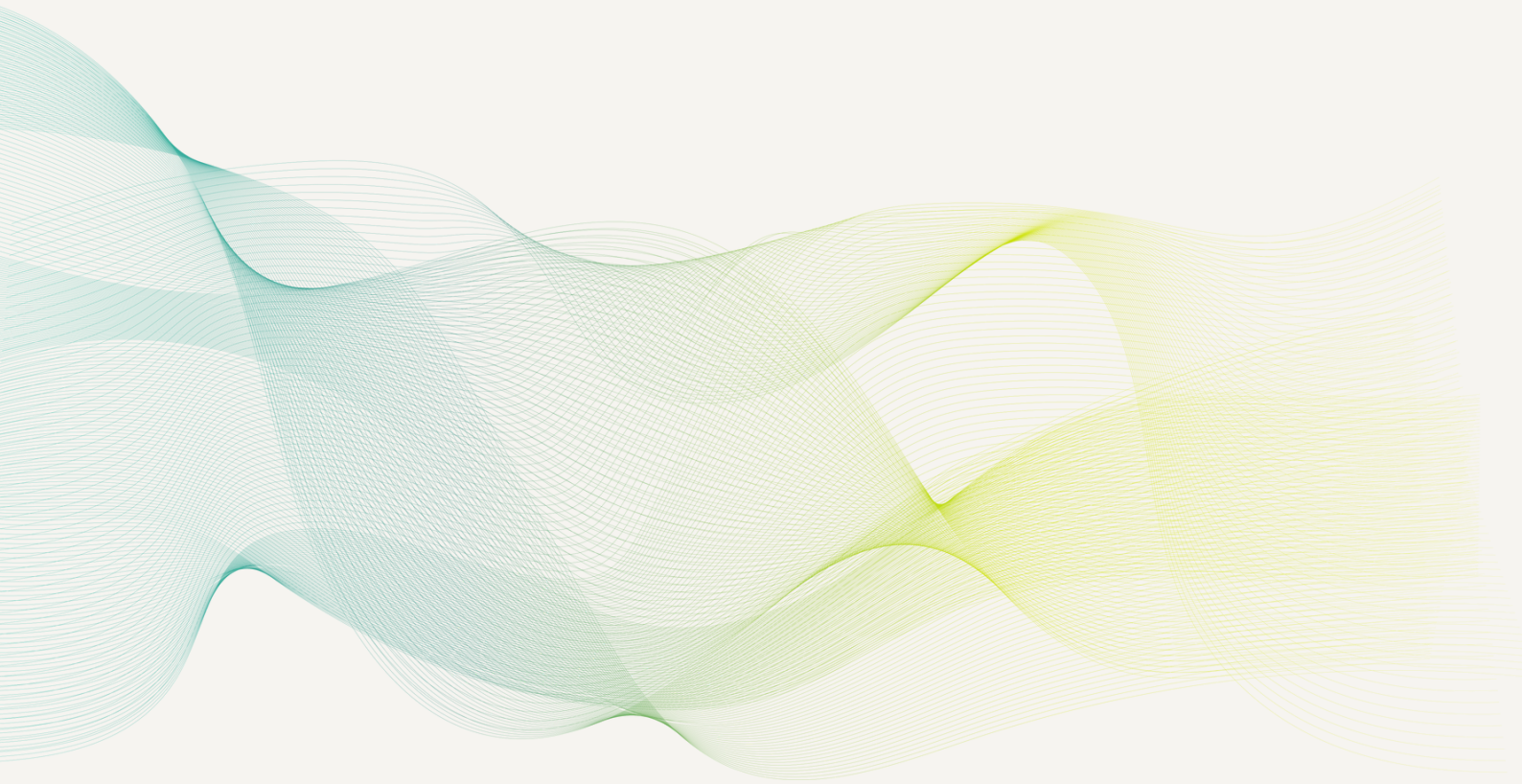
ASPEN INSTITUTE ROMANIA

ENERGY TRILEMMA.

THE TRIANGLE THAT KEEPS THE LIGHT ON

WHITE-PAPER FOR ASPEN ENERGY SUMMIT 2025



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I. INTRODUCTION

This white paper treats energy security, affordable and inclusive access, and sustainability as binding requirements for Europe's energy choices to 2035. In practice, security encompasses a diversified energy mix, robust grids, cyber resilience, and a strong clean tech supply chain. Access depends on predictable retail conditions and protection for vulnerable customers, supported by firm capacity and system flexibility. Sustainability means cutting emissions in a way that works with networks and with European industry, not apart from them.

The paper assesses Europe's exposures and strengths, sets out a trilemma-aligned power mix with the clean, firm capacity it requires, and proposes how Readiness 2030 and the SAFE loan instrument can embed energy security in grids, clean firm capacity, and cyber resilience. The aim is to align market rules, infrastructure, and finance so security, access, and sustainability advance together.

II. WHY THE ENERGY TRILEMMA MUST ANCHOR EVERY DECISION IN ENERGY

Europe's energy system is being rebuilt in real time. The lesson from the 2021–2023 crisis is blunt: there is no durable access or sustainability without security. The EU remains structurally import-dependent for energy, which exposes households, industry, and public budgets to external shocks and weaponised supply[1]. The EU has moved fast to diversify away from Russia and manage price spikes. Still, the core policy test for the next decade is whether every measure: market design, grids, fuels, clean-tech supply chains, will advance security, access (affordability and inclusion), and sustainability together.

Energy security. One of the main roles of an energy system is the ability to provide uninterrupted availability of energy sources at an affordable price. The EU learned in 2021–2023 that when one supplier can weaponise energy flows, the shock ripples through prices, industry, and public finances. Europe moved fast with storage targets, demand cuts, new LNG capacity, and rapid diversification[2].

[1] Eurostat, 2025, Shedding light on energy in Europe – 2025 edition
[2] European Parliamentary Research Service, 2023, EU energy security and the war in Ukraine: From sprint to marathon

Yet structural exposure remains. The following fault line is forming in clean-tech supply chains. A system that relies on China for battery cells, solar modules, wind turbines, and the refining of lithium, cobalt, and graphite builds new single points of failure across power, transport, and defence. The IEA reports that China produces the clear majority of these technologies and dominates midstream processing of key minerals, which turns commercial concentration into a security risk. Europe, therefore, risks trading dependence on Russian gas for dependence on Chinese rare earths and other critical inputs[3].

Energy security must be embedded in EU decision-making. Market design, grids, permitting, industrial policy, and external action all require a security-by-design approach, ensuring that access and sustainability are based on resilient fuels, technologies, and supply chains.

Access (affordability and inclusion). **In the trilemma, access means energy that people and firms can afford and that is available when they need it across regions and hours. Recent Eurostat data show a mixed picture. Household electricity prices in the EU were broadly stable through 2024, yet they remained above pre-crisis levels, and differences between Member States stayed wide[4]. Gas prices for households also rose again in the second half of 2024, which added pressure for many consumers[5]. Moreover, the social signal worsened. In 2023, 10.6% of EU residents reported that they could not keep their home adequately warm, up from the previous year[6].**

At the same time, the supply mix continued to shift. Renewables reached a record share of EU energy production in 2023 and increased their share in gross final energy consumption as well. These trends point to the core access challenge for the next phase of the transition[7].

The EU must keep bills predictable and the system dependable, while the generation mix changes. That requires policies which prioritise stable retail conditions, protect vulnerable consumers, and sustain investment in capacity and networks so new renewable output translates into reliable service for everyone.

Sustainability with system realism. **Decarbonisation must keep the lights on and support competitiveness, which means scaling clean generation together with the networks and supply chains that make it dependable. Europe has already expanded renewables at pace.**
In 2023, renewables supplied 45.3% of gross electricity consumption. The EU also reached 24.5% renewables in gross final energy consumption. These trends confirm that policy, permitting and investment can move the dial. They also underline why grids now decide outcomes. Ageing infrastructure and new connection queues will otherwise strand projects, raise curtailment and weaken public acceptance. The Commission's Grids Action Plan estimates €584 billion for transmission and distribution by 2030 and notes that roughly 40% of distribution networks are more than forty years old.[8]. Investing early in cross-border capacity, digital operations, system flexibility and cyber-resilience is therefore a sustainability policy and an access policy, not only an engineering task.

[3] International Energy Agency, 2023, Overcoming the Energy Trilemma. Secure and Inclusive Transitions
[4] Eurostat, Electricity prices for household consumers
[5] Eurostat, Gas prices for household consumers
[6] https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20250123-2
[7] Eurostat, 2025, Shedding light on energy in Europe – 2025 edition
[8] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX%3A52023DC0757

Finally, Europe must avoid replacing one dependency with another. Clean-tech manufacturing and critical-mineral processing remain highly concentrated in China, and the 2023 decision to require export permits for certain graphite grades showed how midstream chokepoints can spill into deployment timelines. The practical implication for Brussels is clear. Keep accelerating renewables, finance resilient and smart grids, and de-risk supply chains so that security, access and sustainability advance together[9].

Embed the trilemma in every climate action. **Climate policy that overlooks security or access stalls in politics and struggles in delivery. REPowerEU has already tied near-term security to faster deployment by setting gas-storage filling rules, coordinating demand reduction, and lifting the 2030 renewable target, while the EU moved to speed up permitting so projects reach the system faster[10]. The World Economic Forum reaches the same conclusion from a global perspective: durable progress comes when equity and affordability advance together with security and sustainability[11].**

For Europe, the translation is practical. Pair decarbonisation with price and income shields through long-term contracts, targeted support, and an efficiency-first approach, then build the adequacy, flexibility, and cyber-preparedness that keep the power system stable at high shares of variable renewables.

III. A TRILEMMA-ALIGNED EU ENERGY MIX

The European Union's energy balance still relies chiefly on fossil inputs in the overall system, while the power sector is decarbonising faster. In 2023, oil products accounted for 37.6% of gross available energy, natural gas 20.4%, solid fossil fuels 9.4%, renewables 19.5%, and nuclear 11.8%. On the electricity side, renewables supplied 45.3% of gross consumption in 2023. Coal accounted for 12% of EU electricity generation in 2023, while gas made up 17%[12].

In contrast, clean sources reached two-thirds of generation, and power-sector emissions decreased by 19% year-over-year. These trends reduce exposure to imported fuels and carbon prices, yet they heighten adequacy and flexibility needs as electrification and digital demand grow[13]. Provisional 2024 data indicate renewables near half of gross electricity supply, with nuclear about 23%, gas 16%, and coal 11%, confirming the structural shift but also the requirement for firm and flexible assets

[9] International Energy Agency, 2024, World Energy Outlook
[10] https://energy.ec.europa.eu/topics/markets-and-consumers/actions-and-measures-energy-prices/repowereu-3-years_en
[11] World Economic Forum, 2024, Fostering Effective Energy Transition
[12] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_statistics_-_an_overview
[13] Ember, 2024, European Electricity Review

Policy delivery must now close three gaps. First, grids and system flexibility. EU-level analysis shows integration limits without faster network build-out, more storage, and demand-side response. The Commission's grids plan and the IEA both point to higher grid and storage investment as a precondition for reliability at higher variable shares. Curtailment and winter adequacy risks can be managed with interconnectors, digital operations, and flexible demand products that shift load at peak times[14].

Regional interconnectors transform variability into stability, making prices less volatile for consumers. For Romania, priorities now in execution include the second 400 kV Oradea–Békéscsaba circuit on the Romania–Hungary border and the 400 kV Gutinaș–Strășeni link toward Moldova, while upgrades on the Trans-Balkan Electricity Corridor open a north–south spine that connects Serbia, Montenegro, and Bosnia and Herzegovina with Romania and Hungary[15]. ENTSO-E and ACER show that more cross-zonal capacity tightens price convergence, reduces volatility, and lowers congestion costs across the region.

Second, build a clean and firm baseload. **Nuclear remains the EU's largest single source of electricity by technology and rebounded in 2023 as French output recovered[16]. The system needs a dependable baseload to stabilise high shares of variable renewables; therefore, lifetime extensions where safe and cost-effective should proceed, and new nuclear projects should advance where financeable. These actions provide round-the-clock capacity, maintain adequacy with near-zero operational emissions, and lower exposure to imported gas during tight markets.**

The Black Sea can take the leading role and anchor this baseload for the CEE region. Neptun Deep is moving toward first gas in 2027, with volumes around 100 bcm and an expected plateau near eight bcm a year[17]. In efficient CCGTs and industrial CHP, this gas complements nuclear, sustains adequacy, and displaces coal-era emissions. In Europe's market design, gas-backed capacity still provides a reliability hedge and can be procured through capacity mechanisms that carry binding emissions limits. That links security to decarbonisation rather than setting them apart. Not the least, the Black Sea green corridor, roughly 1,100 km of 525 kV HVDC from the South Caucasus to Romania and onward to CEE, creates the import–export valve to scale these resources.

Third, close the flexibility gap. **The EU power system lacks sufficient dispatchable capacity to cover peak demand and multi-day periods of low wind and solar generation, while storage, interconnection, and demand-side response scale. Capacity mechanisms must procure fast-ramping, high-efficiency units to meet winter adequacy targets, with binding emissions-intensity limits, availability obligations, and planned year-on-year reductions in operating hours. In parallel, rapid deployment of batteries, demand response, and targeted grid reinforcement reduces the shortfall each year, so gas utilisation declines in line with the decarbonisation path[18].**

[14] International Energy Agency, 2024, World Energy Outlook
[15] Transelectrica, 2024, RET Development Plan 2024–2033
[16] Ember, 2024, European Electricity Review
[17] https://www.omvpetrom.com/en/news/omv-petrom-and-romgaz-announce-the-decision-to-develop-neptun-deep-the-largest-natural-gas-project-in-the-romanian-black-sea
[18] Ember, 2024, European Electricity Review

Putting the trilemma into the energy mix means a balanced portfolio. **Raise wind and solar where they are cost-effective, supported by accelerated grid reinforcement and added cross-border capacity. Maintain existing nuclear through life-extension and, where projects are financeable, add new nuclear to provide clean, firm baseload and system services. Retain gas-fired capacity to ensure flexibility and security of supply, planned mainly for peak coverage rather than continuous operation, with a pathway of lower annual utilisation as storage, demand response, and interconnection scale. Expand storage across short, medium, and long durations and deploy demand-side response at volume in industry and buildings.**

With these elements in place, the system meets extreme temperatures and intraday peaks, manages multi-day periods of low renewable output, and keeps retail conditions predictable while emissions fall. Evidence from EU data and international assessments indicates this direction is feasible if infrastructure, market design, and firm-capacity decisions integrate the principles of the energy trilemma: security, sustainability, and affordability[19].

IV. ENERGY SECURITY MEANS READINESS

Readiness 2030 and the SAFE loan instrument aim to raise European defence readiness by improving financing conditions for priority capabilities and industrial capacity. Energy security should be part of this agenda. Reliable electricity, resilient grids, secure fuels, and protected corridors are enabling factors for operations and for the defence industrial base. European policy already recognises that energy and other critical infrastructures are central to resilience during crises. NATO frames secure and resilient energy supplies as essential to the Alliance[20]. The joint EU–NATO assessment highlights that energy networks are frequent targets in hybrid confrontation[21]. What is left is just to put our money where our mouth is.

Including energy security in Readiness 2030 and SAFE would rest on clear evidence. **The European Union remained structurally import-dependent for energy in 2023, with an import dependency rate of 58.4%. Exposure to external shocks raises costs for public budgets, defence producers, and logistics in a contingency.**

System needs are quantified. The EU Action Plan for Grids estimates around €584 billion in electricity-grid investment by 2030 and reports that about 40 percent of distribution assets are more than forty years old.

[19] International Energy Agency, 2025, Global Energy Review
[20] https://www.nato.int/cps/en/natohq/topics_49208.htm
[21] https://commission.europa.eu/system/files/2023-06/EU-NATO_Final%20Assessment%20Report%20Digital.pdf

Underinvestment in transmission, distribution, cross-border capacity, flexibility, and cyber-resilience can turn a local fault into a wider disruption[22]. Clean-tech supply chains and midstream processing are also concentrated in a few countries. That concentration creates potential chokepoints for equipment and components that defence suppliers increasingly rely on.

A practical way forward is to create an energy-security window within the Readiness 2030 and SAFE framework. **The window would co-finance dual-use projects with direct readiness value and would complement existing EU and national instruments.**

Three components should be eligible to ensure continuity of operations under high-stress contingencies. First, nuclear and low-carbon gas-fired power plants that serve defence industrial clusters and key ports. Projects should include black-start capability and islandable microgrids. Second, grid resilience where it matters most. This means cross-border interconnectors on NATO corridors, hardened and segmented substations, and modern protection and automation, so new renewable capacity translates into dependable service during stress. Third, cybersecurity for electricity and gas systems. Priorities include real-time monitoring, intrusion detection, incident response, and joint exercises between operators and defence authorities.

These interventions align with the existing Readiness 2030 objective to raise credible readiness, while SAFE provides a loan vehicle that can reduce financing costs and speed delivery.

V. CONCLUSIONS

Make the transition shock-proof by design. Europe now needs delivery at scale and with discipline, which means building the networks and the digital operations that can move power where needed, adding firm capacity that holds the system stable when wind and solar are low, shielding households and industry through credible long term hedges, and diversifying clean tech and critical mineral chains so that a disruption in one link does not stall deployment across the whole economy.

These measures reinforce one another when policy treats security and affordability as integral parts of climate action rather than as afterthoughts, and when institutions translate that view into market rules that put adequacy and flexibility at the centre, into faster cross-border and distribution upgrades, and into routine cyber preparedness for electricity and gas systems. The same logic supports a focused energy security window inside Readiness 2030 and SAFE that can co-finance dual-use assets, from hardened substations and strategic interconnectors to islandable clean power near industrial clusters and system-wide monitoring and response.

If Europe treats the trilemma as a set of binding requirements rather than a menu of trade-offs, it can keep bills predictable, cut emissions, and raise resilience at the same time.

[22] European Commission, 2023, EU Action Plan for Grids

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