintaining an almost fixed FX as a pivot of its monetary policy. The appreciation of RSD is a side effect of this policy. In October 2023, the RSD surged against reserve currencies, reaching its highest level since January 2016. This policy has had a detrimental impact on a significant portion of the domestic tradable sector. The overvalued RSD makes imports cheaper while making exports less attractive. However, FDI exporters have been more resilient, benefiting from transfer pricing mechanisms.

What does the NBS aim to achieve in the fight against inflation? The NBS was among the first monetary authorities to shift from a hawkish to a dovish policy stance. Benchmark lending rates have been increasing, including rates for the 1-year and 5-year LPR, as well as inverse repo rates (for 7, 14, and 21 days). The key policy rate of 575 bps at the end of 2024 remained unchanged for more than six months. As inflation risks persist, the NBS is prepared to either maintain the interest rate at this level or consider another rate hike. To stay on track toward a neutral interest rate in relation to growth, while maintaining a vigilant stance on inflation by keeping the policy rate at a relatively high 575 bps, the NBS has capped the interest rate spread at 400 bps.

Despite the evident cooling of inflation, inflationary pressures have not dissipated, as inflation is not just transitional but a structural phenomenon. Inflationary pressures are growing due to various external and internal factors. Much of Serbia's inflationary pressure has been imported via geopolitics. In a time when geopolitics is driving up energy, food, and commodity prices globally, national economies are quickly sliding into unintended macroeconomic chaos. Thus, keeping inflation within the target tolerance band in the long run remains a challenging task. Theoretically, the NBS may need to maintain high policy rates if inflation persists, but this strategy heightens recession fears. Anyway, the polycrisis presents a nightmare for any monetary power, as it is damned if it reacts and damned if it does not.

In an economy with an output gap like Serbia's, the NBS should care not only about inflation but also about growth, aiming to either delay benchmark interest rate hikes as long as possible or implement them more slowly. The NBS generally prefers not to resort to aggressive monetary tightening. However, in the current context, where inflation is rising due to geopolitical factors, slower tightening of the policy rate could prove counterproductive because it might contribute to the acceleration of de-anchoring of inflation expectations, thereby exacerbating recession fears.

Monetary tightening has its monetary rationale, but it faces fiscal and political constraints. The Treasury Department is much more sensitive to policy rate hikes than the central monetary authority. This explains the divergence between the NBS and the Treasury Department regarding monetary easing (both in terms of level and timing), particularly after Q4 2024, a period burdened by increased political polarization and rising mediation costs[8].

Despite many risk stressors, core banking has remained stable and even prospered. Despite monetary tightening, the NPL ratio remains at a historic low of 2.7%, signaling the viability of monetary policy. However, the real issue lies in the capital market, which is thin and underdeveloped. To be honest, some of the problems in the capital markets are unsolvable. Serbia's monetary power lacks the necessary tools to address challenges imported from global financial markets. A typical example is the trend of an inverted yield curve on fixed-yield assets, where short-term yields are elevated relative to long-term yields on government bonds. The NBS tries to keep the yield curve under control using conventional monetary measures, but in a thin market, an inverted yield curve is nearly uncontrollable. Another challenge is the turmoil in the global bond market and the ongoing recalibration. To maintain confidence in the local capital market and create a positive correlation between bonds and stocks, the NBS has been buying bonds of state-owned companies. However, this is not only insufficient but also risky. On the other hand, the Treasury Department has been active in issuing bonds. In mid-2024, a 10-year ESG Eurobonds denominated in USD, amounting to USD 1.5 billion, were successfully issued. The final borrowing cost of 4.75% is favorable compared to neighboring countries that already hold an investment-grade credit rating [32].

An ongoing challenge for the architects of the economic system is managing both the transitional and current output gaps, the latter emerging intermittently. The prolonged output gap, coupled with significant pressure on state and household income, requires mitigation. In response, the government has opted to implement structural policies, focusing on impact investments in infrastructure (both physical and digital), as well as industrial policies targeting tradable sectors. In an economy grappling with an output gap, structural policies can boost economic growth. Among the tradable sectors, investments in ICT, construction, power, and manufacturing have been particularly growth-enhancing. This policy aims to increase GDP and improve its structure, creating space for income (and pensions) growth. However, a key challenge of this strategy is the rise in corruption associated with large-scale projects, which may trigger a series of negative consequences, including political instability.

Anyhow, Serbia's development strategy has increasingly pivoted around FDI, given its significant positive impact on macroeconomic liquidity and growth. The primary effect of FDI is on FX stability through an expanded monetary base (M2). The second effect involves the positive impact of increased employment and export expansion on growth. The third effect is improved competitiveness, driven by a more favorable output structure and productivity growth, resulting from capital infusion in leading edge technologies. In addition to its role in financing the current account deficit and increasing liquidity in the short term, the most significant long-term contribution of FDI is the growth total factor productivity.

Unfortunately, while public and foreign investments have experienced growth (both absolute and relative), private investments have declined relatively. This trade-off is evident, because a relatively high tax burden negatively affects private investments. While tax income having a positive effect on public investments, reduction of retained earnings having negative impact on private sector. Reducing profit tax and other fiscal instruments

8 Aiming to avert a general strike, the government has reached a tentative deal with various groups, including universities, unions of elementary and high schools, Serbian electricity distribution company, etc., thereby breaking budget proportions.

could create room for new private sector investments. A potentially more effective alternative could be fostering public-private partnerships, particularly those focused on the green transition.

The new economic context has created a favorable climate for savings. In 2024, household gross national savings reached historical highs, amounting to 23%. The savings-investment balance stands at a tolerable level of 4.7%. In December 2024, FX reserves reached a record EUR 29.3 billion, sufficient to cover seven months of imports of goods and services. During the same month, monetary gold holdings rose to nearly 48.15 tonnes, valued at around EUR 4.0 billion, sufficient to cover more than one month of the trade deficit. In contrast to previous data, both categories of liquid assets, state savings and household saving, contribute significantly to expanding fiscal space for future state impact investments

By adhering to strengthened macroeconomic fundamentals, an approved and strictly monitored policy mix by the IMF[9], and an investment-grade credit rating, policymakers are able to create a countercyclical buffer in the first stage and build fiscal space in the next stage by attracting various sources of capital. By doing this, they make capital blending necessary for green investment feasible. With these achievements, Serbia is on track to attract financing for green investments through EU special-purpose funds, IMF/WB credit lines, and/or other multilateral financial institutions, making green investments financeable. The WB/IMF estimates suggest that developing countries require approximately USD 1 trillion annually by 2030 to effectively address climate change and transition to sustainable energy systems [47]. This dynamic is expected to relax private sector risk aversion and encourage private investment in the green energy transition.

Despite the echo of respectable macroeconomic fundamentals from the last two years, Serbia entered a (geo)political crisis in Q4 2024, with postponed and unpredictable economic consequences. The momentum for a sustainable growth trajectory has weakened. Students and professors, supported by opposition parties and the NGO sector, have consistently challenged the potential positive impact of key government infrastructure projects (primarily lithium and EXPO 2027), while ignoring the impact of the so-called "Kosovo issue" on the country's geopolitical positioning vis-à-vis the EU. The opposition has focused on direct confrontation with the government, the ruling party, and the President of the Republic, accusing them of using heavy-handed tactics in critical aspects of economic life and, consequently, being laden with fraud, abuse, and waste. (Geo)political malaise may significantly reduce Serbia's attractiveness to investors, particularly foreign direct investors. This adversarial trend raises a pressing question: should the related investment portfolios, particularly for strategic projects, continue to be financed amid political uncertainty? As general risk aversion grows, the economy shifts quickly from a path of transition to one of confusion.

Following the onset of political malaise in Q4 2024, due to the growing costs of mediation, the Treasury Department shifted focus to phasing out the previously established countercyclical buffer to prepare the economy for potential "black swan" events. The political distress has slowed both foreign direct and domestic investments, creating an investment crunch that could be a headwind for the stability of RSD and the financial system as a whole. This environment will make it exceedingly difficult for the NBS to stabilize inflation within its target tolerance band while keeping FX rate unchanged.

From the perspective of the Treasury Department, during a political crisis where confidence becomes a fundamental sentiment, many fiscal measures are likely to deviate from established fiscal rules. Moreover, such measures may not be in line with the available fiscal space. This paves the way for a policy of soft budget constraints to enter through the back door, undermining adherence to fiscal discipline and eroding respect for fiscal rules. Over time, this could jeopardize Serbia's hard-earned investment-grade credit rating.

The latest external asymmetric shock stems from recently imposed U.S. economic sanctions on NIS, a joint venture between Serbia's state-owned company and Russian equity partners (Gazprom Neft and Gazprom),

9 The IMF's ultimate goal is to slow the outflows of state money from the Treasury Department. To achieve this, the IMF insisted on a 3% of GDP red flag, targeted an optimal government size of 15% of GDP, and urged restructuring of the energy sector.

both holding the majority stake. The potential closure of NIS, Serbia's largest provider of oil and oil derivatives, has heightened supply risks, significantly accelerating concerns over energy security. The potential closure of NIS, Serbia's largest provider of oil and oil derivatives, has heightened supply risks, significantly increasing concerns over energy security. In addition to disrupting the oil market, sanctions are expected to raise the prices of oil derivatives, contributing to the inflationary spiral. Meanwhile, global oil prices have reached a 5-month high due to U.S.-imposed trade levies on some oil producers (such as Canada), with the targeted countries responding with counter-tariffs against the U.S.

Implications of Two Development Scenarios for the Energy Sector

In today's world, no nation's economy can afford to be overly independent when it comes to combating climate change with zero-tolerance attitude. These characteristics are neither mere side effects of shifting political focus, nor simply the result of changing mindsets among policymakers. Instead, they stem from the deep roots of an economy and society: what they are and what they stand for if they intend to survive and prosper? This is a universal truth that no nation can escape.

Bracing for a better normal in the case of Serbia is not easy. From the early 1990s until now, Serbia has, explicitly or implicitly, been an excommunicated country. As a result, it has lost touch with the EU mainstream. Being an "exotic" country, isolated from EU trends, is far from an ideal starting point for sustainable and inclusive development, particularly in the context of network technologies in general, and in the energy sector specifically. The installed energy production capacity of 4,300 MW exceeds the actual capacity of 2,800 MW. Moreover, the current energy output gap, which is roughly 30% of production, makes progress in the energy transition and EU integration even more difficult.

If Serbia intends to become part of the EU, it must undergo rapid and radical transformation across all sectors, particularly in the energy sector. For every EU member state, transitioning by mid-century to net-zero, or at least to a significantly lower-carbon development trajectory, is a key priority. The expectation that private investors from the EU or other parts of the global economy will leapfrog Serbia's economy on the path to mitigating the negative consequences of climate change and, by doing this, closing the energy output gap is unrealistic. Moreover, achieving energy security with an adequate structure of energy mix requires convergence in both economic performance and alignment with EU regulatory frameworks[10], energy strategies, and targets. These are hygienic prerequisites for addressing climate challenges and ensuring Serbia's energy sector becomes as competitive and sustainable as possible.

Serbia has already started to align its regulatory settings with EU framework, particularly in areas such as the regional energy market and the assessment of energy-related hazards, including mitigation and opportunity costs. Without an expansion in energy production, Serbia risks a potential reduction in GDP that could reach double-digit figures by 2050. Also, without significant investment in green energy transition, this aspect of energy security will remain a major barrier to further economic growth.

Mitigation costs for identified obstacles are indeed high, but the benefits, both direct and indirect, can be even greater. According to [48, p. 2], Serbia would need to invest roughly USD 9.5 billion over the next decade, or about 0.4-0.6% of GDP per year, to mitigate climate-related hazards.

Convergence in the level of development is a critical performance indicator for countries in the EU accession process. Serbia faces a significant development gap compared to the EU. From 2011 to 2024, Serbia's GDP PPP per capita accounted for only 55% of the EU-27 average. Investments (level, speed, and effectiveness) are key drivers for catching up. In 2024, the investment level in Serbia amounted to slightly over 24% of GDP, which is fair enough. The share of investment in GDP formation is increasing. Despite this, the average growth rate for the period 2014-2023 was 3.12%, which is not enough. To bridge the gap with the EU, Serbia would need CAGR = 7% over a 10-year period, assuming the EU grows at a CAGR = 2.5%. If we factor in investments needed to offset the costs of the COVID-19

10 Recently, the EU carbon border tax has come into play.

pandemic, the required timeframe for convergence may need to be extended by at least 5 more years [9].

The bottom-line assumption for any development scenario in Serbia is that there will be no significant investments in the energy sector. Given that the government predicts a growth rate of 4-5% for 2025 and 2026, we have decided to calculate a moderate growth scenario, or "as-is" scenario, with a CAGR = 4.5% (Table 1A). Given the energy output gap of 30% at the start of the projection, in this scenario the energy output gap would increase to 54.93% of energy production by the end of the projection period.

In a robust growth scenario, or "to-be" scenario, Serbia would experience a 7% annual growth rate over a 10-year period (Table 1B). This scenario would lead to the energy output gap expanding from 30% to 64.42% of energy production by the end of the 10-year projection (Table 1B).

The general conclusion is clear. Without significant investments in the energy sector, the energy output gap will remain a major barrier to further economic growth in both scenarios.

Another problem lies in the structure of energy output. To meet the net-zero emissions target by the middle of the century, Serbia must completely phase out fossil fuel-based energy production and replace it with a diverse range of renewable energy sources.

Achieving economy-wide net-zero emissions by 2050, along with a significant increase in energy production, requires even higher investments in the deployment of climate-neutral technologies enabling strong growth. This calls for a decisive action plan, such as the Integrated National Energy and Climate Plan (INECP) [31], which outlines strategies for the energy sector along sectoral decarbonization pathways. While the plan is in place, it is still too early to say that the green energy transition has truly begun.

The action plan includes incremental investments to scale up renewable energy sources with moderate power capacity, such as solar, wind, geothermal, and hydro capacities. Alongside significant penetration of these renewable sources, the phase out of lignite-based electricity production must primarily rely on investments in the most potent renewable energy sources, such as biomass (in the medium term), and nuclear energy (in the long term). The transport, construction, and agriculture sectors, along with hard-to-abate sectors like cement, steel, and ICT, will also require substantial investments in the green transition, with a focus on green hydrogen-based fuels, energy efficiency improvements, electrical grid optimization, and the adoption of electric vehicles. Also, the industrial sector will need to undergo a significant transformation, shifting from fossil fuels to renewable

Table 1: Energy output gap for two development scenarios

A. As-Is scenario (CAGR = 4.5 %)

Year	Growth [%]	GDP	Energy Investment YoY	Energy Output Gap [%]
0				**30.00**
1	4.5	1.045	1.000	33.01
2	4.5	1.092	1.000	35.90
3	4.5	1.141	1.000	38.66
4	4.5	1.193	1.000	41.30
5	4.5	1.246	1.000	43.83
6	4.5	1.302	1.000	46.25
7	4.5	1.361	1.000	48.56
8	4.5	1.422	1.000	50.78
9	4.5	1.486	1.000	52.90
10	4.5	1.553	1.000	**54.93**

B. To-Be scenario (CAGR = 7.0 %)

Year	Growth [%]	GDP	Energy Investment YoY	Energy Output Gap [%]
0				30.00
1	7.0	1.070	1.000	34.58
2	7.0	1.145	1.000	38.86
3	7.0	1.225	1.000	42.86
4	7.0	1.311	1.000	46.60
5	7.0	1.403	1.000	50.09
6	7.0	1.501	1.000	53.36
7	7.0	1.606	1.000	56.41
8	7.0	1.718	1.000	59.26
9	7.0	1.838	1.000	61.92
10	7.0	1.967	1.000	**64.42**

Note:
Eprod = X(1 + INV)(1 + INV)...
Econsump = Y(1 + GDP)(1 + GDP)...
Energy Output Gap = 1 – Eprod/Econsump = X/Y(1 + INV1)(1 + INV2).../(1 + GDP1)(1 + GDP2)...
Present value (Year 0) X/Y = 0.3
Energy consumption assumed as: Econsump = Y(1 + GDP1)(1 + GDP2)...
GDP1- first year, GDP2 - second year
Production assumed as: Eprod = X(1 + INV1)(1 + INV2)...
Energy Output Gap [%] = 1 – Eprod/Econsump = X/Y(1 + INV1)(1 + INV2).../(1 + GDP1)(1 + GDP2)...

energy sources, including the installation of energy and/or carbon capture/storage/utilization capacities.

Substantial green investments require, in terms of quantum, equally substantial green finance, as well as robust regulatory and policy efforts enabling capital blending from different sources to create the critical mass needed to finance climate change-induced investments. For example, to deploy biomass technology with high power capacity and large-scale electricity production potential, Serbia would need to invest at least an additional EUR 10 billion over a period of 3-4 years.

Investments in green technologies, being capital-intensive, high-risk, and low-yield, are often non-financeable. On one hand, there is widespread consensus that public capital alone cannot counteract climate change. On the other hand, private capital is either short-term, expensive, and insufficiently flowing, or lacks the critical mass needed for large-scale green projects ("big shots"). The EU pre-accession financing and special-purpose funding from international financial institutions, such as the IMF and the WB, aimed at extending fiscal space to support state impact investments in decarbonization, will be the primary sources of financing for major energy infrastructure projects (production capacities, grid, storage). Also, the catalytic role of the government in developing innovative capital-blending strategies, along with the development of capital markets for the issuance and trading of thematic securities (green bonds, for example), as well as leveraging guarantees for green credits and public-private partnerships, are essential to counteracting climate change.

Anyway, the major source of financing for all types of investments will come from institutional investors, with an estimated total investment potential of USD 100-200 trillion per year. However, green financing accounts for a smaller portion of that potential. According to [5, p. 4], approximately USD 50 trillion in incremental investments will be required by 2050 to counteract climate change. One of the problems is the internal limit due to the mismatch between risk appetite and inadequate de-risking strategies within credit institutions. Moreover, institutional investors are very selective when it comes to either the projected stream of free cash flows or the macroeconomic stability of the national economy. Therefore, for adequate capital blending to finance green energy transition projects, both the bankability of proposed green projects and sustained macroeconomic stability are necessary. This "double bottom line" is a hygienic precondition for green financing.

A Big Idea for a Homegrown Renewable Energy System

In this part of the paper, we are going to talk about energy security from relevant perspectives, including energy market specifics, risks to energy supply, the unsustainable nature of the "as-is" development scenario aiming for a CAGR = 4.5% over a 10-year period, and the necessity of the "to-be" development scenario aiming for a CAGR = 7% over the same projection period.

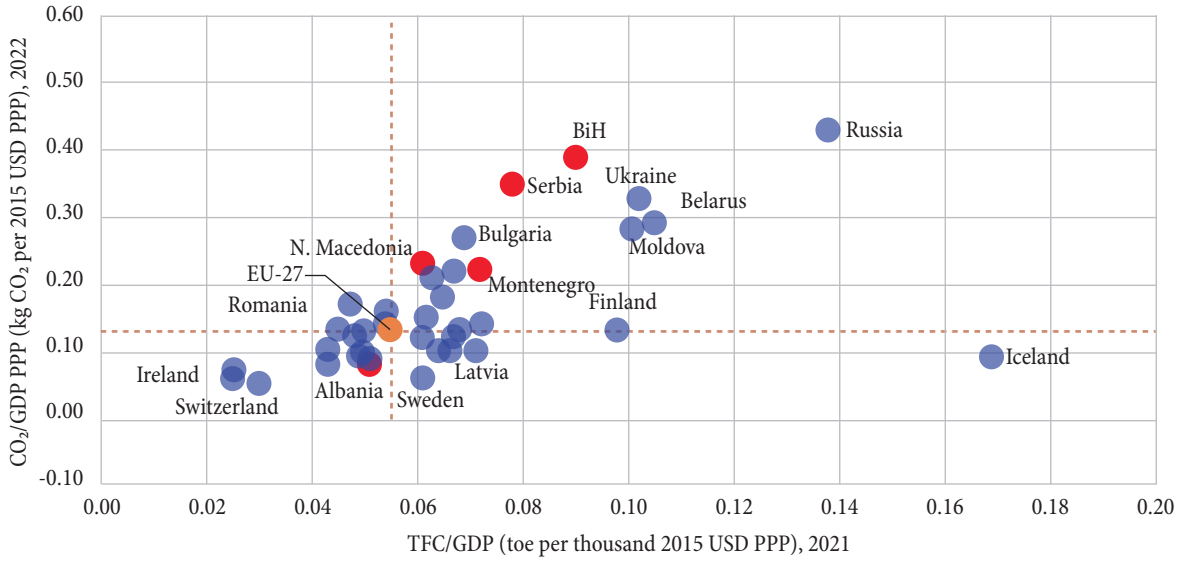
Also, we are going to consider the feasibility and affordability of the proposed energy strategy. The main goals of this strategy should include the core business rightsizing (assets, capital, and the number/structure of employees), as well as an expansion into a diversified portfolio of climate-neutral technologies based on homegrown renewable energy sources (biomass, hydro, waste, geothermal, solar, wind). The role of EPS in this energy transition is crucial. As a utility company, EPS has an obligation to supply the local market with an adequate amount of electricity and heat. As a joint-stock company, EPS is also responsible for delivering a satisfactory return on investment to its shareholders during the proposed investment cycle.

Serbia consumes more primary energy per unit of GDP (PPP) than the world average. Moreover, Serbia energy supply portfolio and GDP formation are more carbon-intensive compared to the world average, and significantly beyond the EU27 average, as indicated in Figure 2.

Serbia's carbon intensity of 6t CO_2 per capita is only somewhat smaller than the EU27's per capita carbon intensity (6.2t CO_2 per capita)[11], while its GDP per capita is considerably below the EU27 average. The use of lignite dominates Serbia's carbon intensity (2/3), followed by transport fuels (1/5), and natural gas (>1/10) that makes

11 Ember estimates a further reduction in the EU27 carbon intensity during 2025 following further closures of coal-fired power plants.

Figure 2: Comparative Final Energy Consumption (TFC) intensity of GDP (PPP) versus carbon intensity of GDP (PPP)



Source: World Bank [49, p. 20]

about 98% of carbon emissions from the energy sector[12]. While international climate change policies dictate considerable uncertainty related to carbon intensity, it is safe to assume that a carbon intensity of this magnitude is a political and financial hazard that Serbia cannot easily afford in case of a climate emergency.

It must be considered that Serbia has a stake in the eventual success of global climate change policies. The country's territory is exposed to a variety of external asymmetric climate risks, flooding in particular. The massive floods in 2014 highlighted the critical nature of this issue. Major energy infrastructure (lignite mines and power plants) is located in lowland areas and exposed to most significant risks of flooding. Therefore, interventions to reduce climate impacts across its territory (forestation, flood protection, and the prevention of erosion and landslides) have to be combined with active engagement in international climate change policies.

Extreme weather and the decreasing predictability of its consequences are affecting the demand for natural gas and electricity. This dictates the maintenance of (costly) fuel reserves (natural gas in underground storage, water in hydropower accumulation lakes, coal stocks), with both formation costs[13] and opportunity costs[14]. These costs are further magnified as access to international waterborne energy markets is constrained, and the procurement of energy commodities from international markets with different price formation patterns than those in Europe is more costly. Therefore, Serbia is forced to acquire commodities at additional cost and hold stocks for longer periods, with further cost of capital. Alternatively, the country may subcontract its security of supply to third parties, with additional security and political risks [2].

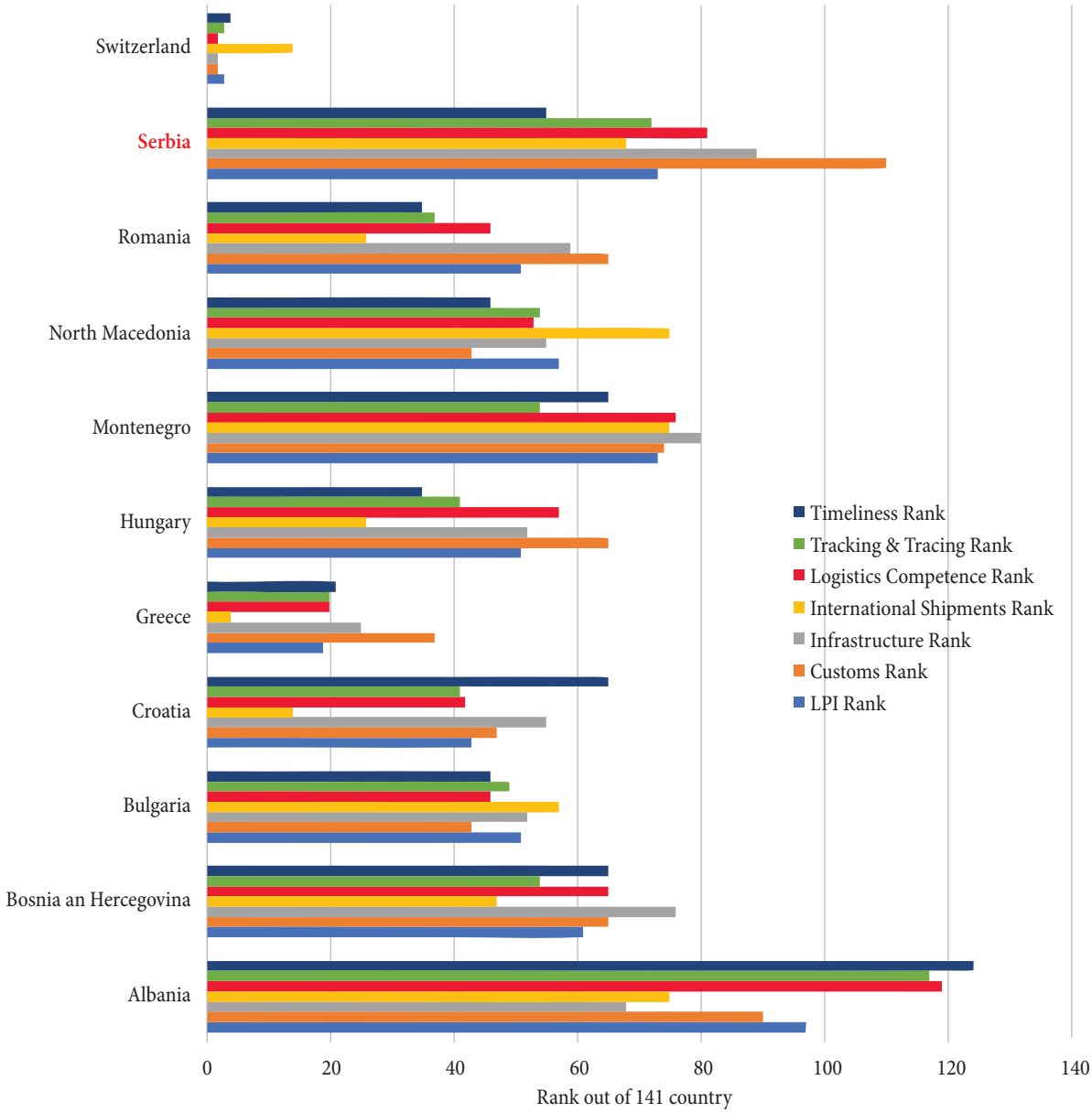
As a landlocked country, Serbia's economy is heavily dependent on trade and transit through neighboring countries [46]. Unfortunately, Serbia is surrounded by economies with fairly poor Logistical Performance Indexes (LPI), well below European comparisons. Furthermore, Serbia itself performs below European standards. That creates considerable cost and supply risks when it comes to trading energy and fuels in international markets.

12 Authors have conducted analyses using extensive "Our World in Data" comparative data sets.

13 The compression of natural gas into underground storage implies expenditure of gas for compression while the quality of lignite deteriorates during storage and exposure to elements. Fuel storage implies the engagement of turnover capital and lesser utilization of available infrastructure that needs to be oversized to respond to volatility and peak demand. Returns on investments into infrastructure are reduced by lower utilization rates.

14 When hydro accumulation is held back to meet domestic demand volatility, it cannot be used to trade in European electricity markets where flexibility is on high demand and commands premium price.

Figure 3: LPI for selected countries (lower rank indicates better performance)



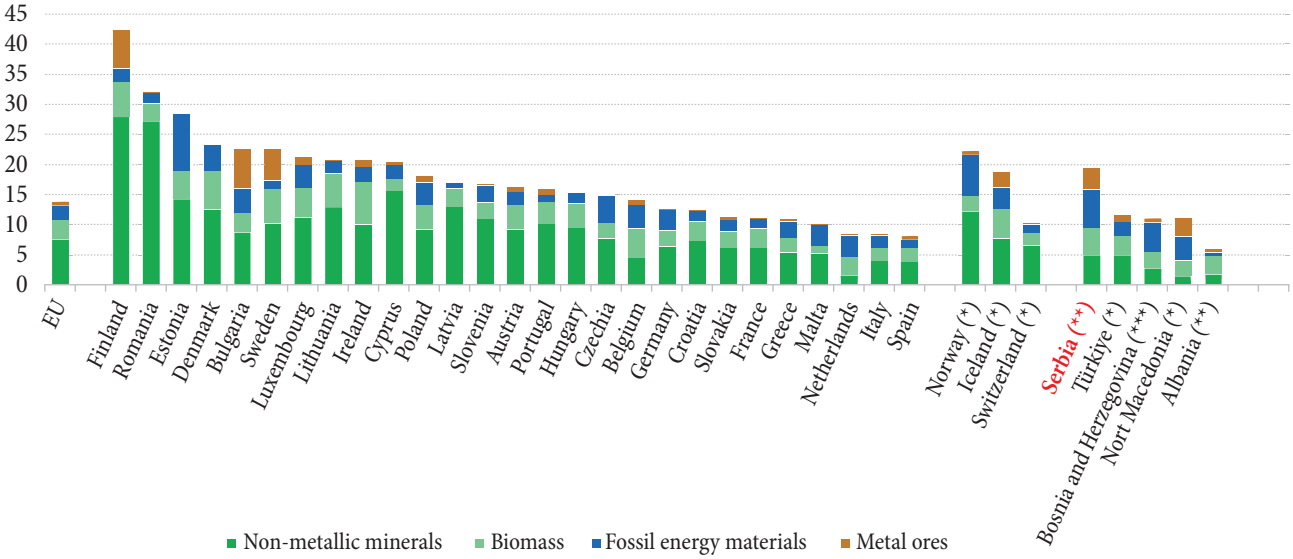
Source: LPI Database, assembled by authors

Figure 3 is developed using the World Bank LPI database. The data for Switzerland indicate benchmark performance of landlocked country.

As for major fossil fuels like crude oil, petroleum products, natural gas and coal, Serbia encounters serious limitations, risks and costs of supply. The navigation regime on the Danube River, the only international navigable waterway with direct unobstructed access for Serbia, is undergoing major changes following the conflict in Ukraine [7]. It remains to be seen whether political and regulatory limitations on navigation will be lifted. If they are, it will be a major challenge for Serbia's economy to capitalize on trading opportunities by adjusting ports, shipbuilding, and the river-sea-going fleet.

The challenges to the security of supply for natural gas, crude oil and coal are growing and getting more complex as time goes by. Access to seaports is to be considered as a major obstacle to direct access to international seaborne energy markets. The utilization rates of major transport infrastructure are limited below the minimum economies of scale, which turns up transit costs per unit of volume. As a consequence, trade in petroleum products is limited to the regional market, with further limitations and costs penalties.

Figure 4: Domestic material consumption by main material category in 2023 (tonnes per capita)



(*) 2022 instead of 2023, (**) 2021 instead of 2023, (***) 2019 instead of 2023
Source: Eurostat
Note: The 'Other products' and 'Waste for final treatment and disposal' categories are included in the 'Non-metallic minerals' category

Following the major failure in Serbia's power generation system from December 12, 2021 [3], fuel wood prices increase by over 150% in 2022 [39]. As a consequence, fuel wood prices per unit of useful energy, taking into account the low efficiency of heating stoves, exceed electricity prices.

During 2023, grid losses accounted for over 14% of the electricity delivered to customers [11]. Another 3% was consumed within lignite mines for extraction, handling and delivery of lignite and overburden. In fact, fuel wood (biomass) and lignite (fossil energy materials) are the bulk of material intensity in Serbia's economy. This includes about 7 million m^3 of fuel wood [16, p. 14] and 31-39 million tonnes of lignite [11], combined by several million tonnes of agriculture products. Figure 4 demonstrates Serbia's material intensity in comparison with other countries in Europe. This volume of material consumption is well beyond the EU27 average.

The economic value of these materials is limited, leading to very low resource productivity in Serbia. As a consequence, Serbia's resource productivity, measured by GDP (PPs) per unit of domestic material consumption (DMC), is only 27% of the EU average [13] and remains the lowest in Europe.

To make things worse, the extraction productivity of fuel wood (where high-productivity forest machinery is not available) and lignite remains well below European comparisons (see Figure 5).

Fuel wood is used in light heating stoves, which are on average over 15 years old and are 3-4 times less efficient than standard stoves (including masonry stoves) found elsewhere in Europe. Lignite provides half the fuel energy per tonne compared to average lignite elsewhere in Europe. It takes 4-5 times more labor to produce that lignite in Serbia than elsewhere in Europe, and this fuel produce only 2/3 of the electricity per unit of fuel energy due to the low combustion efficiency of existing power plants.

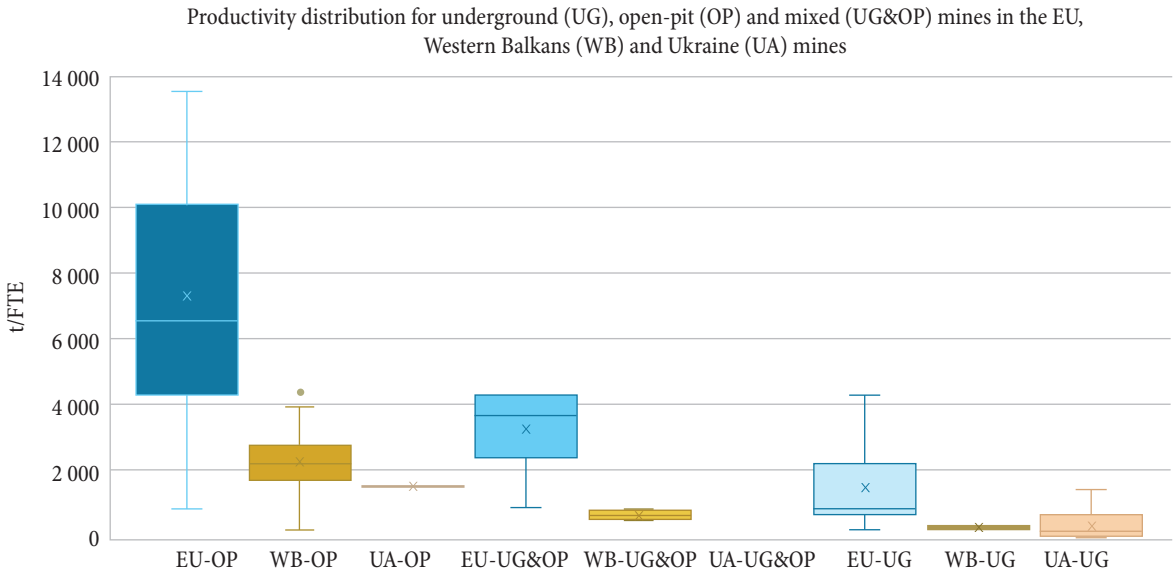
However, it produces more harmful emissions, leading to health impacts and soil acidification, which further accelerates erosion, landslides, and the degradation of forest cover, while also disposing further 6-10 million tonnes of ash to landfills.

Full-time employees (FTE) in lignite mines and power plants operate massive amounts of machinery, handling such big amounts of material, and command disproportionally high wage-adjusted labor productivity in 2022[15] versus other sectors of Serbia's economy [40, p. 206].

While the security of supply with imported fuels (crude oil [41], natural gas [12], [38], imported coal) is

15 That equates to a 2.45-times higher wage-adjusted labor productivity than the Serbian average. This suggests that any transition strategy relying on low-capital-intensity jobs with inferior remuneration is unlikely to gain acceptance within miners' communities.

Figure 5: Lignite mines productivity comparisons in volume per full-time employee (FTE)



Source: Ruiz Castello et al. [35, p. 27]

at risk due to exposure to logistical, infrastructure and geopolitical risks, the extraction of lignite in domestic open-pit mines is reduced from about 40 million tonnes to about 31 million tonnes. As a result, Serbia's power sector has become a net importer of electricity, natural gas, and coal.

While there are no data in the public domain, it is plausible to assume that the probability of technical failures in existing lignite-fired thermal power plants has now increased to 15-20% for units that started operating in the 1980s, and even more for older units. The average full-capacity operation equivalent for these power generation units is about 270,000 hours during more than 40 years of service. Major units are equipped with complex and large-volume flue gas desulfurization plants, which increase the probability of failures and divert scarce maintenance resources. The quality of lignite has deteriorated and is now mixed with imported coal from a variety of origins and with variable quality. This exposes power plants to additional operation challenges, further increasing maintenance requirements.

Serbia has recently acquired a new lignite-fired power plant unit, Kostolac B3. This additional power generation capacity increases production by 8.5% or 350 MWe. However, it may not provide that much service as the company is looking for. Paradoxically, the operational performance of similar plants in China (with more consistent coal quality) is somewhere between 4,300h – 6,000h [26], so the new unit may have a lower utilization rate than aging units in Serbia.

In very short, domestic power generation is not secure and may be exposed to major risks of technical failures as well as an increasingly ruthless electricity market. To make matters worse, the security of electricity supply in the Western Balkans region is exposed to similar risks, augmented by the actual depletion of some lignite mines.

Key policy documents (the National Energy Strategy [33] and the National Energy and Climate Plan (NECP) [31] do not fully address the inadequate quantity and structure of supply. The NECP calls for a gradual increase in energy import dependency from about 30% to about 45% and a maximum GDP growth rate somewhat over 2% per annum, which is well below to the less ambitious "as-is" scenario of 4.5% presented here. We are going to make assumption that the available policy framework does not provide sufficient tools for EPS to preserve (or improve) its market share and meet shareholder expectations. However, the policy framework does not prevent an ambitions development scenario that the company may pursue. Taking into account that the company's strategy comprises more ambitions decarbonization goals than those outlined in these policy documents, the analyzed documents provide ground for taking an active position

in international carbon markets, following the principle of additionality.

The corporate EPS strategy is to comprise the following objectives. First and foremost, the rapid replacement of the current lignite-fired thermal power generation portfolio with more suitable alternatives. The existing power generation portfolio (excluding the new Kostolac B3 unit) is likely to accumulate an average of 3 million operational hours by 2030. At that point, the probability of failures is likely to increase beyond a manageable level, causing an irrevocable loss of market share. Kostolac B3 is likely to reach 30-40 thousand operational hours, resulting in the depletion of its technical resources.

Second, the new power generation portfolio should be capable of providing superb energy security, flexibility and reliability of energy services to commercial, industrial, public and residential customers across the country. It is to offer energy service right to the customer's doorstep, competitive to any alternative supply that customer may have.

Third, EPS needs to reduce material intensity, enhance production productivity and power generation efficiency to levels competitive with its European peers.

Taking into account the need to facilitate GDP growth at a CAGR = 7% over the period of ten years, the aim of the strategy is to double the volume of electricity available for commercial and industrial use.

Fourth, to eliminate (or considerably reduce) the weather sensitivity of power demand, EPS needs to offer heat supply with adequate heat storage capacity.

We are hereby taking an assumption that wind and solar power resources in Serbia provide medium competitiveness in Europe circumstances. Better solar energy yields are available south from Serbia and along Mediterranean coasts. These resources are likely to deliver over 20% more electricity per year compared to the same investment in Serbia. In similar fashion, wind farms installed in the Black Sea region or even north of Europe are likely to deliver over 30% more electricity for the same investment.

Therefore, investments into wind and solar energy in Serbia are more capital-intensive per unit of production and exposed to a higher Weighted Average Cost of Capital (WACC) than identical investments elsewhere in Europe.

Serbia's territory comprises outstanding hydropower potential that has already been captured by lead-edge, large-scale hydropower plants. However, the full commercial potential of these technologies is constrained by the need to reserve these capacities for responding to technical failures in thermal power plants and weather-induced demand spikes. Furthermore, changes in water inflow regime toward more frequent flooding, caused by the loss of forest cover and water conservation over the territory, constrain the optimal commercial validation of these assets. There is a minimal, yet strategically important, addition to the hydropower production portfolio. Beyond that, Serbia's territory is one of the most interesting places in Europe for developing pumped storage hydropower plants that may, in the future, deliver strategic flexibility services to the European market. Some projects that were considered in the past are currently being reconsidered, but we believe a much more comprehensive re-examination is needed in the context of: new physical realities across the territory, the availability of new advanced hydropower technologies, new opportunities in the European power markets, and the potential establishment of a more appropriate electricity trading regime with the EU27.

Lignite production at the major Kolubara lignite basin is declining in both quality and quantity. The deterioration of lignite quality creates an additional layer of operational risk for existing power plants. Starting with 30 million tonnes in 2020, production declined to 27 (2021), 25 (2022) and 22 (2023) million tonnes. There are ongoing efforts to restore somewhat better production outcomes, but these efforts may gain only temporary relief as inadequate productivity is unlikely to change and lignite quality is not expected to significantly improve in the long term. The optimal strategic decisions will be: to focus on the best-quality local resource that is available in the mid-term and extract the most economic value out of it, while shifting power generation to a new paradigm.

Geothermal resources in Serbia provide interesting development opportunities, provided that the country is able to resolve legal issues and bring in investors with access to advanced technologies.

Moreover, Serbia is one of the best places in Europe to grow short-rotation softwood plantations: there is

considerable unused land, well-supplied with shallow water resources, suitable quality soils, at low and medium altitudes, all covered by massive transport infrastructure: navigable waterways and electrified railways, both of which are heavily underutilized [24]. The actual production of disposable agricultural waste is sufficient to produce more than 800 thousand tonnes of methane per year. Furthermore, conventional forest resources from managed private and state-owned forests provide the equivalent of 7 million m^3 of fuel wood per year for low-efficiency heat-only applications. More than 100 thousand tonnes of valuable mineral fertilizer ash are thrown away per year, rather than being used to maintain soil quality.

Loss of forest cover (including softwood plantations) causes erosion, landslides, wind erosion, and further problems with water conservation across the territory. Consequently, a large-scale reforestation plan provides further production potential.

One ton of biomass delivers about 2-3 times more fuel energy than one ton of average-quality lignite in Serbia without the need to remove another 3.5 tonnes of overburden and devastate the land to any extent. Quite the contrary, sustainable biomass production that takes into account biodiversity and sustainability criteria improves the land's value.

From an efficiency perspective, biomass combustion has the potential to deliver over 1/3 more electricity per unit of fuel energy than actual lignite fired-power plants. In other words, 1t of biomass delivered to a modern power plant is going to produce about 3.45 times more electricity than 1t of lignite delivered to existing power plants. In same fashion, tonne of biomass in a modern power plant may produce well over ten times more useful energy equivalent than burning that biomass in a light burning stove.

Finally, industrial-scale power generation ensures the sustainability of biomass resources. It allows for the application advanced growing technologies that are well-known in Serbia's agriculture sector.

In a very short period (3-4 years), it is possible to establish an efficient value chain for biomass energy supply, encompassing production, transportation, combustion, and re-growing of biomass, all of which would be entirely clean (green) and carbon neutral. By combining the efficiency of energy conversion with the physical properties of biomass, it is sufficient to produce about 12 million tonnes of biomass to replace the electricity currently produced from 40 million tonnes of lignite (which also delivers over 6 million tonnes of dangerous ash waste). This shift would reduce the material intensity of Serbia's economy by ¾ of the actual lignite handling, as well as eliminate the need to remove 100 million tonnes of overburden, which is not accounted for in material intensity reporting.

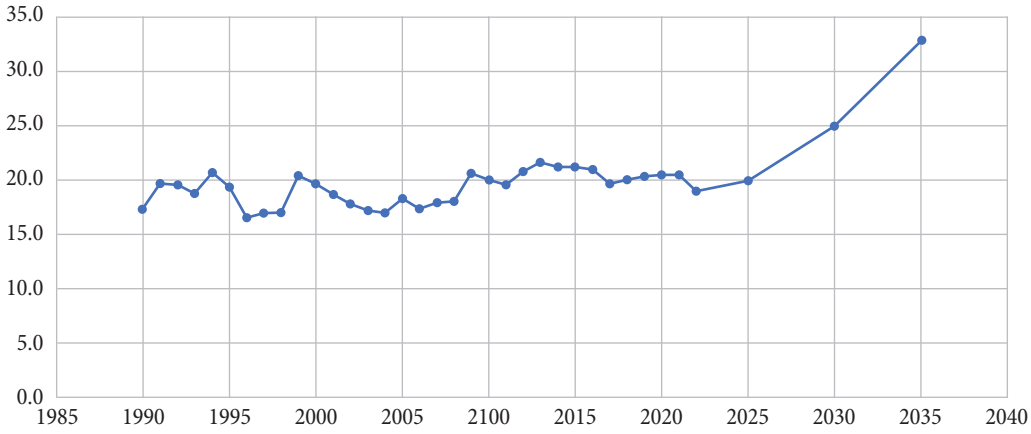
Production and labor productivity, as well as transport efficiency, which could be achieved in Serbia are probably unattainable in other parts of Europe, except for the former Soviet Union.

The more efficient conversion of primary energy into electricity, which is more proficient, sustainable and effective, is a key driver of economic growth. Developed countries are steadily improving electricity-to-TPES (total primary energy supply) ratio. The EU27 improved its electricity-to-TPES ratio from 15% in 1990 to about 21% in 2022, while the world average followed suit, by improving from about 13% to about 18% in 2022. China saw its electricity-to-TPES ratio grow from 8.5% in 1990 to about 22% in 2022, overtaking the EU27 between 2017 and 2020. In this context, Switzerland and Norway are great performers: landlocked Switzerland with about 31% and Norway approaching 50%.

Sweden managed to increase the share of electricity in its total primary energy supply (TPES) portfolio from 39.8% in 2010 to 48.6% in 2020. Finland increased the share of electricity in its total primary energy supply (TPES) portfolio from 28% in 2013 to 38.6% in 2023. The 10% increase over 10 years was possible as both countries[16] applied ambitious expansion of renewable energy production, considerable use of biomass in power generation and significant provision of district heating from cogeneration (Combined Heat and Power, CHP) plants. Both countries are leaders in modern combustion technologies. They, however, failed to apply a sufficiently high level of standardization to CHP installations, which made developments somewhat more expensive.

16 The authors' research uses extensive comparative data sets from "Our World in Data".

Figure 6: Electricity-to-TPES ratio in Serbia, 1990-2022 with projection to 2035[17]



Source: Authors calculations' using the IEA/OECD database

Serbia inherited a fairly high electricity-to-TPES ratio of over 17% in 1990 and was bouncing between 18-21% during the 2000s. To achieve an electricity-to-TPES ratio of >32% (see Figure 6), Serbia needs to replicate the rapid growth demonstrated by Sweden and Finland. This would bring its economic growth opportunities to a level comparable to that of Switzerland.

During the period 1976-1987, EPS was able to install and commission 3,747 MWe of lignite and natural gas power plants, mostly through greenfield projects that required associated infrastructure, roads, railways, lignite mines and grid connections. These undertakings were part of massive international framework investment arrangements [25].

Convergence to the EU27 average in the power sector requires achieving a long list of ambitious goals: 1) a one-third reduction in material intensity; 2) a reduction of carbon intensity by half; 3) a reduction in import dependency, including the elimination of politically and socially sensitive imports; 4) improvements in overall energy efficiency through structural changes in primary energy use; 5) alignment with the EU Industrial Emissions Directive standards and clean air regulations; 6) an increase in domestic renewable energy use in transport to 10% or more; 7) an overall increase in total final energy available for consumption; 8) a doubling of electricity available for industrial and commercial use; 9) making the system's final energy supply-to-GDP formation more resilient to external shocks; 10) a higher utilization rate of new power generation systems with low capital intensity; and 11) better returns on capital, while offering customers more competitive and affordable tariffs to support economic growth. By doing so, Serbia will delay its overshoot day in the mid-term.

Finaly, the transition is to be achieved by people with well above-average renumeration, due to the opportunity to operate high-capital-intensity economic processes (rather than exceptionally high productivity). To make it more interesting, as the probability of technical failures increases, utilization rates decrease, but the relative capital intensity of output actually increases, tempting operators to request further wage growth. It is therefore critical to offer outstanding renumeration within the new energy paradigm in exchange for outstanding performance, to prevent the status quo from prevailing.

Based on previous assumptions, the green energy transition plan[18] includes the following steps. The first step involves providing waste heat from existing lignite-fired power plants to existing district heating systems, aiming to replace the source of waste heat with biomass or methane of waste power plants once these plants are built. It is to be considered that envisaged plant locations should be able to cover 92% [42] of actual district heating services in the country. Once low-cost and entirely renewable heat sources are available, local district heating companies should be able to expand district heating coverage and cover twice

17 Data for Total Primary Energy Supply for the period 1992-2020 have been adjusted upward to reflect fuel wood volumes that were actually consumed but not reflected in public statistics.

18 A similar investment scenario has been considered in the past with far less developed technologies [50].

Table 2: Power generation estimates in GWh

Year	Lignite[19]	Oil	Natural gas[20]	Hydro[21]	Biofuels[22]	Waste	Solar PV[23]	Wind[24]	Total
2022	23546	15	1449	9274	252	6	15	949	35506
2035 (estimate 1)	2450	0	3096	10895	20480	1440	2625	5200	46186
2035 (estimate 2)	525	0	3096	11440	22405	1440	3675	7280	49861

Source: Authors' estimates based on IEA data for 2022

as many customers. This is going to reduce domestic fuel wood use by about half and clean air in the urban areas. At the same time, these installations are going to resolve balancing problems with actual wind farms and open up further installation opportunities. This is likely to increase the value of real estate in various cities and municipalities. The following step includes the deployment of methane-fired power plants with biomass-to-methane conversion facilities to further enhance grid flexibility, reduce grid losses, and provide district heating services. Methane could also be used as a fuel for large-scale biomass cultivation and transportation. The third step includes increasing the assets of EPS with state-owned unused land and moving a considerable portion of the workforce from lignite mines to earthmoving tasks, as well as preparing land areas for biomass cultivation, infrastructure construction, and training. A gradual introduction of efficient transport systems is also planned. EPS will be immediately relieved of a portion of its wage bill, as the required investments will need to be financed separately. The fourth step is the development of a master plan for municipal waste management, assuming a single waste-to-energy and recycling hub with efficient and clean transport. This will relieve almost the entire country of waste disposal issues and landfills, offering a modern, modular solution. EPS needs to identify a partner for waste management and recycling and retain power generation. The fifth step focuses on deploying biomass-to-heat/power plants, with the subsequent decommissioning of lignite-fired power plants in an appropriate order.

As a result of the aforementioned 5-step restructuring plan, the power generation portfolio from 2022 will undergo radical changes by 2035, as described in Table 2:

There is going to be a reduction of 1,000 GWh in grid losses and another 1,000 GWh in electricity consumption in lignite mines. This energy will become available for commercial and industrial use.

Generation portfolio based on all relevant climate-neutral technologies supporting the restructuring plan, with exception of geothermal, intended to facilitate robust growth (CAGR=7%). It maintains energy security, reduces import dependency, increases efficiency in energy production, while preserving current headcount in EPS.

In the final year of projection (2035), the generation portfolio is going to provide about 14,000 GWh for residential and institutional use, about 30,000 GWh for industrial and commercial use, 4,000 GWh in network losses, and about 1,200 GWh for hydro pump storage. This provides twice the amount of electricity for industrial and commercial use compared to 2022.

Also, this generation portfolio provides ground (both in terms of grid flexibility and stability, as well as the robustness of governance and biogenic CO_2 management, to enhance the economics of nuclear power) and establishes the infrastructure prerequisites for the installation of at least 2,000-2,400 MWe of nuclear power plants from 2035 onward. Once installed, this capacity will serve commercial demand and further support economic development beyond 2035. Comprehensive standardization and adequate strategic partnerships are prerequisites for delivering this investment portfolio according to the agreed timeline, taking into account the supply chain issues currently

19 Actually, available resource. Immediate improvement in performance due to focusing on the best portions for a limited period of time.

20 Domestic natural gas production followed by the production of bio-methane from available agri residues.

21 Existing production assets, average production during 1990-2022 period.

22 Biomass resources. Requires 350,000-400,000 hectares for new softwood plantations.

23 Already agreed-upon utility-scale projects, plus residential domestic hot water production, are intended to relieve the load on the distribution grid and power generation system in the short term.

24 Existing plus new wind farms. The introduction of modern biomass and methane plants, combined with district heating models, resolves balancing issues and significantly increases grid connection capacity. This unlocks EUR 6-7 billion in private commercial investments.

Table 3: Investment portfolio for homegrown renewable energy system, period: 2025-2035

#	Project class	Power & Heat capacity (MWe; MWt)	Fuel	Investment (million €)	Investor	Carbon capture ready?	Carbon negative option?
1	Biomass Heat & Power plants	Power: 2800 MWe Heat: 4560 MWt	Biomass	**7840**	**EPS**	Yes	Yes
2	Methane power plants	Power: 800 MWe Heat: 1200 MWt	Natural gas, methane, bio-methane, e-methane	**800**	**EPS**	Yes	Depending on fuel
3	Waste-to-energy plants with recycling facilities	Power: 180 MWe Heat: 480 MWt	Combustible waste, more than 50% biogenic	**900**	**EPS**	Yes	Yes, >50%
4	Wind power	Power: 4000 MWe – 6000 MWe	Wind energy	5-6000	Private	N.A.	No
5	Solar power	Power: 2000 MWe – 3000 MWe	Solar energy	2000	Private	N.A.	No
6	Geothermal	To be considered	Geothermal heat	Unknown	Private	Yes	Possible
	Total dispatchable	Power: 3780 MWe Heat: 6240 MWt	98% Biogenic renewable	**9540**	**EPS**	Yes	Yes
	Total variable	6000-9000 MWe	Renewable	>7000	Private	N.A.	No

Source: Authors' estimates

experienced by key equipment vendors. Therefore, upfront planning is a key factor for success.

The summary long-term plan of generation portfolio is presented in Table 3. Of the total investment of EUR 9.5 billion, EUR 7.8 billion is to be allocated to biomass technology. This will involve eight units, each with a capacity of 200-500 MW, located in accordance with the electricity grid configuration, heat and power demand density, and the logistics of fuel supply. Four of these units will be located near the Kolubara thermal power plant. The minimal required volume of biomass per unit of energy makes this scenario feasible within the boundaries of available land, biomass production, and fuel wood use. Consequently, emissions of particulates, nitrogen oxides, or sulfur dioxide are nearly zero, making the flue gas suitable for carbon capture at an exceptionally low cost. This provides further opportunities to produce fertilizers needed for local agriculture and biomass growth.

The envisaged portfolio reduces waste in landfills across the country, air pollution in key urban areas, and the acidification of soils, erosion, floods, and landslides in the most productive regions. It requires the same level of employment as the current lignite portfolio, while offering somewhat higher remuneration to employees as a result of massive improvements in productivity and efficiency.

Biomass-to-heat/power plants and methane plants are suitable for non-recourse funding based on carbon credits and a commitment to close coal-fired power plants, as the scenario is more ambitious than the current National Energy and Climate Plan (NECP) [31] as required by existing EU regulations. No sovereign guarantees are needed. The dispatchable portfolio provides a foundation for long-term power offtake agreements, facilitating a portion of private wind power investments.

With such a portfolio, EPS could produce and sell approximately 40% more electricity and 12 times more heat with the same number of employees and lower maintenance costs, all while eliminating harmful emissions and achieving roughly 11 times lower material intensity. It may also generate higher revenues while providing more affordable electricity and heat to consumers.

Thanks to this energy platform, total primary energy supply could be reduced from 671,255 TJ to about 485,000 TJ, representing a reduction of 28%.[25] This is a consequence of structural change in energy supply. Further growth will be stimulated by competitive prices of electricity for industrial and commercial customers, as well as increased domestic spending due to reduced residential heating costs. Reduced dependence on natural gas imports will mostly contribute to a decrease in the current account deficit.

Last but not least, the electricity surplus could be used to simultaneously electrify new forms of transport and phase out conventional transport solutions. This can be achieved through the introduction of an effective urban rail system in Belgrade and the rollout of electrified rail services along the Subotica – Novi Sad – Belgrade – Niš axis, as well as a car-by-rail service Čacak – Kolašin in Montenegro. Furthermore, the electrification of public bus and taxi services could accelerate this transition.

25 For macroeconomic effects of this structural change, please consider [8].

Nota Bene

At the beginning of 2025, the global economy finds itself at a crossroads. During the polycrisis, structural imbalances, social fractures, and cultural tensions have deepened, expanded and exacerbated to intolerable levels. Efforts to mitigate such a complex, fast-moving and radical changes are increasingly influenced by geopolitics. Geopolitics promotes a mercantilist approach and leads initially to deglobalization and, subsequently, to re-globalization. Re-globalization, driven by geopolitical criteria, is fostering further fragmentation of the global trade and investments.

The scarcity of natural resources has become in spotlight. If there was ever an illusion of abundant natural resources, it has completely vanished with the measurement of World Overshoot Day. The disregard for natural boundaries and laws of nature, entrenched in the nexus of rules of market fundamentalism, has led to overconsumption. Socio-economic system in rules-based disorder without built-in corrective mechanisms and effective policy responses, is becoming increasingly self-destructive. As geopolitics increasingly serves as a macroeconomic variable, economic rational is losing its power. Given that the threat of so-called "2WMD" is intensifying, the key question remains: how long can the global economic powers sustain their dominance based on the neoliberal model, and which path will ultimately prevail, economic or non-economic?

The green transition is striving for a better normal, as crisis mitigation and the subsequent revival pave the way toward a net-zero point by 2050. Estimates suggest that achieving this goal will cost between USD 5 and 10 trillion per year globally [22], [29]. While projections are not destiny, this remains a substantial amount of money. Therefore, a reality check on the scale and profitability of green investment, and related financing model are necessary.

As Serbia faces a significant 30% energy output gap, it needs more energy to overcome its energy security challenges. At the same time, Serbia needs a quite different energy structure, a shift from fossil fuels to renewable energy sources. It is crucial to recognize that the phased-in of climate-neutral technologies, alongside the phase-out of lignite-based technologies, will ensure a reliable and adequately structured energy mix. We believe that biomass-based technology should be at the very center of Serbia's green energy transition in its initial stage, with nuclear energy taking on a central role in later phases. Nuclear energy will be pivotal for "to-be" scenario of economic development (CAGR = 7%), and beyond. A responsible roadmap for the green energy transition also requires regulatory measures such as carbon pricing, climate finance, and the issuance and trading of thematic securities.

Geopolitics is an important element in this endeavor. Serbia seeks EU accession but has not yet been fully integrated. Socio-economic movements within the EU are further energizing Serbia to commit fully to the green energy transition. The collective actions taken by the EU in the green energy transition could serve as a replicable blueprint for Serbia. The key goal of EU energy policy is to deploy a homegrown renewable energy system that is more powerful, diversified, and resilient.[26] In Serbia, much of the GHG emissions abatement before 2030 will be driven by the phase-in of existing technologies based on renewable sources (biomass, solar, wind, hydro, geothermal) with low-to-medium power potential. Beyond 2030, emissions abatement will rely on new technological solutions with medium-to-high power potential (green hydrogen, nuclear fusion, advanced nuclear fission, green ammonia, etc.), as well as energy and/or carbon capture/storage/utilization solutions. In addition to the imperative of compatibility with the EU, access to financing from the EU Green Deal and complementary initiatives from multilateral financial institutions also matter.

For such massive investments, macroeconomics has a role to play. In today's complex and ever-changing global context, the distinction between probability and predictability is widening, especially for a small, developing, landlocked economy on the EU accession path. Everything is relative, as significant achievements are tentative. Inflation, particularly core inflation, is a typical example. In economic theory, the question of how long headline inflation persists during a polycrisis remains largely unanswered, with tentative answers varying. For

26 For example, in 2024, solar energy overtakes coal in the EU energy mix for electricity generation.

developed and highly financialized economies, such as the US and the EU, the most reliable forecasts tend to show a downward trend with cyclical ups and downs. In contrast, developing and highly industrialized economies, such as China, are facing deflation due to overcapacity and lack of demand, both domestic and global. Deflation can often distress an economy even more than inflation. For Serbia, the lack of domestic supply, due to the energy output gap and dependence on global commodity markets, will likely increase inflationary pressures and exacerbate the energy security problem.

Also, reaction policies, primarily core policies like monetary and fiscal, are ineffective in addressing mainly imported inflationary pressures, as supply shocks and inflationary pressures are influenced by geopolitics, making them disconnected from economic logic. The combination of power shortages and rising inflationary pressures reduces growth potential of the real economy, negatively affecting all public sectors (healthcare, education, science, and public services).

In such a challenging and unpredictable global context, the big picture visionaries must recognize the necessity of "sustained sustainability" by carefully navigating global macroeconomic and geopolitical headwinds. In this strategic game, central monetary authority and treasury have distinct but complementary roles. Both are inspired by the same idea, a sustainable and inclusive economy, both toward people and toward planet. The proposed energy hub will consist of biomass technology and a lithium carbonate refinery on the same site where the phase-out of lignite-based technology will proceed gradually.

In this complex endeavor macroeconomic stability has role to play. Sticky prices have fueled expectations of further interest rate cuts in Serbia, which, in turn, encourage more investments. The legacy of the NBS's monetary easing policy in 2024 could lead to a slightly expansive monetary policy in 2025, which is a prerequisite for energizing investments in the green transition. The Treasury Department pursued an expansive fiscal policy, too. Building on last year's achievements, it is expected that a stronger stance will be taken on this policy platform, signaling an even more investment-friendly or expansive approach to monetary and fiscal policies in 2025. In this context, state-backed investments in energy infrastructure and solar energy could serve as an anchor in supporting this strategy.

Last not least, technology change is enabler of economic development. These days, the trends in cutting-edge technologies are profound. A dramatic leap in converging technologies across three key fields (information and communication technologies, industrial engineering, and biotechnology) has been accelerated by the evolution of specialized artificial intelligence toward general-purpose technology (GenAI – Generative Artificial Intelligence). With GenAI enhancing these converging technologies, they become "intelligent." The impact of such technology change on incumbents is profoundly disruptive, but it is chance for newcomers. These advancements and, in some cases, setbacks, have pushed socio-economic systems into a new era, known as the "Intelligent Age," as conceptualized by K. Schwab [36].

GenAI in Intelligent Age is the biggest technological game changer, with potential to reshape the economy, industries within it, and even the way people live and perceive themselves and society. Moreover, GenAI has ability to empower human cognition beyond biological limits, which, at the end of the day, can improve interpersonal relationships by shifting the focus from dominance to cooperation. Human superintelligence, emerging from the symbiosis of the biological brain and the silicon brain, could open up new avenues of development that go beyond technology alone. In this evolving context, collaboration is not only critical but also increasingly challenging. It requires redirecting human motivation from egoism toward collective well-being, A circular model of growth and a heterodox economic policy platform should make technology change implementable.

The ICT sector is Serbia's largest exporter, with exports amounting to roughly EUR 4 billion. This highlights the country's critical mass of talent and skill sets essential for the development of GenAI. To avoid the risk of creating a cascading effect of uneven distribution of new technological opportunities, Serbia has joined the Global Partnership on Artificial Intelligence (GPAI), an international initiative established to promote the responsible development and application of GenAI [18]. Serbia is excited about the

potential of GenAI to support the green energy transition. As a small country, Serbia should focus on small number of critical issues. The key challenge will be how quickly GenAI can be integrated into solutions that bring an entirely new level of efficiency and effectiveness in areas such as climate modeling for a net-zero future, green investment selection, capital blending, risk management, electrical grid optimization, energy and carbon capture and use, and other related issues. Increasing energy production to revitalize growth is crucial, as GenAI and data centers, as key infrastructure, will require substantial power. An additional challenge is the massive re-skilling, upskilling, retraining and relocation of workforce to match the emerging labor demand patterns [43, p. 133].

In recent times, the (geo)political context in Serbia has strongly undermined macroeconomic stability, as well as squeezed current fiscal space and build-up of funds for investments. Geopolitics (Kosovo issue and sanctions to Russi) and internal political polarization, intertwined together, are hindering the economy's ability to meet growth prospects. The costs of mediating internal political tensions (primarily, wage increases in the public sector and utilities, CAPEX/OPEX increases in local communities, funds refraction, etc.) are growing rapidly. The investment community is in a wait-and-see mode due to concerns over a potential breach of fiscal rules, particularly the 3% budget deficit target. A key explanatory detail of Serbia's strategy consistently implemented by policymakers for years, along with a fixed FX rate policy, a mix of prudential monetary measures, expansionary fiscal policies, and industrial policies for tradable sectors, is the sufficient quantum of FDIs. Is it realistic to expect a sufficient level of FDIs to maintain macroeconomic stability when (geo) political malaise is intensifying? Is it possible to keep the FX rate stable when current monetary reserves cover only 7+1 months of the trade deficit? Is it feasible to invest the huge amount of money required for the green energy transition when the current fiscal space has already been used as a counter-cyclical buffer? The simple answer to these questions is likely both "Yes" and "No," with "Yes" probably contingent on a (geo)political settlement.

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