DISCUSSION PAPER

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Building Economic Security into Europe's Clean Energy Agenda

Eight Recommendations for Europe's Net-Zero Course Correction

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Credit: CANVA

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ACKNOWLEDGEMENTS / DISCLAIMER

This Discussion Paper is part of the EPC's strategic project on the EU's economic security, currently running under the umbrella name of the Brussels Economic Security Forum. It is the product of two dedicated roundtables held in spring and autumn 2024, followed by a range of workshops, interviews and discussions with policymakers, industry practitioners and experts.

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A full list of partners can be found on the project's website: https://economicsecurity.epc.eu

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Executive summary

A European consensus may still exist on the end goal of climate neutrality, yet there is no such consensus on the political, economic and social choices required to reach it. Each possible pathway carries a distinct set of costs and trade-offs across the **energy trilemma of sustainability, affordability and security**.

An excessively benign reading of the international environment, political and economic negligence and a **lack of sufficient action on key parameters of the trilemma have put Europe on a decarbonisation trajectory of high prices and low security**. This has become increasingly untenable. The long-term reliance on Russian natural gas was a fateful symptom of this predicament but is not a stand-alone example. **Europe's situation is currently aggravated by a series of equations that do not compute**, with targets being set not matched by the required efforts and investments across core areas of Europe's ambitions, such as wind, hydrogen, nuclear, net-zero manufacturing and energy efficiency. Europe is, consequently, on paths towards **endpoints that are inconsistent with the EU's Fit for 55 and 2040 climate scenarios**.

All too often, the EU's energy choices have been an outcome of inner-EU compromises, rather than a reflection of the long-term strategic approach. All this is happening in a **stormy international environment**, with President Trump abandoning international cooperation and climate ambitions while China's overcapacities are taking global economic relations to the brink. Consequences are bound to be dire. Unless **yearly energy system investments can be significantly ramped up**, suggestions that Europe can no longer pursue its 2050 net-zero objective at the expense of **cost competitiveness and economic security** will only get stronger.

Europe should not abandon its net-zero ambitions, but a significant course correction is required. Building on the former European Central Bank President Mario Draghi's call for a joint approach to decarbonisation and competitiveness and adding an economic security perspective, this paper proposes **eight recommendations for Europe's net-zero course correction**. We argue that the best course of action for Europe is to gain 'escape velocity' on the green transition: **prioritising cost-effective investments in clean industry and energy infrastructure**, which are essential to enable a transition to clean energy.

While the competitiveness debate tends to focus on the more immediate ways of activating growth, **economic security encompasses a broader, forward-looking framework that emphasises resilience**. This includes managing risks, reducing dependencies, and preparing for potential disruptions. Staying on track toward achieving net-zero emissions by 2050 must remain Europe's overarching objective, coupled with a parallel goal of optimising economic value-creation and reducing the cost, uncertainty and risks of the energy transition.

EIGHT RECOMMENDATIONS FOR EUROPE'S NET-ZERO COURSE CORRECTION

1. Prioritise and coordinate large-scale investments to achieve 'escape velocity' in the energy transition.

Europe is in the paradoxical situation of needing significant investments to accelerate its energy transition towards reduced emissions, lower prices and more security, but bound to encounter difficulties in facing the price effects of electrification and upfront grid investments in a transition period. The public-private investment shortfall in Europe stands at 2.6% of GDP. **European-wide coordination of large-scale investments is therefore a precondition of solving Europe's energy trilemma.**

2. Set realistic targets and priorities using foresight and analysis recognising the interdependencies between policy levers at EU and national levels.

All too often, Europe's energy choices have been the outcome of unrealistic policy targets and inner-EU compromises, rather than a reflection of foresight, analysis and a long-term strategic approach to the energy trilemma. **The clean energy transition needs to rely on updated objectives that are balanced, evidence-based and implementable** within an economic security perspective.

3. Double down on electrification through proactive technology-neutral supply policies, grid investment, strategic industrial policy and enabling frameworks.

Active, cost-effective supply policies and an accelerated electrification are the only means to structurally lower costs and ensure a stable supply of affordable energy, as free as possible from exogenous shocks. As REPowerEU and NextGenerationEU are phased out, the EU should agree on a 2040 investment programme coordinating investments and planning in support of electrification, including **an 'EU electrification and competitive decarbonisation bank' funding high impact projects chosen through Europe-wide competitive bidding**. In parallel, an enabling regulatory framework is needed both as regards accelerated permitting and energy taxation.

4. Elaborate and implement a dedicated 'masterplan for energy system flexibility, grid investment and energy storage'.

Europe's network faces significant coordination and planning issues that contribute to driving up investment costs. **More centralised planning as well as intelligent grid and redundancy management**, including through AI optimisation, **are needed to avoid excessively high network tariffs for end users**. Flexibility, storage and demand management opportunities should similarly be considered and prioritised within the EU flexibility masterplan.

5. Anchor the Clean Industrial Deal on an 'economic security yardstick' involving strategic funding for European ecosystems, enabling infrastructure and necessary shielding.

The EU's future Competitiveness Fund should provide equity for a series of public-private 'sub-funds' crowding in private capital and investment towards the critical clean tech ecosystems currently developed by the EU's Industrial Alliances, mobilising fully also the risk reduction potential of the European Investment Bank (EIB) and National Promotional and Investment Banks (NPIBs). Competitive frameworks remain paramount, yet given the overbearing pressures of distorted global competition, **early-stage technology developments and industrial scaling must be actively shielded by appropriate trade policy measures** and supported by "buy European" policies.

6. Factor in nuclear power investments as an essential component in Europe's net-zero scenario.

Safe lifetime extensions of Europe's existing fleet of reactors are critical to meeting Europe's future energy mix scenarios. In parallel, "new nuclear" could play an important role in Europe's future low-carbon energy supply provided the levelised cost of electricity (LCOE) can be kept competitive with other clean power sources.

7. Strengthen single market coordination, price differentiation and investment incentives while expanding long-term contractual solutions.

The 2023 Electricity market reform rightly balances free price setting to develop energy system flexibility with contractual solutions providing price and investment stability. ACER's ongoing **bidding zone review must lead next to better price differentiation in the internal market**, starting with multiple price zones in Germany to address significant inefficiencies and unreasonable price contagion across borders.

8. Develop a comprehensive energy system risk management approach.

China's dominance of the clean energy supply chains and Russia's cyber threats to energy infrastructure testify to the vulnerabilities that the EU policymakers must address. To enhance resilience, **the EU must prioritise strengthening cyber-physical infrastructure**, operationalise the proposed Critical Raw Materials Platform, and pair it with a system of stockpiling to mitigate supply disruptions.

1. Introduction

As emphatically shown by the 2022 energy crisis, **accelerating the transition towards clean energy systems is a matter of vital strategic importance to the EU**. The explosion of European energy prices,[1] especially after Russian invasion of Ukraine,[2] underlined the fundamental threat of the dependence on fossil fuels not only to overcoming climate change, but also to EU competitiveness and a secure economic future.

European energy choices have all too often reflected European misalignments at the expense of a long-term strategic approach to the energy trilemma.

As long as Europe is dependent on imported oil, coal and gas, it will remain exposed to similar supply and price shocks in the future. As recognised by Mario Draghi's report on "The Future of European Competitiveness", **in the absence of a successful transition, Europe's economy will continue to suffer from a competitive disadvantage of higher energy costs** compared to the other main economic players.

BOX 1: OVERCOMING EUROPE'S ENERGY TRILEMMA

Countries and energy systems face competing and often conflicting goals in their pursuit of sustainable energy solutions. The "energy trilemma" highlights the inherent tension between the following three objectives:

- **Energy security:** ensuring sufficient access to energy to meet current and future demand in a reliable manner.
- **Energy sustainability:** decarbonising the energy supply to remain below the global limit of a 1.5-2 °C temperature increase compared to pre-industrial levels, as agreed in the Paris Agreement, and ensuring sustainable use of resources in line with the UN Convention on Biological Diversity.
- **Energy affordability:** providing universal access to energy for both households and companies, at a fair and internationally competitive price.

What these mean in practice, and the trade-offs involved, will depend on the specific context and geography under consideration. An import-dependent region like Europe will interpret and pursue these in a radically different way from a resource-rich region like the Middle East. Advancing on one objective can result in a cost for (one of) the other two. As such, **finding the optimal balance between the three dimensions becomes an essential goal of the green transition**.

This is not to say that renewable energy sources come without risks of their own from the point of view of economic security. **Critical infrastructure faces direct threats,** the **availability of – and access to – scarce raw materials** needed in renewable energy supply chains remains uncertain, and the **manufacturing of green tech** and its various components is subject to geographic concentration and systemic dependence on China. All these are elements of a new and complex risk picture that Europe is insufficiently prepared for.

The geopolitical implications of the energy transition and associated risks of economic coercion are considerable. In today's increasingly shock-prone and fiercely competitive world, approaching these with the necessary strategic acumen and foresight will be indispensable to avoid the mistakes and failings of the past in addressing the trade-offs inherent in Europe's energy trilemma.

The transition towards net zero is an indispensable effort to address the challenge of climate change and place the European and global economies on a sustainable footing. **The risk of the Paris Agreement's net-zero scenario not materialising by 2050 has become substantial**, due to a combination of factors, including US President Trump's commitment to oil and gas production, global coordination challenges, geopolitical tensions, weak carbon markets, investment shortfalls, and deployment bottlenecks.

Potential delays in meeting the net-zero objective by 2050 would generate substantial economic, environmental and societal costs. As more drastic measures would be required to make up for this in the future, the overall cost of achieving net zero and of climate adaptation would also increase. The longer action is postponed, the more severe and costly the consequences of extreme weather events, climate-related health impacts, water scarcity and loss of biodiversity become. From this perspective, **a timely completion of the net-zero transition is an important economic security objective**.

Another vital consideration concerns **Europe's choice of a net-zero scenario and the specific pathway to achieve it**, which will have significant implications for the pace of emission reductions in the 2030s and 2040s. The pathway to net zero is shaped by a combination of base conditions, such as access to renewable energy sources and population density, and fundamental political economy choices, including industrial and trade policies as well as strategies for managing geopolitical exposure and risk.

In the past, **European energy choices have all too often reflected European misalignments** and the purpose of reaching an inner-EU compromise **at the expense of a long-term strategic approach to the energy trilemma**. Building on the Framing Paper of the EPC's Europe's Economic Security Project, this paper calls for a course correction aligning the clean energy and economic security agendas to ensure that the green transition is achieved in a way that enhances long-term EU competitiveness and security.

2. Europe's predicament: decarbonisation with high energy prices and low security

2.1. EUROPE'S UNENVIABLE SITUATION OF EXCESSIVELY HIGH PRICES

Without question, **Europe has made significant strides in speeding up the green transition in response to the energy crisis**. Under **REPowerEU**, launched in May 2022, energy savings, diversification measures and the roll-out of renewables all constituted core components of the EU's response.

The combination of **policy actions and market responses played an essential role in absorbing the 2022 supply shock, leading to a drastic reduction of the energy dependency on Russia**,[3] and a spectacular drop in European electricity and gas prices from their peak levels in the crisis, albeit not to the level seen in other global markets, notably those of the US and China. It has also sizeably contributed to advancing the process of decarbonisation.

Symbolically, **solar energy overtook hard coal in the EU's electricity generation for the first time in 2022**, with 210 TWh of solar energy produced compared with the 205 TWh from hard coal (anthracite) and 241 TWh from brown coal (lignite).[4] The EU coal production and consumption decreased to their lowest recorded levels, according to preliminary data from 2023, with a 22% year-on-year drop, in spite of a sharp increase in hard coal imports, due to stockpiling.

BOX 2: CLEAN ENERGY SHOCK THERAPY: HOW EUROPE ANSWERED RUSSIA'S ENERGY WAR[5]

Russia's attempts at weaponising Europe's energy dependence in the context of the invasion of Ukraine failed because of a combination of ambitious policy actions and market responses:

- **Energy-saving efforts** by households and industry contributed to demand cuts similar to those seen during the most severe Covid-19 lockdowns, with an 8% fall in EU electricity demand in the final months of 2022.[6] Additionally affected by economic stagnation, **natural gas demand** fell by 125 billion cubic meters (bcm) between August 2022 and March 2024, equivalent to an 18% drop, overshooting the voluntary 15% REPowerEU target.[7]
- **3 million heat pumps** were installed across Europe in 2022 alone, together with maintenance of the already installed stock resulting in almost 164,000 man-years of employment.[8] The trend has since radically changed, with a large fall in heat pump sales in Europe in the first half of 2024.
- In parallel, EU **solar power generation** rose by more than half over the past two years, producing 9% of Europe's electricity in 2023 compared to just under 6% in 2021.[9] The share of **wind** in the European power mix increased to 18% last year, overtaking natural gas for the first time.[10]

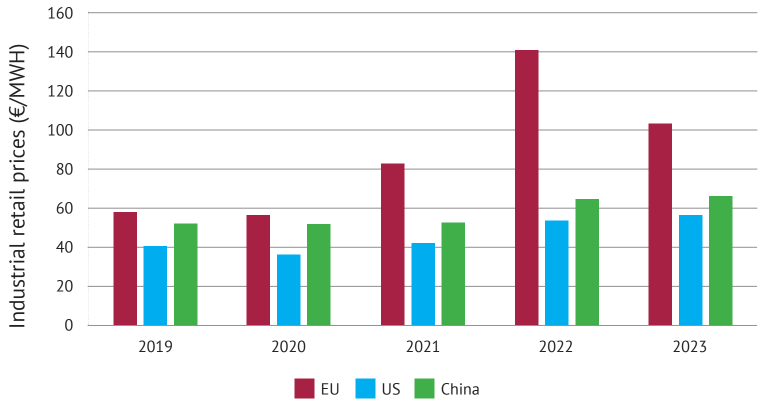
Europe has made significant strides in speeding up the green transition in response to the energy crisis.

The **Electricity Market reform** proposed in March 2023 aimed to further enhance energy security, protect consumers from price volatility, and accelerate the transition to renewable energy. While much of the political debate initially focussed on decoupling electricity prices from gas prices, discussions swiftly moved on to focus on **addressing disproportionate price effects and volatility** through other measures, as viable economic alternatives to marginal pricing and today's pay-as-clear market are hard to engineer.

In the end, the reform addressed the conundrum of **encouraging investments and making electricity prices more reflective of the cost of renewables** by proposing long-term stable price mechanisms like Power Purchase Agreements and Contracts for Difference. The reform also pointed to the need for **increased energy system flexibility** through grid development, demand response mechanisms and energy storage solutions in the context of the steadily increasing integration of renewable energy.

Figure 1

ESTIMATED ELECTRICITY PRICES PAID BY LARGE INDUSTRIAL CUSTOMERS (IN EUR/MWH)



Source: International Energy Agency (2024), "Electricity 2024: Analysis and forecast to 2026", Paris.

These reforms notwithstanding, **energy prices in the EU remain notably higher than those in many other parts of the world**. The price gap between the EU with its main competitors that existed already before the war has further widened, in tandem with other major gas-importing economies like Japan, South Korea and the UK, which have suffered a similar fate.[11] Despite declining by over a third compared to the year before, the 2023 EU electricity prices for energy-intensive industries were over 80% higher than in the US and around 55% higher than in China, compared to respectively 45% and 12.5% higher in 2019 (see Figure 1).

Not only is the EU at a disadvantage with respect to the energy costs today, it is also projected to maintain that unenviable position in the coming years, with some 2030 forecasts indicating that **European wholesale electricity and gas prices could remain twice as high as prices in the US** (see Figure 2). While on the one hand high energy prices provide a stronger investment case into low-carbon energy, on the other they affect profit margins of companies across all industries impacting on their ability to fund their green investments.

European energy-intensive industries are particularly exposed to high prices given t**he prospect of higher carbon emission costs with the full implementation of the EU Emissions Trading System** (ETS). The latter is meant to involve stricter carbon emission caps, expansion to additional sectors or phase-out of the free allowances introduced to prevent "carbon leakage" as industries relocate to regions with laxer climate policies.

Recent research by the European Central Bank (ECB) analysts has shown that **less energy-dependent firms have managed to restore their profit margins after the price shock, but energy-intensive firms have not**. Their emission reductions have been a function of declining output, rather than improved carbon efficiency.

If the greening of production is not successful, there is a real risk that the stated goal of the ETS of balancing emission reductions with continued economic growth could be undermined. To prevent "brown zombies" from emerging, "vast investment in carbon efficiency of the industrial sector" will be needed, it is argued.[12]

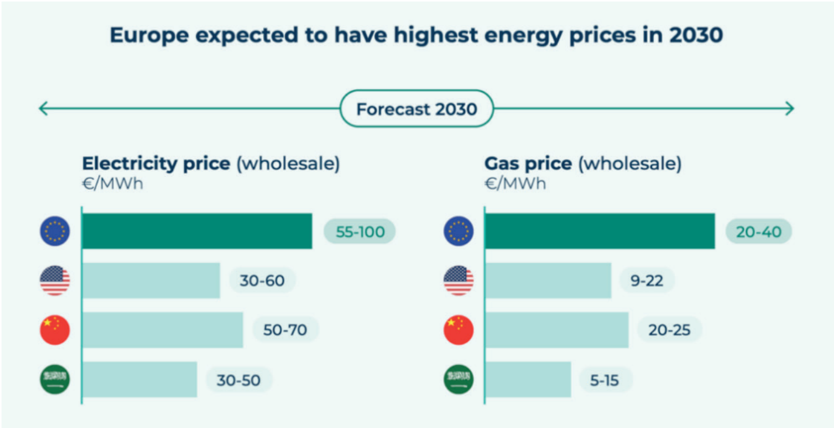
European wholesale electricity and gas prices could remain twice as high as prices in the US.

As the International Energy Agency (IEA) has observed, the hydropower-dominated Nordics remain the only market in Europe with average wholesale electricity prices comparable to those in the US, China, Australia and the Gulf.[13] **Stable cheap electricity in turn engenders future-oriented green industries that are critical in overcoming the energy trilemma.** An example is Sweden's HYBRIT Project, a collaboration between steelmaker SSAB, iron ore producer LKAB, and utility Vattenfall, that uses hydrogen produced via renewable electricity, primarily from Sweden's hydropower resources, to produce green steel.

Projecting future prices is always an uncertain exercise. **The 2024 IEA World Energy Outlook suggests the global energy transition is going too slow for climate targets to be met but at a fast enough rate for important price effects.** This occurs as renewable energy becomes cheaper once upfront investments are made and also, critically, because fossil fuels could soon go into oversupply.[14]

Figure 2

EXPECTED EVOLUTION OF ENERGY PRICES IN EUROPE TOWARDS 2030 (IN EUR/MWH)



Source: European Round Table for Industry (2024), "Competitiveness of European energy-intensive industries", Brussels.

Europe stands to benefit from these dynamics but likely insufficiently so, notably as the cost of upfront grid investment and electrification will be substantial and will lead to high network tariffs for end users, making the transition financially challenging. Europe is in the paradoxical situation of needing significant investments to accelerate its energy transition towards lower prices but bound to encounter difficulties in facing the price effects of these investments in a transition period. **European-wide coordination of investments is therefore a significant factor in solving Europe's energy trilemma.**

2.2. EUROPE'S DECARBONISATION HAS NOT FACTORED IN THE COST OF SECURITY

Over time, high prices and unfavourable competitive positions translate into economic security risks. Industry, in particular energy-intensive industry, tends to relocate close to sources of affordable energy. Given the high energy requirements of production, mature industries such as aluminium and chemical production have increasingly shifted internationally into the vicinity of abundant renewable energy. The same goes for the establishment of emerging critical clean tech supply chains, such as in hydrogen, green steel, fuel cell and wafer production, and increasingly also deep tech such as advanced semiconductor manufacturing.[15]

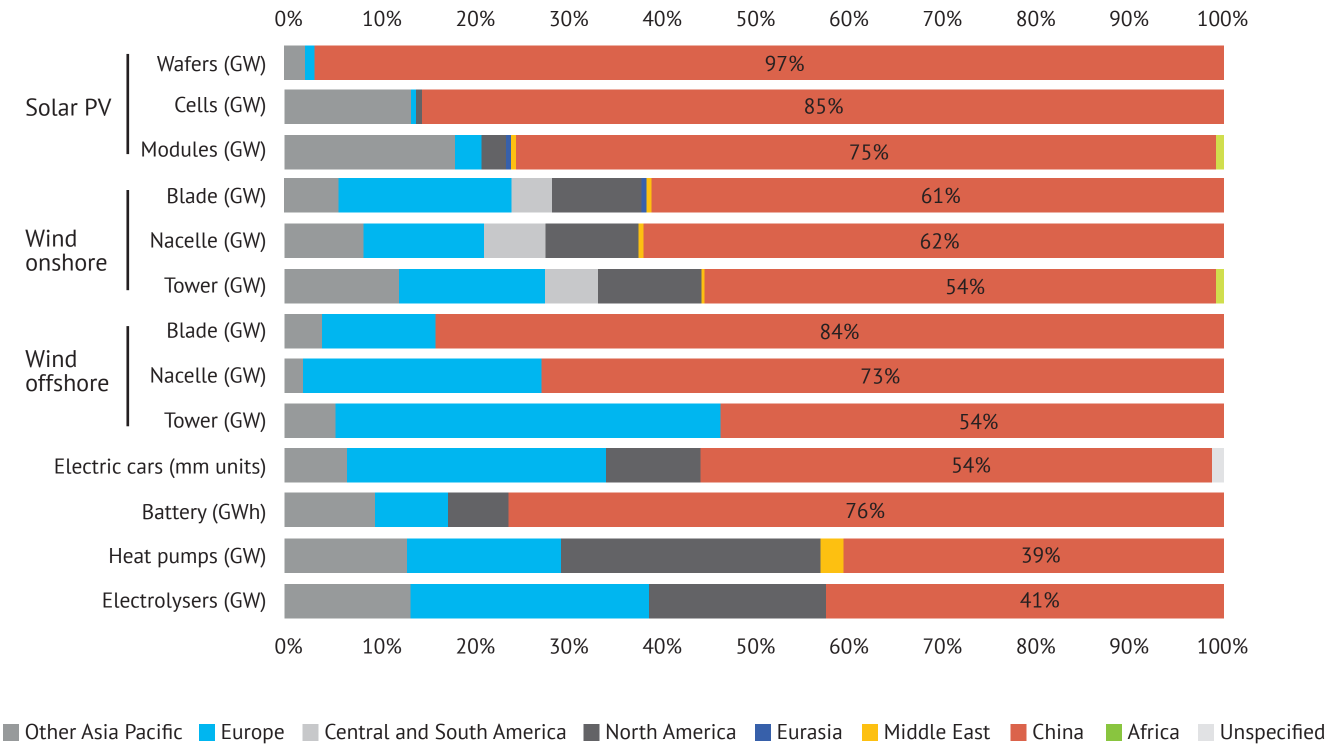
The European Commission's monitoring of EU strategic dependencies and vulnerabilities has identified 204 product categories characterised as foreign dependent in strategic ecosystems.[16] A number of these fall in energy intensive sectors such as chemicals and allied industries (43%). A case in point is magnesium production for which the EU has become 95% import dependent on China after losing its smelters to subsidised lower cost competition in the early 2000s. It is a dependency Europe might come to rue as Chinese policies now place production limits on this raw material that is essential to automotive, aircraft and defence industries.[17]

Over time, high prices and unfavourable competitive positions translate into economic security risks.

Rather ominously, China accounts for more than half of Europe's dependencies in value terms and **Europe's clean energy transition is itself largely reliant on China's productive capacities – and willingness to export**. World mass-manufacturing capacities for climate technologies are currently heavily concentrated in China, whose market share exceeds 95% in the upstream production of wafers for solar power, surpasses 90% in anode and 80% in cathode material used in batteries as well as 80% in wind turbine blades (see Figure 3).[18]

Figure 3

CLEAN TECHNOLOGY MANUFACTURING CAPACITY BY REGION, IN PERCENT (2021)



Source: European Commission, 2024. Based on IEA, Bruegel.

China's rise is undeniably a story of growing geoeconomic leverage with potentially far-reaching strategic and economic security implications. Since 2020, China has withheld exports of graphite, a key raw material in today's battery technologies which are crucial for the clean energy transition. Europe's once up-and-coming – now failing – battery giant Northvolt is among the players that were exposed to these pressures. Behind its troubled position, there likely also lies a Chinese strategy to keep Europe's fledgling battery value chain down while Chinese competitors establish themselves internationally and in Europe.[19]

China's rise is undeniably a story of growing geoeconomic leverage with potentially far-reaching strategic and economic security implications.

These are not the only security risks that are weighing on Europe's energy system and transition. **Most prominently and immediately, there is Europe's continued dependence on Russia, and the threat it poses.** With EU sanctions banning seaborne imports of Russian crude oil and refined petroleum products (as well as Russian coal), imports of Russian pipeline and LNG gas have dropped from a 45% share in 2021 to 18% of overall EU imports up to August 2024. Norway and the US have become the EU's largest gas suppliers – for pipeline and LNG gas respectively – providing 34% and 18% of EU gas imports in the first half of 2024.

At the same time, Russian intimidation, interference and direct threats spill over into other dimensions and areas of Europe's decarbonisation. A striking example of the trade-offs and dire bind Europe finds itself in was given recently by the **decision of the Swedish government to cancel 13 offshore wind projects**, with a total capacity of almost 32 GW and representing possible investments of up to €47bn. The decision was directly linked to **security concerns** citing "unacceptable consequences for Sweden's military defence" (see Figure 4).[20]

As these examples highlight, there is a substantial difference between the costs of selecting and executing different net-zero scenarios with their related pathways. Currently, **the EU is on a trajectory towards phasing out fossil fuels with high energy prices and low security.** While this is a perfectly credible way of reaching net zero from the climate policy perspective, it comes with new challenges such as high capital cost and intermittency of renewables, and dependence on climate technologies and critical materials from countries like China.

Figure 4

OFFSHORE WIND PROJECTS IN THE BALTIC SEA CANCELLED DUE TO SECURITY CONCERNS

Source: The Swedish Government; WindEurope (2024), "Sweden puts its industrial competitiveness and energy security at risk".

A combination of **structural, geopolitical, market and environmental factors** has led to this situation, as well as policy choices made by the EU and its member states. Europe is not as strongly endowed in natural resources as some other continents, but its present predicament also arises from a **decades-long lack of strategic anticipation, security thinking and investment**. The long-term reliance Germany built up upon Russian natural gas is a prominent example, but not the only source of failure within Europe's energy policies.

Significant uncertainty remains as to whether Europe can meet its ambitions and simultaneously address the deep trade-offs involved in the energy trilemma. In an international context where China, and now likely the US, forcefully pursue security and competitiveness at the expense of the climate, **Europe has the choice of either gaining 'escape velocity' towards net zero or remaining trapped in the environment of high energy prices and low security.**

Given the numerous pressures on the European position, a maximum effort now needs to be focused on the necessary course correction. This will require, in particular, more coordinated and "security-minded" investment in low-carbon supplies as well as in the grids, flexibility and storage needed to enable the growing uptake of renewables. Unless yearly energy system investments are now significantly ramped up, Europe will no longer be able to pursue its 2050 net-zero objective at the expense of cost competitiveness and economic security. Conversely, under the right conditions, every gigawatt of additional installed low-carbon capacity in the EU will render Europe economically more secure and bring closer the prospect of a structural lowering of prices.

RECOMMENDATION 1: PRIORITISE AND COORDINATE LARGE-SCALE INVESTMENTS INTO EUROPE'S ENERGY SYSTEM TO ACHIEVE 'ESCAPE VELOCITY' IN THE CLEAN ENERGY TRANSITION

To align its past and future decisions on emission reduction targets and funding frameworks, the EU needs to take a strategic commitment to a net-zero pathway that prioritises lower energy prices and greater security against exogenous shocks. **Currently, the price and security dimensions of the net-zero transition remain an afterthought – this must change.**

In practice, the approach would require **prioritising and coordinating large-scale investments and incentive mechanisms** designed to progressively reduce energy costs while strengthening energy security. Committing to 'escape velocity' would mean embracing an **accelerated and efficient electrification** and the cost-effective integration of renewables and low-carbon sources into EU energy systems, as well agreeing to **address thoroughly the associated security considerations**, including mounting threats to infrastructure, geographical concentration and dependence on critical raw materials and technology.

3. Course correction needed on Europe's path to net zero

In a long list of reasons, **decades of underinvestment in the energy transition and its associated low-carbon technologies and grids as well as in energy savings and efficiency** hold much of the blame for Europe's excessive price and security exposure today. In fact, Europe is just emerging from a decade of historically low investment in its energy system, amounting to a mere 1.7% of GDP in the period 2011-2020 compared to the 3% or more that would be required.[21]

Although renewables overtook fossil fuels to become the main source of electricity in the EU in 2020 with 38% of electricity generation, the **scaling up of renewable technologies has been too slow** for Europe to lead in the international competition for cheap energy and clean tech manufacturing. In parallel, hydropower and bioenergy developments have largely stalled and past years have seen the **largest decreases in nuclear generation since 1990**, a trend that is expected to continue as countries have moved forward with national phase-outs.[22] On the whole, Europe's energy transition lies at least five years behind the required path as set out in the EU's "Fit for 55" framework.[23]

Energy tightness has also resulted from periodic imbalances between supply and demand in energy markets and a **slow shift in consumer habits**. The EU has retained **high taxes on energy** with a direct burden on companies and households and **with rates that bear little relation to the energy content or externalities**, such as CO2 emissions, air pollution or security.

Fossils fuel subsidies and tax expenditures have far outstripped subsidies for energy efficiency and have remained comparable or superior to financial support for renewable energy sources.[24] Still today, the EU's energy tax framework, which has not changed since 2003, contains a range of incentives for fossil fuels, despite the EU's ambitious energy and climate objectives and international commitments.

Decades of underinvestment hold much of the blame for Europe's excessive prices and security exposure today.

Justified and well-grounded policy decisions, such as pricing externalities through a carbon price, **play a significant role in setting Europe's decarbonisation pathway**. As the EU's primary mechanism for reducing emissions in the energy and industrial sectors, the **EU's Emissions Trading System** has had significant impact in incentivising emission reductions but also affects the financial position of energy-intensive companies by increasing operating costs.

Europe's comparative cost disadvantage is also a function of the **inconsistent nature of the global carbon markets** and their regional character, which results in over three quarters of global emissions not being priced and the global average price currently standing at $5. Unless other regions and countries put a price on CO2 which approximates the European one, the playing field will remain uneven, with only partial compensation being offered by the introduction of a Carbon Border Adjustment Mechanism (CBAM).

In parallel, **various new obstacles to decarbonisation in the EU have surfaced over the past two years**. Higher shares of renewables and the uptake of technologies like electric vehicles (EVs) and heat pumps have put a strain on the European grid, which is struggling to keep up with the rising demand for electricity. In many parts of Europe, **grid congestion is becoming a real issue**, with long queues for renewable energy projects to be connected to the grid.[25]

The advent, or rather recent explosion of the phenomenon of negative power prices across Europe[26] also showcases the **insufficient development of interconnections, flexibility and storage solutions** like pumped hydroelectric energy storage, batteries and demand response management to cope with the substantial growth of EU wind and solar generation and the associated fluctuations in supplies.[27]

Renewable energy developers are facing headwinds due to high supply chain inflation (in particular in the offshore wind sector) and rising interest rates.[28] Market volatility translates into more uncertainty with respect to being able to recoup investments. Furthermore, **shortages in net-zero skills** among the EU labour force are an impediment to the energy transition, with clean tech producers encountering difficulties[29] to fill installation jobs as the demand for these skills surpasses expectations.[30]

At the same time, Europe has not been able to translate its strong position as the largest global importer of gas and LNG into correspondingly lower prices. During the energy crisis, the **lack of coordination among member states in gas purchases** led to the situation in which higher bidders impacted the overall level of prices across the EU by being willing to pay more to ensure continuity of supplies. High reliance on purchases on spot markets have further amplified volatility and increased the likelihood of supply disruptions.[31]

BOX 3: A SNAPSHOT OF EUROPE'S CLIMATE AND ENERGY EQUATIONS THAT DON'T ADD UP

Russia's attempts at weaponising Europe's energy dependence in the context of the invasion of Ukraine failed because of a combination of ambitious policy actions and market responses:

- **Investment:** Energy system investment needs amount to more than 3% of GDP per annum yet stood on average at a mere 1.7% over the period 2011-2020.
- **Taxation:** Exemptions and reductions under the EU's energy tax framework, which has not been reformed since 2003, de facto incentivise the use of fossil fuels.
- **Wind:** Reaching the EU's goal of 425 GW onshore/offshore wind capacity in 2030 requires installing 28 GW more per year. In 2024, less than 15 GW new wind farm capacity was built and the average over 2025-2030 is expected to reach a maximum of 22 GW per year.
- **Solar:** Member states' plans for solar capacity expansion currently add up to a total of 650 GWdc by 2030, falling 15% short of the EU's REPowerEU target of 750 GWdc.[32]
- **Hydrogen:** The EU's target of deploying 20 million tons of green hydrogen in 2030 would require all of the world's projected production to go to Europe, according to IEA figures.
- **Clean tech manufacturing:** The Net-Zero Industry Act sets the ambition that EU clean tech production should meet at least 40% of the EU's annual demand by 2030. For solar PV that share stood at 3% in 2022, with over 90% dependency on China in certain upstream segments, and cost differentials of over 25%.[33]
- **Energy efficiency:** Only 10 member states have submitted final National Energy and Climate Plans (NECPs) with large ambition gaps overall.

Resolving decarbonisation bottlenecks and managing security vulnerabilities in a cost-efficient way will determine the speed and success of the clean energy transition and the extent to which it will deliver resilience and competitiveness. In parallel, **a paradigm shift will be required** in European energy policy to tackle the energy trilemma in a cohesive and evidence-based way.

Recent policy initiatives such as **REPowerEU, the electricity market reform and the Green Deal Industrial Plan (GDIP) were all launched** in response to exogenous security and economic shocks and events, often under conditions of political pressure.[34] **They have largely resulted in well-intentioned, but ultimately overoptimistic, or misguided policies.** One example is the target under REPowerEU to produce 10 million tonnes and import 10 million tonnes of green hydrogen by 2030.[35] The IEA states that globally the production of low-emission hydrogen (i.e. produced from renewables and from fossil fuels with carbon capture utilisation and storage) could reach 20 million tonnes if all the announced projects worldwide materialise. However, only 4% of these projects are currently under construction or have reached a final investment decision.[36] In other words, the odds of all the announced projects becoming operational by 2030 are slim to none.

The low likelihood of achieving the targets is further undermined by the lack of off-takers for low-emission hydrogen in the private sector, which leaves producers without the steady demand base to justify and support large investments in new infrastructure.[37] Even if the REPowerEU targets could be achieved, the question would remain whether that would be desirable. It could bring hydrogen into places where it is not in fact needed, i.e. where direct electrification is possible, in turn leading to higher system costs (and a loss of competitiveness) without visible benefits for either the security or sustainability of the EU's energy supply.

The recent Net-Zero Industry Act is based on similarly unrealistic targeting, pointing in turn to fundamental challenges at the heart of the EU's energy strategy. **The targets set at the European level for clean energy produce equations that often do not compute.** They overestimate current capabilities, greatly underestimate investment needs, and overlook other opportunities. Actively pursuing them could in some cases be a losing formula across all three objectives of the energy trilemma.

The targets set at the European level for clean energy produce equations that often do not compute.

Good policymaking must project not only the ends, but also the means. It also has to be based on a granular reading of the challenges and trade-offs involved. One example of an area where this has been missing is the European Commission's Impact Assessment for the 2040 reduction target, where costs were estimated for the entire energy sector, without making a distinction between, for example, power and heating, which are characterised by very different challenges and needs.

Arguably, at the root of this issue is inadequate foresight in managing the transition. **At present, policy often seems inspired by a desire to be bold in areas**

where economic rationality needs to be the guiding principle. Or it appears to be designed with the explicit purpose of reconciling differences and reaching an inner-EU compromise rather than the accomplishment of a tangible policy objective.

Only rarely, however, do measures embody strategic thinking across the long-term goals of the energy trilemma and about the realistic pathways to achieve them in line with climate neutrality by 2050. Such strategic foresight must become – arguably, should always have been – the foundation of EU energy policy.

RECOMMENDATION 2: SET REALISTIC TARGETS AND PRIORITIES USING FORESIGHT AND ANALYSIS RECOGNISING THE INTERDEPENDENCIES BETWEEN POLICY LEVERS AT EU AND NATIONAL LEVELS

As many targets are indicative in character, or are treated as such, the clean energy transition needs to rely on **objectives which are balanced, evidence-based and implementable**. Improving **foresight and analysis to inform EU policy, with a holistic overview of interdependencies between the different policy levers**, at European and national levels, would go a long way towards addressing today's deficit.

In setting priorities, **co-opting national administrations of the member states and the EU's private sector** in this process will enable a more comprehensive analysis and understanding of the bottlenecks to EU electrification and decarbonisation. It can also significantly facilitate the systematic screening of the various risks to economic security tied to the energy transition. In this context, **more focus on the specific needs of the individual sectors and countries and their starting points is also needed**. Deepening cooperation with significant knowledge centres, such as the IEA, and close regional allies – notably the UK, Norway and Ukraine – could help to further build and complement the EU's knowledge and foresight base.

4. Doubling down on the logic of green energy investment and electrification

The crucial difference of the green energy system, compared to the one run on fossil fuels, is that **it requires investments up-front while obtaining zero marginal cost of energy generation once the installed capacity is in place**.[38] The IEA projects the need to increase annual investment in the net-zero transition from $1 trillion in 2020 to $3.5-4 trillion annually by 2030, with 70% spent on building larger, decarbonised power systems. The investment needed is projected to amount to 3.3% of the combined global GDP per year in 2030 and would have to continue for the subsequent 20-30 years.

In the EU, climate investments grew by 9% in 2022, reaching €407 billion across 22 sectors. Still, according to the Institute for Climate Economics, the European economy needs to double its climate investments to at least €813 billion per year to deliver on its 2030 targets.[39] **The public-private investment shortfall in Europe stands at 2.6% of GDP, which is considerable.** Just as investments made today shape Europe's future, the lack of investment conversely puts Europe in a steadily more adverse position in terms of its capacity to address the energy trilemma. In addition, climate investments are critical for building lead markets where Europe's clean tech industry can develop.

Investments gaps are particularly dramatic in wind power, where only 17% of annual investment needs are currently met. Only battery storage and hydropower saw investments higher than the annual needs in 2022, whereas for solar panels 78% of annual investments were covered.[40]

Although strong market incentives during the energy crisis and REPowerEU brought meaningful progress, the 23% share of electricity in the EU's final energy consumption[41] reveals that the transition is far from achieved. To remedy current shortfalls, **the EU must build new European investment scenarios taking as a starting point the investment needs in individual countries as well as the relevant costs of transition**. The European Commission omitted doing so as it prepared its Communication on Europe's 2040 climate target and path to climate neutrality by 2050.

Active, cost-effective supply policies and an accelerated electrification are the only means to structurally lower costs and ensure a stable supply of affordable energy free from exogenous shocks. **All zero- and low-carbon energy solutions will be necessary** to decarbonise the energy system by 2040, hence including not only renewables, but also nuclear, energy efficiency, storage, CCS/CCU, carbon removals, geothermal and hydro-energy and other future net-zero energy technologies.

Electrification offers **a direct pathway to decarbonising key sectors of the economy** by replacing fossil fuels with renewables as energy sources for electricity generation. It also allows for **demand-response mechanisms**, where electricity consumption can be adjusted based on availability.

The **electrification of sectors such as transportation and heating relies on the parallel decarbonisation of Europe's power supply** reducing the need for fossil fuel backup during periods of elevated demand. As more renewables are integrated into the grid, the carbon intensity of electricity declines, making electrification a key enabler of carbon emissions reductions across the economy.

Large-scale electrification based on intermittent renewables will also require more storage and sector-coupling solutions. The latter include power-to-heat technologies like electrode boilers or heat accumulators, which allow the conversion of surplus power production into heat distributed via district heating grids.

Investments gaps are particularly dramatic in wind power, where only 17% of annual investment needs are currently met.

As Mario Draghi noted in his report, **a major downward effect of decarbonisation on energy prices "will take time"**. Such an effect can only be foreseen "when renewables combined with nuclear are regularly price setting and relevant investments in grids, storage and flexibility are completed (and amortised), so that the system can be managed in a cost-efficient way".[42] However, Draghi also warns that the increase in the share of renewables will be challenging to manage given that "expectations on increased price cannibalisation and price volatility may deter investments in renewable energy and slow and the energy transition". Even more so, **the uptake of renewables needs to be accompanied by adequate investments in grids, flexibility and storage**.

Significant investment must therefore be devoted to upgrading and rethinking Europe's power networks, with an estimated €375-425 billion of investment needed up until 2030.[43] The grid will need to optimise all energy that is not necessary in terms of consumption at a given point in time, to minimise the cost and improve the demand management. More hardware and connections will be needed in the distributed grids, but also for growing digitalisation.

BOX 4: ENERGY SYSTEM INVESTMENT NEEDS 2030-2050

European Commission modelling foresees **annual energy system investment needs (excluding transport) at or above 3% of GDP for the two decades from 2031 to 2050**, in all scenarios under consideration. This means 1.5 to 2% points of GDP higher investment than in the period of 2011-2020.[44] Average investment needs in power plants are projected to be around €140 billion per annum, more than 80% of which would be in renewables. All Commission scenarios require significant investment in electricity storage, at about €8 billion annually in 2031-2050. Similarly, upscaling and upgrading of the power grid will demand annual investment of €85 billion. Finally, investment in carbon storage is projected at around €5 billion per annum on average in the years 2031-2050.

Sizeably improving the power supply and capability of the grids is also a function of **the effectiveness of the permitting process**. Environmental and climate impact assessments and other administrative procedures can significantly impact the permitting processes and the overall duration of the investment. Permitting times vary widely between member states, influencing the functioning of the energy market.[45] In spite of the significant effort in the recent period, more progress is needed, as exemplified by the fact that only five member states implemented the easing of the permitting rules prescribed by the end of June 2024. Additionally, initiatives are needed to standardise and expedite grid connection procedures for renewable energy installations to better align energy supply with industrial demand.

Accelerating energy efficiency measures and incentivising a shift in consumer behaviour will also need to play an important role. Electrification leads to **improved energy efficiency**. Electric vehicles tend to be more energy-efficient than internal combustion engine vehicles. They convert more of the energy stored in batteries into motion compared to petrol-based engines, which waste energy as heat. Similarly, electric heat pumps are more efficient than traditional fossil fuel-based heating systems.

The uptake of renewables needs to be accompanied by adequate investments in grids, flexibility and storage.

Among different sectorial challenges which stand out, **decarbonising heating is one of the "elephants in the room" of achieving emission reduction targets**. The heating and cooling of buildings accounts for half of the total EU energy use, with close to 70% currently generated from the fossil fuels coal, natural gas and oil. By the sheer weight of numbers, the sector must significantly contribute to Europe's decarbonisation path, in addition to helping improve air quality in cities, by switching to fossil-free energy.

Currently about 10% of heating demand is covered by district heating systems. According to the revised Energy Efficiency Directive, all the approximately 17,000 operational district heating systems across Europe will have to reach climate neutrality by 2050 at the latest.[46]

However, the specific conditions of district heating reflected in the local nature of operations, as well as the high variability of production throughout the year, create challenges that must be overcome in view of a deep decarbonisation of the sector.

Still, this is an area of significant innovation and potential.[47] **One of the solutions to decarbonise district heating systems is to convert renewable electricity into heat** by large-scale heat pumps and electrode boilers. The so-called "power to heat" technologies can support the power system in times of excessive variable renewable generation by creating additional demand and limiting the curtailments – especially from PVs.[48] The latter needs to be considered in any further elaboration of the energy efficiency rules.

RECOMMENDATION 3: DOUBLE DOWN ON ELECTRIFICATION THROUGH PRO-ACTIVE TECHNOLOGY-NEUTRAL SUPPLY POLICIES, GRID INVESTMENT, STRATEGIC INDUSTRIAL POLICY AND ENABLING FRAMEWORKS

Doubling down on electrification, pursued in a strategic and economically rational way, lies at the heart of the course correction needed in the EU. There are four conditions which need to be met to optimise the pursuit of electrification.

First, the phase-out of the unabated use of fossil fuels and the intermittency of renewables needs to be compensated by **proactive, technology-neutral supply policies in the direction of all available low-carbon technologies**, breaking with discriminatory policies of the past (notably as regards nuclear). The investment push would also concern strategic, forward-looking technologies, such as floating offshore wind or next generation nuclear power.

Second, **infrastructure and grid investment** need to be boosted, creating maximum flexibility across European sources, production and demand basins through investment in interconnectors, smart grids, and energy storage solutions. As REPowerEU and NextGenerationEU are phased out, **the EU should agree on a 2040 investment programme in support of electrification**, providing predictability for investors and developers.

Its adoption would be a recognition of the fact that electrification is a capital-intensive process which requires **long-term and coordinated planning**, reducing uncertainty by demonstrating the EU's commitment to electrification. A critical tool could be the creation of an **'EU electrification and competitive decarbonisation bank' providing funding for high impact projects based on Europe-wide competitive bidding procedures**. An investment floor, as baseline level of funding, could be reviewed periodically to align with updated technological costs and market developments.

Third, **targeted industrial and technological policy** is required to boost the necessary capacities (see below). Fourth, **an enabling regulatory framework** is needed both as regards **accelerated permitting** and **energy taxation**. As Mario Draghi points out in his report, energy taxation can play a fundamental role both in lowering energy costs for end users and in incentivising the transition through the establishment of an appropriate framework for surcharges, covering taxes, levies and network charges, across the single market or between a subset of member states.[49]

5. No transition without transmission and distribution: the role of flexibility, grids and storage

The primary challenge in completing Europe's electrification lies in the need to balance the energy system and achieve flexibility. Flexible options are essential for balancing supply and demand as variable renewable sources are integrated into the grid, reducing reliance on traditional fossil-fuel baseload generation. Without energy system flexibility, there is no pathway to meet Europe's near- and medium-term goals, including those of bringing down prices and securing the energy supply.[50]

Today, the average yearly gain from the integrated electricity market for European consumers is estimated at about €34 billion per year, but **recent years'**

market phenomena illustrate the need for further integration and flexibility.[51] In 2024, average prices dropped significantly compared to previous years in the first three quarters, but surged again in the fourth quarter as higher gas prices combined with days of '*Dunkelflaute*' (or "dark doldrums"), which are periods when little or no renewable energy can be generated because there is neither wind nor sunlight.

At the same time, **Europe had close to 1500 instances of negative prices in 2024, or a total of 17% of the time in a least one bidding zone.**[52] As these singularities suggest, Europe's electricity market is screaming for more integration and flexibility between bidding zones and over time.

Enhancing the flexibility and resilience of Europe's energy systems require **improved spatial interconnection, grids and sector coupling, as well as more flexible generation and efficient demand-response and storage**. It must also be underpinned by effective market mechanisms and price signals. Power supply and demand need to be continuously matched to maintain the stability of the grid and an optimised power system. This is required on a second-by-second basis, between day and night, as well as on a seasonal basis.

5.1. OVERCOMING EUROPE'S UNDERINVESTMENT IN GRIDS

In countries like Germany, the rapid expansion of renewable energy sources, particularly wind power in the north, has outpaced the development of the electricity grid infrastructure necessary to transport this energy to industrial centres in the south. This imbalance leads to grid congestion and necessitates measures like curtailing renewable energy production and implementing redispatch strategies, which can delay grid connections for new renewable installations and industries' efforts to decarbonise.

After years of underinvestment, **European grid operators now face an unprecedented increase in investment needs, both at transmission and distribution levels** towards newer, more flexible and smarter systems. The EU has set a cross-border interconnection target of at least 15%. In addition, over 40% of Europe's grids are over 40 years old. For transmission and distribution alone, the overall investments have been estimated at €584 billion by 2030, out of which €375-425 billion of investment in distribution grids.[53]

The expected steep increase of investment puts the current model of financing through network tariffs under strain, and stands, in the short to medium term, directly at odds with the objective of lowering prices to end users. While the electricity component represents 31% and taxes and levies 41%, network tariffs already account for 28% of the electricity bill in Europe.[54] **Avoiding excessive high network tariffs for end users in the future due to the payback of upfront grid investment and electrification is therefore a key regulatory objective at the EU and national levels.**

The 2023 EU Grid Action Plan is a first step, and its swift implementation should remain a priority for the Commission, member states and industry.[55] The Plan identifies concrete and tailor-made actions to improve access to financing for grid projects but further measures such as cost-reflective time-of-use network tariffs to incentivise a sustainable and efficient use of the electricity system must be explored.

A debate is also needed on current redundancy standards and grid buffers. There are multiple ways of revamping the power grid. Today's colossal investment estimates reflect calculations on anticipated upgrades to new power lines and more powerful lines. The alternative is to increase the throughput of existing power lines, which, most of the time, run at 70% of maximum capacity.

Europe has close to 1500 instances of negative prices in 2024 across bidding zones, which screams for more energy system flexibility.

Security and resilience of energy infrastructure must remain a key priority for a secure and stable energy supply. Today the importance of strict n-1 redundancy lies in its ability to maintain the reliability and resilience of the power grid in case of the failure of a component. At the same time, the development of storage capacities and buffers offer opportunities for better planning, more intelligent control and reactive management.

Europe's grid sector, often characterised by myriads of small operators, readily admits to significant coordination and planning issues across Europe's network. This experience could lead to **a comprehensive masterplan for accelerating the development of European integrated energy infrastructure**.

5.2. BOOSTING FLEXIBILITY, STORAGE AND DEMAND MANAGEMENT

The other significant part to ensuring continuity and flexibility within the variability of energy flows is appropriate storage capacity and demand management. In contrast to fossil fuels, storing electricity remains a challenge today. There is a need to further develop easily deployable, scalable and cost-efficient storage solutions for a future where up to 75% of the grid could be powered by renewables. If Europe is to attain its transition and climate targets, storage solutions are projected to have to reach 172 GW in 2030 and 275 GW in 2040, mainly in the form of pumped hydro storage and batteries.[56]

Hydropower is not only Europe's second largest renewable electricity source, it can also deliver critical flexibility and storage services to Europe's electricity system to help the integration of growing shares of intermittent wind and solar energy. According to Eurostat, hydropower accounted for 29.9% of the EU's renewable electricity production and provided 12.3% of the EU's electricity in 2022. Worldwide, pumped hydro energy storage comprises about 96% of global storage power capacity currently.[57]

Life-cycle assessments show that closed-loop pumped storage hydropower systems have the lowest emissions amongst storage technologies. In integrated markets with appropriate price signals, it is a sustainable and effective energy storage solution that can mitigate both intra-day and seasonal fluctuations of renewable energy sources, as in the case in the Nordics. While some studies indicate that the pumped storage capacity in the EU will not increase due to environmental and geographic constraints, opening cross-border markets for balancing capacities in Europe could serve as an important incentive to upgrades of current capacity.[58]

Life-cycle assessments show that pumped storage hydropower has the lowest emissions amongst storage technologies.

Through considerable technological advancements in the past years, batteries have also fast become more efficient and cheaper. Batteries can be deployed in different sizes and options together with generation, with consumption or independently to store energy not used. Rapidly falling prices means batteries can compete with pumped hydro for short-term storage (minutes to hours). In Germany, solar PV combined with batteries have proven cheaper than gas power. However, pumped hydro continues to be much cheaper for large-scale energy storage (several hours to weeks).

The **deployment of utility-scale battery storage solutions is expected to accelerate**, with projects like the Hornsdale Power Reserve in South Australia[59] or California's 10-GW battery storage system[60] demonstrating their effectiveness in balancing the grid and reducing reliance on fossil fuel-based backup power. One of the advantages of battery storage over other technologies is the speed of the investment process and fewer apparent environmental concerns, although supply chain issues must not be overlooked.

Utility-scale batteries must increasingly provide storage and flexibility.

In addition to daily balancing, batteries must increasingly provide ancillary services to the grid, such as frequency regulation and load balancing, which are essential for maintaining a stable and reliable electricity system. While batteries are a key part of the solution, they are often used in conjunction with other technologies, such as demand response, and even hydrogen storage, to create a more resilient energy system with several sources of flexibility to handle fluctuations in supply and demand.

A final, critical component of future energy system flexibility is to enhance demand-side response and flexibility, both at the level of consumer end users and in industry. Encouraging customers to reduce their electricity use, either during peak hours or overall, offers significant benefits for the system overall and for customers through lower bills. Demand management technologies such as the production of hydrogen with electrolysers and – to a lower extent – the production of other renewable fuels of non-biological origin are another significant part of the demand equation.

Hydrogen has potential to be a cleaner long-term energy storage solution, while transition fuels such as natural gas will continue to be needed for peak demand times, especially in winter, in the foreseeable future. Produced with excess renewable energy, hydrogen can be stored and used later when energy demand rises and renewable production is low. This said, converting renewable energy to hydrogen has its limitations as it leads to significant losses of electricity.

So far, **Europe's strategy towards hydrogen has been characterised by overly ambitious targeting and a lack of realistic planning or a corresponding support landscape**. The EU must move on from the initial hype to more prudent planning where hydrogen is targeted for sectors where no other decarbonisation pathway is possible.[61] For this, hydrogen requires new infrastructure for production, storage and distribution, which is at best nascent in most parts of Europe.

Due to limited transport infrastructure, hydrogen prices vary significantly across Europe. To address this, **the EU recently initiated its first EU-wide renewable hydrogen auction as a pilot project**, attracting 132 bids – a clear indication of the strong interest in this emerging energy source. Notably, however, the auction closed only about 10% of the price gap between clean and dirty hydrogen, highlighting both the potential and the challenges of the technology. As technology advances and production scales up, hydrogen costs are expected to decline further.

RECOMMENDATION 4: ELABORATE AND IMPLEMENT A DEDICATED 'MASTERPLAN FOR ENERGY SYSTEM FLEXIBILITY, GRID INVESTMENT AND ENERGY STORAGE'

Although increasing the role of flexibility is central to the EU's energy transition, a comprehensive and realistic European approach to flexibility is currently lacking. The recent EU Grid Action Plan is a first step, and its swift implementation should remain a priority. It should be complemented with **a comprehensive "masterplan" for accelerating the development of European integrated energy infrastructure, covering both grid development and storage potential**.

Europe's network, often characterised by myriads of small operators, faces **significant coordination and planning issues** that contribute to driving up investment costs. Opportunities for better planning and more intelligent grid management, also linked to Europe's n-1 redundancy rule, must be seized to avoid excessive investments and high network tariffs for end users.

As part of the 'escape velocity' approach, diverse types of **storage and demand management opportunities should be realistically considered and prioritised**, including pumped hydro storage, batteries and hydrogen, to enhance grid resilience and flexibility. Battery solutions must scale and deployed in different sizes and options both independently, and in conjunction with generation and consumption.

Well-functioning markets and price signals remain critical to developing and operating all flexible capacities, as well as for end-user demand management. Cross-border markets for balancing capacities in Europe could serve as an important incentive to upgrades of current pumped storage capacity, while hydrogen ambitions and investments must be more targeted.

6. Putting Europe's clean tech industry back in the game

Given the economic security considerations, an industrial dimension needs to be a central part of Europe's clean energy agenda. The stakes are enormous given the evolution that the energy mix needs to undergo to meet decarbonisation objectives. Various net-zero scenarios envisage clean energy reaching a 75-100% share of the power mix by 2050, with intermittent sources (wind and solar) accounting for the bulk of that output, generating 60-90% of Europe's renewable electricity.[62]

So far, the industrial component of the Green Deal has lagged, leading to the continued loss of Europe's market position in some of the key clean technologies. The most extensive element of the European strategy for clean tech, the Net-Zero Industry Act (NZIA) only entered into force on 29 June 2024. It adopted a blanket approach, aiming to establish a robust manufacturing base for a vast range of technologies expected to play a key role in the energy system of the future. Its headline target is to have 40% of EU clean tech deployment needs covered by domestic manufacturing by 2030.

Launched shortly after the Biden administration's Inflation Reduction Act (IRA), the NZIA promises little of the IRA's unbridled financial support and simplicity, and in fact comes without a dedicated budget or new resources. The Strategic Technologies for Europe Platform (STEP) is meant to provide the financial backing for the programme. However, it remains a nascent mechanism relying on unspent cohesion funds and very little money overall.

As the new Clean Industrial Deal is being launched, its groundwork should involve a proper anticipation component, based on the optimal energy mix to be reached by 2050 under the net-zero scenario. Short- and medium-term implications should then be drawn regarding the necessary capacity, home-grown production versus imports, and the role of innovation policy. For solar energy, the transition means an over 6-fold increase, from 182 TWh in 2021 to 1166 TWh in 2050. For wind, this is an over 5.5-fold increase, from 390 TWh in 2021 to 2138 TWh in 2050.[63]

The conclusion which needs to be drawn from these figures is that foregoing a share of the market today means foregoing a significantly larger market in the future, with all the associated innovation, and employment. The wind sector in Europe already employs more than 300,000 people.

Foregoing a share of the clean tech market today means foregoing a significantly larger market in the future.

A first economic security benchmark indicates the **need for preserving a sizeable part of the clean energy market in all key technologies**, primarily in wind and solar, which together will constitute two-thirds of the 1.8 times larger power production needed in 2050 to cover the total demand. The current market share in renewable technologies, such as solar (See Figure 5), needs to be viewed in the context of the enormous market demand envisaged between now and 2050. One should also keep in mind that technology value chains are complex, and a considerable market position could be retained or regained.

Europe must implement an 'economic security yardstick' as part of its renewed clean industrial ambitions.

What is more, the industrial consideration should not only consider the projection for the European market but also the evolution of the market demand globally. Solar will be the predominant method of electricity generation in Africa, Latin America, Southern and South-East Asia. According to the Institute for Essential Services Reform (IESR), solar energy could make up to 88% of Indonesia's electricity mix by 2045.

With future market evolution in mind, the EU needs to build on its current strengths while identifying and addressing the shortcomings in its current approach to clean industrial development. The newly adopted Competitiveness Compass offers an opportunity to **implement an 'economic security yardstick' as part of Europe's renewed clean industrial ambitions.**[64] Comprehensive economic assessments need to be the starting point for the announced Clean Industrial Deal with "by-the-metrics" analysis opening the way to targeting the right areas with the right means.[65]

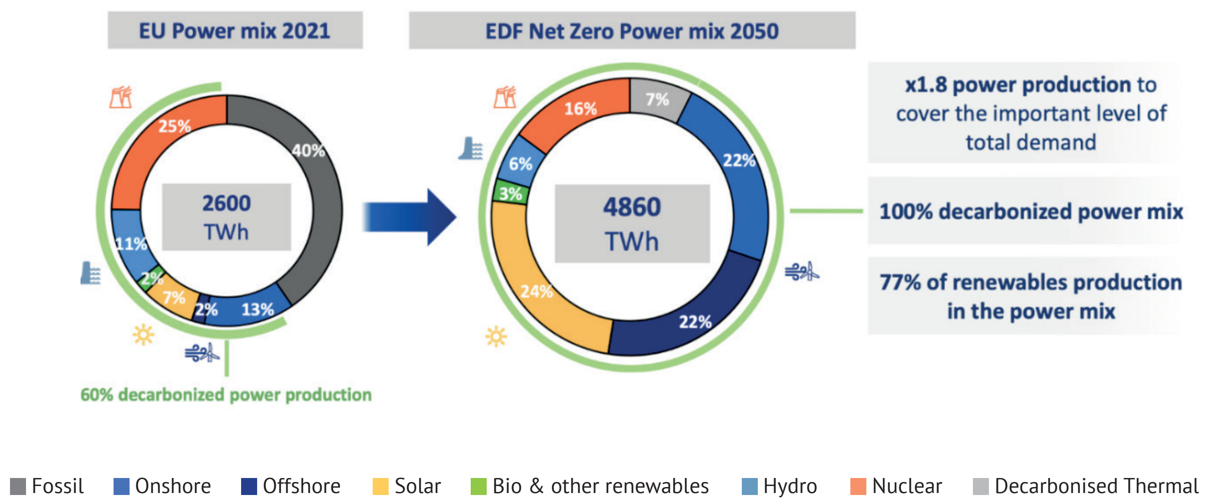
In line with such a yardstick, the **EU should prioritise industries** where the **level of competitive advantage is high** or where there is a **strategic interest in retaining the relevant industrial capacity** and talent for economic security reasons.[65] In addition, new emerging fields should be treated as high priority areas, given their future high growth potential. In both cases, a combination of different policy tools will be required.

Conversely, **in areas where the EU has lost economic advantage**, regardless of the exact pathway, **reliance on imports should be accepted, if strategic dependencies are avoided or can be mitigated**. Finally, there is the intermediate category where Europe is agnostic about the underlying technologies and relies on inward investment, including in some high technology areas, but where the EU should focus on protecting a level playing field and employment and securing a home-based manufacturing capacity to reduce import dependencies.

Making the future Clean Industrial Deal deliver along these lines requires a systems approach, starting from strategic investment in research and development, with guardrails against technology leakage, all the way to scalable deployment. Although hard for European policymakers to swallow, there are important lessons to draw from East Asian "developmental environmentalism" and its sophisticated economic statecraft.[67]

Figure 5

TRANSITION OF THE EU POWER MIX UNDER THE 2050 NET-ZERO SCENARIO



Source: EDF. *Note: All the figures are given for EDF Net Zero geographical perimeter.*

China's recent success story in building industrial strength in the clean energy sector comes not only from innovative technology, but also **extensive ecosystems able to develop enormous capacity and low manufacturing costs**, and massive funding with **state subsidies four times higher than in other major economies.**[68] As a result, China has achieved its target of 1,200 gigawatts of installed solar and wind capacity six years ahead of schedule.[69]

Competition in the research and development phase of clean tech development is intensifying as well. According to an analysis by the German Patent and Trademark Office (DPMA), Chinese entities filed 117 patent applications in solar technology in 2023, more than twice as many as in 2022. While German patent registrations also increased by an impressive 11%, this was the first time that China published as many applications in solar technology as Germany.[70] **The R&D issues are strategically important given that the net-zero transition requires further technological breakthroughs**, as illustrated by the IEA's Net Zero scenario which envisages that 35% of the effort will need to come from technologies that do not exist today.

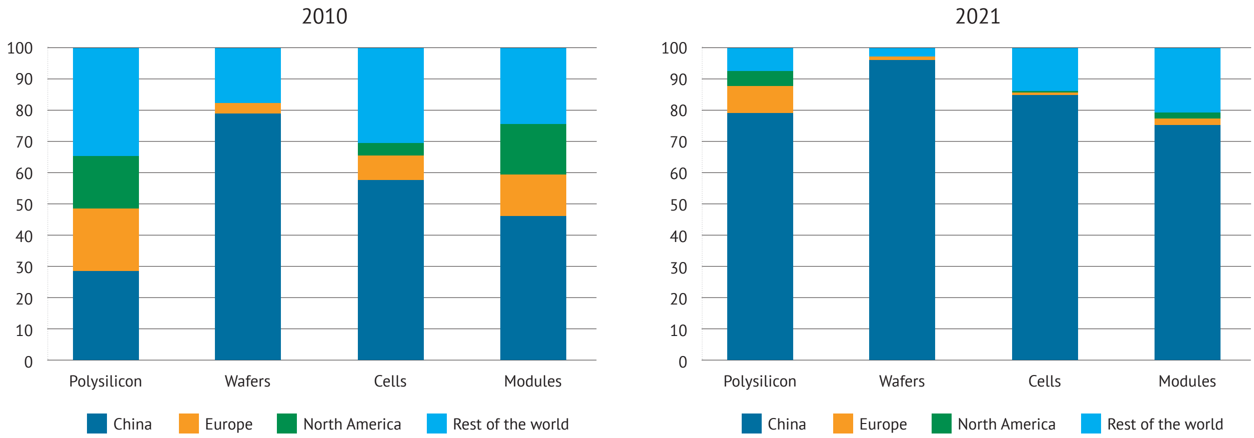
Although Europe's position in research remains strong, the manufacturing reality is much gloomier. Global solar supply chains, in which Europe still held a leading position until the early 2010s, are now utterly dominated by China, which produces 88% of the global supply of polysilicon (the main raw material for solar PV), 97% of the silicon wafers (the core component of solar cells), and 85% of the world's solar cells (see Figure 6).[71] As such, over 90% of solar PV capacity installed in the EU is covered by Chinese imports.[72]

As highlighted by the Draghi report and ECB simulations, if the Chinese EV industry were to follow the same trajectory of subsidies to that applied in the solar PV industry, "EU domestic production of EVs would decline by 70% and EU producers' global market share would fall by 30 percentage points".[73] **Europe's deepest challenge in reviving its clean industrial future therefore lies in warding off the obverse effects of others' industrial policies, and in particular Chinese export manufacturing and overcapacities.** As industrial policies create new geopolitical facts in today's economic security era, this has become a matter of vital strategic importance.

Europe's deepest challenge in reviving its clean industrial future lies in warding off the obverse effects of others' industrial policies, and in particular Chinese export manufacturing and overcapacities.

Figure 6

SOLAR PV MANUFACTURING CAPACITY BY COUNTRY AND REGION, 2010-2021
(IN % OF GLOBAL CAPACITY)



Source: International Energy Agency (2022), "Solar PV global supply chains", Paris.

RECOMMENDATION 5: ANCHOR THE CLEAN INDUSTRIAL DEAL ON AN 'ECONOMIC SECURITY YARDSTICK' INVOLVING STRATEGIC FUNDING, ECOSYSTEM FORMATION, ENABLING INFRASTRUCTURE AND NECESSARY SHIELDING

An economic security assessment and "yardstick" must accompany the implementation of the EU's Competitiveness Compass based on a mix of economic, technical and intelligence insights. As part of the coming Clean Industrial Deal, the EU should prioritise industries where the level of competitive advantage is high or where it is in Europe's strategic interest to retain the relevant industrial capacity and talent for economic security reasons. This requires the simultaneous pursuit of three key actions:

Strategic funding allocations driven by a strong investment case

Clean tech has to become a top priority spending category for the EU together with digital sovereignty and security and defence. Since **a massive leveraging of private capital will be required**, a powerful investment case must be built for all clean tech developments, enabling increased manufacturing and scaling. In the context of the future EU Competitiveness Fund, the **risk reduction potential of the European Investment Bank (EIB) and National Promotional and Investment Banks (NPIBs)** should be used to their full extent. Expanding InvestEU actions towards different blending and counter-guarantee instruments should be envisaged to provide financial backing that reduces the risk exposures for financial intermediaries.

Ecosystem formation and enabling infrastructure

The EU's future Competitiveness Fund should be constructed as the 'mother fund' that provides equity and risk alleviation for **a series of 'sub-funds' each targeting a specific sector of Europe's technological and industrial revival** in a spirit of ecosystem formation. Each sub-fund would act as the financing arm, crowding in private capital and investment, for the ecosystems already identified and developed by the EU's Industrial Alliances. Critical enabling infrastructure could also be funded on this risk alleviation model.

In parallel, Europe's ability to deliver clean tech at scale must be supported by demand generation. Policy needs to be sufficiently bold to enable rapid access to clean energy products and services, with the rollout of EV charging infrastructure being a case in point (see Figure 7).

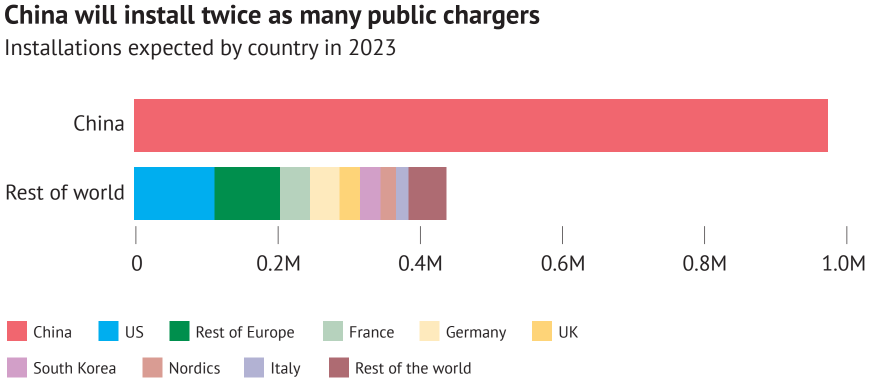
Dynamic shielding approach through trade and demand-focused policies

Given the overbearing pressures of distorted global competition, all EU policies should be combined to make sure European companies operate without undue disadvantage. As **procurement is often the most effective innovation policy**, standardised criteria for clean tech procurement should be introduced to scale up cross-EU purchases and "buy European"-policies should be envisaged in respect of Europe's economic security yardstick.

As the case of EV batteries demonstrates, ramping up of production needs to be supported with extensive financing frameworks for manufacturing in sectors of comparative advantage. Finally, and critically, breaking with decades of relatively unassertive EU trade policy, **early-stage technology developments and industrial scaling must also be actively shielded by the appropriate trade policy measures**.

Figure 7

INSTALLATION OF EV CHARGING INFRASTRUCTURE



Source: BloombergNEF. *Note: Chart shows annual installations in BENFs 2023 Long-Term Electric Vehicle Outlook Economic Transition Scenario.*

7. Making the supply equation add up: The nuclear component

As part of the EU's necessary course correction, nuclear energy holds significant potential for supporting Europe's electrification and reducing reliance on fossil fuels. Unlike renewables, whose energy generation depends on weather conditions, nuclear power plants can enhance electricity security by adjusting their output to meet shifts in demand and supply. Furthermore, as the world's second-largest source of low-carbon electricity, nuclear can complement efforts made by the other lead renewables, such as wind and solar, to replace fossil fuels.

As part of the EU's necessary course correction, nuclear energy holds significant potential for supporting Europe's electrification and reducing reliance on fossil fuels.

However, not all that glitters is gold. While nuclear is a success story in terms of carbon reduction, it poses many challenges including safety risks, high investment costs, long construction time, fuel sourcing, and waste handling. **This has led in the past to significant EU misalignment on nuclear power, reflecting broad challenges in balancing national sovereignty, public opinion, and the urgency of climate and energy security goals.**

However, more recently, the EU policy landscape has been evolving significantly. **In 2022, the European Commission acknowledged nuclear's potential in supporting Europe's energy security.**[74] By 2023, nuclear energy was included in the list of environmentally sustainable economic activities covered by the so-called EU Taxonomy[75] and designated as a "Strategic Project" under the NZIA,[76] therefore able to benefit from expedited permitting processes and financial support.

In the same year, **at COP28, nuclear was categorised among the solutions to fight climate change and meet the 2°C Paris Agreement goal**.[77] In 2024, worldwide leaders from over 30 countries attended the Nuclear Energy Summit and they all[78] signed a declaration[79] reaffirming their commitment to fostering nuclear energy.

Despite the more favourable environment, Europe is losing ground in nuclear developments. The EU's nuclear capacity has declined from its peak of 136 units in the late 1980s to the current 100 reactors (96 GW generating capacity). Germany,[84] Italy and Lithuania[85] have permanently closed their last nuclear power plants and Sweden's[86] fleet has halved over the past decades. The remaining EU reactors are ageing, with an average age of almost 37 years.

Unless their lifespans are extended, most European reactors will need to be decommissioned by the end of the next decade, with decommissioning costs potentially reaching up to €1.9 billion per reactor and the shutdown process lasting 15 to 20 years.[87] Provided the safety case can be demonstrated, life-time extensions currently represent the most cost-effective investment into Europe's nuclear capacity. Whereas Europe's nuclear fleet operates with lifespans of 40 to 50 years, in the US, reactors have already been approved to operate for a total of 80 years.[88]

Looking forward, nuclear reactors have an important role to play not only by contributing 15-25% of Europe's energy supply, but also in ensuring flexibility of the energy system. They are designed to reduce output sizeably in a short period of time (twice a day in under 30 minutes). In France, given the large number of nuclear reactors, the fleet effect plays an additional role, with a contribution to power system stability achieved by controlling grid frequency.

Unless their lifespans are extended, most European reactors will need to be decommissioned by the end of the next decade.

As China accelerates its already impressive expansion of nuclear energy[89] and Russia retains its dominant position in the global nuclear supply chain,[90] **Europe must act quickly to diversify its portfolio**, strengthen its nuclear supply and promote its independence to avoid unwanted disruptions to its nuclear energy markets.

BOX 5: EUROPE IS LOSING NUCLEAR GROUND

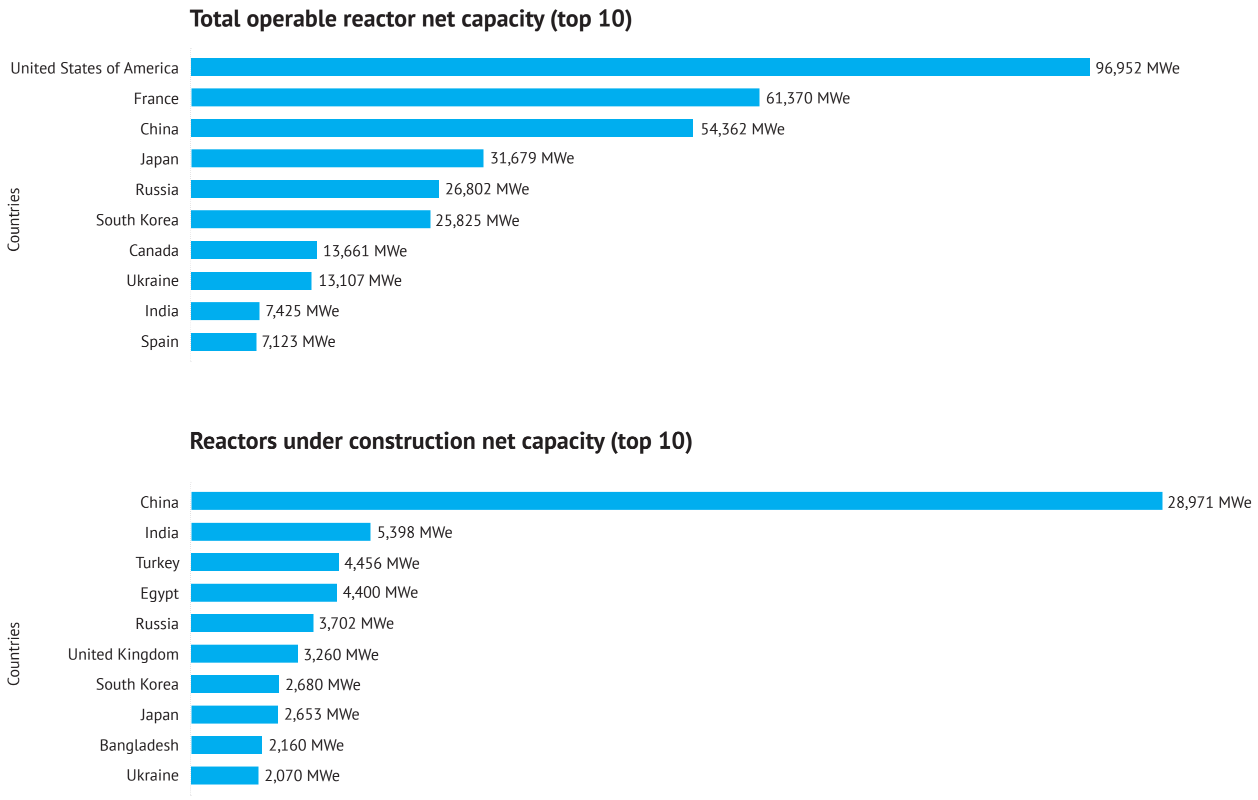
Globally, around 10% of electricity is generated by nuclear power, while in advanced economies it reaches 20%.[80] Many global players, especially in Asia and the Middle East, have been increasing their efforts to secure nuclear electricity while industrialised economies with ageing fleets, including the EU, are losing market leadership.

In 2022, nuclear energy accounted for over **a fifth (21.8%)** of the total EU electricity production, with France producing almost half.[81] Currently, out of the 440 nuclear power reactors operating worldwide, 100 are stationed in 12 EU member states (over half of them in France) and 67 in five non-EU countries.[82]

Beyond the currently operational reactors, there are about 60 reactors under construction and a further 110 are planned globally, with the majority of these to be built in Asia. According to the World Nuclear Association there are currently two reactors under construction in the EU with 2,121 MWe capacity and another 12 reactors planned with capacity of 13,590 Mwe.[83]

Figure 8

TOTAL OPERATING REACTORS VERSUS REACTORS UNDER CONSTRUCTION (MWE NET CAPACITY)



Source: World Nuclear Association, "Reactor Database" (accessed 6 January 2025).

RECOMMENDATION 6: FACTOR IN NUCLEAR POWER INVESTMENTS AS AN ESSENTIAL COMPONENT IN EUROPE'S NET-ZERO SCENARIO

To step up its net-zero game, **the EU and member states must establish the right conditions through consistent and coherent long-term policies that facilitate the deployment of nuclear technologies**. To meet future energy mix scenarios, this initially entails **lifetime extensions of the existing fleet** of reactors, provided safety concerns can be fully met.

In parallel, "new nuclear" could play an important role in Europe's future low-carbon energy supply by **building new nuclear reactors using established technologies**, if the levelised cost of electricity (LCOE) can be kept competitive with other clean power sources.

Finally, the commitment of the European Commission **to encourage the development of Small Modular Reactors (SMRs)**, notably through the European Industrial Alliance on SMRs, needs to be continued.[91] In fact, according to the IEA's Net Zero Emissions by 2050 Scenario[92] (NZE) half of the emissions reductions by 2050 come from technologies that are not yet commercially viable, SMRs included.

Simultaneously, **the EU should provide the necessary guarantees to the EU's nuclear sector for major investments in uranium conversion, enrichment and spent fuel recycling** projects to strengthen Europe's position in the nuclear fuel supply chain.[93] This is particularly pertinent given the strategic implications of Russia's dominance in the global enrichment capacity, controlling nearly 50% of the market and wielding significant influence over uranium supply dynamics.[94] Lastly, enhancing collaboration among member states and with global partners will be crucial to advancing nuclear energy projects and sharing best practices.

8. Preserving the role of the market

Well-functioning, efficient markets are indispensable to ensure that all energy actors fulfil their role in Europe's net-zero transition. Markets are essential to provide adequate investment signals for renewable and low-carbon deployment, and they are critical in ensuring operational efficiency in supply and demand. The supply side must be able to meet demand through generation with lowest marginal cost and demand side response is necessary when supply is tight.[95]

Yet, when the 2022 energy crisis hit, many cast doubt on Europe's traditional market orthodoxy. Amid record-breaking gas and electricity prices, von der Leyen called for structural reform, even going as far as stating that "[the market] is no longer fit for purpose."[96]

Ultimately, as prices returned to relative calm in 2023, **the ensuing electricity market reform opted, rightfully, for more modest adaptations**. The 2023 market reform promotes Power Purchase Agreements (PPAs) and Contracts for Difference (CfDs) as instruments to help further address the energy trilemma, but Europe's market logic remains essentially intact with free price setting to solve the coordination between supply and demand and develop Europe's energy system flexibility.

This said, **Europe has not reached the end of its debates on price volatility, contagion and market reforms**. In two recent letters to the Commission, the Prime Minister of Greece has called for more determined action to address "unacceptable" electricity cost disparities between countries in the single market.[97] At the other end, Sweden has conditioned the expansion of interconnection through the Hansa PowerBridge project on Germany overhauling its energy market to help address price contagion.[98]

In his report, **Draghi also highlighted how the passing on of price volatility** may prevent the full benefits of decarbonising power generation from reaching end-users and pose **a political risk to the net-zero transition**. Should the prices of Europe's energy transition and market, while steadily integrating more renewables, continue to be structurally higher and more volatile than those of fossil fuel-dominated energy systems, the incentive to continue the path of decarbonisation could be seriously undermined, he warns.[99]

> **If Europe is to reach decarbonisation 'escape velocity', it is precisely higher market prices that provide the best signal for the additional investments needed.**

The (geo)political and economic risks of high prices are undeniable, but there are significant caveats to be introduced to arguments that point to a weakening of market principles and of the marginal pricing system. **If Europe is to reach decarbonisation 'escape velocity', it is precisely higher market prices that**

BOX 6: AN UPDATE ON THE EU'S 2023 ELECTRICITY MARKET REFORM

The EU's recent electricity market reform was concluded in December 2023, with less than two months of negotiation. It relies in particular on two instruments to ensure more stable and predictable energy prices while avoiding market distortions:

- **Power Purchase Agreements (PPAs)** are tailormade long-term contracts for the supply of energy concluded on a voluntary basis directly between producers and customers (usually restricted to large companies). The main purpose of a PPA is to reduce and allocate the price risk between the two. By offering producers and customers price certainty over a period of 10 to 15 years, they can help encourage investments in new renewable projects while allowing customers to accurately forecast their energy cost.
- **Contracts for Difference (CfDs)** are contracts between public entities and generators that provide direct price support to renewable projects. A CfD defines a strike price (e.g. 80 EUR/MWh). In periods where the market price is lower than the strike price, the generator will receive the difference between the two. Conversely, when the reference price is higher than the strike price, the generator would need to pay back the difference. In practice, the CfD amounts to a subsidy aiming to cover some of the generator's cost but also helping reduce its exposure to volatile prices.[100]

The main difference between the two is that **PPAs rely on private initiative, whereas CfDs shift part of the investment risk to the state**. The reform defines several design principles that national CfDs need to adhere to, and strengthens consumer protection in the case of PPAs. CfDs have become obligatory if government wants to introduce price-based subsidies for renewable and low-carbon investments. Yet they are not mandatory across all investments, and non-priced base support schemes remain possible for less mature technologies.

In a context of strained public finances, encouraging private initiative, cost-efficiency and purely commercial projects, with or without PPAs, remains paramount. However, **the uptake of both instruments is likely to increase significantly**, especially after 2030 when electricity generation will be predominantly based on zero-emission sources. This means that the price paid by customers will increasingly be determined by the cost of CfDs that ultimately are financed not only through the energy bill but also the tax bill.

provide the best signal for the additional investments needed in low-carbon technologies, flexibility sources and storage, which in turn will eventually reduce the role of gas in setting prices at peak hours. They will exert their impact "as long as it takes", namely until Europe's clean energy system reaches the critical mass needed for price-setting not to be unduly influenced by fossil fuels.

Additionally, with the electricity market reform recently entered into force, **a growing share of renewable and nuclear generation is no longer expected to be remunerated at market clearing prices** as Power Purchase Agreements (PPAs) and two-way Contracts for Difference (CfDs) come into play, ensuring both investability in these technologies and limiting consumers' exposure to price volatility.

At the same time, today's debates must recognise that **diverging prices between different bidding zones in the internal market also reflect past investment strategies and national decisions on the energy mix**, which have remained a national prerogative. Single market integration and interconnection can only go so far in compensating deficiencies in national strategies.

A case in point is **Germany's insistence on maintaining a single price zone**, against the **recommendation from the EU's Agency for the Cooperation of Energy Regulators** (ACER)[101] and strong pleas from neighbouring countries.[102] Artificially low prices in southern Germany prevent necessary investments. As the market operates under the illusion of sufficient generation and transmission capacity, it further leads to significant bottlenecks and inefficiencies.[103] When supply is tight, it is also a major factor of price contagion across Europe putting stress on neighbouring countries' social contract and the very idea of integrated markets.

Ignoring regional differences in supply and demand can lead to significant inefficiencies and higher costs overall. Looking ahead, **further European coordination will be needed to ensure both fair single market integration and the optimal use of new investment and contractual instruments**. Absent better cooperation between member states on investments, major structural mismatches between electricity supply and demand could arise. A serious, lasting mismatch, due to the lack of cross-border coordination of renewable support schemes for instance, could put member states on the hook for tens of billions of euros a year to be channelled through CfDs to renewable energy producers.[104]

The same consideration applies to **national capacity mechanisms**, which remunerate generators to keep conventional (oil, coal, gas) capacity online to accommodate the growing shares of renewables in the power mix and safeguard security of supply. Combined EU spending on these schemes has increased from €2.5 billion in 2020 to more than €7 billion in 2023.[105] While it would be a far-reaching change to see a joint instrument emerge in these domains, there is a strong **rationale from the perspective of cost efficiency for coordinating national measures to the greatest extent possible**.

RECOMMENDATION 7: STRENGTHEN SINGLE MARKET COORDINATION AND INVESTMENT INCENTIVES WHILE EXPANDING LONG-TERM CONTRACTUAL SOLUTIONS

The EU needs to **ensure the pre-eminence of market mechanisms to efficiently allocate investments and balance supply and demand in a flexible, decarbonised energy system**. The marginal price setting principle remains the most efficient system to ensure that the least costly technologies are produced first, and that Europe scales up generation, flexibility and storage solutions such as batteries, pumped hydro and hydrogen storage.

In line with the urgency of reaching decarbonisation 'escape velocity', the EU should **prioritise market policies that create strong, predictable investment signals** for the energy transition. It needs to avoid frequent experimentation with new market design elements, which may deter the deployment of the significant investments required for power generation, grid and storage infrastructure.

At the same time, **national competencies in determining the energy mix and regional differences** in supply and demand mean that there cannot be a single price across the internal market. In line with ACER recommendations, **appropriate market design must establish bidding zones that reflect underlying physical and economic assumptions**, also as an instrument to limit market inefficiencies, unwarranted volatility and price contagion.

The **use of long-term contract solutions** envisaged in the 2023 Electricity market reform **in the form of Contracts for Difference should be promoted** to create a reliable link between investments in renewables and predictable returns. In parallel, **coordination should be enhanced between member states** to maximise their efficiency and effectiveness.

Consumer participation in energy management should be enabled by allowing consumers to combine spot market purchases with long-term Power Purchase Agreements (PPAs) as part of their energy strategy. Regulatory and competitive barriers should be removed to ensure consumers can easily enter into one or multiple PPAs with various suppliers.

9. Acting before the damage is done: risk-preparedness and resilience

Renewables' mounting share in the European energy mix and **the rising dependence on critical raw materials and clean tech imports from China are fast becoming new frontiers of Europe's security equation**. China's daunting hegemony in clean energy supply chains and its propensity to leverage strategic dependencies as tools for economic coercion, in addition to Russia's numerous cyberattacks on both Ukrainian and EU energy infrastructure,[106] should leave policymakers in no doubt as to where the primary threats originate from in the energy sphere.

The rising dependence on critical raw materials and clean tech imports from China are fast becoming new frontiers of Europe's security equation.

The resilience of Europe's critical energy infrastructure has never been more important, with Europe's power generation capacity, networks and infrastructure already under heavy pressure from **ongoing cyberattacks and physical attacks both on the ground and undersea**. If unaddressed, such attacks can lead to **cascading damage**. One example is the cyberattack on satellite communications carried out on the day of Russia's invasion of Ukraine disabled space-based command-and-control for Enercon's wind turbines in Germany, with the subsequent loss of remote monitoring access to more than 5,800 wind turbines.

An assumption has to be made that critical infrastructure will be a permanent target for malignant actors around the world, especially in the context of its further, dynamic expansion. Pre-positioning operations, aiming to infiltrate networks to implant malicious software or gain persistent access, and grey zone cyber operations, typically designed to destabilise, intimidate or coerce without crossing the threshold of a conventional attack, are likely to be a constant challenge to European infrastructure, as it undergoes a massive upgrade and development.

Particular attention needs to be devoted to parts of the cyber-physical infrastructure where the new and legacy elements, control sectors, or intersections with external actors are integrated in the grid, the integration of Chinese wind turbines into the EU's energy system being a case in point.[107] AI can play a significant role in strengthening anomaly detection, anomaly-based intrusion detection systems, intrusion protection systems, and in predictive maintenance.[108] Resilience-based engineering practices need to be introduced, addressing the growing heterogeneity of systems design, and higher network segmentation. All this with the intention of ensuring the most complete and rapid restoration possible of the functions of the system in case of need.

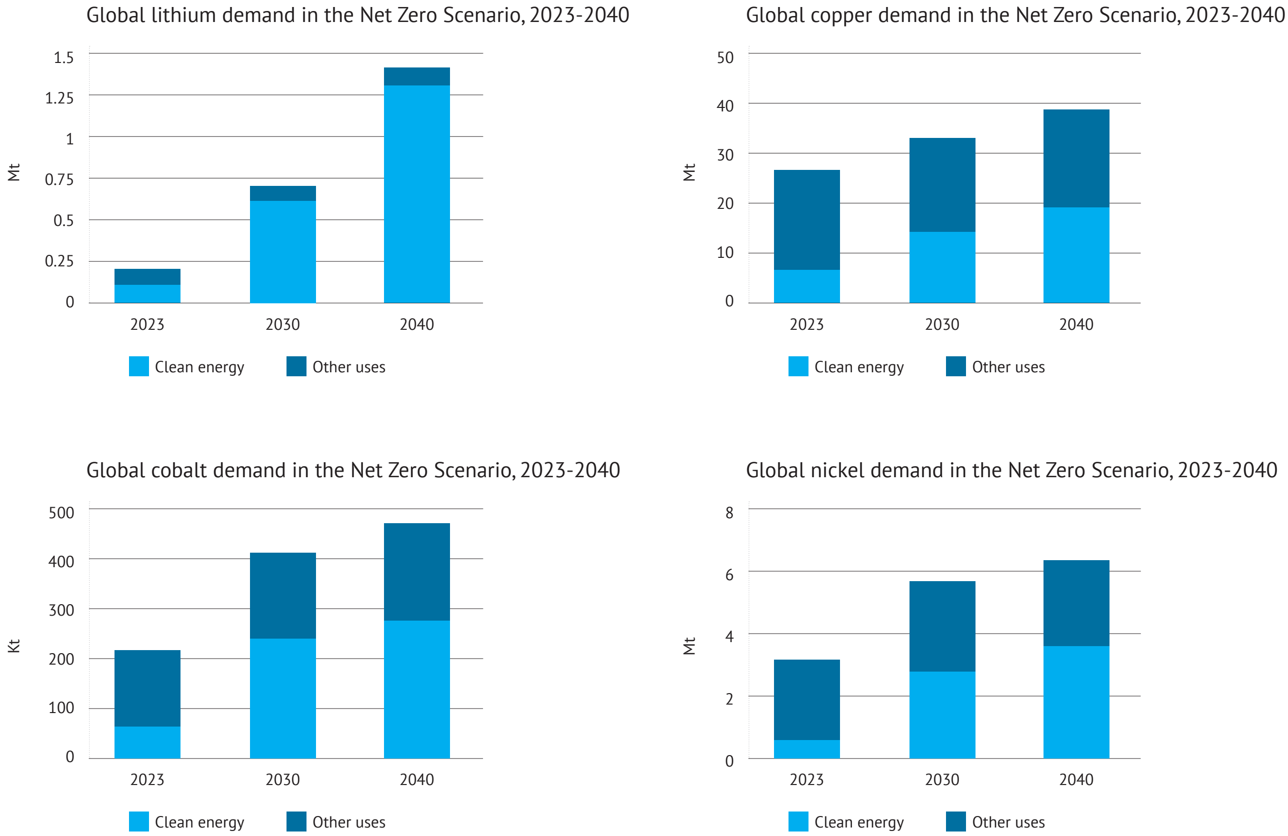
While initially measures to protect European critical infrastructure covered two sectors, transport and energy, **the recent EU Directive 2022/2557 covers 11 sectors and introduces resilience-enhancing obligations for member states and critical entities.** In June 2024, the EU adopted a Council Recommendation on a Blueprint to coordinate a response at Union level to disruptions of critical infrastructure with significant cross-border relevance.[109]

In parallel, **the EU needs to further develop its supply chain resilience, with a range of proactive measures as well as effective response to disruption**. Single source supply for critical minerals, components and services should be avoided. Given the current pace of technological progress in the clean energy sector, **adaptability and an open mindset to the inclusion of new categories of risk** (or exclusion of those no longer relevant) **is imperative**.

The EU needs to further develop its supply chain resilience, with a range of proactive measures as well as effective response to disruption.

Figure 9

GLOBAL DEMAND FOR LITHIUM, COPPER, COBALT AND NICKEL
IN THE NET ZERO SCENARIO 2023-2040, IEA



Source: IEA.

RECOMMENDATION 8: DEVELOP A COMPREHENSIVE RISK MANAGEMENT SYSTEM

The current threat environment, and plans to scale up Europe's investment in the power sector and the grid, require a holistic approach to risk management. The hitherto ad hoc sectoral reports on supply chain resilience[112] no longer suffice.

Without turning into a new reporting obligation for companies, a new tool must foresee continued and methodical monitoring of the various risks to clean energy supply chains, which include:

- **Critical raw material risk:** the risk of supply disruption to scarce and/or geographically concentrated minerals needed for the manufacturing of clean energy technologies;
- **Market concentration risk:** the geographic concentration of the manufacturing of finished products or components for clean energy technologies in a limited number of countries, which could lead to an outsized impact if the supply from one of these countries is disrupted;
- **Know-how risk:** the loss of the level of knowledge necessary to produce certain components or technologies in a cost-competitive fashion and at scale where manufacturing has shifted abroad;
- **Cyber-security risk:** the risk of cyberattacks on clean energy infrastructure by malicious actors;
- **Climate risk:** the risk of climate hazards such as extreme weather events disrupting renewable energy production and supply chains and causing damage to infrastructure networks.[113]

A review of EU Regulation 2017/1938 on the security of gas supply outlined several areas for further improvement in the gas sector.[114] In the energy sector, EU Regulation 2019/941 on risk-preparedness in the electricity sector, *inter alia* imposing obligations upon national regulators to draw up "risk-preparedness plans", should be subjected to **a similar post-crisis performance review**. Questions to be posed include identifying at what point in the crisis risk-preparedness prevented further escalation; what was not foreseen or taken into account (e.g. climate risk for EU hydropower and nuclear output); which measures required under this regulation contributed neither positively nor negatively to the evolution of the crisis; and which of its provisions further exacerbated problems.

The review should propose amendments to the current framework where necessary. Additionally, it should consider how the regulation fits within the EU's broader security of energy supply architecture, and how current procedures under the different sectoral instruments for power, oil and gas can be further aligned and consolidated to maximise synergy and interoperability.

Once completed, the performance review can be used to design and implement new tools and revamp existing tools in line with the principles of adaptability and directionality. The resulting upgraded foresight apparatus should then enable a more granular understanding of the risks to economic security in the energy sector and beyond.

Together, these probes into the different problems and potential ways to resolve them will serve as a solid basis to ascertain the optimal mix of Promote, Protect and Partner measures to align the EU's clean energy transition with the objectives of security and competitiveness in the short-, medium- and long-term. Such conscious policy planning will, in turn, help to remedy the EU's practice of deciding the strategy and setting the targets before an in-depth assessment of risks, challenges and solutions.

Finally, given that a significant share of the clean energy infrastructure comes from third countries, there is a need for **stronger measures to protect Europe's data sovereignty**. Wind farms in particular count a high number of sensors, which offer the ability to control the functioning of entire components. In this context, it is important to ensure that data from offshore wind farms stays in Europe, in line with the requirements of the Network and Information Security (NIS) Directive.

From the economic security perspective, the surge in deployment of clean technologies has led to a concomitant **increase in Europe's reliance on China for their components and critical raw materials**. While not surprising considering the overwhelming Chinese dominance in clean energy supply chains,[110] **this dependence is of increasingly strategic proportions in the current context of mounting geoeconomic and geopolitical confrontation**.

In addition to measures required to preserve a **sizeable part of domestic manufacturing for all key technologies** (as discussed in chapter 6), **ensuring a stable and secure supply of essential materials** is primordial for the green and digital transition.

Critical minerals are the lifeblood of the clean energy transition with the demand for lithium expected to triple, for copper more than double, for cobalt nearly quadruple and for nickel increase more than five times by 2030.

This objective is at the heart of the **EU's Critical Raw Materials (CRM) Act**, whose different measures, including greater reliance on recycling and active partnerships with third countries, are all equally important. In addition, as proposed by Mario Draghi, **a dedicated EU Critical Raw Material Platform** would allow Europe to strengthen its position at the procurement stage, leveraging market power by aggregating demand and negotiating jointly with producer countries.[111]

Such measures should be supplemented by **effective CRM stockpiling, involving not only the physical accumulation of materials but also strategic coordination across member states and internationally** to manage these reserves efficiently. This approach is designed to mitigate supply chain disruptions and market volatility, ensuring that industries reliant on these materials can continue to operate smoothly.

The complexities of organising such a system are significant. It involves establishing clear guidelines for the amount and types of materials to be stockpiled, determining the roles and responsibilities of various stakeholders, and setting up mechanisms for the maintenance and rotation of these stocks to prevent degradation. Additionally, creating incentives for private producers to participate in stockpiling efforts is crucial.

The EU should achieve this through regulatory measures that **mandate storage requirements or through financial incentives such as fixed price contracting**, which guarantees producers a stable return on their investments.

Internationally, the importance of stockpiling strategic raw materials is also being recognised. In the US, a similar initiative has gained traction, with the bipartisan congressional committee proposing the establishment of a critical minerals reserve. This move reflects a growing awareness among global policymakers of the need to safeguard supply chains for key materials essential for national security and economic stability.

10. Conclusions

Economic security is an important accelerator of the net-zero transition by 2050, whose essential value must lie **in simultaneously increasing Europe's resilience** and capacity to face a new threat environment and **reducing the cost of the transition**. As a case in point, Europe's leadership in the global decarbonisation effort cannot be achieved at the expense of continued deindustrialisation resulting from high energy prices and loss of the competitive edge in the clean tech sector.

Similarly, efforts to lower the cost of energy are indispensable for easing the burden on households, ensuring commitment to the transition and for the longer-term resilience of the EU's socio-economic model. Should Europe fail to course correct its net-zero transition, EU policy would do little to incentivise other countries' decarbonisation efforts.

Economic security must become an important accelerator of the net-zero transition by 2050.

Massive investments are now urgently needed to gain 'escape velocity' and complete Europe's green transition. The lowering of the energy prices and significant improvements in resilience will not happen instantaneously. However, avoiding a determined and strategic shift towards low carbon energy, relying instead on temporary downswings in fossil fuel prices or the mercy of large producer countries, can only make Europe's vulnerability chronic. Economic security therefore needs to be firmly embedded in the new strategic approach aiming to forge a joint plan for decarbonisation and competitiveness, as argued by Draghi in his flagship report.

Compared to the focus on competitiveness, the notion of economic security implies a similarly robust effort to strengthen the foundations for growth and ensure vibrancy. However, it is also significantly broader. Europe's competitiveness must be future-proof through greater emphasis on resilience – reducing dependencies and vulnerabilities, preparing for the unthinkable, and carrying out active risk management. In short, Europe's competitiveness and decarbonisation requires addressing deep trade-offs in resource allocation, but also will not be achieved by following the rules of the past.

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9 Ember (2024), "European Electricity Review 2024", p. 59; Ember (2023), *op. cit.*, p. 48.

10 Ember (2024), *op. cit.*, p. 63.

11 See also: Letta, Enrico (2024), "", p. 62.

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