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DIVERSIFICATION AS THE CORNERSTONE OF THE EU'S ENERGY AUTONOMY

INTRODUCTION

As Vaclav Smil, one of the leading thinkers about energy issues invokes

> "Energy is the only universal currency: one of its many forms must be transformed to get anything done. '…History acts in unpredictable ways. Events in history, however, necessarily take on a structure or organisation that must accord with their energetic components'" (Smil 2017: 1).

Being so universal, it is not surprising that energy is a decisive element of politics on both national and international level. However, being part of the European Union's (hereinafter EU) policies, too, for a long time it is quite a new phenomenon that energy appeared in the discourse of strategic autonomy, however, the question of energy security had already popped up periodically due to the Russian–Ukrainian gas disputes in 2006, 2009, 2014. This turn is caused by the unprecedented challenge triggered by the Russian–Ukrainian war, which brings the agenda of energy again back at the centre of attention for the decision-makers and analysts. This study argues that diversification in the field of energy is a core concept which has to be achieved in the case of energy security. Given the fact that natural gas supplies suffered the most serious damage due to the large amount of losses incurred in a relatively short period of time, the study focuses on how natural gas supplies could be diversified or replaced by other sources. At the same time, it must to be underlined that even though energy supply diversification has different ways, divided into external and internal dimensions from a European perspective – as it will be presented later – the EU has to conduct its strategy extremely carefully since some of its unique features like insufficient domestic natural gas production or lack of critical raw materials in its own soil pose a serious handicap in the attempt of diversification. There are at least two significant threats the EU needs to focus on and evade as much as possible: the recreation of a new over-dependent energy relation and the potential political backfires which may arise from inside or from third parties as a consequence of a

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Table 1. *Conceptual framework*

From strategic autonomy to energy diversification			
External dimensions of energy diversification		**Internal dimensions of energy diversification**	
External natural gas supply diversification	**External replacement of natural gas by new sources**	**Internal natural gas supply diversification**	**Internal replacement of natural gas by new sources**
Liquefied natural gas	Hydrogen	Natural gas production	Renewables (solar, wind, hydrogen)
	Electricity	Natural gas consumption curtailment	Nuclear energy
		Energy network integrations	

Source: Compiled by the author.

wrongly conducted, unrealistic energy policy. These threats would be able to erode the EU's strategic autonomy, while the EU is working on strengthening it. Finally, since the REPowerEU plan has linked the need for reduced fossil fuels and fast-forwarded clean transition, not only strategic autonomy but also the whole green transition depends on the success of energy supply diversification.

FROM STRATEGIC AUTONOMY TO ENERGY SUPPLY DIVERSIFICATION

At the beginning, energy issues were not part of the discussions about European strategic autonomy. Regarding, for example, the often-cited *St. Malo Declaration* from 1998 as an important step in the history of European strategic autonomy, the concept was grounded on a military, defence-related consideration. "To this end, the Union must have the capacity for autonomous action, backed up by credible military forces, the means to decide to use them, and a readiness to do so, in order to respond to international crises" (CVCE 1998).

Since the St. Malo Declaration, it took 15 years until the explicit use of the term *strategic autonomy* (Damen 2022) appeared in the European Council conclusions on common security and defence policy in relation with strengthening Europe's defence industry (European Council 2013), showing that the concept remained predominantly on the same basis during this period. Nevertheless, it had started to change from the upcoming years.

In 2016, the EU published a document called *Shared Vision, Common Action: A Stronger Europe. A Global Strategy for the European Union's Foreign and Security*

Policy in which the linkage between energy and strategic autonomy was highlighted. As it stated: "An appropriate level of ambition and strategic autonomy is important for Europe's ability to promote peace and security within and beyond its borders. We will therefore enhance our efforts on defence, cyber, counterterrorism, energy and strategic communications" (European External Action Service 2016: 09). Moreover, energy security also got its own sub-section in this document, as it was listed among the other priorities of the EU's external action. According to this:

> "In line with the goals of the Energy Union, the EU will seek to diversify its energy sources, routes and suppliers, particularly in the gas domain, as well as to promote the highest nuclear safety standards in third countries. Through our energy diplomacy, we will strengthen relations worldwide with reliable energy-producing and transit countries, and support the establishment of infrastructure to allow diversified sources to reach European markets" (European External Action Service 2016: 22).

Around 2021, the concept of strategic autonomy started to change by becoming more inclusive in term of topics and the expression *open strategic autonomy* started to pop up. This can be observed for example in a policy report published by the European Commission's Joint Research Centre in 2021. The document highlights different trends and emerging issues which would have a potential influence on the open strategic autonomy in the long term in five key domains: geopolitics, technology, economy, environment, society. In this document the relation of energy to environment and green transition is highly emphasised (Cagnin et al. 2021).

In 2023, during the Spanish Presidency of the Council of the European Union, Pedro Sánchez presented a non-paper published by Spain's National Office of Foresight and Strategy related to open strategic autonomy. The document stressed: "What we need now is a comprehensive framework that allows us to transform this OSA concept and the ongoing measures into a true future-oriented strategy for the EU" and this non-paper "presents a comprehensive, balance and forward-looking open strategic autonomy strategy to ensure the economic security of the EU and its global leadership by 2030 in four critical sectors (energy, digital technology, health and food)" (Spain's National Office of Foresight and Strategy 2023: 22).

As it can be seen, European strategic autonomy became a widely used expression during the years, which makes it hard to detect its relation with energy. This study tries to present one potential way for the interpretation. For ground zero, the upcoming quasi-definition can be chosen as a core concept "EU strategic autonomy refers to the capacity of the EU to act autonomously – that is, without being dependent on other countries – in strategically important policy areas" (Damen 2022: 01).

The next step is to highlight the part of *without being dependent* from it and ask what does it mean *being dependent* in the field of energy? In short, energy dependency means being dependent on a given energy source and its related technology.

If the given energy arrives predominantly from 'outside', like in the case of the quasi-definition, energy dependency means supply dependency as well. The extent of supply dependency depends on how highly the given actor relies on the given resource and the given supplier. The greater these values are the lower the potential to act autonomously. In the same logic but from the opposite direction, mitigating energy and supply dependency should lead to regaining/strengthening autonomy. But what could be a tool for mitigate supply dependency and at the same time to regain autonomy? This study argues that these two aims could be achieved together via the implementation of the so-called energy supply diversification. Based on the above-mentioned considerations, diversification could be achieved in two ways in two different dimensions. The first dimension is the external one. In this dimension there are two ways to mitigate supply dependency: rerouting the import of the given resource or start to import other ones.

Regarding the internal dimension, which is the second one, there are also two sets of options. First, by increasing self-production and/or lowering demand of the given resource could mitigate supply dependency, while starting and/or boosting the use of other/new sources would result in lower resource dependency, thus, supply dependency could decrease, too.

In the following sections this frame will be used for the EU's energy relations in the context of the Russian–Ukrainian war. The study will focus on natural gas, which has a twofold motive. On the one hand, the natural gas situation was by far the most decisive question given, among others, its share in heating, thus threatening the very basics of human needs, while, on the other hand, replacing natural gas is in the heart of the green transition, too, and the two topics, had already been combined into one strategy by the *REPowerEU plan* when it was stated that "REPowerEU is about rapidly reducing our dependence on Russian fossil fuels by fast forwarding the clean transition and joining forces to achieve a more resilient energy system and a true Energy Union" (European Commission 2022a).

EXTERNAL DIMENSIONS OF ENERGY SUPPLY DIVERSIFICATION

The external dimensions of the EU's energy supply diversification are import centric. Whether it is the question of reshaping and changing the routes or origins of the natural gas already imported, whether creating new routes for new resources, by doing these the aim behind is to lessen the weight of a certain resource and/or supplier in the energy import mix, thus potentially mitigating supply security risks.

Since the eruption of the war, a big reshaping could be observed in the EU's overall natural gas import structure, while potential new energy networks like green electricity grids or hydrogen pipelines are in strategic consideration.

External natural gas supply diversification

The biggest change related to the external supply diversification is the restructuring of the EU's natural gas import mix regarding especially the parallel trends of the decreasing Russian and the increasing American (U.S.) natural gas import in it.

In 2021, Russian gas export (pipeline and LNG together) covered 45% of the EU's total gas import while the U.S. covered only 5% by its LNG. Within 2 years this scheme had dramatically changed. In 2023, Russian export dropped to 15% of the overall import, moreover around 40% of it arrived as LNG compared to the preceding pipeline dominance (European Council 2024a), which is not surprising since two out of the four Russian natural gas pipeline routes (the Yamal and the Nord Stream 1) had already stopped by the second half of 2022. These two routes had 88 billion cubic metres (bcm) yearly transport capacity. Meanwhile, the U.S. gas export climbed up from that 5% to more than 19% by 2023 and the U.S. became the second largest provider of natural gas for the EU following Norway and its 30% overall contribution to the total gas import mix (European Council 2024a).

What made possible this significant growth was on the one hand the so-called *shale revolution* in the U.S., and on the other hand the EU's already existing and growing LNG receiving infrastructure capacity.

Concerning the former, the s*hale revolution* is a complex phenomenon having technological, economic, geopolitical aspects all at once. All in all, the lucky combination of these variables had made the U.S. from a net natural gas importer into the world's biggest LNG exporter country by 2023 within less than 10 years. Meanwhile, its LNG infrastructure is still increasing and will potentially double by 2030 (Zaretskaya–Ober 2023).

Concerning the latter, LNG facilities have also shown increasing trends within the EU's territory as well. In 2023, the EU's LNG import capacity had grown by 40 bcm and during 2024 more 30 bcm is expected to come on pipeline (European Council 2024b). Also, in 2023, the EU imported 120 bcm LNG. Given that the total natural gas import of the EU was around 290 bcm that year, this means that around

40% of it arrived as LNG. The largest LNG importers among the EU countries were France, Spain, the Netherlands, Belgium and Italy (European Council 2024b). Regarding especially the U.S.-origin LNG, the first three countries consecutively receive jointly about more than half of the overall U.S. import by year. In 2021, it was around 14 bcm from 21 bcm, in 2022 37 bcm from 54 bcm, in 2023 37 bcm from 61 bcm (Makarewicz-Jaller 2024).

The measure of the U.S. LNG and the ongoing facility expansion on both sides of the Atlantic raise, however, the geopolitical question of dependency shifting. When a resource or its supplier becomes too decisive in the export share, it will always raise the question of dependency. Paying regard to this premise, the EU and its Member States have to arrange carefully their energy relations. Over reliance could lead to dependency even if the partner is generally a long-term firm ally like the U.S., which in turn may spill over to other domains of the parties' relations. This may weaken the EU's position on any particular subject, because the U.S. would have the chance to use the 'energy card' against the EU to put it under increased pressure in order to achieve its goals, or if its interests require so. What makes this situation extremely difficult and challenging is exactly the task to estimate and to detect where is the line beyond which this 'overreliance spill-over' scenario starts taking shape and actually becomes a relevant geopolitical hazard.

External replacement of natural gas by new sources

In the field of the energy resource diversification, the main aim is to change the already existing energy mix and routes for a new one. In this regard, importing electricity and/or hydrogen instead of natural gas has gained more and more attention and seems to dominate the current European discourse. Although, in their current situation, both options exist rather as strategic plans than already available options. At the same time, the two concepts are connected to each other, thanks to the particular role which both envisage to the African continent.

Africa has already played an important role in the European energy system. While the North African region provides natural gas supply which accounted for 14% of the whole European natural gas import in 2023 (European Council 2024a), Sub-Saharan Africa provides some other crucial natural resources. For example, most of the world cobalt supply – which is a crucial element in accumulator production, thus linked to digital and green transition at the same time – is mined in the Democratic Republic of the Congo. Another important element in terms of digitalisation, tantalum, which is used for capacitor production, also arrives predominantly from the Democratic Republic of the Congo and Rwanda. Meanwhile, platinum group metals (iridium, osmium, palladium, platinum, rhodium, ruthenium) which are essential elements in auto capacitor making are produced mostly in South Africa. Some Sub-Saharan countries like Angola or Nigeria also export natural gas to the global market in the form of LNG.

At the same time, the northern part of Africa is highly abundant in solar and wind energy (International Renewable Energy Agency 2023; Global Solar Atlas 2024; Global Wind Atlas 2024), which unique features make the region an exceptional candidate for installing high scale renewable infrastructures like solar panel parks or wind farms. These facilities would allow the countries of the region to generate green electricity – electricity is said to be green, when it is produced by renewable sources like solar or wind – then directly export it or use it to produce first green hydrogen – hydrogen is considered green, when the electrolysis which is used to produce it via splitting water to oxygen and hydrogen, got its electricity from a renewable source, for example from solar or wind – and then export that one as a commodity. Hydrogen could be exported via pipelines or could be liquefied similarly to natural gas. However, the specific steps of technological implementation are different compared to natural gas, e.g. unique pipelines for transmission or lower temperature for liquefaction. The green electricity and hydrogen gain increasing attention nowadays because besides their potential role of replacing natural gas, their direct production emit no CO_2; therefore, implying these technologies could contribute to achieve climate aims as well.

The EU is willing to become a partner in both scenarios whether it is about electricity or hydrogen and enforce the relations on these two domains, as it can be inferred from multiple documents. One of these is the joint communication entitled *EU External Energy Engagement in a Changing World,* which states that

> "Africa is a key partner for the EU [...] African countries can also contribute to the EU's energy security, today with oil and LNG supplies, and in future through green hydrogen and renewable fuels as well as raw materials critical to the green energy transition" (European Commission 2022b).

Another, earlier one is the EU's 2020 hydrogen strategy, which highlighted the potential role of Africa even before the energy and the Russian–Ukrainian crisis emerged.

> "Some of the EU's current gas suppliers and countries with a strong potential for renewables are considering opportunities to export renewable electricity or clean

hydrogen to the EU. For example, Africa, due to its abundant renewables potential and in particular North Africa, due to geographic proximity, is a potential supplier of cost-competitive renewable hydrogen to the EU requiring that the deployment of renewable power generation in these countries strongly accelerates" (European Commission 2020: 19).

Furthermore, it is worth mentioning that the EU's current list of *Projects of Common and Mutual Interest* (hereinafter PCI–PMI) contains an electricity interconnection project between Sicily and Tunisia called *ELMED* (European Commission 2023a: 04). Meanwhile, in 2022 Team Europe proposed a continent-wide Africa–EU *Green Energy Initiative (AEGEI),* which "aims to increase electricity production and access to energy, promote energy efficiency, create a conducive regulatory environment for private investments and advance market integration" (European Commission 2022c).

Even though energy relations based on renewables between Africa and the EU are generally framed as mutually benefiting, there exists another approach which is less discussed in the West arguing that this relation is founded on exploitation. One of the explicit summaries of this point of view is pointed out by Samuel Furfari former senior official at the EU's Energy Directorate-General.

"As for hydrogen, REPowerEU sets a target of 10 million tonnes (Mt) of renewable hydrogen production and 10 Mt of hydrogen import by 2030. Ideas are therefore being put forward to use renewable energy produced outside Europe, by producing green hydrogen in Africa, but these are proposals which push towards a new form of colonialism: ecocolonialism. How can we ethically think about producing a luxury product on a continent where not even half of the population is connected to the electricity grid? Not to mention that transport to Europe results in a considerable loss of energy. If Africans had the economic capacity to produce electricity from intermittent renewable sources (as we do with subsidies), they should use it to guarantee access to electricity for local populations rather than produce hydrogen for EU ecologists" (Furfari 2024: 109–110).

Besides the ethical considerations highlighted by Furfari, tangible tensions against some initiatives have already occurred among the local African population. These originate from the matter of territorial disputes (Albrecht – Ladekjær Gravesen 2023) or the question of water usage (Keskes–Haytayan 2023).

Water alone is a precious natural resource across the whole region, and green technologies are water-dependent. For example, water serves for cooling and cleaning

(European Commission 2019), like it is the case at Noor I concentrated solar power plant (CSP) at the Noor Ouarzazate Solar Complex (Power Technology 2020), which is one of the biggest such facility around the globe. In case of green hydrogen production, the water itself is split into hydrogen and oxygen by renewable-generated electricity, which means that in this particular example without water there is no hydrogen either. Moreover, if renewable infrastructures are deployed to water scarcity areas, water supply has to be solved, especially if these infrastructures were to be used for green hydrogen production. Therefore, scare resource management related to water supply could be on the one hand difficult and on the other hand conflictual, taken into account that the MENA region is affected by high water stress (Al Jazeera 2023).

One particular case which could represent the complexity of the question of renewables in the MENA region is the example of Tunisia. The country signed a Memorandum of Understanding with the EU in 2023, which contains green energy transition and emphasises renewables and hydrogen production by "speeding up the implementation of Tunisia's ambitions for renewable energy production" and "the Parties shall endeavour to strengthen the production of renewable hydrogen [...] in Tunisia, which could serve its internal market and international demand, while taking into account the need to protect its water resources". All in all, "to explore the possibility of strengthening cooperation on supply chains for clean energy technologies and electricity generation in a mutually beneficial manner" (European Commission 2023b). At the same time, a study from 2022 highlights that energy transition has a unique connotation in Tunisia.

> "The energy transition could provide answers to the expectations of the Tunisian population who seek to assert their political and economic sovereignty [...]. The Tunisian energy transition is not only a technical challenge but it is the hope of a profound societal change which could be channelled by the Tunisian authorities as a common societal objective for change, within the framework of the slowed political transition by the countless macroeconomic difficulties" (Mokrani 2022: 20).

The potential import of green electricity and hydrogen to replace natural gas is indeed an opportunity for which the EU has high hopes in relation to Africa, particularly its northern part. However, as it was briefly highlighted in general terms and using the example of Tunisia, these ideas are at least as challenging as they are promising. The EU must therefore arrange its future energy relations with North Africa very prudently to evade any potential political backlashes originated in the accusation of green colonialism or in a badly conducted or failed cooperation based on renewable energy. This seems to be an especially important task in case of green hydrogen, since the EU laid down imposing benchmarks in the *REPowerEU plan* by 2030, which are openly debated, for example, being called unrealistic (Balanyá 2023).

INTERNAL DIMENSIONS OF ENERGY SUPPLY DIVERSIFICATION

The internal dimensions of the EU's energy supply diversification are production centric. On the one hand, the EU could try to increase its own natural gas production as well as try to decrease its natural gas demand. In both cases, dependence on supplies could be reduced by decreasing overall dependence on natural gas imports. On the other hand, the EU could develop alternative energy networks to replace natural gas. In this latter case, the EU needs the related technology to be able to do so. However, related to certain green technologies, the EU lacks crucial raw material, which leads to the consequence that even internal production is heavily import reliant as it is the case with solar and wind power. Green hydrogen looks less dependent than the former examples, in return it is the less available option at the moment since the concept is being mostly in strategic phase. Besides renewables, rising interest toward nuclear energy – which could also serve as replacing natural gas in electricity generation – shows a mixed picture.

Internal natural gas supply diversification

Regarding the internal supply diversification, the EU has three main hypothetic options to enhance its possibilities. Increase its own natural gas production, reduce natural gas consumption and create a more integrated energy network, thus increase flexibility, therefore, efficiency.

Regarding the internal natural gas production, the EU shows a decreasing trend. In 2021, overall gas production in the EU was 50.6 bcm (European Commission 2021: 03–04). The biggest producers were the Netherlands with 21 bcm followed by Romania with 8.9 bcm (European Commission 2021: 09). In 2022, gas production dropped by around 7% meaning that it was approximately 47 bcm in total. The main producers remained the same countries highlighted above (Eurostat 2023). According to the available gas reports in 2023, the EU produced 29.7 bcm natural gas until the end of the third quarter, which is 18% less year-on-year; still, the Netherlands goes first and Romania second (European Commission 2023c: 08).

However, changes are expected in the near future and in the medium term at both major producers, which will be in opposite directions, and may also affect their positions. After consecutive earthquakes in the last decade, the Dutch Government decided to advance the closure of the Groningen field from the originally provisioned 2030 target. The field was shut down in October 2023. At the same time "after the closure, the government retained the option to activate up to five drilling sites for a temporary period in case of potential shortage or pressure for volumes in the market" (Ghilotti 2024), which actually already happened in early 2024. Before its closure during the final year of its operation, Groningen produced 2.4 bcm natural gas, which was around 1% of the total European demand volume and 10% of the Dutch one in 2022 (Bedeschi 2023).

In the near future Romania will, however, experience the exact opposite trend. In June 2023, the final investment decision was taken in relation to develop the Neptun Deep project. According to the plans, drilling starts in 2024 and production is expected in 2027 at 8 bcm annual capacity, which is almost equal to Romania's total 2022 production.

Regarding the question whether the European countries would like to extend their production, one of the natural gas reports noted an important observation:

> "Even amid extreme high wholesale gas prices at the European hubs, domestic production in most of the European countries could not increase significantly, suggesting that there are technical and societal/environmental obstacles (e.g. depleted gas fields, significant resistance from the society for further gas production owing to damages in some countries, etc.) play more important role than economic profitability, which result in permanently dwindling production in the EU. Relatively long lead time to mobilise investment and develop economically viable and socially/environmentally acceptable projects in the densely populated European territory may also have contributed to the overall insignificant increase in domestic gas production" (European Commission 2022d: 07).

In this context one may ask if neither the crises nor the higher economic profit was able to mobilise higher gas production then what would be able to do so?

In addition to internal natural gas production, changing in demand could be an important factor, too, to alter supply security. The EU's overall natural gas consumption, just like its production, shows a declining trend. According to the quarterly gas reports, the EU's total gas consumption amounted to 412 bcm in 2021, 356 bcm in 2022 and 330 bcm by the end of the third quarter of 2023, representing a 10% decrease year-on-year.

In early 2023, the *International Energy Agency* (hereinafter IEA) published an analysis and summarised the key factors that drove the record fall in the natural gas demand in 2022 (Zeniewski et al. 2023). In their analysis they identified overall 10 factors in three key sectors: power, buildings, industry. Going more into the details, several connections can be noticed that may have a decisive role in the future, as well.

For example, one could take notice that the whole decrease was actually 85 bcm instead of 55 bcm. However, there were variables which increased gas consumption. The two notable examples are the lesser output from nuclear power and hydropower. In both cases, the missing volume was replaced mostly by more natural gas usage. These two examples highlight that technological and environmental criteria are also factors to be taken into account in the diversification of future energy supplies.

The former was primarily the result of the French capacity drop, caused by factors including corrosion problems and routine inspections postponed due to Covid-19, which together resulted in such a significant change that a large number of reactors were shut down for a long period of time. In August 2022, at its peak, this ratio was 65%, when none of the 56 reactors were in operation. As a local consequence, France became a net electricity importer in that year, which was unprecedented since 1980 (RTE 2023).

The latter was the consequence of a significant drought affecting mostly the southern European countries and causing troubles around hydropower production, especially in Spain and Italy (Lauro 2022). Considering that 2022 was the 6th hottest year (National Oceanic and Atmospheric Administration 2023), and 2023 was the hottest by far (National Oceanic and Atmospheric Administration 2024), if the trend lasts longer, serious hydropower outages can be expected in the upcoming years, too.

In addition to the question of natural gas production and consumption, the final element which could influence the internal supply diversification is the condition of the energy systems. The more interconnected a system is, the greater its flexibility, which can improve security of supply by reducing delivery times, enabling larger quantities to be delivered and providing more potential players. This could be applicable to the gas system and the electricity grids as well. Regarding the natural gas infrastructure, some notable expansions since 2022 are the Baltic Pipe, the Greece–Bulgaria interconnector, the Poland–Slovakia interconnector and new LNG facilities in Finland, France, Germany, Italy and the Netherlands. Regarding electricity, the aforementioned current PCI list contains more than 20 electricity interconnection projects. Moreover, the EU's *Action Plan for Grids* also emphasised that "an accelerated energy transition requires a shift towards a decentralised, digitalised, integrated and flexible system […]. In the next seven years, we should double our cross-border transmission infrastructure" (European Commission 2022f).

One particular example representing the need for greater integration of natural gas and electricity networks is Spain. Even though the country receives a great amount of LNG and has huge renewables potential and has presented ambitious hydrogen plans, it is hardly integrated into the European gas and electricity networks, therefore the Iberian Peninsula is often referred to as an energy island (Ribó Pérez 2023).

Internal replacement of natural gas by new sources

For higher internal diversification of the existing energy production, three ways seem the most probable currently: more renewable energy, nuclear energy and hydrogen. 2023 was a record year regarding renewables. For the first time, more than a quarter of EU electricity (27%) was provided by wind and solar in 2023, up from 23% in 2022. "This drove renewable electricity to a record high of 44%, passing the 40% mark for the first year in the EU's history" (Brown–Jones 2024). "Also wind generation reached a major milestone, surpassing gas for the first time" (Brown–Jones 2024).

In case of substituting fossil fuels and accelerating Europe's clean energy transition the *REPowerEU* plan envisages a massive buildout of renewable capacity. In this context, the document proposed to increase the already settled target for the share of renewables in gross final consumption from 40% to 45%. The amended *Renewable Energy Directive* in 2023 set out a target of 42.5% while suggesting that "beyond mandatory level, Member States should endeavour to collectively achieve an overall Union renewable energy target of 45% in line with REPowerEU" (European Parliament 2023). In this progress, solar and wind power were appointed to play a crucial role.

In case of solar power, 320 GW of solar photovoltaic capacity should be installed by 2025 and almost 600 GW by 2030 (European Commission 2022e). The 2023 solar generation capacity was 260 GW (European Commission s. a.a).

In case of wind power, the target is to reach over 500 GW by 2030 (European Commission 2023d), more than doubling the 2023 capacity of 221 GW (European Commission s. a.b).

Both the *Solar Energy Strategy* and the *European Wind Power Action Plan* estimate the annually required capacity expansion to meet their target. In case of solar power, it is around 45 GW and for the wind power 37 GW. Regarding the last two year's instalments, new solar capacities were 41 GW and 56 GW, while new wind capacities were 16 GW and 17 GW in 2022 and 2023 respectively (Brown–Jones 2024). As it can be seen, the EU assigns solar and wind powers as the backbone in its green transition strategy since the *REPowerEU plan* envisioned a total of

1,236 GW renewable energy generation by 2030 (European Commission 2022a). Even though this was measured by 45% share and finally 42.5 was accepted in the amended *Renewable Energy Directive,* so the final target is slightly less, but this does not affect the overall question, notably will the EU be able to achieve its aims? Since, as it can be noticed in terms of installed wind capacities, the EU is already behind its estimated annual projections.

Higher internal installation rate means, on the one hand, more production of the given technology or, on the other, more import of it. Even though the EU has adequate production bases, the lack of necessary raw materials in its soil inevitably means that sooner or later import becomes a must even in case of domestic production. To underpin this statement, the supply chains of solar and wind energy infrastructures with their respective elements need to be examined.

The *Joint Research Centre* (hereinafter JRC) the Commission's science and knowledge service has published its report in 2023 providing systemic and detailed analysis of 15 key technologies which are indispensable in the green and digital transition by assessing supply chain dependencies and forecasting material demands. The study applies a universal 5-stage-long supply chain model; raw materials, processed materials, components, assemblies, super assemblies. At each stage of each technology the global production shares of countries or groups of countries are represented. Note that not every technology owns all the 5 stages as it will be seen regarding the percentages below.

In case of solar photovoltaics, the EU's share is stage by stage 4%–12%–11%–2% respectively. The biggest player of the sector is China, owning 45%–41%–54%–70% respectively. The 70% is more overwhelming in the light of the fact that the second biggest share belongs to the rest of Asia with 10% (Carrara et al. 2023: 62).

In case of wind turbines, the EU's share is stage by stage 2%–15%–24%–10%–34% respectively. The biggest player in the sector again is China, owning 42%–36%–49%–53%–52% stage by stage respectively (Carrara et al. 2023: 46).

Even though the gap in the final stage which is related to the manufacturing of wind turbines is the lowest, it is worth mentioning that, since the previous report in 2020, "EU share in global production has decreased from 58% to 34%, while the Chinese share has increased from 23% to 52%" (Carrara et al. 2023: 47).

Furthermore, in terms of magnet manufacturing, which is an essential element in many wind turbines, China owns more than 90% of it and conducts 63% mining of a group of elements, the so-called *Rare Earth Elements* (hereinafter REEs) from which some are necessary for preparing these magnets (Carrara et al. 2023: 50).

The REEs are part of a bigger group of elements called *critical raw materials* (hereinafter CRMs) which are "raw materials of a high importance to the economy of the EU and whose supply is associated with a high risk" (Grohol–Veeh 2023: 44). This high risk of supply derives from the fact that the production or processing of these raw materials are geographically concentrated. The risk usually refers to a tangible transport issue or to a fear that because of the delicate relations between some of the countries and the EU, politically motivated and conducted supply disruptions could appear. Some CRMs like REEs are also considered *strategic raw materials* (hereinafter SRMs) as well, which in turn reflect their "importance for technologies that support the twin green and digital transition and defence and aerospace objectives" (Grohol–Veeh 2023: 46).

According to the aforementioned data it looks like the European green transition which is profoundly built on solar and wind power is heavily dependent on China, especially in case of the former, which is, moreover, the more prominent one among those two in terms of projected capacities in the EU's strategy. China, of course, is far from being the only example for this kind of CRMs–SRMs concentration, however, regarding its geopolitical influence, probably the most notable.

By failing to settle the supply security issue of CRMs–SRMs, the EU would risk being the subject of Chinese dominance, which could potentially undermine not just the internal diversification efforts, but the whole course of green transition.

Acknowledging the importance of these raw materials, the EU Commission proposed their regulation in 2023 by the so-called *Critical Raw Material Act* (hereinafter CRM Act) with the general objective "to improve the functioning of the internal market by establishing a framework to ensure the Union's access to a secure and sustainable supply of critical raw materials" (European Commission 2023e). To achieve this, the regulation among others, proposes three benchmarks:

> "(1) Union extraction capacity is able to extract the ores, minerals or concentrates needed to produce at least 10% of the Union's annual consumption of strategic raw materials, to the extent that the Union's reserves allow for this; (2) Union processing capacity, including for all intermediate processing steps, is able to produce at least 40% of the Union's annual consumption of strategic raw materials; (3) Union recycling capacity, including for all intermediate recycling steps, is able to produce at least 15% of the Union's annual consumption of strategic raw materials" (European Commission 2023e).

Besides solar and wind power, there are two other means for replacing natural gas, which are nuclear power and hydrogen. What they have in common is that both receive more and more attention nowadays and are expected to ramp up massively by the upcoming decades.

Different sources have suggested that a new, more supporting narrative for nuclear energy has started to emerge recently. "For the first time since the annual climate summits commenced in 1995, the 198 signatory countries to the UN Framework Convention on Climate Change (UNFCCC) officially called for accelerating the deployment of low-emission technologies including nuclear energy to help achieve deep and rapid decarbonisation, particularly in hard-to-abate sectors such as industry and through the low carbon production of hydrogen" (Donovan 2023).

An IEA report published in 2022 suggested that

> "there are economic and technical challenges to be overcome, and not all countries will pursue nuclear energy as an option, but rising climate ambitions in many countries and today's energy crisis offer reasons to take a fresh look at what nuclear energy can deliver [...]. Since that last report, the policy landscape has shifted in ways that favour nuclear energy" (Fraser 2022).

Pro-nuclear public opinion seemed to rise from 2021 to 2022 as well in some EU countries like Belgium, France, Germany, Italy or Spain. A particular element as a related study highlights is that the biggest increase in favour "is particularly strong in countries where anti-nuclear positions are predominant and entrenched such as Italy or Germany" (Brugidou–Bouillet 2023). The study also argues that in case of support for nuclear energy "the shift from a risk-based framework, due to the health crisis, to an economic-based framework, this time essentially linked to the war in Ukraine, is a factor" (Brugidou–Bouillet 2023).

The latest symbolic and meaningful sign of the growing interest in nuclear power was the very first *Nuclear Energy Summit* held on 21 March 2024 co-hosted by Belgium and the International Atomic Energy Agency in Brussels, where more than 30 countries and the EU gathered and focused entirely on nuclear energy and presented national statements as well as participated in panel discussions dedicated to relevant aspects of the sector.

During the summit, Ursula von der Leyen had marked four tasks in relation with the nuclear sector: "(1) invest now in climate neutrality 2050, (2) broaden your engagement with clean energy transition, (3) consider the extending of lifetimes of existing plans with full commitment to the highest level of safety and (4) innovate." She also highlighted: "If the industry and governments can deliver on these tasks then I can see a way forward for nuclear power to make a significant contribution to a rapid safe and secure Net Zero future" (European Commission 2024).

At the same event French President Emmanuel Macron underlined that currently our challenge is to deliver on climate change, improve our sovereignty by securing our energy and improve our competitiveness. To reconcile these elements, a relevant and consistent energy approach is needed, which is for him reliance on efficiency and innovation, renewables and nuclear energy. In order to do so he also provided his eight remarks which gravitated around these phrases: producing more capacity, financing, securing the industry's value chain, competence, waste management, innovation, interconnection and safety (IAEA 2024).

What Macron says is extremely relevant in at least two respects. On the one hand, nowadays there is a so-called *Nuclear Alliance* forming around France in which "ministers and high-level representatives agreed to work together on a road map to deepen their cooperation and trigger the involvement of the European Union in the field of nuclear energy" (Réunion des pays de l'Alliance du nucléaire 2023). On the other hand, France is the leading country in the EU in terms of nuclear energy capacity.

Throughout the whole summit, the *Small Modular Reactors* (hereinafter SMRs) had come up frequently by different participants and in different situations, which implies that the concept itself within the broader topic of nuclear energy has started to gain more and more attention. It is not surprising, since the concept has the potential to revolutionise the entire sector because it could be produced and installed cheaper, faster and easier.

Considering these factors, SMRs could serve the energy supply diversification attempts in many ways, for example by decentralising the nuclear energy system, the power grid, or contribute to the production of hydrogen. There are around 80 SMR designs and concepts worldwide, while the earliest commercialisation of the technology is expected around 2030.

The recent change and growing prospect around nuclear energy, however, also raise some questions about the future as well, especially regarding the value chain of uranium. Since the element is the most frequently used fuel in nuclear reactors, attempts to increase significantly the nuclear capacities have therefore consequences on the uranium's value chain as well, especially regarding its mining and enrichment. Both cited stages show some concentration similar to the CRMs, nevertheless, not on as high level as in the case of REEs.

In terms of mining, Kazakhstan was the first producer supplying around 40% of the global natural uranium, while the second largest global producer was Canada with around 15% (World Nuclear Association 2023). Meanwhile, regarding enrichment, the main actor is Russia dominating this market segment by around 40% share in 2023 (Enerdata 2024).

In 2022, the EU procured 17% of its natural uranium from Russia, while the figure for enriched uranium was 30%. Other significant partners for the EU were for natural uranium Kazakhstan (27%), Niger (25%) and Canada (22%). Regarding the enriched uranium, there were no other significant external partners, yet the intra-EU share was 62% (Euratom Supply Agency 2024).

Growing interest, especially on a global scale, could result in more projects and upcoming capacity expansions. In case of the EU, around 50GW new capacity is envisioned by 2050 (Réunion des pays de l'Alliance du nucléaire 2023).

Regarding the growing interest and the central role of uranium, Russia's position in the sector could become more prominent. The potential consequences are hard to guess, but if demand grows significantly, maybe even faster than the supply could cope with it, interruptions along the supply chain and price increases may be expected, just like a stronger Russian influence in the sector. These potential changes could challenge the way for achieving a more profound European strategic autonomy as well.

Finally, the last structural opportunity to diversify the internal energy sector is related to green hydrogen. This energy vector gets probably the most hype even though the distance between related existing infrastructures and future projects is the greatest also.

In addition to its envisioned revolutionary potential as a fuel, thus replacing fossil ones in the transport sector, hydrogen could be used in the energy system as well. Regarding its inter-convertibility, it could be used either as storage or balancing in electricity networks.

The REPowerEU plan set an overall target of 20 million tonnes of renewable hydrogen by 2030 from which 10 million tonnes should be produced domestically and the other 10 would arrive as import. To be able to produce that quantity inside, the EU needs producing capacity and transport infrastructure as well.

Regarding infrastructure, there is already approximately 1,600 km hydrogen pipeline in Europe (Martin 2023). These pipelines "at the moment mostly deliver hydrogen from the place of production to the points where it is consumed by specific sectors (such as oil refining or petrochemical industry)" (Patonia et al. 2023: 6). According to the *Clean Hydrogen Monitor 2023* published by Hydrogen Europe in 2023: "The refining and ammonia sectors together account for 81% of the total consumption of hydrogen in the EU, EFTA, and the UK" (Fonseca et al. 2023: 12).

Regarding the upcoming transporting infrastructure, the *European Hydrogen Backbone's* latest report from November 2023 "highlights a set of 40 concrete projects managed by the EHB's TSO members, representing 31,500 kilometres of hydrogen pipelines with expected commissioning prior to 2030" (European Hydrogen Backbone 2023: 4). The already mentioned PCI–PMI list also contains hydrogen related projects from which 30 is related to hydrogen infrastructures and interconnections, 17 to electrolysers and 7 to hydrogen storages.

In addition to the envisioned growing hydrogen transport infrastructure, the increasing demand would mean a growing need for internal production as well, for example, via growing needs for electrolysers. This scenario, similarly to the case of solar, wind and nuclear power, brings up again the question of supply chain. Thanks to being part of those 15 key technologies which were elaborated, the already cited JRC report deals with the electrolysers as well which has the duty to split water into oxygen and hydrogen. Actually, the report examines 4 types of electrolyser supply chains.

The average production share of the EU for these 4 types stage by stage were 3%–20%–35%–50%, so a very small share of raw material combined with a quite high one related to manufacture. Here, China is once again an important player with a share of 30%–20%–10%–8%, but less dominant than in the case of renewable energy sources already examined, thanks to the greater diversity of the global market. In terms of raw materials, Africa (24%), Latin America (11%) and the rest of Asia (11%) are the main players, while in terms of components and assemblies, the U.S., Japan and the rest of Europe are the other influential players, with shares ranging from 10% to 30% (Carrara et al. 2023: 35).

Regarding its potential usage and the EU's market share, it would be tempting to conclude that hydrogen could play a decisive role in replacing natural gas. However, this depends largely on the extent of future use, which undoubtedly promises to be ambitious, but the current infrastructure could hardly be taken into account in this context. Furthermore, as it is intended to be a 'green' energy source, the future of the hydrogen sector in Europe is currently linked to the development of renewables, while only a small percent of the global and European hydrogen production currently comes from electrolysis and renewable energy sources. Most of it is produced using natural gas and a process called "steam reforming".

CONCLUSIONS

The Russian–Ukrainian war had presented an unprecedented challenge to the European Union in the field of energy. As a reaction, the *REPowerEU plan* has emerged, which appoints the speed up of the dual strategy of abandoning Russian fossil fuels and accelerating green transition. Both the challenge and the response can be interpreted in relation to strategic autonomy, since the very essence of these concepts is to act autonomously – that is, without being dependent, thus, autonomy could be increased by reducing high energy dependence. To do so, energy supply diversification serves as a cornerstone, however, it is itself a complex issue and brings up not just solutions but new challenges, as well.

This becomes more evident by examining the concept in more detail. As the external dimension of the energy supply diversification, which is import centric by nature, the EU could rather reshape the origins of its natural gas import mix or start to look for new resources to replace it. In the case of the former, the significantly increasing LNG import from the U.S. is probably the most noteworthy. While this could be considered a success in the short term, it may raise certain questions in the long term especially in the event of an accidental overreliance, which could pose a challenge to European strategic autonomy, given the shift in dependence from Russia to the U.S. As an alternative to natural gas import, the EU could also import electricity or hydrogen, which, according to the EU's strategic guidelines, should come from renewable sources, mostly by solar or wind power. Africa appears to be a key potential supplier of both electricity and hydrogen in the future, thanks to its unique features in terms of abundant solar and wind energy. Even though the parties involved have already developed strategies and approaches, these opportunities raise technological and political questions, the latter of which could have repercussions for the EU.

As an internal dimension of energy supply diversification, which is production and technology intensive, the EU could instead accelerate its own natural gas production and/or reduce its demand and/or replace it. The former involves events with various consequences, such as the closure of the Groningen gas field in the Netherlands or the envisioned production ramp-up in the future, related to Romania's Neptun Deep project. Although this project is likely to make Romania the EU's number one producer of natural gas, and the amount of natural gas potentially produced from 2027 onwards could be significant at local and regional level, it will be far from being a decisive factor in the overall European gas demand, which is orders of magnitude greater than this. All this is supplemented by the fact that EU countries in general do not seem to be willing to significantly increase their natural gas production, which means that internal natural gas production seems to be a limited option in terms of diversification.

At the same time, renewables (solar, wind and green hydrogen) and nuclear energy could serve as a tool to replace natural gas. In these cases, the EU either has to import the related technology and infrastructure or create and build it out its own by itself. Nuclear energy is undergoing a reappraisal by both the public and politicians, and growing interest could lead to growing demand. In this case, Russia's influence may also increase, as uranium is the most commonly used nuclear fuel and Russia is the world's leading uranium enricher. However, the EU's exposure in this area appears to be lower than for certain key renewable energy raw materials. Concerning the infrastructure related to solar power, wind power and green hydrogen production, the EU has a good foundation, but in terms of critical raw materials, it is anything but abundant, which means that these elements must be imported. Observing the value chain for these infrastructures reveals that one country, China, has a significant presence in many cases all along the supply chain and for a number of different critical raw materials. Chinese dominance is sometimes so overwhelming that one may say that the whole future of the European green transition project is currently in China's hands. Since the green transition is a key part of energy supply diversification in both practice and in theory, this Chinese dominance could also have a strong impact on the future extent of strategic autonomy.

As a summary, it can be said that energy supply diversification had already reached some serious success and will continue to serve as a cornerstone in the EU's strategy related to energy issues. However, what must be emphasised is that energy supply diversification is far from being an easy fired silver bullet. Rather, it is – as it was elaborated throughout the previous chapters – a really complex multi-level, multi-sectoral, multi-temporal and multi-policy issue. The EU must therefore develop a real masterplan to balance all of these and thereby maximise its strategic autonomy in the field of energy.

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