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New economic and geopolitical balances in the 21st century: Renewables and critical minerals in the energy transition

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Bonum certamen certavi, cursum consummavi, fidem servavi;
in reliquo reposita est mihi iustitiae corona,
quam reddet mihi Dominus in illa die, iustus iudex,
non solum autem mihi sed et omnibus, qui diligunt adventum eius.

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Introduction

This thesis aims to provide an overview of the geopolitical risks associated with the recent energy transition, the latter being devoted to the large-scale adoption of renewable energy sources. Renewable energy is referred to as defined by the International Energy Agency: *"*[Renewable Energy are] *derived from natural processes that are replenished constantly. Included in the definition is energy generated from solar, wind, biomass, geothermal, hydropower and ocean resources, and biofuels and hydrogen derived from renewable resources"*[1].

The geopolitical risks linked to the low-carbon transition will be examined through the analysis of the three fundamental clean energy supply chain steps: the extraction and refining of the so-called critical minerals, and the manufacturing of green technologies, many of which rely on critical minerals. It will be necessary, before delving into these key steps of the value chain, to provide a historical framework through what have been the past transitions and their respective energy sources, i.e. coal, oil and gas. The initial historical framing will be necessary to define the meaning and use of the energy weapon from the beginning of fossil sources, i.e. the coal weapon until the latest gas weapon deployed in the 2022 Russian-Ukrainian conflict.

The concept of energy weapon will show to be important in understanding geopolitical risks related to the energy transition and the emergence of two new possible and future weapons, the mineral weapon - already used in 2010 by China against Japan - and a weapon linked to the sale of electricity as a finished good. For critical minerals this thesis will refer to four specific minerals, defined as critical due to their high geographical concentration and their importance in the production of renewable energy sources: copper, nickel, lithium and cobalt. Indeed, several studies, among which the IEA's *"Energy Technology Perspectives 2023",* underscore the fact that a clean energy supply chain is characterised by a high degree of geographical concentration, both for the mining and refining of critical minerals and finally in the manufacturing of clean technologies. China leads the global clean energy supply chain and has a dominant position in the refining of critical minerals, as well as in the manufacturing of relevant clean energy technologies.

"The current energy transition globally can broadly be understood as a response to the imperative of climate change. Previous transitions, as from wood to coal, and from coal to oil and gas, have been driven by the availability, lower cost and improved convenience and utility of the new energy source"[2]. The interest and push for clean energy is relatively new and there has still not been a

[1] IEA (2005). *"Renewables Information 2005",* 2005th edn. OECD Publishing, Paris, p. 29. Available at https://www.oecd-ilibrary.org/energy/renewables-information-2005_renew-2005-en (Accessed 24 August 2024)

[2] Mills R. (2020). *"The Geopolitics of the Global Energy Transition in MENA"*, in Lecture Notes in Energy book series (LNEN), volume 73, p.116.

significant shift in the world's energy supply yet. Since the 2016 Paris Agreement, most nations have increased their policy support for renewable energy, a support which has grown even more as a result of Covid-19 economic recovery packages and the recent gas-crisis. To date, 195 countries have ratified the 2016 UNFCCC Paris Agreement to limit the global average temperature increase to 1.5°C above pre-industrial levels. To reach this goal, the renewables' energy sources will play a key role.

Renewables were at first regarded as useful tools important for decarbonization. However, it was in the 2022 energy crisis aftermath, triggered by Russia's invasion of Ukraine, that the green technologies assumed a role of primary importance given the European fossil-fuels' dependence on Moscow. The energy crisis following Russia's invasion of Ukraine has highlighted vulnerabilities from relying on fossils fuels and raised concerns on national energy security.

According to IEA (2024)[3], solar photovoltaic (PV) panels and wind turbines will represent almost 95% of the renewable energy sources put in place until 2050 as they benefit from lower costs than both fossil and non-fossil fuel alternatives. Electric vehicles (EVs) will cover a key role in the society's decarbonization too. The new energy system powered by clean technologies will be substantially different from the fossil-fuelled one. As a matter-of-fact solar PV plants, wind turbines farms and EVs don't need any fossil fuel to generate electricity. Indeed, renewable energy sources shift focus from the safety of maritime routes and oil pipelines to the security of electricity grids and the supply of critical materials. Therefore, compared to fossil fuels, renewables appear less exposed to political and market disruptions once a production unit is active and operational, even though uncertainty will be a consequence of technologies and materials' price unpredictability. New clean energy sources do require a vast amount of minerals for their construction and to operate. For instance, nine times more mineral resources are required for an onshore wind plant *vis-à-vis* a gas-fired plant which generates the same amount of electricity. Therefore, it is evident that the shift to renewables' clean energy comes with a stark shift from a fuel-intensive to a mineral-intensive system. Renewables use different types of minerals according to the leading technology but the main mineral resources employed are nickel, cobalt, lithium and rare earth elements (REEs), with copper and aluminium being base materials for virtually all electricity-related technologies. Usually lithium, cobalt and REEs prevail the energy transition minerals' discussions, this is because metals such as copper and nickel are not only employed in the transition's technologies but register a wide array of uses worldwide. *Ça va sans dire* that, as technology determines which minerals and in which amount are employed in manufacturing, technological innovation is set to cover an extremely important role. Indeed, innovations can determine the end of import, therefore of dependence, of critical minerals' or

3 IEA (2024). "*Renewables 2023"* [online]. Paris: OECD Publishing, pp. 7-8. Available at: https://www.iea.org/reports/renewables-2023 (Accessed 28 June 2024).

the latter's more effective use, resulting in a balance of power renegotiation between the exporting and importing state.

It arises that there will be a significant and complex change brought about by the clean energy transition, which might result in new types of conflict, e.g. new energy weapons. As a consequence, it seems that most innovative nations with the availability of competitive funding will emerge as the long-term winners of this transformation, despite the fact that China is the clean energy transition current leader, managing from 60 up to 95 % of the critical minerals' refining and renewables' manufacturing, a data that will hardly change in the short term.

Chapter 1

Historical background: from coal to critical minerals

"It was eight bells ringing,
For the morning watch was done,

[…]

Now the sunset breezes shiver,
And she's fading down the river,
But in England's song for ever
She's the Fighting Téméraire" [4]

In 1921 these lines by Sir Henry John Newbolt were inspired by the exposition of the 1838 painting "*The Fighting Téméraire, tugged to her last Berth to be broken up"* by Joseph Mallord William Turner. In his masterpiece, Turner portrays the vessel "Téméraire", which played a significant role in the 1805 British victory at Trafalgar. The ship is depicted while towed for dismantling by a little steam-powered tugboat. At that time, the Téméraire stood as one of the last remaining vessels that participated in Nelson's historical victory. The artwork fully grasps the symbolic loss of the ship to embrace a new future, summarizing the passage from the old to the modern. The *grandeur* of the vessel stands in stark contrast to the little grey tugboat as the sun sets. The painting reflects, among the others, a broader acknowledgment of the end of the era dominated by Nelson's wooden sail-powered navy.

Before the industrial revolution, energy sources were purely natural and were exploited without being transformed, e.g. human strength, wind to push boats' sails or mills' blades … With the onset of the industrial revolution men learned to exploit and transform elements present in nature to obtain energy. The first major source of fossil fuel energy was coal, followed later on by oil and gas. The term "fossil fuel" has not always meant the same thing along history. During the XIX century, it was used to make a distinction between coal and charcoal[5]. In the early XX century, fossil fuel meant coal

[4] Newbolt, S. H. J. (1921). "*Poems New and Old: By Henry Newbolt"*. London: John Murray.
[5] Holland, J. (1835). "*The history and description of fossil fuel, the collieries, and coal trade of Great Britain"*. London: Whittaker.

and oil together, finally, later that century, it indicated different energy sources produced by different means.

Fossil fuel sources of energy, unlike the natural ones as wind and sun, are not equally distributed on earth; they rather appear concentrated. Therefore, some nations have found under their soil massive fossil fuels' deposits while other were totally devoid of it. Since the latter's first appearance, the country who held the largest production of that period's dominant energy source and its related technologies has been world's hegemon; this was the case of Britain with coal from 1815 to 1873 and the United States of America with oil from 1945 to present days[6]. Given the uneven distribution of these materials, countries have often used fossil fuels as a geopolitical weapon and leverage *vis-à-vis* other countries to their own advantage. This has been the case of England with its rich coal fields since the XIX century industrial revolution.

[6] Podobnik, B. (2006). "*Global energy shifts: Fostering sustainability in a turbulent age*". Philadelphia, PA: Temple University Press.

1.1 **Coal**

1.1.1 The fossil fuel

Coal was a vital source of energy to foster European countries' industrialization during the Industrial Revolution aftermath. The precious material was used as a geopolitical weapon by England in the first decades of the 1800s as the country held the largest coal deposits and the major share of its international trade. As a matter of fact, the Industrial Revolution and the transition to coal initiated modern economic growth while, simultaneously, laying the foundation of British geopolitical hegemony too[7]. Indeed, in the Industrial Revolution aftermath, coal was extracted extensively, and Britain became the world's largest coal producer[8] and exporter all along the XIX century, establishing coal depots in the Empire in order to extend and project British Isles' power and hegemony. England was able to project its influence all over the world since they held the largest coal reserves and dominated coal-related industry and technology. In the XIX century, coal emerged as the primary energy source for industrial economies and their armed forces, especially employing the mineral in steel production. Indeed, coal was used in industry, for rail transportation in both peace and war, by merchant fleets and naval forces and was the energy source employed in the iron ore smelting to manufacture steel. Both the availability of coal mine production and iron ores soon became critical and vital resources for states. Welsh steam coal was ideal for its natural properties and conveniently positioned close to large ports, i.e. Cardiff. Therefore, it could be easily sent halfway across the world, despite the fact that China and many other colonial territories had enormous coal reserves. The result was that the commercial and military naval power behind European colonialism came to be dependent on coal; this is why English colonialism has also been referred to as "*coalonialism*" but did not rely on coal deposits in colonies themselves[9]. Starting the first half of the XIX century, British coal export increased from 4 to 13 % of England's total output to the extent that its coal accounted for over 85% of all worldwide trade by 1900. By building an infrastructure that could support the Industrial Revolution abroad and link it to its ambition, England leveraged coal exports to project its power

[7] Bergquist, A.K., Lindmark, M. (2023). "*Economic history and the political economy of energy transitions: A research overview"* [online]. Uppsala Papers in Economic History, p. 2. Available at: doi: 10.33063/upeh.v2i.576 (Accessed 24 April 2024).

[8] Ediger, V.Ş., Bowlus, J.V. (2019). *"A Farewell To King Coal: Geopolitics, Energy Security, And The Transition To Oil, 1898–1917"* [online]. The Historical Journal, 62(2), p. 433. doi:10.1017/S0018246X18000109.

[9] Singer, C. (2008). "*Energy And International War: From Babylon To Baghdad And Beyond"* [online]. World Scientific Publishing Company. Available at: https://www.perlego.com/book/847027/energy-and-international-war-from-babylon-to-baghdad-and-beyond-from-babylon-to-baghdad-and-beyond-pdf (Accessed 27 April 2024).

while offshoring and outsourcing their competitors[10]. More to that it should be kept in mind that coal is not the same all over the world. The predominant role in the international chessboard played by England is explained by the importance of coal in the XIX century and by the superior English coal's properties, especially the Welsh one. Indeed, coal was the dominant source of energy for industrial and domestic activities, e.g. it was used as fuel, lighting and for domestic heating and cooking. Since they held the largest coal mines and controlled its trade, England owned a powerful geopolitical weapon, being able to decide which nations supply the precious material with and which to leave without.

1.1.2 The "*Coal weapon*"

One of the first examples of coal used as a geopolitical weapon is reported by Chandler[11]; it was perpetrated by the British in response to the continental blockade decreed by Napoleon between 1806 and 1814. Indeed, during the Napoleonic Wars, due to the absolute British Navy superiority in the Seven Seas, London hindered Paris' access to both English and French colonies' coal. The latter being essential for the *Hexagon* to power its industries and army, therefore, the blockade weakened its economy and limited its military capabilities. As a matter of fact, coal mined on the continent, of a lower alloy than the English one, was not sufficient to meet French industrial needs.

Nevertheless, a major example of the fossil fuel used as a geopolitical weapon was coal's role in the XIX century navies. In 1871, thirty-three years after the dismantling of the fighting Téméraire, the HMS Devastation, the first Royal Navy ship entirely powered by steam without sails, was launched, marking the beginning of the mastless steamship era. As noted by an American correspondent "*if working up to full power all day [it] consumes 150 tons of coal per day*"[12]. This meant that: "*fuel stands first in importance of the resources necessary to a Fleet. Without ammunition, a ship might run away, hoping to fight another day, but without fuel, she can neither run, nor reach her station, nor remain on it, if remote, nor fight*"[13]. As a consequence, one of the major problems for modern European navies was a safe and regular supply of quality coal. Therefore, Britain was only able to project its power and protect its commercial interests by ensuring a reliant and efficient coal supply system around its empire. The need for an efficient infrastructure to supply ships with coal

[10] Barak, O. (2015). "*Outsourcing: Energy and Empire in the age of Coal, 1820–1911*" [online]. International Journal of Middle East Studies. 47(3), 425–445. Available at: doi: 10.1017/s0020743815000483 (Accessed 30 April 2024).
[11] Chandler, D. G. (1966). "*The campaigns of Napoleon*". New York: Macmillan.
[12] Gray, S. (2017). *"Steam Power and Sea Power"* [online]. Palgrave Macmillan UK. Introduction. Available at: https://www.perlego.com/book/3482992/steam-power-and-sea-power-coal-the-royal-navy-and-the-british-empire-c-18701914-pdf (Accessed 23 April 2024).
[13] Mahan, A. T. (1975). "*Letters and papers of Alfred Thayer Mahan*". Annapolis: Naval Institute Press, p. 399.

eventually led to the creation of a global coaling station infrastructure that London controlled for the use of its navy. Therefore, coaling stations emerged as a *conditio sine qua non* of the Pax Britannica. Indeed, coaling stations, as pointed out by Lambert[14], were an integral part of the maintenance and expansion of global British influence from mid-XIX and first decade of the XX century. The loss of coaling stations could hinder or paralyse the British navy in the areas where the coal station was located[15]. By the turn of the century, with the Anglo-German naval race, a '*coal consciousness'* emerged, highlighting coal's importance in order to maintain British power overseas. It was publicly accepted that "*coal is the source of [Britain's] commercial prosperity and the secret of our naval supremacy… coal is the first requisite of empire*"[16]. Even the American 'National Geographic' declared that by the twentieth century, *"a modern war between two naval powers has reduced itself largely to a war of 'coal and cables'*"[17]. Therefore, navies required coal, yet not any type of it. British admiralty required a fuel having specific qualities: it needed premium steam coal that could offer the most energy per ton ratio, wouldn't degrade in storage, and burned cleanly, i.e. without emitting black smoke that would have made ships visible for miles. Furthermore, large supplies of this coal had to be available throughout the empire. Welsh coal was globally and unanimously considered as the world's best type of fuel for navies' use due to its white smoke when burnt and its optimal energy per ton ratio. Commercial lines, on the other hand, often used cheaper local fuels since economy was more important than clean emissions and speed. Nevertheless, Welsh coal was the most preferred by world's military navies[18]. Because of this hegemony over high-quality fuel in the world, coal from other sources would almost certainly be inferior in quality and its supply inconsistent, forcing foreign navies to frequently change coals' mix according to what they found available in the ports where they docked to refuel. Thus, London had a strategic edge since it supplied its maritime rivals too with its high-quality Welsh coal. Therefore, in case of hostilities, British opponents would have to retrieve other sources of coal during conflicts if London decided to stop exporting its precious fuel.

This was the case with the Russian Baltic Fleet during the 1905 Russo-Japanese War. Sent from the Baltic to the Pacific to engage the Japanese fleet; the British denied the Russian fleet access to its coaling stations as it journeyed across the globe to engage in the Pacific, creating huge logistical problems that led the Tsar's fleet to be completely annihilated by the Imperial Japanese navy the 28th

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[14] Lambert, A. (1995). "*The Shield of Empire (1815–1895)*," in Hill, J. R. & Ranft, B. (1995). *"The Oxford illustrated history of the Royal Navy"*. Oxford [England]; Oxford University Press, p. 161-199.

[15]Gray, S. (2017). *"Steam Power and Sea Power"* [online]. Palgrave Macmillan UK. Available at: https://www.perlego.com/book/3482992/steam-power-and-sea-power-coal-the-royal-navy-and-the-british-empire-c-18701914-pdf (Accessed 23 April 2024).

[16] Hurd, S. A, (1898). *'Coal, Trade, and the Empire'*, in "The Nineteenth Century", November 1898.

[17] Squier, G. O. (1901). "*The Influence of Submarine Cables upon Military and Naval Supremacy*". Vol. XII, p. 1.

[18]Gray, S. (2017). "*Steam Power and Sea Power*" [online]. Palgrave Macmillan UK. Available at: https://www.perlego.com/book/3482992/steam-power-and-sea-power-coal-the-royal-navy-and-the-british-empire-c-18701914-pdf (Accessed: 23 April 2024).

of May 1905[19]. The case of the Baltic fleet demonstrates the strength that Britain possessed because of its global infrastructure and control over high-quality coal. By depriving its adversaries of a reliable fuel supply, London managed to significantly hinder their operations. In addition, British ships' global refuelling capabilities intimidated neutral nations, deterring them from supplying fuel to others, e.g. Russians. With this kind of power, Britain might seriously impair and disrupt an adversary's fleet without ever having to fight. Due to its massive and extended coaling facilities, English did not rely on neutral powers, something that a possible adversary would have to do. Indeed, if, in peacetime, Welsh coal suppliers freely traded with foreign navies, this would be prevented in case of war or British interests' direct involvement. Therefore, any enemy would lose their primary source of high-quality coal and move to a lower quality fuel of uncertain supply. Britain's coaling stations efficiency was in contrast to those of its enemy, e.g. Germany. The latter was forced to use Westphalian coal, of variable quality and never as good as the Welsh one, due to its incapability to retrieve English coal, on which the *Kaiserliche Marine* relied during peacetime.

A major example of coal used as a geopolitical weapon, this time not at the hands of the English, was the use of coal as leverage during the Ruhr crisis. In the WWI aftermath, from 1923 to 1926, the French and Belgian government occupied the Ruhr industrial region in Germany as a response to the non-payment of war reparations imposed by the Versailles treaty. The blocking of coal and steel exports from the Ruhr was intended to weaken the German economy and force Berlin to yield to Allied demands. In 1923 a Franco-Belgian army marched into the Ruhr District to secure reparations deliveries of coke and coal. The French advocated to establish complete control through military occupation of the territory east of the Rhine, in order to acquire the Rhine–Westphalian coalfields and its metallurgical industry. By taking control of the German coal basin, they would have left the country deprived of its industry and its most profitable resources, creating incalculable damage to the domestic population and the economy already battered by war. Indeed, *"food apart, gas and electricity supplies became at best erratic as coke works and generators closed down, whilst supplies of household coal ran short, leading people to plunder parks and forests for whatever firewood they could find"*[20]. US president Wilson condemned this as a 'panic programme'; the British were no less hostile, fearing that the French could replace them in international trade by quantity of extracted coal. Just as crucial was the problem arising from the return of Alsace-Lorraine to France, which doubled the latter steel capacity, increasing its dependency on Ruhr coal. This was evident during the French 1919-1920 coal crisis. The latter was a direct consequence of the transition from war to peace, the

[19]DeNovo, J. A. (1955). "*Petroleum and the United States Navy before World War I"*. The Mississippi Valley Historical Review, 41 (4), pp. 641–656.
[20] Fischer, C. (2010). "*The Ruhr Crisis 1923-1924"* [online]. Oxford, 2003; Oxford Academic, 1 Jan. 2010, chapter 5. Available at https://doi.org/10.1093/acprof:oso/9780198208006.001.0001 (Accessed 16 April 2024).

flooding and destruction of mines at the hands of retreating Germans, internal unrest and labour shortages led to a serious coal shortage that stopped French industrial production. Indeed, in 1919 France had to import half of its coal consumption, no less than 70% of which came from Great Britain[21]. After the war, English coal shipped to French ports reached extremely high prices, as a matter of fact, coal's price per ton increased by seven times from its 1913 price. In April 1920, the British cut France's coal share from 60% to 40% of their total exports. Coal supplies soon disappeared. As a result, unemployment spread because of the lack of fuel and Paris rationed heating and light, so that the newly lit foundries were largely extinguished. This event shows that, even in the early XX century, coal was an essential source of energy for that time society so that, having the British reduced the quantities of coal exported, the French government, disappointed and outraged by the attitude of the old ally, looked to the Ruhr coalfield to revive his economy. Coal then became a geopolitical weapon that could allow its owner the industrial reconstruction once the war was over. European countries started a race, with old allies and enemies, in the industrial reconstruction race that would determine the post-war *status quo* and balance of power. Under normal circumstances, the British were internationally the biggest coal supplier, however, there were many exceptions. The Ruhr served as the primary supplier to the heavy industries of eastern France, Belgium, and the Luxemburg Union, as well as western Germany. Moreover, in order to understand the French geopolitical action to invade the Ruhr area in post-WWI aftermath, even though the *Hexagon* was a significant coal producer, Paris was the world's biggest coal importer too. A solution for the Ruhr crisis came with the 1930s Franco-German coal treaty that did stop the Franco-Belgian disruptive activities. Nevertheless, this case showed the importance of the mineral in a country's economy still in the early XX century and the geopolitical power that derives from ensuring coal mines' control, in order to fuel national heavy industry, and its supply on the international market.

1.1.3 Political solution to the *"Coal weapon"*

As we have seen before, at the dawn of the first World War Germany was still not self-sufficient in coal production; it was rather dependent on British supplies, as it was for almost every European nation. With the war Germany had to find another supply source, i.e. the coal mined from the Ruhr and Silesia regions, highly stressing the internal railroads already active for the military supply chain. As observed by Singer: "*Despite and perhaps because of the tactical and strategic mistakes on both sides concerning the importance of coal and steel production, WWI cemented into the European*

[21]Gillingham, J. (1991). "*Coal, Steel, and the Rebirth of Europe, 1945–1955: The Germans and French from Ruhr Conflict to Economic Community*". Cambridge: Cambridge University Press, p. 7.

consciousness the idea that how energy resources are dealt with is a critical element in the balance between war and peace"[22]. For this reason, the second World War aftermath determined the creation of the European Coal and Steel Community (ECSC); it was a political reaction to avoid further wars in Europe for the control of a strategic energy source as coal. On the evening of the 9th of May 1950 French Foreign Minister Robert Schuman interrupted the French radio regular broadcasts to make a historic announcement: *"In order to end the decades-long struggle over coal and steel, France was ready to become partners with its recent enemy, and other nations, in a new West European heavy industry community organized in such a way as to make war politically unthinkable and economically impossible …".* The downturn also contained a silver lining*: "For the first time since the war coal had ceased to be scarce, and France could act without fear of economic blackmail"*[23]. A supranational authority, i.e. ESCS, had been established as a consequence of the Schuman Plan negotiations. In order to end hostilities between Germany and Western Europe, the new institution would act as a peace pact. Only a few economic and financial obstacles were lowered, no new military alliances were formed, and no boundaries were altered by the agreement to establish a heavy industry pool. It did, however, eliminate the primary barrier to an industrial alliance between France and Germany by settling the disputes over coal and steel that had existed between the two countries since World War II. Every prior major attempt to change the Continent's industrial production balance since 1918 had been derailed by competitive bids for heavy industry supremacy, but the ECSC put an end to those type of bids[24]. It should be noted that England, which thanks to its coal reserves and trade during the XIX century had attested its strength and predominance, now merely stood back half hoping that the "European" experiment would fail and half afraid that it would succeed.

As noted by Singer (2008), in the first part of the 1900s, iron and coal were regarded as vital resources. Millions of people perished in World War I attempting to move trench lines erected along fronts meant to prevent access to coal and iron sources. Trade discussions replaced military conflict as the primary means of resolving disputes over these commodities, as evidenced by the establishment of the European Coal and Steel Community in 1952. Still, the establishment of the European Coal and Steel Community effectively ended a protracted period of bloody rivalry between its constituents.

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[22]Singer, C. (2008). "*Energy and International War: From Babylon to Baghdad and Beyond"* [online]. World Scientific Publishing Company, p.75. Available at: https://www.perlego.com/book/847027/energy-and-international-war-from-babylon-to-baghdad-and-beyond-from-babylon-to-baghdad-and-beyond-pdf (Accessed 27 April 2024).

[23]Gerbet, P. (1956). *La Genèse du Plan Schuman: Des origines à la déclaration du 9 mai 1950*. Revue française de science politique, 6 (3), 525–553.

[24]Gillingham, J. (1991). "*Coal, Steel, and the Rebirth of Europe, 1945–1955: The Germans and French from Ruhr Conflict to Economic Community"*. Cambridge [England]: Cambridge University Press., p. 297.

With this, the armed conflicts between the future EU member states over the allocation of land, trade, and the region's initial coal-based industrial development were eventually resolved[25].

In 1913 world coal consumption peaked, coming to represent almost 60 % of total world energy use. The industry experienced somewhat volatility in the interwar period as it was analysed before but it steadily contracted as oil production and technology-related discoveries increased. Britain handed over the 'global hegemon' role to the United States in 1945 as the latter dominated oil production and oil-related industries and technology. While the battle of energy securitization shifted to oil as a result of technological development and state conflict focused on different resources and new geographical regions, this did not mean that coal and steel had completely vanished from the public consciousness. For instance, the European Coal and Steel Community, which came into being in 1952, represents the earliest example of European state cooperation that emerged from the competition for control of strategic energy means after World War II, in order to prevent further power and geopolitical use of energy resources imbalances, thus, new wars.

1.2 **Oil**

1.2.1 The fossil fuel

Similarly to coal, oil too is a source of energy not equally distributed on earth but geographically concentrated in some areas. Nations that have found oil deposits under their soil have thus become extremely rich or were torn apart by wars, consequence of foreign interests. As for coal, the country who was the largest supplier, or the one among the largest producers, of oil and its related technologies was the world's hegemonic power. That is to say, the United States of America. The latter has been, with ups and downs, among the major oil producers until nowadays. To date it is the largest oil producer, as well as the main importing country. With the control of an essential commodity as petroleum and a strong military apparatus, the US are, since 1945 until present days, the world's hegemonic power.

The transition from coal to oil was dictated by a geopolitical need, i.e. the necessity for the energy mix diversification which started in the military field. Energy transitions and great discoveries often take place due to geopolitical security reasons. This is why, often, the military are pioneers in discovering new technologies. Indeed, it is interesting to note that one of the first country to start

[25] Singer, C. (2008). "*Energy and International War: From Babylon to Baghdad and Beyond"* [online]. World Scientific Publishing Company. Available at: https://www.perlego.com/book/847027/energy-and-international-war-from-babylon-to-baghdad-and-beyond-from-babylon-to-baghdad-and-beyond-pdf (Accessed 27 April 2024).

testing no longer coal-fired but oil-propelled warships was the Italian navy, i.e. the *Regia Marina*, due to the lack of coal reserves in the national subsoil, except for small deposits at the Alps' foothills. Petroleum became a commercial good half a century before its appearance as a fuel in the XX century. It acquired a certain importance only after alternative uses for gasoline were found. As a matter of fact, the latter, at first, was only a by-product of kerosene, refined from crude oil, for illumination. Thereon, oil's adoption as a commodity was modelled on coal[26].

According to the British Navy's Admiralty reports, the fighting advantages of oil made its adoption as fuel for London's fleet an absolute necessity. Indeed, using oil to replace coal, British navy's strength was indirectly increased as foreign navies' fighting power would remain unaltered[27]. Nevertheless, due to oil unequal distribution on earth, the British Admiralty could not replace and modernize its fleet until London secured the control of an adequate supply of the new fossil fuel. Indeed, it would have been "*suicidal to discard coal without providing for a certain substitute*"[28]. The coal-to-oil transition was due to geopolitical and security reasons. Indeed, London feared that Berlin could produce oil-fuelled ships faster than them. Nevertheless, the *Kaiserliche Marine* did not develop such warships until the WW1 aftermath, largely because they were not able to secure an access to oil supplies too. Indeed, as underlined by Ediger (2019) [29] "*Germany's handicap in converting to oil was the lack of oil-supply security. It increased imports from Romania and Austria-Hungary from 1906 to 1912, but US oil remained over 70 % of total imports*", the latter being inaccessible in wartime. As past history had already shown, being dependent on other states for what it concerns fossil fuels does pose serious security constraints since it would give to third countries a geopolitical leverage that could be used as a blackmail weapon. Even though for good strategic reasons, the shift to oil-propelled navy caused Britain to lose its advantage of domestically produced fuel and its global coaling stations' infrastructure. Thus, London was forced to depend on foreign countries' oil supply, i.e. Standard Oil and Royal Dutch Shell, in the Admiralty's words: "*we are entirely dependent on the United States for the mobility of our Navy*"[30]. It is fair to say that the UK's conversion to oil is quite remarkable and brave from a strategic and geopolitical point of view since

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[26] Barak, O. (2020). "*Powering empire: how coal made the Middle East and sparked global carbonization"* [online]. Oakland, California: University of California Press. Available at: https://www.perlego.com/book/1343319/powering-empire-how-coal-made-the-middle-east-and-sparked-global-carbonization-pdf (Accessed 24 April 2024).

[27] Gray, S. (2017). "*Steam Power and Sea Power*" [online]. Palgrave Macmillan UK. Available at: https://www.perlego.com/book/3482992/steam-power-and-sea-power-coal-the-royal-navy-and-the-british-empire-c-18701914-pdf (Accessed 23 April 2024).

[28] FISR 6. *'Material relating to the Oil Commission, The Papers of 1st Lord Fisher of Kilverstone'* [online]. Churchill Archives Centre. Available at https://archivesearch.lib.cam.ac.uk/repositories/9/resources/1562 (Accessed 27 May 2024).

[29] Ediger, V.Ş., Bowlus, J.V. (2019). *"A Farewell to King Coal: Geopolitics, Energy Security, and the Transition to Oil, 1898–1917"* [online]. The Historical Journal, 62(2), p. 443. doi:10.1017/S0018246x18000109.

[30] Maclay to Hankey, (1917). TNA, ADM 116/1804. Cited in Brown, W. M. (2003). "*The Royal Navy's fuel supplies 1898-1939 : the transition from coal to oil*", p. 246.

it gave up its fuel advantages, exceeding the domestic interests that favoured coal. Conversely, the cost of importing oil was two to three times higher, and its combustion systems were less dependable. Nevertheless, Britain had to convert its navy to oil because of the geopolitical danger posed especially by Germany and the need to stay up to date with technological advancements.

It is fair to say that oil is strictly intertwined with global politics and power. Oil established its primacy and importance as a geopolitical tool during WW1 when combustion engines started to be utilized for means of transportation and war efforts, e.g. tanks and, more importantly, the newly born air forces. Once again, oil import presented the same problem as its coal ancestor. Indeed, for instance, Germany imported 1.3 million tons of oil before WW1, of which 1 million came from Russia or other sources outside Europe, therefore, not reliable in wartime. During the first world war conflict, Germany, as France, saw its oil imports to increase threefold. Therefore, given the ever-increasing oil importance, Central Powers tried to conquer the Russian oil-producing region of Baku; they eventually failed in this attempt. A failure well recalled when Nazi Germany prepared its war industry plan for WW2[31].

It is fair to say that during the First World War, European countries got interested in the potential exploitation and production of Persian oil, which represented the largest petroleum-production at that time. Petroleum companies merely became the façade for Western nationals' oil companies interests in exploiting the fossil fuel fields. It was especially in the British interest to assure itself of a vast amount of crude to fuel the *Royal Navy* and its industrial reconstruction in the post-war period. To understand the geopolitical value that oil held in that period, it should be recalled the 1916 Sykes-Picot agreement. The latter partitioned the Ottoman's Empire possessions in the Middle East. *De facto*, it was important for the acquisition of potential oil fields to ensure European countries' energy securitization and the economic survival of modern states. In this regard, with the Sykes-Picot agreement London was able to annex under its mandate the northern Mesopotamian town of Mosul, which was expected to be oil-rich. It is interesting to observe that, at first, the latter area was to fall within the French mandate territories. However, France had less than 10.000 men in the entire Middle East when hostilities came to an end in 1918. Therefore, Britain, who had greater forces in the area, was able to dictate its conditions and add Mosul to its own mandate of Mesopotamia[32].

Similarly to coal, the oil sector was initially structured as a monopoly and later as an international cartel, due to the intense geographical concentration of the most inexpensively extracted oil. Indeed, "inexpensive extraction" of oil with fast access to the market was concentrated in a few regions. This

[31] Singer, C. (2008). *"Energy and International War: From Babylon to Baghdad and Beyond"* [online]. World Scientific Publishing Company. Available at: https://www.perlego.com/book/847027/energy-and-international-war-from-babylon-to-baghdad-and-beyond-from-babylon-to-baghdad-and-beyond-pdf (Accessed 27 April 2024), p. 131.
[32] Ivi p. 134.

aspect made it easier to monopolize certain segments of the oil industry. Thus, it led to the creation of trusts and the formation of cartels to influence supply and prices. Initially discovered in Pennsylvania, oil extraction and production ended up in the hands of few major companies, i.e. Standard Oil of New Jersey, the Anglo-Persian Oil Company and Royal Dutch Shell. The latter three created, in the Scottish castle of Achnacarry, the first international oil cartel in 1928, referred to as the "As-Is Agreement". Nevertheless, in those years, new oil discoveries were made. Soon after there were too many producers and too much production outside the "As-Is" framework. As petroleum production surged uncontrollably, the Achnacarry Agreement was washed away. That is to say that long before OPEC creation, an oil cartel was established in order to maximize the fossil fuel-generated profits and to use the crude as a geopolitical weapon, nevertheless the OPEC *ante litteram* failed due to the excessively diverse production[33].

1.2.2 The *"Oil weapon"*

Oil was used as a geopolitical weapon *vis-à-vis* third countries since its first commercialization as it was the case of Italy when it invaded Abyssinia in 1935. Condemned by the League of Nations, international sanctions were placed on Rome, namely by the British government who proposed a coal and oil embargo. Nevertheless, the embargo was limited to British supplies, thus not able to harm enough Italy, which could still rely on American supplies. As reported by Singer (2008)[34], Mussolini later told Hitler: "*If the League of Nations had followed* (British Foreign Minister) *Eden's advice on the Abyssinian dispute, and had extended economic sanctions to oil, I would have had to withdraw from Abyssinia within a week*".

Oil was used as a geopolitical weapon by a Middle Eastern country to blackmail a European country for the first time by the Shah Reza Pahlavi. The Persian king made his country an oil state, on which London, through the Anglo-Persian Oil Company, depended. It was during the 1929 Great Depression that, enraged by low petroleum revenues, the Shah announced that he was unilaterally cancelling Anglo-Persian's concessions in the country[35], threatening the very existence of the company and England's oil supplies. Even though the Shah had eventually to backtrack, his decision had the effect of a bomb on England's Admiralty and public opinion. Indeed, as the latter imported most of their oil needs from Persia, they stood a serious risk of geopolitical dependence. Lifting

[33] Yergin, D. (1991). "*The prize: the epic quest for oil, money, and power*". New York: Simon and Schuster p. 265.
[34] Singer, C. (2008). "*Energy and International War: From Babylon to Baghdad and Beyond*" [online]. World Scientific Publishing Company, p. 139. Available at: https://www.perlego.com/book/847027/energy-and-international-war-from-babylon-to-baghdad-and-beyond-from-babylon-to-baghdad-and-beyond-pdf (Accessed 27 April 2024).
[35] Yergin, D. (1991). "*The prize: the epic quest for oil, money, and power*". New York: Simon and Schuster p. 269.

concessions, as well as embargo or export ban, not only had the effect of creating panic in the importing country but it questioned the international *status quo*.

Oil resources' control played a central role in WWII outcome, both in the Far East and Europe. The fuel was vital during the war as both sides employed a growing number of oil-fuelled equipment, from warships to planes and tanks. Moreover, it was no longer a static trench war but a war of movement and, to move troops, large amounts of crude were required. Therefore, oil covered a primary importance objective in the Axis' war plans. Indeed, the Japanese attacked Pearl Harbor to protect their flank as they conquered the oil-rich territories of the Dutch East Indies; in Hitler's plans, the Soviet Union invasion was aimed at the Caucasus oil fields' capture. Nevertheless, America's superiority in oil production proved decisive. By the end of the war Axis fuel tanks were empty.

In WW2 Japan paid for its historical lack of natural resources which made the country vulnerable to fossil fuels' exporters, as already seen for coal. Indeed, as it will be during the 70s' oil shocks too, Japan suffered a high blackmailing potential for what it concerns its domestic energy sources. It is highly emblematic the fact that the *Empire of the Rising Sun* imported over 90 % of its oil from the US in 1939[36]. An example of this strong oil-dependence, and the arising geopolitical solution, is given, for instance, by the First Battle of Balikpapan. The latter took place at the end of January 1942 off the major oil-producing port of Balikpapan, Borneo, in the Dutch East Indies. In the port was located the largest oil refinery in the region with a complex of petroleum tanks that could hold up to eight million tons of oil. Balikpapan held a strategic importance in defining Japan's plan to conquer the Dutch East Indies, to meet the serious oil shortages. Dutch engineers and workers in the area had orders to mine the oil fields in order not to leave the vital infrastructures to the Japanese, who had their Achilles heel in oil. As Dutch forces destroyed the wells, seriously undermining the *Rising Sun* empire's plans and reserves, they contributed to Japanese impossibility to fuel the Imperial Navy and, therefore, gave a strategic advantage to the US Navy. The latter submarines increasingly targeted Axis oil tankers, so that, by 1944, sinkings were far outrunning new tanker construction. It resulted, in June 1945, a desperate war economy situation, virtually immobilized due to the lack of fuel and the constant naval and aerial American attacks. Clear evidence was given by the fact that Japanese fuel oil inventories before the war, in April 1937, amounted to 29.6 million barrels while in July 1945 they amounted only to 0.8 million barrels. Below the 1 million barrels threshold the Japanese Navy could not operate, thus it was out of oil[37] and of the war. Germany too found itself constrained by oil reserves during WW2 and had to adapt its war plans to these needs. Even though Hitler gained control of

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[36] Singer, C. (2008). "*Energy and International War: From Babylon to Baghdad and Beyond*" [online]. World Scientific Publishing Company, p. 136. Available at: https://www.perlego.com/book/847027/energy-and-international-war-from-babylon-to-baghdad-and-beyond-from-babylon-to-baghdad-and-beyond-pdf (Accessed 27 April 2024).

[37] Yergin, D. (1991). "*The prize: the epic quest for oil, money, and power*". New York: Simon and Schuster p. 364

Romanian oil, he failed to do the same with Soviet Union's oil. Oil shortages prevented Rommel's *Afrika Korps* from taking Suez and Hube's tank divisions to be effective at Stalingrad. German advance into the Caucasus to take possession of the Soviet oil facilities was useless since defenders made "scorched earth" so that the Nazis were never able to make it to Chechnya and Georgia, thus never reaching Baku's rich oil fields.

The WW2 military's oil implications convinced the world of the fuel's strategic geopolitical importance. Nevertheless, it was in the postwar period that oil achieved an even greater geopolitical value due to its fundamental importance in the economies' production process. Indeed, oil eventually substituted coal as power source for the industrialised world, irreparably changing the society as whole, which would be thereon dependent on oil. The world war, just over, had proved how central and critical oil was to national power. This is why a critical Cold War moment was represented by Soviet expansionism in the Middle East. Indeed, the oil resources of the region constituted for the US an interest no less vital than the independence of Western Europe. Middle Eastern oil fields had to be preserved and placed on the Western side of the Iron Curtain to assure the economic survival of the entire Western world; everything was to be done in order to prevent the loss of the region, or, we should say, the loss of the precious fuel of which the region is rich. The White House acknowledged the increased use of oil in Americans' domestic everyday life and, seen the enormous reliance of on foreign oil and the lack internal resources' development due to high costs. Middle Eastern oil was too important to be left to Soviets' influence. Pivotal point in oil shipping to Europe and the US was represented by the Suez Canal, in Egyptian territory. By 1955, the Suez Canal was channelling two-thirds of Europe's oil. At that time, the young Egyptian republic was led by Lieutenant Colonel Nasser, disappointed that while oil-producing Arab countries received 50 % profits from the oil sold, Egypt did not get any profit from the canal. He claimed that Egypt should have the same fifty-fifty terms as oil producers[38]. Nevertheless, British and French governments made clear that they did not want the international traffic to be interrupted, especially the oil one.

The canal held such an important role for the European countries due to the intense oil traffic. Britain's balance of payments was precarious and its economy depended to a great extent on the international commerce active through the canal. In a few years it switched from being the world's greatest creditor to being the world's greatest debtor. Its gold and dollar reserves were sufficient to cover only three months of imports. Britain's oil holdings in the Middle East contributed to its overseas earnings, thus, such a loss would be economically devastating. Nasser's victory in Egypt might unleash uncontrollable oil disruptions and repercussions. Thus, oil nationalization would result in an incredibly powerful geopolitical instrument, a blackmailing weapon, at times, too big to control.

[38] Ivi p. 482

A victorious Nasser would proceed to destroy American and British oil positions throughout the Middle East. British PM Eden warned American president Eisenhower about Nasser's power to deny oil to Western countries, resulting in Western Europe being at his mercy. The British feared the nationalization of the Suez Canal and the consequent repercussions, due to the denial of Middle Eastern oil, it would entail on UK's gold reserves, which would have been exhausted in a short time. As a consequence, in case of gold reserve exhaustion, the sterling area would disintegrate, therefore London would not be able to maintain its military presence in Germany or anywhere else. That is to say, they could not pay for their own defence[39]. Therefore, one of the main preconditions for a state to exist would be lost. At least this was claimed by UK officials in secret negotiations with Washington.

Under Nasser, oil was not an important geopolitical weapon due to its being a fossil fuel vital for Western economy, *sic et simpliciter*, as a matter-of-fact Egypt did not possess any oil field or reserves; oil was used in a broader scheme, Nasser held a much more important weapon wherein petroleum just happened to be a commodity as many others, i.e. a strategic geographical trade hub. Nasser expropriated the Suez Canal, doubting that Britain and France could sustain military intervention. However, an Anglo-French expeditionary corps invaded Suez with Israel's support. Nevertheless, Washington called for its immediate withdrawal as Eisenhower didn't want to risk an Arab embargo on oil shipments *vis-à-vis* all Western countries. Nevertheless, the normal route for three-quarters of Western Europe's oil was now interrupted. At a time European countries lost the oil transit through the canal and the Middle Eastern pipelines[40]. More to that, Saudi Arabia seemed to consider an embargo against Britain and France. The Arab 'oil weapon' was displayed and Western countries discovered the harsh consequence of their geopolitical dependence from Middle Eastern oil.

With Western Europe on the verge of an oil catastrophe following the canal's closure, the "Oil Lift"[41] was put into action, the latter being a collaborative effort between US and European oil firms and governments. However, it is fair to say that a minor part of the Middle East's oil output continued uninterrupted. The most important issue, i.e. transportation, was resolved by using more emergency supplies, the majority of which were imported from the United States. The so-called "sugar bowl" supplies were supposed to be equitably distributed among Western countries. Allocations were decided by the Petroleum Emergency Group, which was established by the Organisation for European Economic Cooperation (later OECD) using a formula that took into account local energy supply and oil consumption prior to the Suez Crisis. Other measures of demand control, such as rationing, were implemented in addition to the Oil Lift. Between the Suez crisis and the '70s, oil demand in Western

[39] Ivi p. 488
[40] Ivi p. 490
[41] Ivi p. 493

Europe increased fifteen times due to the rapid economic growth[42]. Because of the latter, the ensuing industrial expansion and the cars' affordable prices, in those years Europe was the most competitive and oil-reliant market in the world.

Nasser tried to use its military force, again, to avenge the declining Arab world's prestige in the late 60s. The Arab military mobilization in the Sinai and Golan regions led the Israelis to strike with a pre-emptive attack, the so-called Six-Day war, which saw Arabs total defeat. In this third Arab Israeli conflict, MENA's oil-exporting countries acted to counterbalance Israeli's land success by employing their oil weapon. Indeed, on June 6th, 1967, Arab oil ministers called for an oil embargo against those countries friendly to Israel, namely the US, Britain and West Germany. Western oil companies operating in the Middle east, mostly American, were requested not to ship oil to the US or the UK[43]. So that, by June 8th, Arab oil flow was reduced by more than 60%. Middle Eastern countries lost six million barrels of oil per day, not to count the huge logistic disruption. As a matter of fact, not only it was an oil blockade imposed but the Suez Canal and the pipelines from Iraq and Saudi Arabia to the Mediterranean were closed. The crisis was more serious than the 1956 Suez blockade since at that time the problem was only a transportation one. In 1967, instead, over three-quarters of Western Europe's oil came from the MENA region, of which over one-half was now no longer shipped, leaving Europe to face a critical crude shortage never seen before. Due to Europe's high oil-dependence on the Middle East, the former was seriously exposed to the latter's energy weaponization and blackmailing. European allies' - US, Venezuela, Iran and Indonesia - answer was to increase production. Moreover, a producer sharing agreement within the OECD countries reconstituted the arrangements that helped them in the oil allocation during the 1956 Suez Canal crisis. The Arab oil embargo eventually collapsed. A month after the Six-Day war, it was evident that the "Arab oil weapon" did not have the success expected and resulted in failure. Indeed, oil companies and western governments redistributed supplies where needed and the countries that instituted the embargoes appeared to have lost the most as they gave up revenues without any effect. Furthermore, they even had to provide substantial subsidies to the "front-line" Arab states engaged in war as Egypt. By September the oil embargo was lifted. The Six-Day War outcome seemed to confirm that the western alliance could not be a victim of the oil-weapon.

In 1959, under price pressure due to the 1950s large oil fields discoveries, oil companies reduced crude prices. However, they neglected to agree before such a decision with the host governments, whose revenues were hindered and suffered the most. This event led to the OPEC formation, i.e. the Organization of Petroleum Exporting Countries. Latter countries grouped to acquire greater

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[42] Ivi p. 541
[43] Ivi p. 554

participation in the control of both the distribution and the benefits' allocation of their subsoil oil wealth. However, the organization had little to no effect until the 1973 Arab-oil embargo[44]. Indeed, as soon as OPEC was established, its members lost their grip on oil exports due to the new *"elephants"*[45] oil fields found and opened up in the 1960s. These discoveries increased the crude's offer to the already saturated oil-market. As a matter of fact the soon-to-become cartel initially faced huge difficulties since most producing countries, that would eventually become OPEC members, joined the market as competitors first, taking major Arab oil-exporters countries' market shares[46].

On October 6, 1973, Yom Kippur Jewish holiday, Egyptian fighters targeted Israeli positions acquired during the Six-Day war. The fourth Arab Israeli war had begun, proving to be the most destructive, with wide-ranging consequences. Middle East oil-producer countries, once again weaponized petroleum, employing the oil weapon through a new fuel embargo, i.e. production cutbacks and restrictions on exports. Both the embargo and war came out of the blue, producing an "oil shock" on the market. In support to the October 1973 Yom-Kippur war, OAPEC (Organization of Arab Petroleum Exporting Countries) members chose to reduce their oil production from 20.8 to 15.8 mbd (million barrels per day). The production cuts would have disrupted the industrial countries' crucial oil supplies, and there would have been nothing to do in the short term to lessen the price surge due to the removal of significant spare capacity in non-OAPEC countries. Using the "oil weapon", Arab producers imposed an embargo with the goal of influencing policies' change vis-à-vis Israel. The intentional production cutbacks and the selective supply of available oil created the embargo. Despite the embargo not being uniformly applied, Saudi Arabia and Libya shut off almost all supplies to the US, additional embargo targets were South Africa, Portugal, Rhodesia, Denmark, and the Netherlands. Industrialised countries had to acknowledge that they lacked sufficient preparation to take joint actions to manage their economic and political vulnerability. More to that, they understood to have almost no control over one of the essential commodities used in their advanced economies.

When Egyptian president Sadat, in preparation for the upcoming attack, called for the weaponization of oil for political purposes in 1973, the Saudi king Faisal at first disagreed. Saudi Arabia discovered in 1967 that its oil blockade had no effect except for Saudi's loss of revenues and market share. However, sooner than expected, Middle Eastern oil had become supply of last resort, especially Saudi's one, to the extent that the US were dependent on Gulf oil by 1973[47]. This was the

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[44] Singer, C. (2008). "*Energy and International War: From Babylon to Baghdad and Beyond"* [online]. World Scientific Publishing Company, p. 156. Available at: https://www.perlego.com/book/847027/energy-and-international-war-from-babylon-to-baghdad-and-beyond-from-babylon-to-baghdad-and-beyond-pdf (Accessed 27 April 2024).

[45] *"Elephant oil field"* stands for those oil fields that can hold 500 million or more barrels of crude.

[46] Yergin, D. (1991) "*The prize: the epic quest for oil, money, and power"*. New York: Simon and Schuster p. 525.

[47] Ivi p. 588

situation when, later that year, Arab oil ministers agreed to establish an embargo, cutting by 5 % oil production each month until their objectives were met, their motto at first was: *"If you are hostile to us, you get no oil. If you are neutral, you get oil but not as much as before. If you are friendly, you get the same as before"*[48]. However, American dependence on Gulf oil hindered the already precarious US situation in the area; to counterbalance Soviet's influence *vis-à-vis* the Arabs, US became Israel's major ally, constantly supplying the country during the war, while the USSR, conversely, helped Syria and Egypt. In retaliation for Israel's aid request to the US, Saudi Arabia escalated its previous plan for of an all-out embargo on oil export *vis-à-vis* the US. Oil weapon was now improved and fully in battle, a new form of "political blackmail" as defined by Kissinger[49].

Even though, as mentioned before, Saudi Arabian King Faisal had been at first reluctant to resort to the oil weapon, in 1973 the price per barrel skyrocketed and exports allowed to cut production while, at the same time, still increase the total income. The disruption had a dramatic effect on Western European economies, brought back to postwar shortages' years; the 1973 oil embargo caused one of the greatest splits in the Western alliance. Once the embargo began, European allies, led by France, rushed to disassociate themselves from US positions in the Middle East in order to assume new ones closer to the Arab-Palestinian cause. A ceasefire was eventually agreed but the oil embargo remained in place[50]. The latter was then replaced in 1974 by production limits and quotas in order to raise crude barrel prices.

"Although a crisis had been looming, it was the October 1973 Arab Israeli war and subsequent embargo that exposed the vulnerability of the energy system. This came as somewhat of a surprise. Oil supplies had been affordable and seemingly plentiful, and so it was hard to envisage the resulting disruption and price spikes that ensued"[51].

Fossil fuel energy, at last, had finally been successfully used with clear geopolitical effect, re-shaping the Middle East, and the whole world, alignments and *status quo*. It had transformed oil relations between producers and consumers. The Saudis did not want increased costs to obstruct or complicate their goals in the Arab Israeli conflict. Moreover, they were certain that the Shah was excessively driven by his personal objectives and too narrow-minded in his desire for higher prices.

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48 Ivi p. 627
49 Ivi p. 607
50 Singer, C. (2008). "*Energy and International War: From Babylon to Baghdad and Beyond*" [online]. World Scientific Publishing Company, p. 158. Available at: https://www.perlego.com/book/847027/energy-and-international-war-from-babylon-to-baghdad-and-beyond-from-babylon-to-baghdad-and-beyond-pdf (Accessed 27 April 2024).
51 Kissinger, H. (1976). "*The future of America's foreign policy*", speech, July 6, 1976, Chicago, Illinois. (Washington): U.S. Dept. of State, Bureau of Public Affairs, Office of Media Services.

Increases in oil prices would simply give Iran more resources and influence, allowing it to purchase more weapons and tipping the geopolitical balance in favour of the Shah's assertion of Gulf hegemony. Saudis deliberately and forcefully maintained their stance against more price rises at OPEC meetings, for several political and economic reasons.

Large US oil firms had controlled the global crude market for many years and had significant influence over prices paid to oil producers[52]. A surplus of prospective oil supply split among several providers caused petroleum prices to decline throughout the majority of the decade before the 1970s crisis. Under those conditions, there was still enough capacity in the US and elsewhere to give industrialised nations in the US, Europe, and the Far East a comfortable sense of oil security when issues with shortage emerged. However, from late 1960s to early 1970s, the relatively stable oil supply situation eroded to eventually disappear. Indeed, the world relied excessively on this oil. The global oil industry remained dominated mostly by US companies up to 1973. Thereafter, effective cartel action organized through OPEC played a central role. The oil embargo imposed during the Yom Kippur War showed producer countries their newfound potential capacity to wield political influence. OPEC emerged from the crisis as the primary producer organisation with cartel-like powers over the production and pricing of oil in the global market. The organisation soon became the potential force industrialized countries would have to contend with, in the years to come, even though the embargo itself was imposed by the Arab oil producer Members of OAPEC rather than by OPEC itself.

Western countries' oil vulnerability was evident with the 1973 Arab embargo and the shock of rising oil prices. In the years leading up to the '70s crisis, industrial countries became increasingly dependent upon oil imported from the MENA region. This energy dependency was due to a wasteful and inefficient use of fuels, oil *in primis*. European countries full internal oil production potential was not achieved due to insufficient investment in internal oil exploration and exploitation, nor they invested to develop other sources alternative to oil, i.e. energy sources diversification, but were fully dependant on crude (3/4 of which coming from the Gulf). The crux of the problem stemmed from Western abrupt necessity to react to many Arab producers' oil embargo and the cost increase that propelled oil prices to historically high levels. The realisation that the industrialised nations were mostly to blame for the situation they had unexpectedly found themselves in was perhaps even more frightening[53].

[52]IEA/ Scott R. (2004). "*The History of the International Energy Agency - The First 20 Years: Origins and Structure Volume 1"* [online]. OECD Publishing, Paris, p. 27. Available at: https://doi.org/10.1787/9789264020931-en (accessed 23 April 2024).
[53] Ivi p. 19

1.2.3 Political solution to the *"Oil weapon"*

Since countries suffered the embargo and became victims of the oil weapon, internal public opinion became more concentrated on "the energy problem" and the geopolitical implication of fossil fuels distribution. This resulted in a popular awareness of how energy, and, to a greater extent, energy dependence, could be exploited as a weapon of a geopolitical nature. As it was found out in Europe in the mid '70s, in situations of short energy supply, implementing "*beggar-my-neighbour*" policies was to be avoided, as they worsened the economic crisis, in favour of burden sharing policies adoption. As Secretary Kissinger emphasised: "*the energy situation poses severe economic and political problems for all nations. Isolated solutions are impossible*"[54]. This was evident with the 1974 establishment of the International Energy Agency (IEA) whose mandate was to cope with the oil shocks. Similarly for the 1952 ECSC creation, a political reaction to control a strategic energy source as oil and to avoid *beggar-my-neighbour* policies with allied countries, the IEA was created in 1974. Latter's objective was the continent's energy security and energy policies co-operation between member countries. The new Agency was boarded at the OECD in Paris, that already during the Suez crisis and in '67 had taken care to relieve the oil-embargo burden allocating, through a quota system, oil between member countries. International Energy Agency's framework was to be provided by OECD since, in the '70s, the latter was the main economic international organization of the Western industrialized market economy countries, i.e. North America, Asia and Western Europe. The organization's responsibility covered all industrial countries' economic questions, therefore including energy questions[55]. IEA was established as a cooperative mechanism to guarantee industrialized countries' energy security going forward, which included the creation of an emergency oil sharing system and the best possible handling of the energy policy issues that had brought them into the crisis. Oil supplies were to be subject to special allocation quotas decided by an Oil Committee in consideration of serious economic difficulties. In order to do so, Western countries signed in 1974 the "Agreement on an International Energy Program" (IEP Agreement), whose primary aim was to build the means of managing the immediate problems of energy security and long-term energy policy cooperation. The latter included future geopolitical scenarios and evolutions that were not necessarily linked to oil. As a matter of fact, this approach enabled IEA to deal with a series of subsequent new geopolitical situations of crisis, for instance oil supply disruptions in both the Gulf crisis and the current energy forms. Indeed, to date, IEA is active for what it concerns the growing use and blackmailing potential of gas and critical minerals, both subjects not possibly envisaged in the '70s.

[54] Ivi p. 48
[55] Ivi pp. 27-32

Even though during the Yom Kippur, or Ramadan, war the oil weapon was used and it entailed huge repercussions on the world's *status quo,* many scholars doubt the existence of an oil weapon nowadays. Indeed, on the one hand, we may find OPEC countries and their massive oil reserves, however, on the other hand, there is an always greater number of oil-producer countries which are not part of the organization and the constant development of alternative fuel sources for national energy mix. It may be sufficient to consider that among the world's top five oil-producers in 2023 three were non-OPEC countries, namely US, Canada and Russia.

Concerns about the use of oil as an instrument of coercion have been central to state intervention in oil markets[56]. Understanding whether some nations may impose large costs on others by limiting the supply of oil is essential to evaluate the link between oil and coercion. However, by taking into account crude oil output, the theoretical instruments employed to examine this issue reflect reactions to price volatility in the 1970s. The most significant long-term impact of the oil crises was the disintegration of the oil supply chain into a number of interconnected but distinct markets that are not dominated by a single player or set of players. Indeed, oil production nationalization by MENA governments was important to the extent that it fragmented petroleum's supply chain, which was once controlled by a small number of firms predominantly headquartered in the US or Europe, thus making oil a weapon no longer in the hands of companies but states.

As discussed before, the 1973 war entailed two forms of Arab coercion: a military attack vis-à-vis Israel and an economic coercion against those countries that supported the latter. Through the examination of this historical precedent, it appears evident that the oil weapon is a blunt weapon that cannot be applied specifically only to target a few countries nor for any sustained long-term period. Saudi's cuts in oil production to pressure the US to reduce its support to Israel had the effect, in early 1974, to completely dry up oil trade between the two, also because Riad was followed soon after by Abu Dhabi, to which the other OAPEC countries followed closely in retaliation to US "*Zionist support"*. It is fair to recall that the Americans were not the only ones targeted as the "*use of oil as an economic weapon*", as defined by Arab oil ministers, was used to boycott other Western countries too[57]. This became known as the *"oil price shock*". Oil prices skyrocketed to record highs and, while Europe continued to suffer a 10-15 % oil reduction ban, who experienced an even greater loss were Third World countries who underwent a 25-35 % loss of normal oil flow, even though this was not in OAPEC intentions. As a matter of fact, both economies of oil-importing friends and enemy countries

[56]Hughes, L., Long, A. (2014). "*Is There an Oil Weapon? Security Implications of Changes in the Structure of the International Oil Market"*. International security, 39 (3), pp. 152–189.

[57]Among them Rhodesia, Netherlands and other 'European Common Market' countries. Soon after Japan too was blackmailed and experienced a 25 % oil cut. Paust, J. J., Blaustein, A. P. (1974). *"The Arab Oil Weapon-A Threat to International Peace"* [online]. The American Journal of International Law, 68(3). Available at: https://doi.org/10.2307/2200513 (Accessed 29 May 2024).

were deeply affected to the extent, and paradox, that friendly oil-importing developing countries were likely to suffer more adverse economic impacts than the rich industrialised targeted countries did[58].

Five months after embargo's launch, most Arab oil ministers announced their decision to lift the oil blockade against Western countries, US *in primis*. Only four countries opposed the decision: Iraq, who refused to attend the meeting *in toto*, Libya and Syria who refused to give their consensus to the embargo's lifting and Algeria who expressed itself only on a provisional embargo lifting. The oil weapon lasted for almost five months. However, both outside and inside the Middle East, some countries increased oil supplies in the world market economy to the extent that it could be argued that the effective weaponization of oil did not last more than three months[59]. To explain why the embargo was lifted there is public evidence demonstrating that oil imports reduction into the US in the '70s did not negatively impact the country's military capabilities[60]. Thus, even under oil embargo America produced enough fuel to impose its military strength in the Middle East region; today the US military presence in the area is a form of deterrence for a new use of the oil weapon by Gulf countries. However, the oil embargo produced an indiscriminate and uncontrollable damages on food and fertilisers' production and to other apparently unrelated sectors. Therefore, the oil blockade's burden did fall on the civil population in Western democracies but it primarily harmed Third World's population, who suffered both oil shortages and price increase of oil-related technologies and markets. As a matter of fact, the complex global interdependencies between oil, fertiliser, and food showed the rigidity and impossibility to use the oil embargo as a weapon of mass destruction directed only to some countries without further repercussions; such a weapon cannot be perfectly controlled due to its multiple spill-over implications.

It is fair to say that international oil trade involves a large number of exporting countries, which today are even more than the ones active in 1973. Thus, an oil-blockade imposed by one or few exporters will not necessarily deprive third countries of oil supplies access, as long as other crude sources are available. The 1973 war example is explanatory and applicable still nowadays. The only producer to have the necessary weight to do so would be Saudi Arabia, due to its immense oil-reserves. Nevertheless, the Gulf country is also the least likely to resort to the oil weapon. Only if implemented in a tight market a supply production cut could cause prices to substantially increase and adversely hinder importing countries. However, embargoed countries, if endowed with sufficient military power as well as political and economic weight, would start to threaten the country imposing

[58] Mabro, R. (2007). "*The Oil Weapon: Can It Be Used Today?*" [online]. Harvard International Review, 29(3), pp. 56–60. Available at: http://www.jstor.org/stable/43650216 (Accessed 1 May 2024).

[59] Ibidem.

[60] Paust, J. J., Blaustein, A. P. (1974). *"The Arab Oil Weapon-A Threat to International Peace"* [online]. The American Journal of International Law, 68(3) pp. 410–439. Available at: https://doi.org/10.2307/2200513 (Accessed 29 May 2024).

sanctions. Moreover, in the case of oil-exporting countries, it exists a mutual dependence relation with Western countries. As a matter of fact, the latter's dependence, however great and evident, is only based on a single good, i.e. oil, while petrostates are dependent on the West for several types of primary goods. Moreover, oil could not be treated as a single market since it does not take into account the supply chain physical separation into a series of related segments, almost divided into watertight compartments, e.g. production, transportation, refining … This supply chain fragmentation means that the coercion potential could affect different sectors of the oil market, as it was the case, for instance of the Suez Canal blockade in 1956 and 1967 which targeted oil transportation rather than extraction. This argument also implies that the actors empowered with coercion power may vary across different stages of the supply chain, as opposed to coal, a market less fragmented and, therefore with less actors, just the state and the mining companies, the latter being *inter alia* subject to the will of the state.

For what it concerns a possible new weaponization of oil nowadays under the form of an embargo by Iran or Venezuela, the oil-market size ensures a some-what high level of compensation. Indeed, oil shortages could be easily substituted for by new release from Western countries' strategic stocks or by oil-exporting countries' increased production. Moreover, for what it concerns Iran's potential to weaponize crude by enforcing an oil-embargo through its military capabilities, it is evident the impossibility of such a case, especially in a long-term perspective. Teheran is capable of minor military actions directly in the Strait of Hormuz or through attacks on Saudi oil infrastructure[61], resulting only in temporary disruptions fully conditioned on an Iranian surprise attack. Indeed, oil-flow interferences would be minimal, both because of US aerial and naval superiority and Saudi's widespread oil infrastructure being a target too difficult for Iran. Indeed, as historical precedents may suggest, geography and technology can provide short-term advantages but it's the overall naval and aerial dominance that determines the success, as WW2 oil tankers' targeting and the 1980s Tanker war in the Persian Gulf between Iran and Iraq may teach.

A mandatory, but not sufficient, condition for successful coercion is the ability to impose costs[62]. Despite the fact that the oil supply chain experienced less market concentration over the last five decades, US remains among the few nations capable of wielding oil as a weapon due to its absolute military dominance, especially on the sea. As a matter of fact, the U.S. government historically ensured its domestic oil companies access in the Middle East for security reasons; to the extent that American current military presence in the region is due to Arab oil production importance vis-à-vis

[61] Joshua R., Itzkowitz S., Miranda P. (2011). *"A Crude Threat: The Limits of an Iranian Missile Campaign against Saudi Arabian Oil",* International Security, Vol. 36, No. 1, pp. 167–201.

[62]Hughes, L., Long, A. (2014). "*Is There an Oil Weapon? Security Implications of Changes in the Structure of the International Oil Market*". International security, 39 (3), pp. 152–189.

the global crude market[63]. The latter is possible through what Posen (2003)[64] defines as the *"command of the commons"*, i.e. the extent to which military capabilities are concentrated in a single state. The domination of the commons, i.e. land, sea and air, means that a state "*can threaten to deny their use to others; and that others would lose a military contest for the commons if they attempted to deny them*"[65]. Therefore, the "command of the commons" enabled the dominant power, in this case the US since 1945, the ability to impose costs on its adversary.

Now, it is fair to say that the 'oil weapon' used during the Yom Kippur war caused panic in oil-importing countries. However, the latter acknowledged their vulnerability due to their oil-dependency and ran for cover. More to that, oil-exporting countries were quite weak and, when they realized that they were unable to achieve their political goals, lifted the oil embargo[66]. Evidence of this is given by the fact that after 50 years, Israel is still present on much of the land conquered in 1967 and the Arab Israeli conflict is today more than ever still plaguing the region.

Another interesting case happened in 2014 when the Saudis tried, again, to weaponize oil. Nevertheless, this time it was not for a geopolitical need but for a geoeconomic one. Indeed, instead of influencing oil production or transportation they directly acted by increasing crude's prices, to influence the market and, on the long-run, win more market shares. However, as suggested by Leonardo Maugeri[67], they could not displace US shale oil production fighting an oil price war. As soon as they realised it, Saudis decided not to cut production. Riad was ready to wage a one-year war extracting and selling oil barrels at half the price to conquer US shale oil's market share. This measure did not succeed. As a matter of fact, Saudis, who considered American shale oil just a temporary phenomenon due to its higher extracting and refining costs, had to change their mind. Indeed, US shale was the main responsible for the decrease in oil excess production. Therefore, the Saudis' oil was again weaponized but, for the first time, the type of weapon was substantially different from the past. The US were still Saudi Arabian's main target but the latter's aggressive approach left space for a more cautious one. In order to understand the 'new' oil weapon, which should be better referred to as 'oil price weapon', it must be acknowledged first that Riad believes that production cuts are completely pointless. According to them, those cut, within the OPEC framework, would only be a gift to the US, Canada, and Russia. Saudi Arabia would lose more if it cut production in comparison

[63]Ibidem.

[64]Posen, B. R., (2003). *"Command of the Commons: The Military Foundation of U.S. Hegemony",* International Security, Vol. 28, No. 1 (Summer 2003), p. 8.

[65]Ibidem.

[66]Mabro, R. (2007). "*The Oil Weapon: Can It Be Used Today?"* [online]. Harvard International Review, 29(3), pp. 56–60. Available at: http://www.jstor.org/stable/43650216 (Accessed 1 May 2024).

[67] Xiao, A. (2015). "*The Geopolitics of Oil Prices: Analyzing the Effects of Production and Invesment on Global Oil Prices"* [online]. Harvard International Review, 36(4), pp. 26–28. Available at: http://www.jstor.org/stable/43649315 (Accessed 6 May 2024).

to maintaining a higher one. Indeed, in this latter case, it would still suffer but less since other countries would suffer far more as their crude is produced at a higher cost.

Less than ten years later, in 2020, a new "oil war" was waged at OPEC headquarter between two world leaders oil exporters, i.e. Saudi Arabia and Russia, respectively the second and third largest oil producers, accounting for ¼ of global crude's production. In the Covid-19 aftermath, the stalemate between the two OPEC + (thirteen OPEC members and ten non-OPEC members) countries resulted in a substantial crude price-drop in the world market. Once again oil was weaponized and employed as a geopolitical weapon. However, it was not weaponized by reducing its extraction or hindering its transportation but setting a new price. Russia was indirectly affected and had to bear the consequences of geopolitical manoeuvrability, mainly in a Saudi vs US framework, due to the reduction in the oil price below the fiscal breakeven point. Such a narrative of 'oil price weapon' was evident in Russian media 2014 when on the Pravda was wrote that: "*The then US President Barack Obama tried to convince the King of Saudi Arabia to coordinate actions in the oil market to reduce world oil prices, the main source of Russia's export revenues, and "punish its behaviour" in Crimea*"[68]. Therefore, according to this point of view, it exists an oil weapon and it can be used not only by OAPEC countries but it is needed an agreement between the two major oil-producing countries, of which one may guarantee the command of the commons.

It is fair to recall, for what it concerns Russia, an interesting precedent. Indeed, an oil price weapon had already been used vis-à-vis Moscow: in the 1980s, the US and its allies, both in the Gulf and Europe employed a pressure strategy on the USSR by lowering the oil price in the 1980s. The oil price reduction affected Moscow's main source of income through export revenues and was eventually among the main factors that led to USSR collapse; in that precedent Saudi Arabia played a pivotal role in that episode orchestrated during the Cold War's superpower rivalry. Thus, it is fair to say that even though it exists a certain historical amount of Moscow's victimism in international politics, there exists a precedent of the oil weapon employed to harm Russia. Nevertheless, this case stands in clear contrast with the 1956 or 1973 ones. Indeed, in the latter an oil blockade was enacted and crude did not leave the Gulf, production was completely interrupted. In Russia's case, instead, was done totally the opposite: no longer oil was prevented from leaving the Middle East but the world crude market was flooded with excessive production so as to lower the price. The situation worsened even further as China incurred in industrial production downfall as coronavirus pandemic's consequence, which led to a Chinese significant oil import cut. OPEC members, in order to cope with the plummeting demand, called on to cut production. Russia, a non-OPEC nation, rejected the idea

[68]Sudakov (2014). *"Obama wants Saudi Arabia to destroy Russian economy"* [online]. Pravda, 3 April 2014. Available at: https://www.pravdareport.com/world/127254-saudi_arabia_russia_obama/# (accessed 9 May 2024).

and unexpectedly halted the collaboration that had been set up in December 2016 to reduce output to control the unrestricted decline in oil price on the global market. To Russia's disapproval of the output reduction plan suggested by OPEC, Saudi Arabia answered by offering at a further reduced price its oil. That day was the largest one-day drop in oil prices since the first Gulf War. With Saudi Arabia's statement that it will be raising its oil output to an unprecedented level, both Saudi Arabia and Russia officially entered an "oil war"[69]. Saudi Arabia, on its own, maintains the highest global production capacity, therefore, it is able to control an important amount of global crude output and cost. However, lower oil prices enabled Saudi Arabia to steal third countries market shares', especially the ones from Russia and US. It makes sense for Riad to extract and sell oil at any price as long as there is demand for it, since the Gulf monarchy holds in its reserves 2.5 times as much crude as Russia does, that is to say the largest oil reserve in the world[70].

According to some scholars, it is claimed that Saudi Arabia and Russia are focusing on the oil industry in order to "devastate" it and completely change its power relations by taking advantage of the coronavirus epidemic. Saudi Arabia seeks to reclaim its market share by forcing nations like the US and Canada to give up their more expensive shale oil production methods owing to unprofitability, which is why it is backing low oil prices[71]. It was assumed that the American-Saudi oil alliance would have started the 2014 oil price war, pressuring Iran and Russia to follow the formers' actions (i.e. decrease oil price) emulating what was done with USSR's last leaders: *"pump them to death, bankrupt them by bringing down the price of oil to levels below what both Moscow and Tehran need to finance their budgets"*[72]. Indeed, such a narrative was also the Former Russian Prime Minister Yegor Gaidar's one. Even though the latter acknowledged that the Soviet Union's fall have *de iure* occurred in 1991, its seeds were *de facto* to be found in the 1985 Saudi Arabia's plan: *"The Saudis stopped protecting oil price. During the next six months, oil production in Saudi Arabia increased fourfold, while oil prices collapsed. The Soviet Union lost approximately $20 billion per year, money without which the country simply could not survive"*[73]. It is fair to say that this narrative is not only endorsed by a pro-Russia public opinion as the BBC too saw the 2014 price war in the same way. The Russian economy

[69]Evigail N. (2020), "*5 charts that explain the Saudi Arabia-Russia oil price war so far*" [online], CNBC, 1 April 2020. Available at: https://www.cnbc.com/2020/04/01/5-charts-that-explain-the-saudi-arabia-russia-oil-price-war-so-far.html (Accessed 24 May 2024).

[70]Singh, A. K. (2020). "*The "Oil War" of 2020 Between Saudi Arabia and Russia: Examining the Underlying Geopolitical and Geoeconomic Compulsions*". Indian journal of Asian affairs. 33 (1/2), pp. 24–42.

[71]Rjean, R. J. (2020) *"Continental Resources' Harold Hamm leads effort to pursue anti-dumping case against Saudia Arabia, Russia"* [online]. Wilson Harold, March 11, 2020. Available at: https://www.willistonherald.com/news/oil_and_energy/continental-resources-harold-hamm-leads-effort-to-pursue-anti-dumping/article_5afe9df6-63ea-11ea-a4ff-a7a2717b6339.html (Accessed 29 April 2024).

[72] Singh, A. K. (2020). "*The "Oil War" of 2020 Between Saudi Arabia and Russia: Examining the Underlying Geopolitical and Geoeconomic Compulsions*". Indian journal of Asian affairs. 33 (1/2), pp. 24–42.

[73] Friedman, T. L., (2014). *"A Pump War?"* [online]. The New York Times, October 14, 2014. Available at: https://www.nytimes.com/2014/10/15/opinion/thomas-friedman-a-pump-war.html (Accessed 29 May 2024).

was frequently described as being “on the oil needle”, with its reliance on energy resources being likened to heroin addiction. The suffering that follows a drug addict’s withdrawal from drugs is Russia’s suffering due to the drop in oil prices on the world market. This is being done with clear geopolitical intentions to weaken the nation’s economy and its standing in the international community[74].

Oil has shown its importance and its crucial role in reversing or determining the fate of a war, should one of the two contenders find oil fields beneath national a soil. This is why rebel forces have tried to gain access to oil fields and their revenues. Examples of such conflicts are the ones currently taking place in South Sudan and Nigeria which are ascribed in the greatest theory to which we refer as “resource curse”. Fighting for the control of key energy resources that can be employed as geopolitical weapons or even just for its revenues is a relevant issue in most contemporary warfare.

1.3 **Gas**

1.3.1 *The fossil fuel*

Natural Gas is a colourless, odourless, and highly combustible type of fossil fuel which is used in electrical power generation, heating, and cooking. Gas is a well-suited fuel source for the rapidly growing industrialised world energy needs since its combustion is stable, easily manageable, and cleaner burning than the old key alternatives, i.e. coal and oil. Oil deposits were commonly associated with natural gas. However, the latter was originally considered as a nuisance and was burned in flares to avoid asphyxiation or explosion hazard. Long before the development of systems to exploit natural gas within the oil fields, the resource was simply left inside the earth. Oil was valuable, natural gas was not. However, nowadays gas is appreciated for its relatively clean combustion and it increasingly occupy an important and strategic position in global energy markets. Indeed, natural gas became the preferred fuel for electricity generation, to the extent that it has long been the fastest growing source of primary energy in the past decades. Since the start of the century, IEA[75] expected global consumption of natural gas to almost double in twenty years, to the point that, in the coming years, the fossil will surpass coal to become the second most important energy source in the world. In the same manner, it is also expected that by 2050 gas will surpass oil in order to occupy the first position

[74]Zurcher, A. (2014). *“Is the oil crash a secret US war on Russia?”* [online]. BBC, October 16, 2014. Available at: https://www.bbc.com/news/blogs-echochambers-29651742 (Accessed 3 May 2024).
[75] IEA (2004). “*World Energy Outlook”* (WEO). Paris: International Energy Agency.

as the most widely used energy source, although recent price increases may have called into question its future economic viability.

As afore mentioned, natural gas resources are to be found in broader and more plentiful distribution than oil. However, natural gas has followed a different path of development and its use was much slower than that of oil. This is primarily due to the greater ease of transport and use of oil as transportation fuel. As a matter of fact, political and technical obstacles to transport natural gas over long distances through a system of pipelines and the huge expense of liquefying it for tanker shipment have made oil a more attractive energy source. Nevertheless, gas pipeline networks, both at national and international level, are rapidly developing. However, since gas is exported through pipelines, the latter may cross third countries, the so called 'transit countries', before reaching the final destination. This poses several geopolitical problems. Indeed, many pipeline routes involve one or more transit countries, which may complicate the task of negotiating original deals and create additional costs and risks for the enterprises[76]. This is why Liquefied Natural Gas (LNG) has been developed, undergoing scientific and cost optimisation. LNG has become an increasingly globally traded energy source for key energy markets. For instance, Qatar is working to exploit its gas fields with major international energy companies to become a leading LNG exporter due to the geopolitical problem posed by the construction of pipelines in the region. Nevertheless, it is fair to say that LNG tankers too cross the territory of transit nations through territorial waters.

Governments and private investors may be victims of the geopolitical power relationship between supplier, transit and arrival countries. If governments develop a close relationship regarding gas projects, the former will intervene to prevent negative output. However, where such interstate relations do not exist, governments may be willing to use their market power to drive up prices or cut supplies for political purposes, i.e. to weaponize gas. This "gas weapon" will lead investors and governments to avoid projects that could expose them to unpredictable neighbours.

Until WW2, gas pipelines were local systems whose aim was to provide a substitute for synthetic gas originating from coal. In the war aftermath gas trade through pipelines increased exponentially within both Cold War blocs until Italy and Germany began to import Russian gas. However, the ex-soviet country will end up being more dependent on European cash flows rather than the importers were on a secure flow of natural gas[77]. Italy largely invested on natural gas sector, increasing its pipeline system extension more than twenty times by the start of the 1980s[78]. In order to diversify its

[76] ESMAP (2003). "*Removing Obstacles to Cross-Border Oil and Gas Pipelines: Problems and Prospects*". Washington, DC: UNDP/World Bank, p. 130

[77] Singer, C. (2008). "*Energy and International War: From Babylon to Baghdad and Beyond*" [online]. World Scientific Publishing Company, p. 249. Available at: https://www.perlego.com/book/847027/energy-and-international-war-from-babylon-to-baghdad-and-beyond-from-babylon-to-baghdad-and-beyond-pdf (Accessed 27 April 2024).

[78] Ivi, p. 260

gas energy mix, Italy imported gas from Netherlands and Russia by pipeline, and from Algeria under the Mediterraneum. More to that, in the first 2000s, Rome started a project to receive North Sea gas from Norway and, soon after, another underwater pipeline from Libya. European efforts to switch from a small national and local pipeline grid system to a supranational and interconnected one are exemplified by Italy, who, by the end of the century, imported natural gas as far from Russia, the North Sea, and North Africa.

1.3.2 The *"Gas weapon"*

With the end of WW2 gas became increasingly sought and used by national governments as an alternative to conventional fossil fuels. Given the increasing importance of fossil in national energy mixes, soon the source of energy acquired value and the countries holding gas deposits were enriched through the trade of this fuel. As a strategic source for economic development and post-war industrial reconstruction, power relations were created not only between producer and consumer countries but with transit countries too. The mid-XXth century examples demonstrate gas importance in national economies and security, foreshadowing its weaponization in the XXIst century.

The country in Europe that has diversified the most its energy mix and was a pioneer in the extraction and marketing of gas is Italy. Indeed, Rome was the largest gas producer and consumer in Western Europe since 1965. Therefore, it is important to analyse its relations with one of the major gas exporters, i.e. Algeria. The African country's gas reserves were well known since the time of France's occupation. Thus, once independent, Algeria's state-owned oil and gas company Sonatrach, tried enriching itself through the fossil fuel's exports. In the 1970s both Italy and Spain were seeking to expand their national natural gas consumption. This is why, in the early 1980s, Rome's state-owned energy company ENI began to pursue a subsea pipeline, "Transmed", to bring Algerian gas across the Mediterranean. Under ENI's president, Mattei, leadership the company began building a national gas grid to exploit its Po valley gas fields[79]. However, the latter soon became insufficient to satisfy the country's energy needs. As a consequence in the 1970s Mattei sought to diversify the company's gas imports, securing supplies from the Netherlands and the Soviet Union, plus it developed LNG shipments from Libya. As he tried to diversify the growing gas imports needs, Mattei exploited the friendly relations with Algeria, developed at the time of the independence war, to secure a gas contract with Sonatrach under the form of a pipeline under the Mediterranean to connect Algerian gas fields directly with the Italian gas grid starting in Mazara del Vallo, Sicily. This contract held an important

[79] Victor, D.G., Jaffe, A.M. and Hayes, M.H. (2006). "*Natural Gas and Geopolitics: From 1970 to 2040*". Cambridge: Cambridge University Press, p.56.

energy security function, indeed, in the words of Marcello Colitti, this *"'marriage' of partners would ensure greater supply stability. A new Algerian liquefaction train could – in theory – fill a ship heading in any direction, while pipeline gas could go only to Italy"*[80]. However, a hypothetical gas pipeline could not directly connect Algeria to Italy but would need to transit either through Libya or Tunisia. Nevertheless, Tunisian transit risks toward Italy's gas security were perceived to be minimal. As a matter of fact, Tunis once tried unsuccessfully to obtain an excessively higher share from the rents of the project. However, it did not have the desired effect since it almost blocked the entire project in its initial stages. ENI's executives considered the pipeline's passage through Tunisia a necessary risk and Bourguiba, after some initial problems, turned out to be a stable long-term partner and rewarded considerably for its geographical location by the Italian company, which assured the African country a 5% share of the total gas shipment from Algieri as a transit tax[81]. The latter tripled the country's gas supplies without imposing any financial or operational liability. If Tunis proved, in the long-term, to be a stable partner, ENI had major technical and political problem with Sonatrach. Indeed, ENI provided the vast majority of the project's capital, so that, once the pipeline was completed it yielded a huge bargaining power to Sonatrach and the Algerian government. The Italian company will realise later the asymmetric bargaining situation created. Soon after the pipeline inauguration Sonatrach increased the bargained price with ENI. The French and Belgians, who relied on Algerian gas, agreed to the new price imposed by Sonatrach quite rapidly, the Italians found themselves with little negotiating leverage left, since they were paying the multi-billion euros Transmed, still empty. The only weapon in ENI's hand were the negotiations simultaneously held with the representants of Moscow's gas exports[82], with the latter more interested in being politically present in a Western market rather than in a purely economic way. In 1982 an agreement was eventually found with the Soviets and, in the long run, who suffered the most from this first 'gas battle', or better 'gas price battle', was Sonatrach and Algerian reputation as a stable gas supplier.

Even though gas dependency is a well-known phenomenon traceable in different parts of the world, for instance Japanese dependency over Indonesian gas, Argentine and Chilean dependency on the Bolivian one, or the importance of Turkmenistan gas and Qatari LNG in global market, most important and significant cases of gas weaponization and blackmail occurred in Europe. Following the Italo-Algerian 'gas price battle', the other main player, that will revolutionize the 'gas weapon', is Russia. Indeed, the latter holds the world's major gas reserves and it's the first gas exporter, to the

[80] Ibidem.
[81] Ivi p. 63
[82] Ivi p. 63

extent that its massive gas reserves can be piped almost anywhere in Europe or Asia[83]. The Russian-German gas deals have played a leading role in defining the relations between the two countries since the mid-1970s and were highly favourable for both. In the 1970s, at the time of the 'oil shock', the Urengoy-Uzhhorod pipeline, the pipeline connecting Russian Siberia to Germany, appeared as a great import costs' reduction since it allowed Berlin to replace oil with gas and to employ a great number of German workers in the pipeline construction. The US attempted to exert its veto control and ban the project but on the European point of view the Americans feared an imaginary geopolitical threat in which Germany was to rely exclusively on Russia for its gas supplies. That fear eventually took shape with the 2022 Russian invasion of Ukraine. When it was completed, the Urengoy-Uzhhorod pipeline, known as the Brotherhood pipeline, delivered 180 bcm (billion cubic metres) of gas from the Siberian gas fields primarily to Germany but even towards other minor Soviet destinations and Western countries as France, Italy, Austria, and Switzerland[84]. It was the highest amount of gas ever piped. Starting in the 1990s, Russian state-owned gas company Gazprom developed a new project to pipe its gas more rapidly to Germany crossing Belarus and Poland. Moscow's gas exports toward Western Europe transited almost entirely through Ukraine - and still the majority did until the 2022 war broke out - but by the mid-1990s the risk of theft and gas shutoff in the latter country was increasing. Therefore, a new pipeline was projected and aimed to serve Western markets, especially Germany, crossing Belarus. Ironically, Belarus in 2004 will present similar problems as a transit country to Russians as Ukrainians did before[85]. This explains why Gazprom developed another pipeline to bypass both Ukraine and Belarus in the early 2000s, i.e. the Blue Stream pipeline, from southern Russian Caucasus territories on the Black Sea directly to the Turkish market, realised thanks to ENI's deepwater pipeline expertise. The impossibility of relying on the pipeline transit in Belarus and Ukraine, and the consequent creation of alternative pipeline routes, is due to the respective governments. Indeed, the internal political developments caused their governments to focus on short-term gains, thus discounting the long-term consequences of their actions. In a similar way to what occurred to Algeria and Tunisia, it was those countries employing the *'gas price weapon'* who lost in the long run. Prior to Ukrainian and Belarussian attempts, there was little evidence of a "*gas weapon*" use by Russia or other transit countries.

At the apogee of the 2014 Ukrainian crisis, a gas war was avoided. Both Russia, Ukraine, and European consumers deepened their energy ties as the crisis extended guaranteeing a good supra-

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[83] Singer, C. (2008). "*Energy and International War: From Babylon to Baghdad and Beyond"* [online]. World Scientific Publishing Company, p. 267. Available at: https://www.perlego.com/book/847027/energy-and-international-war-from-babylon-to-baghdad-and-beyond-from-babylon-to-baghdad-and-beyond-pdf (Accessed 27 April 2024).

[84] Victor, D.G., Jaffe, A.M., Hayes, M.H. (2006). "*Natural Gas and Geopolitics: From 1970 to 2040"*. Cambridge: Cambridge University Press, p.134.

[85]Ivi p. 125

national collaboration level. Everything started in 2013 with peaceful demonstrations against the Ukrainian government's rejection of the "Association Agreement" with the EU, which rapidly grew into a national revolution and crisis over Russian annexation of Crimea. In order to avoid further destabilisation in Ukraine, despite Moscow's support for the insurgency and Western sanctions against the Kremlin, Russian gas represented an important key resource for Europe, so that Kiev allowed Russian gas to pass freely on its territory toward its European customers[86]. Despite Moscow's predatory "pipeline politics" revival, it is fair to say that Gazprom, even though Ukraine was not paying for Russian gas, delayed its gas cut-off for months into the 2014 crisis. Thus, Moscow refrained from deploying its gas weapon to gain shareholdings at the expenses of a further-indebted country. However, it should be recalled too that Moscow did not use its most effective geopolitical weapon and granted discounts on gas supplies because the 2013 Ukrainian President, Janukovyč, was pro-Russian and was facing increasing contestations at home. Moscow restricted its energy diplomacy to offer, but not renewing further on, price discounts on gas supplies to Ukraine while reaching, in 2013, historical high from gas sale to Europeans customers. The Kremlin softened its measures *vis-à-vis* Ukraine with temporary discount fees until 2015 and European companies had the time to create international joint ventures with Gazprom just as the US and EU started to impose sanctions on Moscow. For what it concerns the 2014 gas crisis, the bargaining conditions were particularly favourable for the Kremlin that could impose its will since Ukrainian and EU customers' positions were worsened by a harsh winter[87], therefore more exposed to Moscow's gas weapon. However, Russia's reliability as a trustworthy supplier was substantially undermined. Indeed, few months after, Russian lack of competition in the gas market and its indifference to free market rules were regarded as a direct threat towards EU energy security by Brussels. Nevertheless, in its pipeline politics, the Kremlin rarely employed actual gas cut-offs in support of its foreign policy objectives, even *vis-à-vis* some of its highest vulnerable customers in the Baltics and the Balkans. Russian coercive gas diplomacy has usually been more nuanced and indirect[88]. Through the use of several tactics, e.g. discretionary price cuts and hikes or "*take-or-pay*" obligations, Moscow employed its natural gas strength and extensive pipeline system against its vulnerable customers, especially the post-Soviet ones, and the transit states. Nevertheless, at times, these measures have been pursued with little to no regard to their spill-over effect towards the downstream customers in Europe and Central Asian supply partners, i.e. no long-term vision. Moreover, at least until the 2022 invasion of Ukraine, the Russian energy weapon was not integrated into a coherent Russian grand strategy.

[86]Stulberg, A. N. (2015). "*Out of Gas? : Russia, Ukraine, Europe, and the Changing Geopolitics of Natural Gas. Problems of post-communism"*. 62 (2), p. 112.
[87] Ivi p. 116
[88] Ivi p. 115

The 2006 conditions were particularly favourable for Russia to impose more restrictive conditions on Ukraine's gas supply by abruptly raising gas price by four times. Gazprom felt compelled to increase pressure on Ukraine due to rising European prices and Moscow, enraged over the Orange Revolution's outcomes, was also keen to punish the newly elected pro-Western administration for its use of nationalist rhetoric and vigorous NATO and EU membership lobbying[89]. At the same time, despite the risks to Ukraine's own energy security, Kyiv's tacit threats to cut off supply as a negotiating chip with the Kremlin gained more weight due to the sharply deteriorating terms of trade with Gazprom and expectations of growing demand of vulnerable Central European states and other large consumers of transited Russian gas, i.e. Germany and Italy. As part of an effort to make Kyiv pay market rates, Russia stopped supplying natural gas to Ukraine for a short period of time starting 2006. However, it is fair to recall that Ukraine has been receiving cheap natural gas from Moscow since the Soviet era, with most gas being inefficiently used to foster national industrial production. Nevertheless, the Moscow-Kyiv pipeline extends to the main Western-Europe markets, causing the latter gas-supply disruption. The crisis was partially over until when, in 2008, Gazprom declared that if its demands for a resolution to the crisis were not met it would stop supplying a fourth of Ukraine's pipeline-shipped gas needs in six days[90]. Even though an agreement seemed to be reached in 2009, with the drop in global prices, consequence of the 2008 crisis and the downstream European gas demand, Gazprom was forced to cover the cost of importing gas from Central Asia and could not afford for Ukraine to fail on its rising obligations. Indeed, Kyiv was once again late in paying its gas obligations and, by the end of 2008, it was unable to repay its debts to Gazprom. Simultaneously, Ukraine's internal political and economic situations rapidly deteriorated. Thus, Kyiv had less to lose by unilaterally raising transit tariffs to European levels, rescinding subsequent agreements on price and debt repayment with Russia[91]. Therefore, Kyiv decided to exploit the transit of Russian gas as a blackmail weapon. Both crises, having feared - and briefly used - gas as a geopolitical weapon, were settled down through an agreement between the two states' energy companies, the Russian Gazprom and Ukrainian Naftogaz. However, in respect to the 2014 crisis, the 2009 one was definitely more dramatic as it entailed a two-week gas-supply disruption with implicit costs that followed on all parties. The suspension of Russian gas supplies affected almost all European nations, with Slovakia and Bulgaria experiencing total gas cut-off. In addition to suffering significant economic and prestige losses, Ukraine had to pay higher natural gas prices than its European counterparts, give up the direct

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[89] Wilson, A. (2005). "*Ukraine's Orange Revolution*". (New Haven): Yale University Press.

[90] Singer, C. (2008). "*Energy and International War: From Babylon to Baghdad and Beyond*" [online]. World Scientific Publishing Company, p. 280. Available at: https://www.perlego.com/book/847027/energy-and-international-war-from-babylon-to-baghdad-and-beyond-from-babylon-to-baghdad-and-beyond-pdf (Accessed 27 April 2024).

[91] Stulberg, A. N. (2015). "*Out of Gas? : Russia, Ukraine, Europe, and the Changing Geopolitics of Natural Gas. Problems of post-communism*". 62 (2), p. 116.

access to its domestic market to a Gazprom parent company, and accept harsh financial penalties for breaking the Russian "take-or-pay" contract condition. More to that, the country was not taken into considerations during the EU-Russia talks on the planning of both Nord Stream and South Stream pipelines, which hindered its strategic position as a transit state. Moreover, Moscow's gas weapon economic consequences cost Yushchenko, incumbent Ukrainian president, a crushing defeat at the polls in the 2010 elections. Not only did he lose the election, but the new president Yanukovych, pro-Russian, received a discount on gas import costs. It is fair to say that Russia too suffered as a result of the 2009 crisis. The latter lost more than $1 billion in export profits. Furthermore, Yanukovych negotiated a 30% price reduction on Moscow's gas supplies.

The EU's decision to diversify its energy mix, reducing its member states' vulnerability was prompted by this prolonged 2009 gas cut-off. This involved new and stronger attempts to build a "Southern Energy Corridor"[92] which could allow to carry out gas through pipelines from competing Eurasian sources, e.g. Azerbaijan, bypassing Russia, as well as increasing financial and political pledges to improve third-party access to Kyiv's transportation network. The latter was done so that Ukraine, protecting gas transport, could prevent giving Russia a blackmailing option vis-à-vis Europe and Ukraine itself. Moreover, the EU adopted the "third energy package" in order to fortify its competition policy for what it concerns production and distribution of gas assets. Similar to this, the EU Commission made an effort to adopt a balanced stance in response to concerns over supply disruptions. Indeed, there was a widespread belief that the EU was vulnerable to short-term gas disruptions, particularly among "price-takers" of Central and South-East Europe[93]. However, it is mind-blowing that in 2014, prior to sanctions being imposed on Moscow but while international tensions mounted, some of the European major energy multinationals doubled the number of investments in the gas sector with Russia, tightening even more their trade links with Gazprom[94]. In a similar way, energy links between the two countries were tightened in 2014 when RWE, second largest German utility company, sold some of its subsidiaries in the gas and oil production sector to Russian privates, resulting in a significant strategic realignment for what it concerned the company's oil and gas production, which shifted from the North Sea to the Caspian region, strengthening

[92] Ivi p. 118
[93] Ivi p. 120
[94] Johnson, K. (2014). *"Digging Themselves in Deeper"* [online]. Foreign Policy. Available at: http://www.foreignpolicy.com/articles/2014/04/22/digging-themselves-in-deeper-big-oil-putin-russia (Accessed 22 April 2024). Most of German energy companies overtly took actions to protect their business with Gazprom from potential political fallout and repercussions. Moreover, they stated that they were and always would be dependent on Moscow's gas and actively campaigned against the imposition of sanctions for Crimea's annexation, that would have irreparably undermined the close German-Russian energy ties. Moreover, the German energy firm E.ON's CEO emphasized Gazprom's reliability by asserting that the latter never used natural gas as a geopolitical weapon against European consumers and that this was not in the Kremlin's plan. Stulberg, A. N. (2015). "*Out of Gas? : Russia, Ukraine, Europe, and the Changing Geopolitics of Natural Gas. Problems of post-communism"*. 62 (2), p. 124.

Moscow's foothold in alternative supply areas in a vital and strategic sector of the German market[95]. It should raise some concerns the fact that the latter company sale was approved by the German federal government. In a similar way, in the same years, Gazprom and the German Wintershall finalised an asset-swap agreement wherein the latter gave up 100% of the company's gas business and its exploration and production activities in the North Sea in exchange for a 25% share in the development of Russia's reserves in the Siberian Urengoyskoye region. With this agreement, Russian government essentially gained control over German gas storage. Moreover, Wintershall felt more confident in pressuring the EU to allow Gazprom to have more access to the OPAL pipeline - German internal pipeline connecting the Nord Stream to the existing European pipeline grid in Middle and Western Europe -, which would have otherwise limited the capacity of the Nord Stream pipeline[96]. Comparable initiatives were carried out by the French company Total, which confirmed its participation in Kremlin's LNG projects, and the Italian ENI, which signed a historic agreement with Gazprom to forgo oil-price indexing in long-term bilateral agreements offering a 7% delivery discount beginning 2014.

When analysing gas as used, or presumed to be used, as a geopolitical weapon it is impossible not to mention the current war which takes place in the heart of Europe, i.e. the 2022 Russian invasion of Ukraine. In the framework of the Russian-Ukrainian conflict, which began in 2014 and never faded, Moscow ordered a large-scale invasion directed to Kyiv beginning 22nd of February 2022. In addition to the massive devastations in the country and *vis-à-vis* the local population, the invasion also caused a serious shock in the international market due to the halt of gas supply to the European market, the largest in the world. In order to support its military operations, the Kremlin used energy policies as a weapon, e.g. reducing the volume of gas supplies, thus increasing its price or requesting to be paid in rubles rather than in dollars.

Moscow deployed all its finest weapons in support of its large-scale "special military operation", as the Russian establishment defines it, among which was the interruption of its natural resources' exports. Indeed, just a month after the beginning of the operations, Gazprom, the Russian state-owned energy firm, declared to have *"completely suspended gas supplies to Bulgargaz* (Bulgaria) *and PGNiG* (Poland) *due to non-payment in roubles"*[97]. In the same manner, the Russian company, soon after, cut its exports to Germany, Denmark, Netherlands, and Finland too[98]. It is calculated that, in

[95] Ibidem.
[96] Ibidem.
[97] Nastassia, A., Neil., H., (2022). *"Gas prices soar after Gazprom halts supplies to Poland and Bulgaria"* [online]. Financial Times 2022. Available at: https://www.ft.com/content/f7945d42-9cbc-401c-939b-c331f4f359a2 (Accessed 23 May 2024).
[98] Reuters (2022). *"Gazprom to cut gas supplies to Denmark's Orsted, Germany via Shell deal"*. Reuters 2022. Available at : URL-https://www.reuters.com/business/energy/gazprom-cut-gas-supplies-denmarks-orsted-germany-under-shell-deal-2022-05-31/ (Accessed 29 April 2024).

February 2024, Moscow's gas exports to Europe dropped by over 80% in comparison to its pre-war levels[99]. The latter is astonishing considering that 45% of the EU's pre-war gas imports came from Russia[100]. These countermeasures were the result of Putin's decree to harm those "unfriendly" countries that imposed sanctions on the Kremlin in the Ukrainian invasion aftermath. This type of measures did not come out of the blue since already in previous occasions, e.g. 2006 and 2009, EU acknowledged its dependency on Russian gas due to sudden supply interruptions. Nevertheless, EU officials complained to be subject of Moscow's blackmailing, claiming to be victims of Putin's gas weapon. It seems that Moscow tried to exploit European countries' gas dependency by weaponizing its energy exports, gas *in primis*, to disincentivize Brussels to support Ukraine and accelerate its military invasion. However, the European Commission, while looking for alternative gas sources to fill the Russian natural gas supply gaps, committed itself to be independent from Moscow's fossil fuels by 2027 by drafting the "REPowerEU" strategy. It is fair to say that the EU suffered short-term economic slowdown but in the medium-term it was able to adapt to the new *status quo*. Moreover, adaptation entails some important long-term consequences. Indeed, as the technology change takes place in national industries, it is highly unlikely that European countries could shift back to Russian gas once prices normalize. Thus, the Russian natural gas shock has brought about a positive change: with the rise in natural gas prices, the EU expressed itself to a faster decarbonisation, which implies a sharper energy security *vis-à-vis* Russia[101]. However, EU's energy dependence on Russia is different among its member states, to the extent that Central and Eastern European countries, Germany *in primis*, are highly dependent on Moscow's pipelines. The Kremlin's gas exports volume outside Europe decreased too in the short run but, even if it was to increase in the long-run, Russian exports in the rest of the world could never reach such high-levels in terms of both volume and revenues as the ones in the European market[102], especially due to a lack of a vast and articulated pipeline system directed toward those new markets.

Currently, the EU's gas supply has shifted toward Azerbaijan and North Africa, insisting on the "South Stream" pipeline, even though most EU imports come from the US and Norway as LNG. The latter choice has been made since it does not represent a hindering possibility to EU's gas security as Moscow's gas was. Therefore, to date, half of the total Russian gas exported to the European market is replaced and comes from Azerbaijan. Imports into the "Southern Stream" from North Africa are either equal or, in some cases, exceed Russian gas flows. It should also be noted that the amount of

[99] Blackburne, A. (2023). "*EU's war response shows Russia can 'never use energy as a weapon' – Ukraine exec"*. Charlottesville: SNL Financial LC.
[100] Ibidem.
[101] Hartvig, Á. D. (2024). *"The economic and energy security implications of the Russian energy weapon"*. Energy (Oxford), p. 294.
[102] Ibidem.

LNG entering the European market is seven times greater than the quantity of Russian pipelined gas. Compared to the same times in 2019–2020 and 2020-2021, when Russia was Europe's top gas provider, LNG's supply is higher[103].

In the Ukraine invasion aftermath, the four main pipelines carrying Russian gas to Europe underwent significant changes. The first one is the Nord Stream 1, which, since 2009, has been the main channel of Russian exports to Northern Europe. However, because of the sanctions and payment issues, supplies were substantially reduced during the 2022 invasion[104] until they completely ended in September 2022. To date, both Nord Stream pipelines are inactive due to the September 2022 sabotage attack in the Baltic Sea to the Nord Stream 1 subsea pipeline. On the other hand, Nord Stream 2 has never been in operation yet, Germany suspended its works before the 2022 Ukrainian invasion. The second vital pipeline for Moscow's economy is the Yamal-Europe pipeline, which represented almost 10% of Russian natural gas exports to the EU in the pre-war period. The pipeline runs from the Yamal Peninsula (Siberia) to Germany, passing through Belarus and Poland. In June 2021 the pipeline registered its final high use, as Poland tightened contacts with Norway and worked to build an LNG terminal, therefore cutting Russian gas imports. Poland's move was made even faster by the start of the war in Ukraine, which resulted in the termination of contracts since Warsaw refused to pay for the gas in roubles. The Yamal pipeline route usage has been definitely stopped since May 2022 due to sanctions applied by both countries. The third pipeline, in use since Soviet period, is the Urengoy-Uzhhorod pipeline. It crosses Ukraine and the pipeline has served as a major route for Russian gas shipments to Europe[105]. Following the USSR break-up in 1991, contentious and disagreements over transit costs and imported natural gas volumes resulted in supply interruptions in 2006 and 2009. The last main Russian pipeline is directed South, i.e. the Turk Stream or Blue Stream, which is always directed to Europe but it transits through Turkey starting from Russian gas fields on the Black Sea coast. Even though it was projected as a four-lines pipeline, to date only two have been built. The Turkish gas grid serves the Balkan area, namely Bulgaria, Serbia, Hungary, North Macedonia, and Greece. The latter export pipeline route is less likely to face delays and short-cuts given TurkStream's strategic significance to Russia and Gazprom's friendly relations with both Turkey and Southeast European countries. On the contrary, it has been suggested that Turkey could become a hub for further deliveries of "blended" Russian gas directed towards Europe[106]. According

[103]Chyong, C. K., Henderson, J. (2024). *"Quantifying the economic value of Russian gas in Europe in the aftermath of the 2022 war in Ukraine"*. Energy (Oxford).

[104]Fulwood M., Sharples J., Stern J., Yafimava K. (2022). "*The curious incident of the Nord Stream gas turbine"*. Oxford Energy Comment.

[105] Hogselius P. (2013). "*Red gas: Russia and the origins of European energy dependence", vol. 54*. Johns Hopkins University Press, p. 992-3.

[106] Reuters (2023). "*Turkey's ruling party presents gas reform in step towards trading hub"*. Reuters.

to this possible plan, gas from Russia would be mixed with other imports, e.g. from Azerbaijan, and sold to Europe. However, this plan presents a number of issues: EU firms are hesitant to buy Russian-originated gas, at least while the crisis in Ukraine is still ongoing. Moreover, Turkey's standing as a gas hub is threatened by its tense ties with the EU, political unpredictability and a lack of appropriate institutional structure.

This situation of dependency and conflict between Russia and Ukraine arose in the '70s, when gas pipelines were built while being part of the USSR and countries' borders were not taken into account. In the end they were all part of the same supranational entity. Thus, pipelines were designed as straight-line routes. There was not much proof that the "gas weapon" could be used until the crisis that occurred in the 2000s involving Belarus and Ukraine. It is fair to recall that the Reagan administration argued *vis-à-vis* the massive Soviet-era projects, among which the gas pipelines that directly connected Moscow to Europe, that one day the USSR, or Russia, would use the oil embargo and gas weapon against the West, as the OPEC previously did in the '70s. This happened to be reality in the starting 2000s with its major example the current crisis in Ukraine. Before the XXI century it seemed that only weak states, on the verge of bankruptcy and plagued by internal unrest, thus making it difficult to pursue long-term strategies, have used gas as a "weapon" by cutting off supplies; in those cases, their actions have caused disruptions to users further down the pipeline, but that was not the intended outcome, as it was the case in 2006 and 2009 in Ukraine. However, in a final analysis, it could be stated, as the IEA executive director Fatih Birol wrote[107] on the 24th of February 2023, that *"Russia played the energy card and it didn't win, (...) It now faces the likelihood of further declines in oil and gas output and a permanent loss of standing in the energy world"*.

1.3.3 National and Supra-national answer to the *"Gas weapon"*

According to Van de Graaf and Colgan (2017) [108], an energy weapon is whenever one country uses or menaces to use its energy resources to influence another country. Even though scholars do not agree on the effectiveness and power extent to which this weapon could be used, it is usually accepted that the "energy weapon" represents a significant political leverage'[109]. This was the case, as it has

[107] Birol, F., (2023). *"Where things stand in the global energy crisis - one year on"* [online]. Linkedin, February 24th. Available at: https://www.linkedin.com/pulse/where-things-stand-global-energy-crisis-one-year-fatih-birol/ (Accessed 28 May 2024).

[108] Van de Graaf, T., Colgan, J. D., (2017). "*Russian gas games or well-oiled conflict? Energy security and the 2014 Ukraine crisis"* [online]. Energy Res. Soc. Sci. 2017; 24:59–64. Available at: https://www.sciencedirect.com/science/article/pii/S2214629616303218 (Accessed 28 May 2024).

[109] Henderson, J., (2016). "*Does Russia have a potent gas weapon?".* In: Van de Graaf T., Sovacool B. K., Ghosh A., Kern F., Klare M.T., (2016). "*The palgrave handbook of the international political economy of energy"* [online]. Palgrave handbooks in IPE, London: Palgrave Macmillan UK; 2016, pp. 461–86. http://dx.doi.org/10.1057/978-1-137-55631-8_19 (Accessed 28 May 2024).

been previously analysed, of Russia. The latter, indeed, as early as the 2014 conflict directly menaced to cut off gas supplies to Europe, even though before it threatened to shut down gas pipelines in respect to singular countries, e.g. Belarus and Ukraine in 2004 and 2009, moreover, Moscow used again the gas trade as a geopolitical bargaining weapon in 2022. The EU eventually had to run for cover and diversify its energy mix, no longer being dependent on Russian gas and oil.

In unstable energy markets, like the one for natural gas, a country's power position plays a critical role in determining the likelihood and possible success of the country's "energy war"[110]. Russia's gas weapon vis-à-vis its European counterparts seems strong and undeniable due to its dominant-power position within the relative energy market and the vast amount of gas trade through its pipelines. Nevertheless, this came to an end in 2022, when *force majeure*, i.e. Russian invasion, obliged Europeans to look for alternative sources of energy, even if Brussels had to do it to the detriment of its stability and economic growth in the short-term, rather than being victim of energy blackmailing by Russia. In order to mitigate the adverse effects of price volatility or discretionary national policies that may otherwise conflict with corporate stakeholders' interests, there exist some shock absorbers: supply diversification, flexibility in LNG delivery, the availability of strategic reserves and storage facilities[111]. To date, Moscow's gas future is very unstable, first and foremost because of the current security threat, that would not exclude others in the future, but even because of the gas boom in North America and in LNG trade. The latter, for some scholars as Stulberg (2015)[112], would result in a reduced prominence of cross border pipelines, mostly affecting Russia. Moreover, Stulberg's analysis was carried out in 2015, therefore his prevision of a lower Russian gas influence in the European market would be even more reconfirmed by recent events in Ukraine. All these factors would affect Gazprom's monopolistic position both in Russia and outside, thus eroding Kremlin's foreign policy gas weapon. This explains why in 2015 Stulberg foresee a future gas conflict - the current one - when he declared that "*Russia's persistent comparative advantages at landing gas in established markets, the continued strategic role played by transit states, diverse energy profiles among Western consumer states, feckless EU regulation, and domestic political costs of breaking up Gazprom's monopoly over piped gas to Europe, together, reinforce Moscow's determination to resist market reforms and engage in no-holds-barred gas warfare to mark its geopolitical resurgence*"[113]. However, it is fair to say that energy may be utilised as a weapon on either side of the supply-demand scheme, depending on their respective positions.

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[110]Stulberg, A. N. (2015). *"Out of Gas?: Russia, Ukraine, Europe, and the Changing Geopolitics of Natural Gas. Problems of post-communism"*. 62 (2), p. 115.
[111]Ibidem.
[112]Ivi p. 113
[113]Ibidem.

According to Keohane and Nye's theory of asymmetric dependence[114], the party that depends more on the other for supply or demand could be more susceptible to geopolitical manipulation. On the other hand, the less reliant party is more likely to use the 'energy weapon'. In theory, exchanges, in this case of energy, entail an unfair distribution of gains and costs. Interdependence asymmetry in inter-state relations provides bargaining power. It is true that European states strongly depend on Russian energy, therefore are theoretically subject to Russian power. Brussels's dependency is exemplified by the fact that the Kremlin accounted for almost 50% of EU's gas imports. At the same time, however, it is also true that Moscow is dependent on Brussels as an export market, it does not exist a such diversified and important gas market outside Europe. The latter represented ¾ of Russia's gas exports, not to consider Moscow's exports of crude refined goods[115]. Therefore, both parties happened to believe to be in the power position within this asymmetric interdependence. According to Mikulska (2024)[116], prior to the current conflict, Moscow had started to use its energy weapon, perhaps in anticipation of the imminent invasion, by cutting natural gas supplies to Europe. In 2021, it limited its gas shipments to uniquely satisfy the contracted volumes in a period of record-high demand brought on by EU's post-COVID rebound. Furthermore, Gazprom allowed its European storage to fall to record low levels rather than replenishing it. After Russian invasion, only the Turkish Stream was able to function at full capacity. The Kremlin's natural gas supplies to Europe significantly decreased, falling well short of the agreed amounts. On the other hand, Russia has faced some kinds of limitations due to the structure of the world market. Indeed, if Moscow had stopped supplying oil and gas, the world would have been immediately affected, harming not only the direct party concerned, i.e. Europe, but also other important players and allies such as China and India. The latter eventually happened since the invasion of Ukraine had massive effects on the 'Third World' leaving the burden of war on them.

As it has already been addressed, the current use of energy as a weapon by Moscow is rooted in 1968, when the Soviets began to export gas to Eastern Europe. Gas pipelines rapidly grew and held strategic payoffs for Moscow, which was able to create a system of energy-dependent states[117]. Soon after, East-West energy relations took off, even though they were regarded more important as business and diplomatic efforts of cooperation to attract the Soviets rather than as energy relations under a security standpoint. In the USSR collapse aftermath, Moscow-Europe energy interdependence was

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[114]Keohane, R. O., (2001). "*Power and interdependence"*. 3a ed. New York: Longman.

[115]BP Statistical Review of World Energy 2021 edition [online]. Available at: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf (Accessed 28 May 2024).

[116]Mikulska, A., Finley, M. (2024). *"Asymmetric Interdependence and Wielding the Energy Weapon: Russia and the EU post Russian Invasion of Ukraine",* Current sustainable/renewable energy reports.

[117] Högselius, P. (2013). "*Red gas: Russia and the origins of European energy dependence", 1st edition*. Palgrave Macmillan transnational history series. New York: Palgrave Macmillan.

seen as an asymmetrical one mostly to the benefit of the Western countries, which held the capitals and technology necessary for the Russian industry to develop.

Prior to the 2022 crisis, scholars are not unanimous on how former-Soviet states, once part of the EU, aligned their energy security strategies *vis-à-vis* Russia. Indeed, Ostrowski (2022) [118] finds former-communist Central Europe countries less concerned of a possible energy threat weapon at the hands of Moscow, still after the 2014 Crimea's invasion. On the other hand LaBelle (2020) [119] registered a higher concern in former-communist Northern-Europe countries, e.g. Poland and Lithuania, whose governments strove to diversify their energy mix, fearing energy to be used by Moscow to gain political influence. In any case, the EU energy market was not thought nor prepared to face a Russian "gas weapon", even though in 2014 some signs could have been foreseen. Moscow used its energy power position to influence ex-Soviet countries now in the EU, which, in fact, all have different gas and oil deals and trade relations between each other with Russia[120]. It soon became a direct assault on European sovereignty to weaponize gas against Western households and companies. Moscow used direct coercion on European society to pressure their governments. Nevertheless, even when power relations are uneven, interdependency involves reliance on both parties. The EU used its institutional stance to unleash its energy weapon in reaction to Russia's invasion of Ukraine in 2022. Russia's participation in the EU energy market was curtailed by the implementation of price caps and both oil and gas embargoes. By attempting to prevent Kremlin from making profits deriving from the oil and gas sale, the EU had a similar direct impact on Russia's sovereignty, even though not at a societal level but at a state one. This scenario exemplifies the concept of "weaponizing" energy, both parties used their mutual reliance and interdependence to apply pressure and make demands for concessions[121].

It is not a mystery that Russia's gas weapon was not effective, at least not as much as the 1973 oil weapon. Indeed, in the latter's aftermath, IEA developed countermeasures as strategic oil reserves stockpiled and managed by the organization itself. Such a similar countermeasure was not taken for what it concerns gas reserves, leading to a short-term European gas shock. However, EU rapidly

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[118] Ostrowski, W. (2022). "*The twenty Years' crisis of European energy security: central and Eastern Europe and the US*. Geopolitics" [online]. 27, pp. 875–897. Available at: https://doi.org/10.1080/14650045.2020.1835863, (Accessed 28 May 2024).

[119] LaBelle, M.C. (2020). "*Energy cultures: technology, justice, and geo-politics in Eastern Europe*". Cheltenham, UK: Edward Elgar Publishing, Chapters 3 and 5.

[120] European Council (2023). "*EU sanctions against Russia explained*" [WWW online Document]. Available at: https://www.consilium.europa.eu/en/policies/sanctions/restrictive-measures-against-russia-over-ukraine/sanctions-against-russia-explained/ (Accessed 28 May 2024).

[121] LaBelle, M. C. (2023). "*Energy as a weapon of war: Lessons from 50 years of energy interdependence*". 14 (3), pp. 531–547.

diversified its imports and Brussels required member states to hold national gas storage at least 80% full to counter their asymmetrical gas relationship[122].

Across all previous *"gas weapon"* examples given in the chapter, only Russia implemented it as a blackmail instrument to support its invasion's outcome while, in the few other cases, gas suppliers reduced their exports below the agreed volumes in order to drive up prices, e.g. Algeria, Belarus... The latter examples are quite few and the gas-bargaining situation is usually very brief. Therefore, it appears that *"gas weapon"*, whether it may be employed for economic or geopolitical purposes, is hardly ever used because of the long-term market effects. Indeed, gas-exporting countries not only will be replaced as soon as alternative gas or energy supplies are found but they will suffer a great reputational damage. Thus, if potential gas-suppliers are rejected due to their bad reputation, the result would be their exclusion from one of the most profitable markets. Governments are aware of this and the "*gas weapon*" has only been used when the countries' executive decision-makers were not able to maintain the government's long-term reputation[123]. For instance, when the new Algerian government came to power in 1980, it prioritised short-term political gains over long-term economic stability. By ending the contracts that previous government experts had accomplished, not without difficulty, it aimed to make a complete break from the past and aimed to do with gas export prices what Algeria previously did in the oil market with OPEC assistance in the 70s. However, the North African country has suffered significant long-term losses in terms of both its reputation and lost gas revenues. For instance Algeria, in the following years, lost the US LNG market, which previously represented the country's largest LNG buyer. The same happened for the other European importers, which looked elsewhere for natural gas starting in the 1980s. Algeria's "gas battle" entailed a severe hidden cost, estimated in lost billions of exports. Even worse was the damage toward its reputation as Europeans and Americans customers bought LNG from more stable countries, e.g. Russia and Trinidad & Tobago[124]. At the same time, the "energy weapon", in this case natural gas, it is not always in the hand of the supplier but it can be placed in the buyers' hands too. For instance, consumers could reduce previously agreed gas-prices unilaterally. This is also referred to as monopsony power and can only be implemented in the event that appropriate energy supply alternatives are available[125]. Nevertheless, it is fair to say that this case is quite rare.

[122] Nevertheless, for what it concerns national gas storage there is a big imbalance at EU level, with Germany and Italy owning almost the 50% the total storage capacity, while Ireland, Lithuania, Luxemburg, Cyprus, Estonia, Finland, Greece, Malta, and Slovenia having no such facilities. Mikulska, A., Finley, M. (2024). *"Asymmetric Interdependence and Wielding the Energy Weapon: Russia and the EU post Russian Invasion of Ukraine"*, Current sustainable/renewable energy reports.

[123] Victor, D.G., Jaffe, A.M. and Hayes, M.H. (2006). "*Natural Gas and Geopolitics: From 1970 to 2040"*. Cambridge: Cambridge University Press.

[124] Ivi p. 333.

[125] Ivi p. 339.

The “gas weapon” does not only concern the supplier and importer countries but, in the case of pipelines, transit countries greatly influence gas trade too. As it has been previously analysed, transit countries can impose quotas or withhold share of revenues. Disruptions in the gas market by hand of transit countries are a little bit more frequent but mostly happen as an unintended side-effect of broader disputes. Nevertheless, even in these cases there may be different transit countries’ attitudes, for instance, on the one hand, Tunisia tried to earn more than agreed upon the Transmed due to its key geographic position but, once the talks blew-up and LNG was taken in consideration, Tunis backed off to its initial agreements, proving, so far, to be a faithful ally. On the other hand, other transit countries have often presented and repeated the same problems as in the case of Belarus in 2004 and Ukraine in 1995, 2006 and 2009 *vis-à-vis* Russia. Disputes over gas prices and pipelines’ ownership often came up, spilling over in diplomatic conflicts and gas volumes’ reduction. Nevertheless, it is fair to say that not all these problems may be uniquely charged to the short-sighted local political class but also to the fact that both Belarus and Ukraine were part of the Soviet Union in the past.

The gas weapon seems to be, at the same time similar but different from the other fuel weapons, as, for instance, the oil one. As a matter of fact, energy weapons may create an immediate shock but, in the long-term, market finds alternative suppliers and fuel sources. On the other hand, gas shock was different compared to oil shock, the latter hindered more the European market in respect to the gas one as most oil-producing countries were organized under a cartel, which is not the case for natural gas suppliers. Starting 2021, Russia tried to use the same strategy OPEC adopted in 1973 against its European buyers. Moscow reduced its gas flows and Brussels answered by restricting the latter’s access to the market generating both economic and political repercussions. Both in 1973 and 2022 the energy weapon was used by exporting states to pressure countries heavily dependent on them, respectively for oil and gas. Therefore, despite all similarities, it sounds difficult to compare “gas security” with “oil security”. As a matter of fact, unlike to oil, it takes years to build new gas infrastructure connections and gas transportation is highly expensive; the only way to ensure short-term supply security is to have a variety of routes for gas delivery to customers. For gas consumers that rely on imports, security is determined by the infrastructure for delivering the required amounts of gas per time[126]. However, for what it concerns oil and gas similarities, concerns about the security of gas supplies and the possible creation of a gas cartel akin to OPEC were raised due to the growing relevance of gas in the economy. For the moment, OPEC’s mission excludes natural gas and other petroleum-based liquids not strictly classified as crude oil. Nevertheless, a large number of OPEC participants hold important positions in the natural gas market. OPEC members may be inclined to

[126] Ivi p. 348.

think about cartelizing their gas sales operations as the world's primary energy need becomes more and more dependent on natural gas consumption, hence reducing the market share for oil. However, countries with the highest oil output are not always the ones that are able to achieve the highest gas production. Moreover, market share rivalry and political conflicts that may result from the gas-on-oil competition between emerging significant gas producers and established major oil producers in important markets, like China or Japan, may potentially erode the market dominance of both cartels[127].

While Russia holds a large share of gas export's market, at least before the war, its sales were primarily directed to Europe where there are several alternative sources of supply, especially from North Africa and Northern Europe. Starting 2020, Russia's dominance was predicted to shrink, even though it is well known that was not the case; in the future a tiny group consisting of Russia, and other members of OPEC (Algeria, Nigeria, Indonesia, Qatar, Iran, Saudi Arabia, and Venezuela) might control up to 50% of the export market. Nevertheless, present war has driven Brussels, as well as Washington and Beijing, to invest extensively on the energy transition. Several new long-term policies were designed at national level in order to tackle the 2022 crisis, e.g. China's 14th Five-Year Plan, and market reforms, e.g. REPowerEU plan and US Inflation Reduction Act, to the extent that, according to the IEA, renewables will acknowledge a significantly faster growth rate than the expected one over the next five years[128]. Overall Ukraine's invasion has proved a game-changer for energy security in Europe.

It can be inferred from all the examples presented for the three fossil fuels mentioned in this chapter that the energy weapon has been used with mixed results. If, on the one hand, England has been able to use the '*coal weapon*' with great success, both oil and gas 'weapons' have had a more contained one. However, generally speaking, differences between the long-term and the short-term effects must be highlighted. The afore mentioned examples seem to indicate that the 'energy weapon' shows maximum effectiveness in the short term but entails full-scale disruption. It is virtually impossible to use the 'energy weapon' against a single and specific target as it will entail uncontrollable spill-over effects on other countries and markets. Therefore, while the 'weapon' is effective in the short-term, it is equally true that, in the long-term, the weaponization of fossil fuels harms the user more than the target. Indeed, in most cases alternative supply sources of the fossil under embargo or different energy mix are found by the country hit by energy blackmail. However, it is also true that the market in question, where the 'energy weapon' is used, must be large enough to allow for such energy

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[127] Ivi p. 456.

[128] Hartvig, Á. D. (2024). *"The economic and energy security implications of the Russian energy weapon"*. Energy (Oxford), p. 294.

diversification and there must be no clear monopoly situation. In the case of Welsh coal, for instance, there was a total London monopoly. The other countries' Navies could easily find on the market other coal but not of the same quality as that of southern England. In this case, Welsh coal is a clear example of an efficient energy weapon.

Chapter 2
Critical minerals' mining and refining

2.1 Minerals' introduction

2.1.1 Energy security in the move to a low-carbon system

This chapter will firstly discuss the new and different challenges posed to energy security by the rapid increase in renewable deployment; it will then analyse the renewables supply chain and eventually delve in the mining and refining of the key minerals for the energy transition: nickel, cobalt, lithium and copper.

Minerals and fossil fuels differ in terms of extracted quantities. According to IRENA (2024)[129], in 2022 nearly 10 million tonnes of minerals intended for low-carbon technologies were mined while, the same year, almost 15 billion tonnes of fossil fuels were extracted. Moreover, the latter is annually responsible for an estimated $2 trillion market size, while the 2021 market for lithium, cobalt, nickel, rare earths and copper exports was accountable for only $96 billion. However, the most striking difference is that fossils are combustion-consumed and cannot be reused or recovered, while minerals used in the energy transition have a high potential for recycling. It arises that security risks associated with the two energy systems are different. Indeed, a disruption in fossil fuels' supply would lead to an immediate price increase and subsequent energy shortages. Notably, in case of oil crisis, all car drivers are affected by higher prices. This lays in stark contrast with critical minerals' risk, since disruptions in the latter's supply chain can arrest or postpone new renewable's construction but it does not affect the already existing and installed ones, i.e. the current energy supply. As a consequence, the low-carbon technologies already built using the minerals that suffer shortages will continue to produce clean energy even in the case of critical minerals' supply disruption. Thus, the risk of minerals' supply interruption is no longer about energy security in its strict sense, as more about a matter of future possible energy transitions' slowdowns. Moreover, as fossil fuel supply could be disrupted, as it has been seen in previous chapter, renewable sources, especially in their final stage of production are more difficult to hinder. Indeed, it is almost impossible for a country to deny another of natural elements such as wind and sun, *"No one can ever embargo the sun or interrupt its delivery*

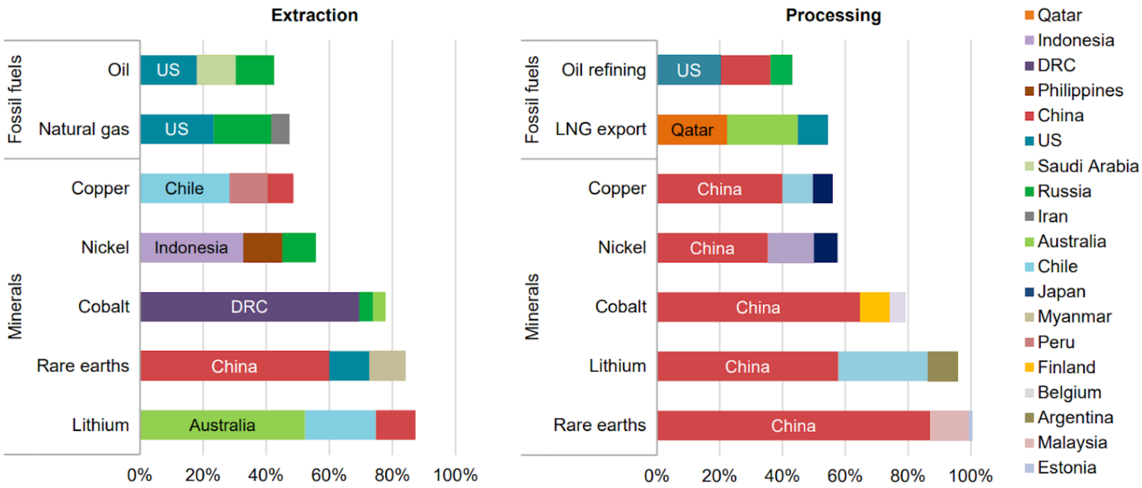
[129] IRENA. (2024). "*Geopolitics of the energy transition: Critical materials*" [online]. Abu Dhabi: IRENA, International Renewable Energy Agency, p. 13. Available at: https://www.irena.org/Publications/2023/Jul/Geopolitics-of-the-Energy-Transition-Critical-Materials (Accessed 10 July 2024).

to us"[130] as US President Carter got to say in 1979. For what it concerns renewables, therefore, the risk is shifted upward in the chain of production, i.e. in their access to technology, which can be extremely costly for developing countries, and minerals necessary to exploit natural source of energy, due to geographic concentrations and availability for instance. Therefore, it is fair to say that the energy transition to low-carbon systems is radically changing the energy security concept hitherto analysed. The concept of energy security is rooted in the disposal of fossil fuels; the IEA (2022)[131] defines energy security as the *"uninterrupted availability of energy sources at an affordable price"*. Nowadays, as renewable technologies are developing and states strongly push both the public and private sector in this direction, major concerns are expressed as the reliance on critical minerals, such as lithium or nickel, may eventually replace the hitherto reliance on fossil fuels. The increasing demand for these materials, as a result of the energy transitions, highlighted the Western dependence on minerals' imports, specifically drawing the attention to issues as the geographical concentration of mining and refining, their shady trade practices and the potential overlapping with the needs of other industries, as the defence one, using the same materials. As it will be seen, there is a high degree of geographical concentration for the minerals examined which do not correspond to the fossil fuel geographic distribution. This fact will partially change the international balance of power, even though minerals differ substantially from fossils since they have to be refined and to be manufactured before producing green energy. Nevertheless, extracting countries will find themselves with a certain degree of power vis-à-vis third nations.

In the graph below it is evident the stark change in producing countries' shares from fossil fuels to critical minerals. If minerals were only to be extracted, as fossils, such a wide distribution of minerals and fossils' endowment would be extremely favourable to international balance and stability. Indeed, as countries need all the listed minerals and fossils, there would be less imbalances and countries would be enticed to cooperate at international level since no government could use as a leverage the possession of one mineral to the detriment of other countries, there would be more "fingers on the trigger", therefore more stability. The problem arises when minerals, unlike fossils, need to be processed - thereon "refined" – and manufactured in final goods. Indeed, both the refining stage and the manufacturing one are highly concentrated in one country, i.e. China. The latter is therefore given a strong bargaining power *vis-à-vis* the other countries.

[130] Press, E., Popkostova, Y., Van de Graaf, T., Rath, E., Tagoe, G. (2024). "*Geopolitics of the energy transition: Energy security"* [online]. Abu Dhabi: IRENA, International Renewable Energy Agency, p. 31. Available at: https://biblio.ugent.be/publication/01HYDAZA0ZH8KQNSNWYPV0D9SC (Accessed 9 July 2024).

[131] IEA (2022). "*Securing Clean Energy Technology Supply Chains"* [online]. Paris: OECD Publishing, p. 11. Available at: https://www.iea.org/reports/securing-clean-energy-technology-supply-chains (Accessed 26 June 2024).



Share of top three producing countries in production of selected minerals and fossil fuels, 2019

Source: IEA (2021), "*The Role of Critical Minerals in Clean Energy Transitions*". Available at: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions (Accessed 29 June 2024)

Minerals necessary for the energy transition are, therefore, often referred to as critical minerals due not to their scarcity but their importance and irreplaceability in the green transition. There is no clear or internationally recognised definition of what critical minerals are and which ones can be labelled as such. However, many countries hold lists of critical minerals, which reflect the technology in use and their level of supply risk. For instance, the EU has classified several minerals as critical in the "Critical Raw Materials for the EU". The European Commission and the Working Group on Defining Critical Raw Materials identified minerals as critical based on their supply risk, economic importance and potential for substitution, rather than its actual scarcity in nature[132].

In a similar manner to the discussion over peak oil, for the last ten years there has been public discussion over a possible critical minerals' shortage. The fundamental premise of this point of view is that there is a finite amount of mineral deposits. It follows naturally that the pace of depletion will depend on how quickly resources are extracted and used. Therefore, production will begin to suffer as soon as current reserves are depleted and new ones become harder to locate due to rising demand. However, as de Ridder noticed already in 2013[133], it should be recalled that, at the moment, there is no scarcity of reserves for energy transition minerals, even though mining and refining capabilities are limited and concentrated in the hands of few actors. Indeed, critical minerals are abundant and it

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[132] Hafner, M., Tagliapietra, S. (2020). "*The Geopolitics of the Global Energy Transition*" [online]. 1st ed. 2020. Manfred. Hafner & Simone. Tagliapietra (eds.). Cham: Springer Nature, p. 284. Available at: https://link.springer.com/book/10.1007/978-3-030-39066-2 (Accessed 4 July 2024).

[133] de Ridder, M., (2013). "*The geopolitics of mineral resources for renewable energy technologies*" [online]. The Hague: Centre for Strategic Studies, p. 4. Available at: https://hcss.nl/wp-content/uploads/2013/08/The_Geopolitics_of_Mineral_Resources_for_Renewable_Energy_Technologies.pdf (Accessed 6 July 2024).

seems they are unlikely to produce any constrain to the supply chain in the long term. Minerals are not actually that rare but, on contrary, abundant. The geopolitics of renewable energy minerals is not affected by the overall amount of minerals present in the crust of the world. The availability of minerals and their supply depends on whether the extraction of mineral resources using current or emerging technologies and market circumstances is economically profitable or not. To date, under the current market conditions, only a small number of nations can extract minerals successfully, this is why the supply of minerals is concentrated. For instance, China is the world's biggest REEs producer but these minerals' concentration is the consequence of recent events. Indeed, over the past few decades, Beijing has methodically established a monopoly over REEs. Formerly there were other REEs production capacities around the globe, e.g. in the US. However, buying the mineral from China on the open market eventually became more affordable than sustaining local mining capacity because of lower salaries and laxer environmental and health regulations in the Chinese mining industry. This explains why, in the short term, critical minerals' extraction is highly concentrated in few countries, usually not the same of the fossil fuels' producers, making supply chain vulnerable to geopolitical risks or export restrictions. Therefore, supply disruptions in the short-term are possible not because there are not enough minerals under the earth's crust but because mining projects require an average of more than sixteen years from discovery to start their initial production and few countries or companies account for the majority of critical minerals' extraction. These lead periods make it difficult to determine if suppliers could quickly increase output in the event that demand increased. Moreover, if mineral resources are a concern they are more about quality than quantity. For instance, over the previous 15 years, the average grade of copper ore has decreased by 30%, and ore quality has continued to erode across a range of commodities. Copper and lithium have high water needs, thus susceptible to water stress. A non-negligible fact given that the majority of their mines are concentrated in regions with severe water stress.

For the purposes of this paper, "critical minerals" will refer those minerals and metals generally recognised as of strategic important for the renewables-based energy transition, i.e. cobalt, nickel, cobalt, lithium and copper, leaving aside the REEs (rare earth elements), which, alone, account for seventeen different minerals.

Critical minerals' production is more concentrated than fossil fuels' one. For instance, more than three-quarters of the world's supply of lithium and cobalt and is controlled by the world top three producers. Moreover, there are cases in which a nation or two accounts for over half of world's productivity as it is for Congo (DRC) which produces 70% of cobalt or Indonesia with 40% of nickel; Australia and Chile supply nearly 80% of lithium combined, with the former representing the 55% of world production and the latter the 25%. For what it concerns the refining activities the picture is even more troubling as China holds a significant overall presence and the concentration is considerably greater. China is accountable for the refining of 35% of world's nickel, 60-70% of world's lithium and cobalt, and nearly 90% of REEs. More to geographic concentration is the fact that a significant amount of the mines extracting the required minerals is located in areas which register a high fragility and corruption score[134].

The supply's disruption risk could decrease to some extent through geographic diversification but, to date, mining, in China or operated by Chinese companies, and refining expansion plans continue to suggest future Beijing dominance. Indeed, significant investments in foreign assets have also been made by Chinese companies in Chile, the DRC, Australia and Indonesia. Complex supply chains and high concentration levels raise the possibility of physical disruption, trade restrictions, and other events in key producing nations. More to that, nowadays, China is the world's top manufacturer and one of the main exporters of renewable energy technologies. For the majority of mass-produced technology, at least 60% of global production capacity is accounted for by China. Europe is regarded as a net importer since virtually all solar PV modules and almost 25% of electric cars and batteries, are imported primarily from Beijing as well. The only exception to this schema are wind turbine components. With the exception of the US market, China directly provides solar PV equipment to all markets[135].

China has secured a "vertical" position of power, i.e. it covers a prominent, at time non-replaceable, role all along green technologies supply chain, from mining to refining and manufacturing. China's far-sighted and visionary planning should be, at least partially, copied and adapted to emerging markets and technologies vital for the green transition. Indeed, to date, minerals' production and refining generates growing concern for possible repercussions given the leverage some countries have gained. Supply disruptions, important threat to national security, may be accidental or the result of political instability but even intentional. The latter is the case of export quotas or pricing measures employed as a strategic blackmailing weapon as it was the case of the Chinese temporary stop to REEs' export to Japan in 2010. Indeed, that year a Chinese fishing boat collided with the Japanese coast guard in proximity of the disputed Senkaku island in the East China Sea. As the two countries claim their sovereignty over the island due to the significant oil reserves in

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[134] Church, C., Crawford, A. (2018). "*Green conflict minerals: the fuels of conflict in the transition to a low-carbon economy"* [online]. Winnipeg: IISD, International Institute for Sustainable Development, p. 16. Available at: https://www.iisd.org/publications/report/green-conflict-minerals-fuels-conflict-transition-low-carbon-economy (Accessed 5 July 2024).

[135] IEA (2023). "*Energy Technology Perspectives 2023"* [online]. Paris: OECD Publishing, pp. 82-146. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024).

the nearby subsoil, the clash has become an international relations' case. The Japanese arrested the Chinese captain and Beijing interrupted, in retaliation, its REEs export to Tokyo. This case demonstrate a re-emergence of the *energy weapon*, although this time not in its finished product as in one of its initial components, i.e. REEs which are vital components for the development of green technologies. Therefore, it is showed that minerals could be effectively employed as a blackmail weapon in the short-term. In this particular case, as seen before the US and other countries have stopped REEs extraction since it is no longer economically valuable, granting the monopoly of the latter to China, which will be able to exploit this monopoly as long as other REEs' mines - that may represent a substantial share of the market - do not come into operation.

In the potential case of other mineral producing countries emergence, therefore a situation in which few countries possess the vast majority of mineral extraction, refining or manufacturing, it might be feared a new OPEC-like organization for minerals. Nevertheless, as stressed out by IRENA (2024)[136] it will hardly be so. Indeed, even though some companies owns the vast majority of refining operations and mineral supply is characterized by heavy geographic concentration, both of which could led to cartels' formation, previous attempts to establish the latter failed, and nothing today suggest a revival of such attempts. Two examples of that may be proposed. With regards to nickel, Indonesia is with no doubt the world's largest extracting country. However, even if the Asian nation accounts for almost 50% of worldwide mined nickel - a larger share than any OPEC country alone -, a cartel creation was extremely difficult since the other major producers of the same mineral, i.e. the Philippines, Australia and Canada, did not support such an initiative. Moreover, in Indonesia's nickel extraction sector does not appear a singular state-owned company, the mining sector is indeed controlled by foreign private firms. Nickel's extraction nationalisation would not come without difficulties, especially given the Chinese strong presence. If this was not enough it should be recalled the existence of large untapped, not to count the undiscovered, nickel reserves outside the Southeastern Asian region. Another cartelization attempt was carried out by Chile, Argentina and Bolivia with the so-called "lithium OPEC", since the three account for the 65% of the world's known reserves in what has been defined the "lithium triangle" and 30% of the worldwide production. Nevertheless, as for nickel, similar challenges to creation of a cartel subsist. For instance, to date, Australia is the primary lithium-extracting country at global level and second for what it concerns the known reserves. Minerals' geographic concentration is indeed a problem. However, the scenario is more complex than that since according to the leading scientists and organizations as IEA (2023)[137],

[136] IRENA. (2024). "*Geopolitics of the energy transition: Critical materials"* [online]. Abu Dhabi: IRENA, International Renewable Energy Agency, p. 17. Available at: https://www.irena.org/Publications/2023/Jul/Geopolitics-of-the-Energy-Transition-Critical-Materials (Accessed 10 July 2024).

[137] IEA (2023). "*Energy Technology Perspectives 2023"* [online]. Paris: OECD Publishing, pp. 87-88. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024).

critical minerals' reserves might be much broader and widespread than the ones known and exploited nowadays, suggesting a high potential of long-term diversification.

2.1.2 Geographic concentration in critical minerals' mining and refining

The transformation from raw material, i.e. mineral ore (a compound where the mineral is present), to one than can be employed in the manufacturing process is complex and ranges across the supply chain. The geological presence of mineral reserves alone does not justify the undertake of mining projects. Indeed, multiple steps precede mining, mostly legal and environmental. Often these steps take many years and involve significant costs. After a certain degree of exploration of the area where the presence of the mineral sought is suspected, it starts the mining process. The extracted ore is thus transported to a mill or processing facility to be crushed. It is eventually purified by separating the mineral from the impurities that may be found in the ore. It is important to underline that the aforementioned processes are typical for larger-scale mining operations (LSM), artisanal and small-scale mining (ASM), much more unsecure, may use rudimentary methods and manual labour. Given the complex and long process, from thereon this paper will use the term "minerals" to refer to the material extracted from mines.

Nowadays the mining industry is highly concentrated. Indeed, the sector is dominated by few major multinational companies and state-owned enterprises (SOEs), which lead to the production of small and often oligopolistic markets. There are few players in the mining industry since to enter in the latter huge capitals are required, together with the technological know-how necessary to develop complex mining projects. It follows a heavily concentrated sector in which multinationals and SOEs hold most of the global trade and output, with the five top mining companies owning more than half of the markets[138]. A mining company's ownership structure influences to a great extent its projects and risk tolerance. Compared to private publicly listed multinationals, SOEs are more inclined to invest in riskier situations that the former avoid in absence of the state's safety net. Clear example of this are the Chinese SOEs who hold a strong position in the African mining sector, Chinese presence is attested even in nations where perceived or actual dangers might dissuade other potential private investors. Some of the biggest mining multinational corporations are vertically integrated in the mineral industry value chain, i.e. they hold important positions and operations at different supply chain's levels, e.g. Rio Tinto, BHP and Freeport. On the other hand, some companies prefer to focus

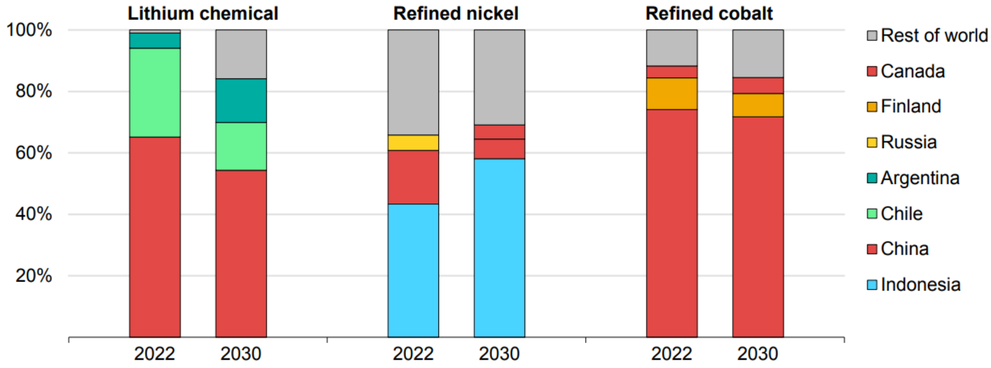
[138] IRENA. (2024). "*Geopolitics of the energy transition: Critical materials"* [online]. Abu Dhabi: IRENA, International Renewable Energy Agency, p. 44. Available at: https://www.irena.org/Publications/2023/Jul/Geopolitics-of-the-Energy-Transition-Critical-Materials (Accessed 10 July 2024).

and specialise only on few stages, e.g. only on extracting minerals but lacking the infrastructure to refine them or the other way around.

The only mineral which is widely traded in spot and futures markets at the London Metals Exchange (LME) is copper, prevalently under the form of three-months contracts - given that in 1877, when the LME was set up, metals took three months to arrive from Chile's copper mines to London. The other minerals are mainly traded through producers-to-consumers bilateral contracts.

Before giving a definition and explaining the refining process, at least the common refining part for the four minerals taken into account, it is important to highlight the mining industry backlash. Indeed, for the moment almost 80% of lithium mines' projects and nearly 50% of nickel and copper ones are located in indigenous peoples' territories or farmers' land facing water risk and food insecurity. Indeed, not only the waste per unit of mineral produced increased as ore grades declined - an increase in waste rock, materials removed in ore extraction, and tailings, materials left after separating the valuable fraction of the ore, are registered - but given mining's high-water requirements, alarming water stress levels are affecting the regions where minerals are extracted and depleting their natural resources. Therefore the critical materials search could trigger geopolitical competition in those areas which are known or supposed to contain untapped reserves, e.g. the Arctic, deep sea or space.

The refining process involves removing residual impurities and converting the ore from an oxidised condition to a pure form in order to create minerals and metals suitable for the manufacturing use. This process occurs once the ore, crushed, is transported to its adequate infrastructure who will sell the pure mineral to manufacturers. The refining process involves several advanced physical and chemical treatment techniques which are highly intensive both in terms of energy, capital and skills. The different techniques will be eventually analysed further on. The refining sector has historically rewarded concentrated global "hubs" which specialised in time in the metallurgical or chemical transformations of ores required for high-tech. As it was seen before, investors encounter considerable obstacles when developing new refining projects because of margin constraints brought on by its position in the supply chain. Indeed, it has little room for manoeuvre between the prominent extractive industry's market power and the dominance of downstream equipment manufacturers. Although price fluctuation between raw material and downstream component prices had to be managed by the intermediate supply chain, price hedging sometimes proved challenging in small and illiquid marketplaces.



Geographic concentration of refined key mineral supply in 2022 and 2030 based on announced projects

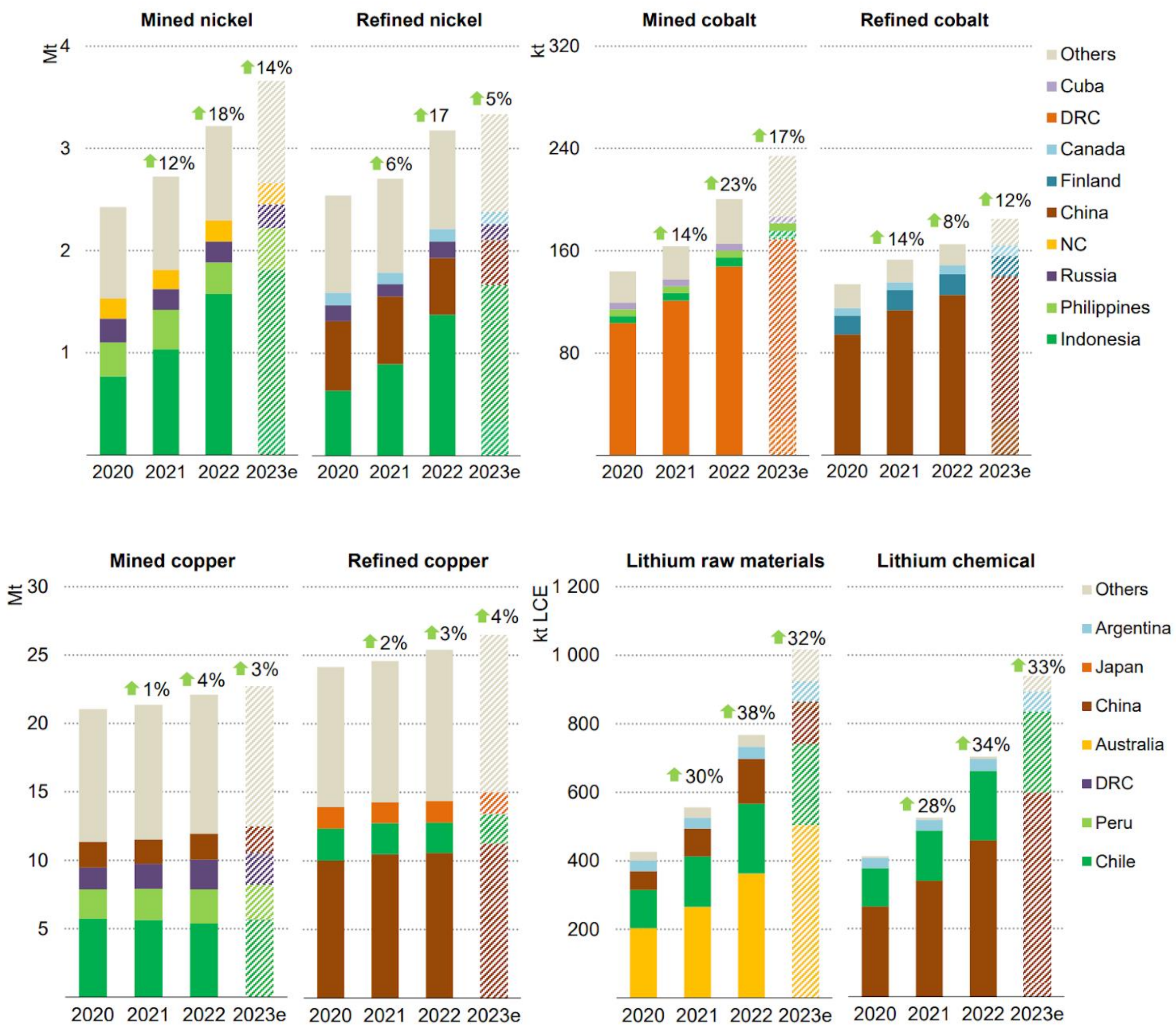
Source: IEA (2023), "*Overcoming the Energy Trilemma: Secure and Inclusive Transitions*". Available at: https://www.iea.org/reports/overcoming-the-energy-trilemma-secure-and-inclusive-transitions (Accessed 25 June 2024)

Critical minerals' refining is even more geographically concentrated than the extracting sector, with China controlling an uncontested dominant position for several minerals, e.g. 30% of global nickel refining (the share is even higher if Chinese companies' operating in Indonesia were to be included), 60 to 70 % of lithium and cobalt. No other nation possess more than a fifth of critical materials production. As it can be inferred from the graph above, the only exceptions, even though to a lesser extent, are Chile and Indonesia. The South American country processes one-third of global lithium supply and Jakarta does the same with nickel. Since decades China has been far-sighted enough to build integrated supply chains that range from mining to manufacturing, with particular attention to some minerals' refining process, as it is evident in the sector of permanent magnets, necessary in wind turbines and EVs manufactory. For what it concerns those minerals whose subsoil is not abundant, China is among world's top ore-importers for refining, so to integrate them into their domestic supply chains. For instance, lithium is imported from Australia, to be refined and eventually integrated into the domestic EV batteries manufactory industry. China is expected to be the setting of most critical minerals' refining projects announced.

However, a serious problem connected to the refining stage is that the midstream operations which fall under the term 'refining' tend to be energy intensive. Indeed, the majority of greenhouse gas emissions from most minerals arises during this process. Therefore, a key factor influencing nations' overall emissions is the mix of power used in refineries. Nowadays, China and other nations with coal-based grids process a great portion of the world's minerals. Emissions vary greatly depending on the mineral refined and the technique employed. Nevertheless, in general, cobalt and nickel do register significant amount of energy consumption and greenhouse gas emissions per tonne. As mentioned, China leads the announced refining capacities for those minerals that will be crucial in the energy transition - 95% for cobalt, and around 60% for lithium and nickel - and accounts for 80% of the new production capacity for copper by 2030. The result is an almost paradoxical effect. In order to comply with the Paris climate agreement, the intensive use of fossil fuels is abandoned in favour of less polluting energy sources to reduce emissions. However, renewables are, especially at the initial stage of extraction and refining, highly polluting. This happens especially if there is a lack of appropriate investments in technology that could make the supply chain more carbon friendly. Indeed, as underlined by the IEA (2023) [139], the use of clean energy technologies may involve fewer emissions, but their supply chains may result in significant emissions and other environmental impacts.

Finally, how it can be inferred from the graphs below, the forecasts project a stark dominance in the short and medium term of China both in the mining and refining sector of the four minerals taken into account. China's strength is especially evident in the refining sector. However, even though it seems in the graphs that only a smaller portion of the four minerals is extracted in China, as it will be analysed further on, a substantial number of the extracting companies are Chinese. Therefore, even if materials are not physically mined in China, it is fair to say that Beijing has substantial stakes in the sector. Moreover, nickel's refining sector, the only one in which the Asian country has not a clear advantage but Indonesia has the lead, is mostly in the hands of Chinese refining companies operating in Indonesia due to the latter restrictive policies on nickel.

[139] IEA (2023). "*Energy Technology Perspectives 2023*" [online]. Paris: OECD Publishing, p. 83. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024).



Production trends for copper, lithium, nickel and cobalt

Source: IEA (2023), "*Critical Minerals Market Review 2023"*. Available at: https://www.iea.org/reports/critical-minerals-market-review-2023 (Accessed 27 June 2024)

2.2 **Copper**

2.2.1 Characteristics

Copper is believed to be the first metal worked by humans in a period of time between seven and ten thousand years ago[140]. Nowadays it is the most extensively employed metal in low-carbon energy technologies in addition to its historical use in industrial machinery and plumbing. Copper's unique thermal and electrical conductivity make it difficult to substitute and extremely useful for electronic, industrial applications and cables. Indeed, more copper is used in solar and wind energy installations than in fossil fuel-powered plants. More to that, copper is a mandatory component of batteries in electric vehicles (EVs) which employ four times the amount of copper than combustion-engine automobiles do. Copper is a difficult mineral to substitute in the green energy production chain given its unique performance in electrical applications; only aluminium is sometimes used as a substitute in power cable, electrical equipment, or cooling and refrigeration while optical fibre and plastics have been employed as copper substitute, especially in telecommunications and water pipes.

2.2.2 Production by country

Total worldwide output of copper mine production, in 2023, is believed to be about 22 million metric tons[141]. The mineral extraction and production has seen a steady and sustained growth since the early 2000s. The extraction process mainly takes place in Chile and Peru which account for around 40% of total mined copper, followed by China, Congo (DRC), USA and Australia. Global copper output is concentrated for the 57 % in developing countries, the figure becomes 47 % if China is not taken into account.

As it can be inferred from the graph there is a substantial difference from the country where copper is extracted and mining companies' nationality. Indeed, leading copper mining companies worldwide in 2023 are mainly Western ones[142], with the American Freeport and the Australian BHP holding the first two levels of the podium with almost 2 million and 1.4 million tons of copper extracted. They are followed shortly by the Chilean SOE Codelco with 1.3 million tons[143]. There is just one copper

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[140] The Economist, (2021). "*People may one day drill for copper as they now drill for oil*" [online]. London: The Economist. Available at: https://www.economist.com/science-and-technology/2021/07/07/people-may-one-day-drill-for-copper-as-they-now-drill-for-oil (Accessed 11 July 2024).

[141] Statista, (2024). "C*opper mining industry worldwide*" [online]. Available at: https://www.statista.com/topics/1409/copper/#editorsPicks (Accessed 20 July 2024).

[142] Statista, (2024). "C*opper mining industry worldwide*" [online]. Available at: https://www.statista.com/statistics/281023/leading-copper-producers-worldwide-by-output/ (Accessed 20 July 2024).

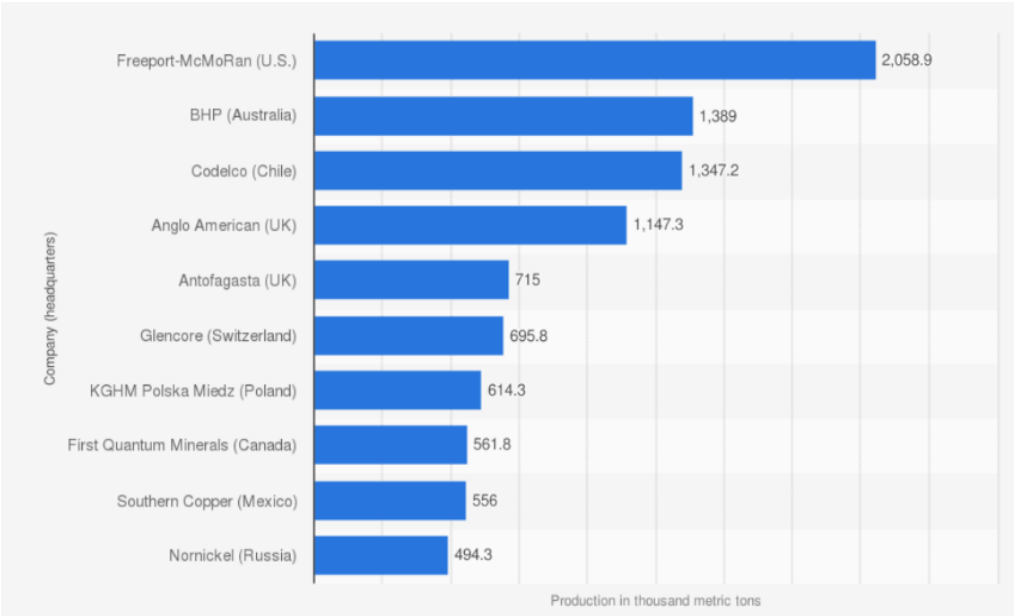
[143] Based in the United States, Freeport-McMoRan is one of the world's largest publicly traded copper producers; key assets include the Grasberg mine in Indonesia and the Morenci mine in Arizona. The Australian multinational mining company BHP is one of the largest producers of copper, with significant operations in Chile (Escondida mine) and

mining company in Europe but its level are not comparable to the ones of the rest of the world. Indeed, The European mining company is KGHM Polska Miedź, a Polish-based company which extracts and refines Polish copper, it does not stand comparison with Latin American and Asian mining and refining capacities.

Copper	29 Cu Copper
Chile	23.6%
Peru	10.0%
Democratic Republic of the Congo	10.0%
China	8.6%
United States	5.9%
Russian Federation	4.5%
Indonesia	4.1%
Australia	3.7%
Zambia	3.5%
Mexico	3.3%
Kazakhstan	2.6%
Canada	2.4%
Poland	1.7%
Others	16.1%

Copper's key mining countries

Source: IRENA (2024). "*Geopolitics of the energy transition: Critical materials*". Available at: https://www.irena.org/Publications/2023/Jul/Geopolitics-of-the-Energy-Transition-Critical-Materials (Accessed 10 July 2024)



Leading copper mining companies worldwide in 2023, by production output in 1,000 metric tons

Source: Statista (2023). "*Copper producers ranking by production output 2023*". Available at: https://www.statista.com/statistics/281023/leading-copper-producers-worldwide-by-output/ (Accessed 20 July 2023)

As for production, copper reserves are concentrated in developing countries - 46 % of the total amount, 50% if China is considered developing country too. Undiscovered reserves might contain 3.5 billion tons of untapped copper, vis-à-vis the 2.1 billion tons of proven reserves nowadays mapped[144]. Even though the companies are mainly Westerners, the world's largest copper reserves by country is hold by Chile by far, with 190 million metric tons as of 2023. It is followed by Peru,

Australia (Olympic Dam mine). The state-owned Chilean Codelco operates several mines, including Chuquicamata, El Teniente, and Andina.

144 The Economist, (2021). "*People may one day drill for copper as they now drill for oil*" [online]. London: The Economist. Available at: https://www.economist.com/science-and-technology/2021/07/07/people-may-one-day-drill-for-copper-as-they-now-drill-for-oil (Accessed 11 July 2024).

120 million metric tons, and Australia, 100. China's copper reserves were estimated at approximately 41 million metric tons. This figure placed China eighth on a global ranking based on copper reserves, with the US having 50 million tons of copper reserves.

The mineral extracted is of two different types: copper sulphide and copper oxide, which represent respectively the 80 and 20 % of global output. The former is processed through a pyrometallurgical process called smelting, the compound is then shipped to be refined. China is the top refining country as it holds more than 40% of the refined mineral's market share but, worthy of note in the refining process, are Chile, Japan and Russia too. China's largest share should not frighten in this case as the Asian country also accounts for 50% of the refined copper worldwide demand; it is a case somewhat similar to the US for what it concerns oil, Washington is the world's bigger oil-producer but it is also the main importer given the massive internal demand. Copper oxide, on the other hand, is processed through the solvent extraction and electrowinning (Sx-Ew) process which takes place near the extracting mines. *Ça va sans dire*, China is also the main refiner using this technique.

In 2022, the total global refining production of copper stood at approximately 25.6 million metric tons[145]. Chinese refineries, as mentioned, dominate the refining scene as it can also be inferred from the graph below, representing the leading copper refining companies worldwide in 2023, by output. The Guixi refinery, property of Jiangxi Copper Corporation in China, was ranked as the first copper refinery company since its capacity amounted to some 1.1 million metric tons of refined product annually at that time. By comparison, the second largest copper refinery in the world was the Chinese Shandong Fangyuan, with a capacity of 700 thousand metric tons. More than half of the largest copper

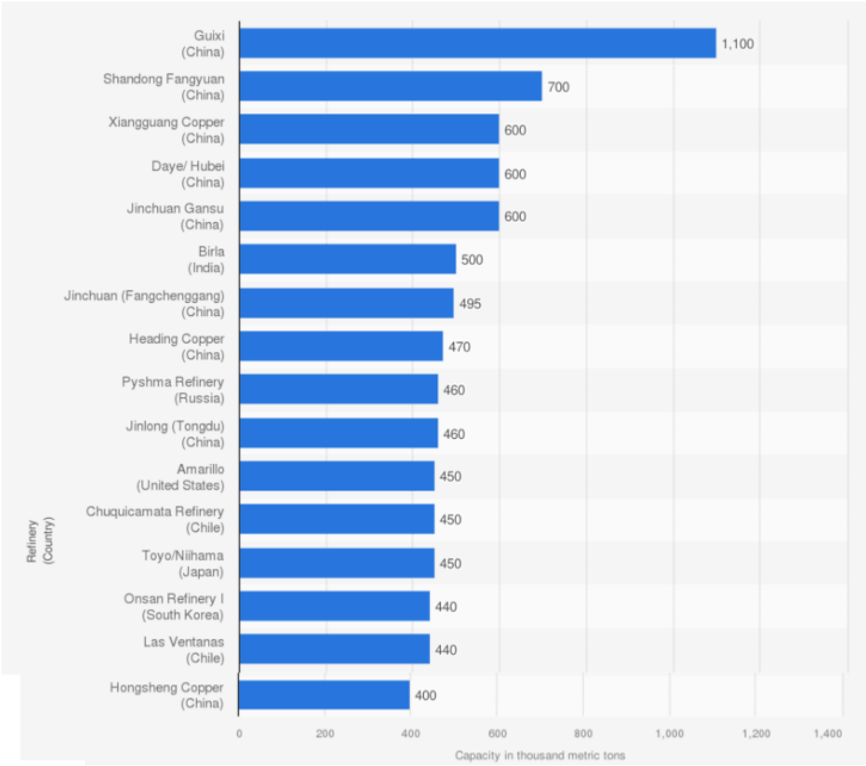
refineries worldwide are located in China. The first non-Chinese refinery is Birla's one in India which process 500 thousand metric tons, it occupies the 6th position. There are two copper refining companies in Europe, one in Germany and one in Poland.

[145] Statista, (2024). "C*opper mining industry worldwide"* [online]. Available at: https://www.statista.com/topics/1409/copper/#editorsPicks (Accessed 20 July 2024).

Copper	29 Cu Copper
China	42.3%
Chile	8.1%
Democratic Republic of the Congo	6.5%
Japan	6.2%
United States	3.9%
Russian Federation	4.2%
Korea	2.5%
Germany	2.4%
Poland	2.3%
Others	21.6%

Copper's key refining countries

Source: IRENA (2024). "*Geopolitics of the energy transition: Critical materials*". Available at: https://www.irena.org/Publications/2023/Jul/Geopolitics-of-the-Energy-Transition-Critical-Materials (Accessed 10 July 2024)



Leading copper refineries worldwide in 2023, based on capacity (in 1,000 metric tons)

Source: Statista (2023), "*Leading copper refineries worldwide in 2023*". Available at: https://www.statista.com/statistics/1180215/global-leading-copper-refineries-by-capacity/ (Accessed 20 July 2024)

2.2.3 Copper demand

Clean energy technologies represent one of the highest shares of copper demand both in terms of weight and monetary value. The market for copper is the one expanding at the quickest rate in the clean energy technology sector. As a matter of fact, the IEA projects that by 2030, the proportion of total copper consumption would increase by around 24 to 40 %, depending on the policies implemented at global level. In order to meet the growing demand for copper, new mines and refining projects will be required; currently, over 250 mines in almost 40 nations do extract more or less 22 million tonnes of copper. This amount represents a 30% increase from a decade earlier. Nevertheless, caused by resource exhaustion and the fact that ore grade is rapidly diminishing where not depleting, today's main copper mines' output has either peaked or is predicted to peak in the first part of the 2020s. A case that depicts quite well the situation is the one of the largest copper mine in the world, Escondida mine in Chile, the latter seems to have reached its production peak and it is projected that, starting 2025, its output will be almost 5% lower. However, starting 2021 high hopes were placed on some large mining projects, some of them completed on time and already in operation as Quellaveco in Peru and other still under expansion in the DRC and Mongolia. These mines should provide, at least in the short term, a considerable help to the global copper output but, on the long term, the world's expected copper output is still insufficient to meet the global demand. As for mining, according to the IEA forecasts[146], Chile and Peru are regarded to remain the largest producers still for a few years before being overcome by Congo and Indonesia if the announced projects are completed on schedule.

For what it concerns the refining stage, forecasts agree that no great change is to be expected. Thus, China is believed to continue to hold its dominant position and, furthermore, increase its refining power capacity so to reach the 50% of worldwide capacities. China is expected to gain increasing influence on the trade and cost of intermediate goods that exploit the green energy as its refining share increase, its mining ones, on the other hand, are somewhat limited. Reduced ore quality drives increased production costs and emissions, more improvements in the efficiency and technology innovation will be therefore required. Although there is no lack of resources, since extraction has been increasing over past years, the fundamental reason for the difficulty in constructing new projects is the deteriorating ore quality in the major mining area. Moreover, deteriorating ore grades bring with itself both water stress problem and one of higher impurity which includes arsenic and do cause water and air pollution. Thus, it will result in higher costs and energy consumption result from extracting copper from lower grade ores, not only for on-site processing but also for activities further down the value chain. The copper sector faces significant challenges from increasing costs, yet resource depletion may be mitigated by technological innovation. The latter is necessary to ensure a sustained level of copper supply in the future.

Estimates are that by 2025 mined copper production is projected to reach approximately 26.14 million tonnes[147]. This growth is supported by major projects in Indonesia, Chile and Peru; while short-term production is set to rise, long-term supply might not keep pace with demand, especially as the green energy sector's needs grow. Indeed, it seems difficult for the supply to keep pace with its global demand, at least until prices increase significantly. Existing operations face the ongoing challenges cited above, such as declining ore grades, and potential supply chain disruptions are feared by experts with a slowdown in production growth post-2024. Moreover, Copper resources, unlike oil, are diffused across large regions and the technology employed to find the mineral is not as efficient as seismic testing, used for fossil reserves. Indeed, compared to oil drilling, copper mining is more regionally focused and the development of a "greenfield" copper mine require even more than a

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[146] IEA (2021). "*The Role of Critical Minerals in Clean Energy Transitions"* [online]. Paris: OECD Publishing, pp. 136-139. Available at: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions (Accessed 29 June 2024).

[147] Statista, (2024). "*Copper mining industry worldwide"* [online]. Available at: https://www.statista.com/topics/1409/copper/#editorsPicks (Accessed 20 July 2024).

generation to be opened up, whereas an oil field may only require a few years. The silver lining is that oil wells exhaust faster than copper mines. As a matter of fact, there are still mines in action that are over a century old[148]. However, according to the IEA[149], if demand increases due to China's economic recovery and accelerated energy transitions, the market could shift to a deficit, impacting long-term prices.

[148] The Economist, (2023). "*Copper is the missing ingredient of the energy transition* [online]". London: The Economist. Available at: https://www-economist-com.mutex.gmu.edu/business/2023/03/30/copper-is-the-missing-ingredient-of-the-energy-transition (Accessed 11 July 2024).

[149] IEA (2023). "*Critical Minerals Market Review 2023"* [online]. Paris: OECD Publishing, p.53. Available at: https://www.iea.org/reports/critical-minerals-market-review-2023 (Accessed 27 June 2024).

2.3 **Cobalt**

2.3.1 Characteristics

Cobalt is a hard and shiny mineral that may be retrieved only in the Earth's crust. Once despised for many years, cobalt compounds only provided a blue tint, thus it was historically used to colour glass and tile, now it is an essential component of the green transition. Refined cobalt minerals are mostly used in lithium-ion batteries, which are currently its main demand source; it is noteworthy its use in super-alloys and magnets too. The mineral was originally found in 1735 by Georg Brandt, a Swedish chemist, and has been used to prevent surface oxidation. Cobalt is essentially a by-product of nickel and copper mining extracted in Large-scale mining (LSM) but is also extracted as a primary product by artisanal and small-scale miners (ASM). More than fifteen elements could be used as cobalt's substitutes but cobalt is preferred for its ratio quality-cost[150].

2.3.2 Production by country

Cobalt mining production reached 230,000 tonnes globally in 2023. Congo (DRC) produces almost 70% of its cobalt as a by-product of its copper mining, in the so-called Copperbelt. Mostly generated as a by-product of copper mining, the leading country in worldwide cobalt mine production in 2023 was Congo, as it could be inferred from the graph below, having produced an estimated 170,000 metric tons that year. The African country is the world's largest producer followed by Indonesia and Russia, with 17,000 and 8,800 respectively, a production therefore ten times lower than the DRC's. Global cobalt output is concentrated for the 75 % in developing countries, the figure becomes 70 % if China is not taken into account.

A similar data arises from cobalt reserves, where developing countries hold 68 % of it, 67 % if China is not considered. The DRC has the largest cobalt reserves in the world, with some 6 million metric tons in 2023, almost 50% of global reserves amounting to 11 million metric tons. The DRC was followed by Australia, which held 1.7 million metric tons of the global cobalt reserves in 2023 and Indonesia, third with 500,000 metric tons. It is evident that cobalt's extraction and reserves pose

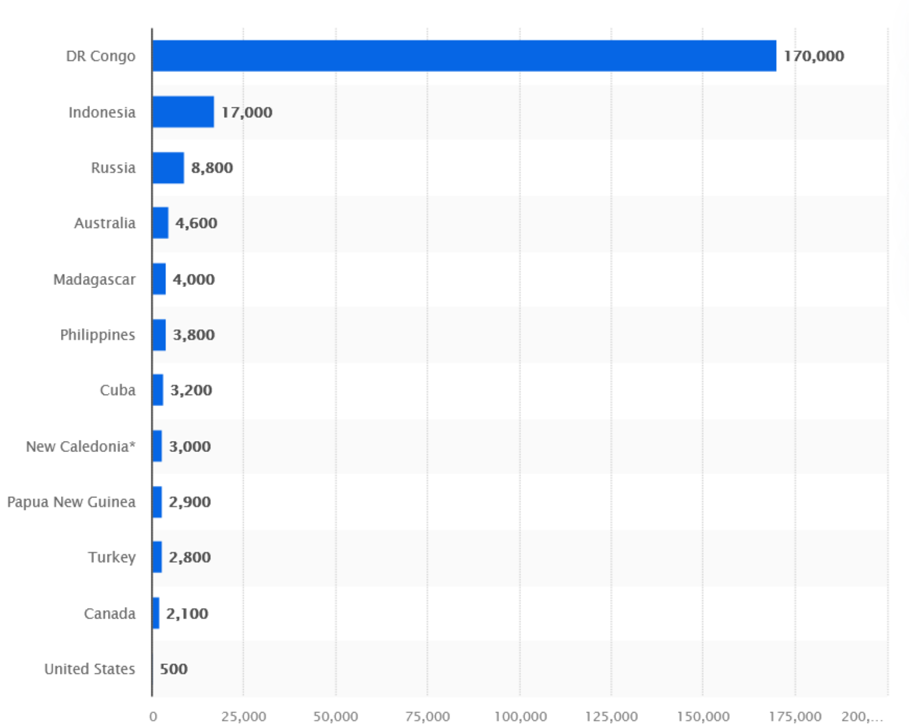
[150] Arrobas, D. L.P., Hund, L. K., Mccormick, S. M., Ningthoujam, J., Drexhage, R. J., (2017). "*The Growing Role of Minerals and Metals for a Low Carbon Future"* [online]. Washington, D.C: The World Bank/International Bank for Reconstruction and Development, p. 36. Available at: https://documents.worldbank.org/en/publication/documents-reports/documentdetail/207371500386458722/the-growing-role-of-minerals-and-metals-for-a-low-carbon-future (Accessed 6 July 2024).

evident geopolitical problems due to the large mineral concentration[151]. However, cobalt resources identified with certainty are about 25 million tons but it is estimated that in the depths of the oceans may lay more than 120 million tons[152].

Cobalt	27 Co Cobalt
Democratic Republic of the Congo	70.0%
Indonesia	5.4%
Russian Federation	4.8%
Australia	3.2%
Canada	2.1%
Cuba	2.0%
Philippines	2.0%
Others	10.5%

Cobalt's key mining countries

Source: IRENA (2024). "*Geopolitics of the energy transition: Critical materials*". Available at: https://www.irena.org/Publications/2023/Jul/Geopolitics-of-the-Energy-Transition-Critical-Materials (Accessed 10 July 2024)



Leading countries based on cobalt mine production worldwide in 2023 (in metric tons)

Source: Statista (2024). "*Leading countries based on cobalt mine production worldwide in 2023*". Available at: https://www.statista.com/statistics/264928/cobalt-mine-production-by-country/ (Accessed 22 July 2024)

As for copper, mined cobalt is mainly extracted by few Chinese and Western companies, operating non only in DRC, which is the main mining hub, but in Madagascar, Greenland and Bolivia as well. Eight of the ten biggest cobalt mines in the world in 2022 are to be found in Congo, with Metalkol RTR Project mine being by far the largest mine in the world with an estimated 57,060 metric tonnes in 2022. The first non-Congolese mine of the major ten mines is found in Indonesia, with 4,360 metric tons, thirteen times lower than Metalkol mine alone[153].

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151 Statista, (2024). "*Global cobalt reserves*" [online]. Available at: https://www.statista.com/statistics/264930/global-cobalt-reserves/ (Accessed 21 July 2024).

152 Arrobas, D. L.P., Hund, L. K., Mccormick, S. M., Ningthoujam, J., Drexhage, R. J., (2017). "*The Growing Role of Minerals and Metals for a Low Carbon Future*" [online]. Washington, D.C: The World Bank/International Bank for Reconstruction and Development, p. 36. Available at: https://documents.worldbank.org/en/publication/documents-reports/documentdetail/207371500386458722/the-growing-role-of-minerals-and-metals-for-a-low-carbon-future (Accessed 6 July 2024).

153 Statista, (2024). "*Cobalt mine production by country*" [online]. Available at: https://www.statista.com/statistics/264928/cobalt-mine-production-by-country/ (Accessed 21 July 2024).

About 40% of Congo's cobalt output is produced by the Swiss Glencore, followed by China Molybdenum (CMOC) which owns 12% of the sector in the African country[154]. The Congolese SOE Gécamines is involved in the mining supply chain too as it owns from 20 to 50% of most mines' shares. Small-scale artisanal mining is important in Congo as it accounts for 10 to 20% of the DRC's cobalt output, which alone is still more than Russian total cobalt extraction.

The DRC is expected to continue being the primary source of cobalt supply for the foreseeable future, as it can be inferred by the planned mining sites projects at international level, even though Australia, Canada, Russia and Madagascar too intend to boost their national cobalt production, mostly by recovering the precious mineral from copper and nickel mines. Thus, it is fair to say that cobalt's concentration may cause serious disruptions not because of mining interruption by Gécamines but because of possible restrictive policies at national level. Indeed, whether Kinshasa was to adopt policies similar to the Indonesian ones - protectionist policies and ban on exports which require mined nickel to be refined near the extraction site, removing the refining stage from China - cobalt price would skyrocket, hindering the green transition. Even worst would be the possibility of export restrictions, even though that would primarily harm refining countries not consumer countries directly. Latter scenarios are somewhat difficult to occur in the short term. A much higher risk in the medium-term could come from the country itself. Indeed, despite its abundant mineral resources and biodiversity, the DRC's recent history has been marked by instability, corruption, and violence[155]. The latter could have a great influence on the mineral's supply chain and if there were difficulties in getting the ore out of the country to be refined, higher costs would incur for the refined product, thus higher manufacturing costs and, as a consequence, for consumer countries. Not to mention that cobalt extraction could be used to fund armed groups as diamonds were in Sierra Leone, driving up the price per ton of this precious material. Therefore, cobalt could classify as classical case of "resource curse". However, at least for the moment, cobalt does not figure within the "conflict minerals" lists of both US and EU, i.e. respectively U.S. Dodd–Frank Act and EU's Conflict Mineral regulation.

ASM represents a significant challenge in cobalt supply chain. Indeed, this type of mining it is, at the same time, important for the cobalt supply chain, since it contributes to the market's stabilisation, and it supplies the international supply chain. However, ASM is particularly vulnerable to social and

[154] Although Glencore has had to cut its output in the region because of low market pricing and high mine maintenance costs, the facilities have the potential to resume and increase production capacity when the maintenance is finished and the market prices are competitive again.

[155] The Second Congo War left a legacy of human rights abuses and exploitative practices that continue to date. The DRC ranks high on global indicators of fragility and corruption, being the 5th most fragile country and the 19th most corrupt as of 2019. Its low positive peace ranking indicates that, despite some economic improvements, the country's stability remains vulnerable to shocks. See in particular: Hafner, M., Tagliapietra, S. (2020). *The Geopolitics of the Global Energy Transition* [online]. 1st ed. 2020. Manfred. Hafner & Simone. Tagliapietra (eds.). Cham: Springer Nature, p. 289. Available at: https://link.springer.com/book/10.1007/978-3-030-39066-2 (Accessed 4 July 2024).

economic shocks, e.g. wars or the past pandemic[156]. The advantage of these mines is that they can operate as swing producers, choosing to mine copper or cobalt based on the respective pricing, and can hand-dig higher grade ores than those extracted by LSM. However, ASM sites are generally unregulated and informal[157]. In the latter it is rather common the presence of child labour and the absence of safe working conditions. Therefore, several Western businesses, given these concerns, are trying, not without any difficulties, to pull out of the ASM supply chain.

Congolese companies must own by law the trade depots that purchase ores. However, they are typically funded by foreigners, mostly Chinese. To understand the degree of Beijing's influence and investments, ASM depots in Congo are informally referred to as *La Maison Chinoise* (the Chinese house)[158]. Additionally, due to foreign direct investment, China, which holds the almost totality of cobalt's refining operations, controls a large number of assets in the DRC. The IEA (2021)[159] estimates that at least one-third of China's imported minerals come from mines in which Beijing has a stake.

Cobalt production and supply chain is deemed to remain concentrated in these two countries, without registering major changes. Even though it seems necessary to no longer buy, therefore fund, ASM mining sites, a fast and clear-cut disengagement could severely harm the population and the stability of the market, making the situation even worse. Moreover, it is particularly difficult to detach ASM-extracted cobalt from the mineral's international supply since ASM cobalt is usually mixed with LSMs' ore so that it results difficult to trace back cobalt's origins. International companies involved in cobalt's trading, refining and manufacturing addresses differently the challenges of artisanal mining; several firms have sought greater transparency in their supply chains or tried to reduce their reliance on DRC-sourced cobalt, mainly from ASM at least[160].

[156] IEA (2021). "*The Role of Critical Minerals in Clean Energy Transitions"* [online]. Paris: OECD Publishing, pp. 150-153. Available at: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions (Accessed 29 June 2024).

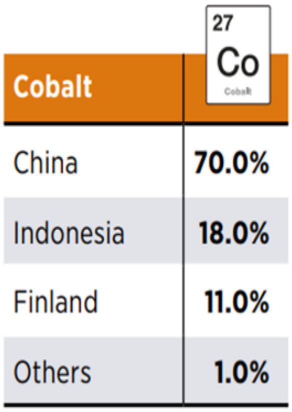
[157] It is estimated that in the Copperbelt, between 140,000 and 200,000 people are employed by ASM.

[158] The Economist, (2022). "*How the world depends on small cobalt miners"* [online]. London: The Economist. Available at: https://www-economist-com.mutex.gmu.edu/middle-east-and-africa/2022/07/05/how-the-world-depends-on-small-cobalt-miners (Accessed 11 July 2024).

[159] IEA (2021). "*The Role of Critical Minerals in Clean Energy Transitions"* [online]. Paris: OECD Publishing, pp. 150-153. Available at: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions (Accessed 29 June 2024).

[160] Apple publishes a list of all its cobalt refiners, Tesla and Volvo are implementing blockchain technology to track down the origins of the cobalt they use. BMW, on the other hand, claims to source its cobalt exclusively from Australia and Morocco. Moreover, Tesla is developing batteries that use no cobalt at all. Finally, some firms are distancing themselves from artisanal cobalt altogether, as it was the 2020 case of Huayou Cobalt, a major refiner, which announced that it would cease purchasing artisanal cobalt, although it is uncertain if this policy remains in effect. The Economist, (2022). *How the world depends on small cobalt miners* [online]. London: The Economist. Available at: https://www-economist-com.mutex.gmu.edu/middle-east-and-africa/2022/07/05/how-the-world-depends-on-small-cobalt-miners (Accessed 11 July 2024).

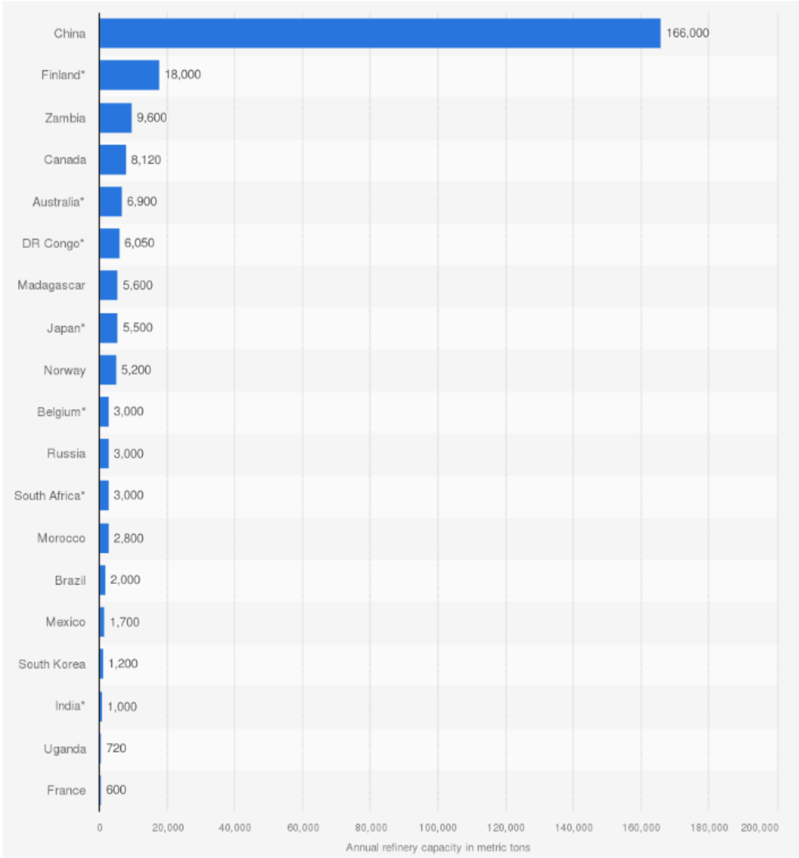
Nearly all of the DRC-extracted cobalt is exported; around 70% of the total cobalt output is refined in China, followed, to a lesser extent, by Western countries as Finland and Belgium. Once extracted and smelted *in loco* cobalt ore is sent to be refined and, as it can be inferred from the graph below, China has the largest refinery capacity for cobalt in the world, with a capacity amounting to 166,000 metric tons in 2021[161], followed by Finland, with a much smaller capacity of 18,000 metric tons, nine times lower. The undisputed Chinese refining capacity and its market dominance are still the case in 2023 since that year the country accounted for over the 78% of world's refined cobalt production, Finland did not reach the 9%.



Cobalt	27 Co Cobalt
China	70.0%
Indonesia	18.0%
Finland	11.0%
Others	1.0%

Cobalt's key refining countries in 2023

Source: IRENA (2024). "*Geopolitics of the energy transition: Critical materials*". Available at: https://www.irena.org/Publications/2023/Jul/Geopolitics-of-the-Energy-Transition-Critical-Materials (Accessed 10 July 2024)



Refinery capacity of cobalt worldwide in 2021, by leading country (in metric tons)

Source: Statista (2023). "*Refinery capacity of cobalt worldwide*". Available at: https://www.statista.com/statistics/339798/annual-cobalt-refinery-capacity-by-country/ (Accessed 23 July 2024)

The total global supply of refined cobalt is estimated to amount to 210,000 metric tons in 2023, an increase of 24% compared to 2022. Chinese market dominance is demonstrated by data as the world's largest cobalt refining company, i.e. the Chinese Zhejiang Huayou Cobalt Company Ltd. which refined some 37,000 metric tons of cobalt. Moreover, eight of 2022 and 2023 world's leading 10

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161 Statista, (2024). "*Annual cobalt refinery capacity by country*" [online]. Available at: https://www.statista.com/statistics/339798/annual-cobalt-refinery-capacity-by-country/ (Accessed 21 July 2024).

cobalt refining companies are Chinese. Since global refined cobalt demand amounted to 205,000 metric tons in 2023, an 8% increase compared to 2022, experts forecast a cobalt market surplus of nearly 5,600 metric tons in 2023.

2.3.3 Cobalt demand

Most striking spike in cobalt production last year was registered in Indonesia, which now projects to extract 18.000 tonnes while few years ago it did account for almost no production[162]. Nevertheless, the dominant position of Congo for the mining part and China for refining – they both account for almost the 70% of the global supply chain – will not be altered in the future, recording a high reliance on the two countries. Such a high reliance, as it has been seen for fossil fuels, is never a synonym of secure supply chain, even though the former are very different in their production process *vis-à-vis* minerals. Given such high degree of concentration it is mandatory to investment outside the two aforementioned countries and fuel technology development; incidents that may occur regionally on the trade route or changes in legislation in these nations could have significant impact on the cobalt supply chains.

The cobalt market was at first very limited but experienced an explosive growth due EVs' development starting mid-2010s, which led to volatile price fluctuations. At first, price increased due to supply constraints brought on by the swift spike in demand. This resulted into a variety of supply reactions, including a spike in artisanal small-scale mining operations and significant project investment, all of which helped to price stabilisation[163]. The need for cobalt is decreasing as cathode chemistries make more and more use of nickel-rich components, to the detriment of cobalt-intensive ones. Nevertheless, even if this trend continues, the robust adoption of these less cobalt-intensive batteries for EVs supports a long-term increase in cobalt demand for clean technologies that might range from a seven- to a twenty-fold increase. It is believed that in the medium term, the projected output from both active mines and ongoing projects would be adequate to fulfil demand. However, long-term demand is foreseen to exceed production. Therefore, a further acceleration in mining projects is needed. The fact that cobalt is a byproduct of other minerals' production as nickel and copper adds another layer of complexity. This results in the fact that investments to develop new

[162] The Economist, (2023). "*Cobalt, a crucial battery material, is suddenly superabundant"* [online]. London: The Economist. Available at: https://www-economist-com.mutex.gmu.edu/finance-and-economics/2023/02/16/cobalt-a-crucial-battery-material-is-suddenly-superabundant (Accessed 12 July 2024).

[163] IEA (2021). "*The Role of Critical Minerals in Clean Energy Transitions"* [online]. Paris: OECD Publishing, pp. 150-153. Available at: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions (Accessed 29 June 2024).

cobalt's projects are unlocked by reason of the copper or nickel market conditions rather than to a properly cobalt market[164].

[164] IEA (2021). "*The Role of Critical Minerals in Clean Energy Transitions"* [online]. Paris: OECD Publishing, pp. 150-153. Available at: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions (Accessed 29 June 2024).

2.4 **Lithium**

2.4.1 Characteristics

Also referred to as “white gold”, lithium is a soft mineral extremely reactive and flammable with a silvery-white hue necessary in the EVs (Electric Vehicles) batteries creation. Lithium is used in a variety of applications, the most well-known of which is probably lithium-ion batteries. The latter sales in the previous two years drove up the mineral global prices twelvefold, encouraging miners to invest, automakers to sign supply agreements and governments to designate it as a strategic mineral. In 2023, 87% of the world’s lithium usage came from batteries and as the race to power electric cars picks up speed so does the amount of lithium used for this purpose. Indeed, it was the rapid EVs demand increase that made lithium the fastest-growing mineral[165]. Substitutions for lithium compounds are possible, but not always convenient, in batteries, ceramics and manufactured glass. Examples of the latter are calcium, magnesium, mercury, and zinc as connection material in batteries[166].

2.4.2 Production by country

Lithium does not exist in its elemental form in nature. The mineral, instead, does exist as a component of chemical compounds because of its strong reactivity. The process of extracting lithium for use in commerce involves electrolysing and lithium chloride[167]. These two processes reflect the two types of sources from which lithium is retrieved: brine and spodumene.

Brine resources, found in arid regions like the Atacama Desert in South America – mostly Chile but Peru too – and Western China, benefit from the dry climate which speeds up brine evaporation, concentrating minerals such as lithium. In these regions mineral-rich brine is extracted from the ground and placed in evaporation ponds for up to two years to concentrate the lithium chloride salt in the brine; the process is largely powered by solar evaporation, which is not energy-intensive and

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[165] IEA (2021). “*The Role of Critical Minerals in Clean Energy Transitions”* [online]. Paris: OECD Publishing, pp. 140-144. Available at: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions (Accessed 29 June 2024).

[166] Arrobas, D. L.P., Hund, L. K., Mccormick, S. M., Ningthoujam, J., Drexhage, R. J., (2017). “*The Growing Role of Minerals and Metals for a Low Carbon Future”* [online]. Washington, D.C: The World Bank/International Bank for Reconstruction and Development, p. 44. Available at: https://documents.worldbank.org/en/publication/documents-reports/documentdetail/207371500386458722/the-growing-role-of-minerals-and-metals-for-a-low-carbon-future (Accessed 6 July 2024).

[167] Statista, (2024). “*Global lithium outlook”* [online]. Available at: https://www.statista.com/topics/3217/lithium/#topicOverview (Accessed 22 July 2024).

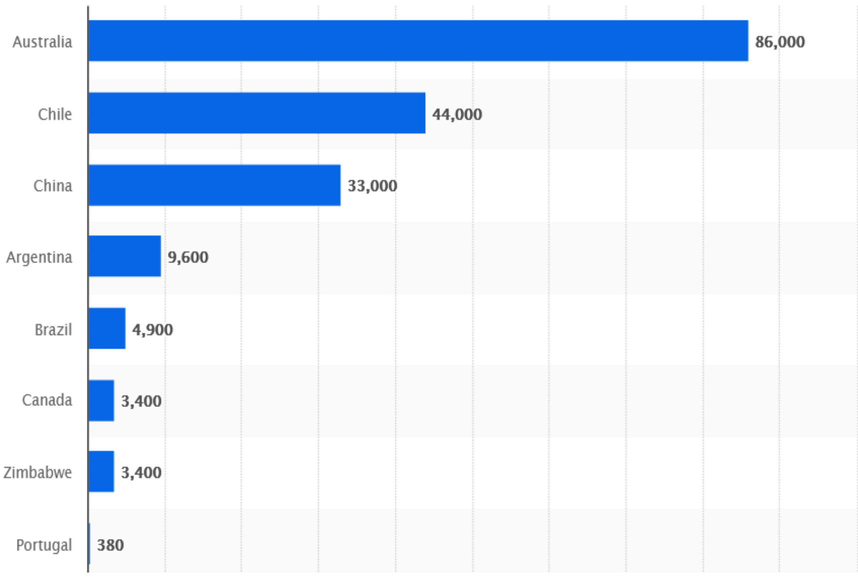
does not require high temperatures. However, it does involve substantial use of water and chemicals, contributing to pollution and indirect emissions.

Spodumene, on the other hand, is a mineral made up of both lithium and aluminium spodumene, it is significantly more energy- and carbon- intensive and is mainly extracted in Australia. The process is more complex and energy-demanding since the rock must be heated to 1,100°C and roasted at 250°C with sulfuric acid to get lithium. These heating steps are typically powered by coal, contributing to higher carbon emissions. Although there is potential to replace fossil fuels with renewable electricity, research in this area is still limited[168]. While historically brine extraction has been cheaper, the gap is narrowing due to advancements in spodumene processing technology and the increasing demand for lithium, which is pushing investments in more efficient extraction methods. EV batteries use either lithium carbonate (lithium-iron-phosphate batteries) produced from brines, or lithium hydroxide (nickel-manganese-cobalt batteries) produced from hard rock ore or from lithium carbonate through chemical processing. As it can be inferred from the graph below, Australia in 2023 was the world leader in terms of lithium mine production, with an estimated output of 86,000 metric tons. Chile and China ranked second and third, with lithium production totalling 44,000 and 33,000 metric tons, respectively[169].

Lithium	3 Li Lithium
Australia	46.9%
Chile	30.0%
China	14.6%
Argentina	4.7%
Brazil	1.6%
Others	2.2%

Lithium's key mining countries

Source: IRENA (2024). "*Geopolitics of the energy transition: Critical materials*". Available at: https://www.irena.org/Publications/2023/Jul/Geopolitics-of-the-Energy-Transition-Critical-Materials (Accessed 10 July 2024)



Major countries in worldwide lithium mine production in 2023 (in metric tons)

Source: Statista (2024). "*Countries with largest lithium output*". Available at: https://www.statista.com/statistics/268789/countries-with-the-largest-production-output-of-lithium/ (Accessed 24 July 2024)

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168 IEA (2023). "*Energy Technology Perspectives 2023*" [online]. Paris: OECD Publishing, pp. 179-181. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024).

169 Statista, (2024). "*Countries with the largest production output of lithium*" [online]. Available at: https://www.statista.com/statistics/268789/countries-with-the-largest-production-output-of-lithium/ (Accessed 22 July 2024).

Australia is home to the largest rock lithium mine in the world. It extracts lithium and other alkali metal from the spodumene, which is a mineral containing lithium. Lithium output in Chile, on the other hand, is derived from brines, pumped from below the earth's surface into evaporation ponds in the Atacama Desert. The two companies that hold the world's largest market share among lithium chemical producing firms are the American Albemarle and the Chilean Sociedad Quimica y Minera de Chile S.A. (SQM). They are followed by the two Chinese companies Jiangxi Ganfeng Lithium and Tianqi. However, it is fair to note that Tianqi was also a major shareholder of SQM as of 2023, having over 22 % of SQM's ownership shares[170]

Lithium ores, once extracted, are typically exported to China to undergo the refining process. The production of lithium is highly concentrated in a few numbers of regions, with China accounting for 60% of global production. Therefore, there is a high percentage of bottleneck possibility in the industry. Moreover additional prices do arise since mines in South America and Australia are exposed to high levels of climate and water stress[171]. While China is among the leading producers of lithium worldwide, it is also the leading consumer of the metal, as it currently dominates lithium-ion batteries production. As for the other minerals taken into account, lithium mining and refining are characterized by few large companies active in the sector, eventually leading to oligopolies, with China carrying out a prominent role and dominating both activities.

China has boosted its shareholdings and investments in the critical minerals' extraction and refining sectors. The country is now an undisputed leader in the lithium supply chain; in 2020 five companies accounted for 90% of lithium extraction and three of them were Chinese or financed by Chinese capital, i.e. SQM, Tianqi Lithium, and Jiangxi Ganfeng Lithium[172]. The refining sector, both capital- and technology- intensive, is extremely polluting and the Chinese dominance is even more evident as the almost totality of lithium ore is shipped to the Asian country to be refined. Moreover, China has gradually increased its capacity for lithium mining domestically in recent years, especially in the Jiangxi province, as Beijing's EV companies, such as CATL, Gotion and BYD, are trying to vertically expand. More to that, Chinese mining ventures are also expected to start operating in Argentina and Canada. Global lithium output is mostly concentrated in developing countries. A

[170] Statista, (2024). "*Distribution of world lithium mineral production by producer*" [online]. Available at: https://www.statista.com/statistics/606799/distribution-of-world-lithiuim-mineral-production-by-producer/ (Accessed 22 July 2024).

[171] IEA (2021). "*The Role of Critical Minerals in Clean Energy Transitions*" [online]. Paris: OECD Publishing, p. 135. Available at: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions (Accessed 29 June 2024).

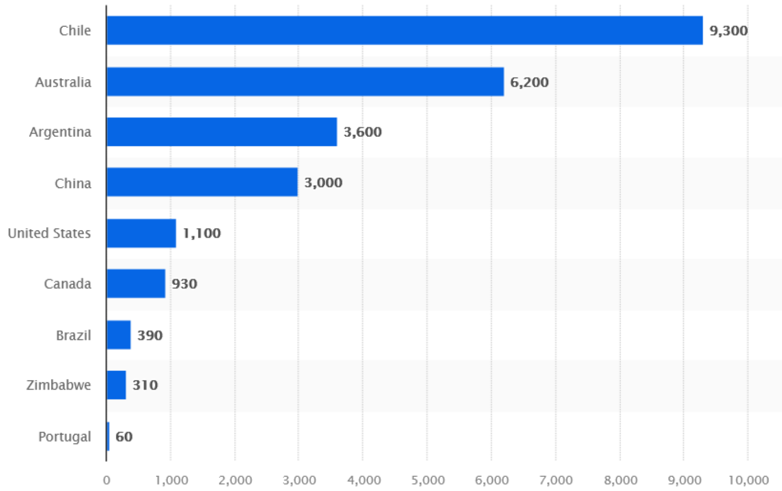
[172] Hafner, M., Tagliapietra, S. (2020). "*The Geopolitics of the Global Energy Transition*" [online]. 1st ed. 2020. Manfred. Hafner & Simone. Tagliapietra (eds.). Cham: Springer Nature, p. 39. Available at: https://link.springer.com/book/10.1007/978-3-030-39066-2 (Accessed 4 July 2024).

similar data arises from cobalt reserves too, where developing countries hold 91 % of it, 68 % if China is not considered. Chile, as inferred from below, has the largest lithium reserves on the globe by a significant amount. Australia comes in second.

Lithium	3 Li Lithium
China	58.0%
Chile	29.0%
Argentina	10.0%
Others	3.0%

Lithium's key refining countries

Source: IRENA (2024). "*Geopolitics of the energy transition: Critical materials*". Available at: https://www.irena.org/Publications/2023/Jul/Geopolitics-of-the-Energy-Transition-Critical-Materials (Accessed 10 July 2024)



Reserves of lithium worldwide as of 2023, by country (in 1,000 metric tons)

Source: Statista (2024). "*Countries with largest lithium reserves*". Available at: https://www.statista.com/statistics/268790/countries-with-the-largest-lithium-reserves-worldwide/ (Accessed 17 August 2024)

As lithium prices registered a non-negligible increase, investors were drawn to the "lithium triangle", that spans over Bolivia, Chile, and Argentina, which is deemed to be the home of 59% of the world's "lithium resources", the largest potential supply area. However, not all the three nations have been as quick to take advantage of the chance. Chile is well ahead as international supplier because of its market-oriented economy and internal stability. Indeed, the country can offer the lowest extracting and production global costs, a lower level of national corruption and a better quality of its bureaucracy and courts. More to that, Chile's lithium reserves are geographically located in strategic positions since situated close to Antofagasta and other Chilean ports. The location is strategic to such extent that even the lithium extracted in the Argentinian Jujuy province exploits the Chilean maritime infrastructures[173]. As it was mentioned, in South America, lithium is primarily extracted from brines, a process that is highly water-intensive and polluting. Consequently, conflicts in all three countries largely revolve around water access and control, as well as alleged incursions by mining companies

[173] During the 1970s and 1980s Santiago de Chile enacted laws to classify lithium as a "strategic" element since its potential use could have been employed in nuclear fusion power plants. To date there is little to no chance that Chile intends to build one of these but restrictions on lithium extraction are still in place to safeguard the desert's delicate environment. The brine extraction is therefore restricted. Indeed, in 2017 only two companies were allowed to mine brine under leases negotiated in the 1980s, i.e. the ex-state-owned company Sociedad Química y Minera de Chile (SQM), now private, and the American Albermale. Not only few companies were allowed to extract lithium brine in the Atacama Desert but they were subject to production quotas too173, and still is the case in some cases.

onto Indigenous or protected lands. Argentina is not far to catch up *vis-à-vis* Chile, Buenos Aires aims to increase its share by enhancing investment appeal through reduced export taxes and relaxed currency controls. Bolivia has the most identified lithium resources at global level but it does not seem intended to exploit them due to internal instability and lack of mining know-how.

Despite the South American region hosting approximately 58% of the world's lithium resources, countries like Australia, China, and Zimbabwe have found in hard rock a production competitive advantage. Australia offers better and more secure investment conditions, although the extracting process is much more expensive and it must be shipped to China to be refined. However, some Australian firms are developing vertically integrated production systems in order to refine and manufacture lithium domestically. Zimbabwe is believed to hold one of the world's largest lithium deposits outside South America, with estimated reserves of 23,000 metric tonnes. However, these deposits have yet to be extensively exploited due to the country's "failing" governance, it lacks a proper national investment framework and the ability to ensure that the mining sector may benefit the whole society. Indeed, it is likely that mining benefits flow primarily to a select group of companies and elites due to the high corruption and state fragility[174].

2.4.3 Lithium demand

Lithium demand for clean energy technologies is increasing at the fastest rate among the other major minerals taken into account, driven by the significant rise in EVs production. Unlike other minerals used in EVs, which face uncertainties due to the different battery chemistries that could be developed and employed in the future, e.g. cobalt-free batteries, lithium demand is deemed to remain stable due to its natural characteristic which make it impossible to renounce to.

Currently, clean energy technologies account for almost 30% of total lithium demand. Both the largest spodumene mine, Greenbushes (Australia), and the largest brine production site, Salar de Atacama (Chile), are doubling their production capacities due to the increase in demand. While lithium mining sector is expected to answer positively and sufficiently to the market demand in the near term, significant challenges are foreseen in the midstream value chain, especially in the refining sector which converts raw materials into lithium chemicals. Indeed, only few firms can produce high-quality and high-purity lithium, with five major firms responsible for three-quarters of the global lithium production output. This high level of market concentration poses several challenges. As

[174] Church, C., Crawford, A. (2018). "*Green conflict minerals: the fuels of conflict in the transition to a low-carbon economy"* [online]. Winnipeg: IISD, International Institute for Sustainable Development, p. 30. Available at: https://www.iisd.org/publications/report/green-conflict-minerals-fuels-conflict-transition-low-carbon-economy (Accessed 5 July 2024).

mentioned above, approximately 60% of global lithium production is located in China, where companies have also made significant investments in the whole supply chain, especially in South American mining companies, e.g. the major Chinese lithium refiner Tianqi Lithium acquired 24% of the Chilean SQM[175]. However, initiatives are being implemented to diversify the downstream processing capabilities that refine lithium not all centred in China. Conversion capacity near mines and in Europe are receiving new investments[176].

Lithium-ion batteries are the preferred choice in the EV market due to their high energy-density-to-weight ratio. Therefore, as long as the EV market expands, the demand for lithium is set to rise, particularly driven by the major lithium refiner, i.e. China, which is also the main lithium batteries manufacturing country. While there are several battery technologies under consideration for EVs, experts have identified lithium-ion batteries - the most lithium intensive ones - as the most viable option for the foreseeable future[177]. This explains why US and EU delegations rushed in the lithium triangle, especially in Chile, to diversify their supply away from China to acquire and secure resources necessary in the energy transition. However, South America is experiencing a strong wave of economic nationalism as proven by the left-wing president of Chile, Boric, who declared his intentions to establish a SOE lithium production company; other South American countries are proceeding in the same direction. However, these types of resource nationalism is extremely dangerous, especially in the region, where nationalisation has a poor success history[178].

By 2030, it is believed that lithium demand will be more than two million tonnes, which is expected to double by 2025. This growth will be mainly driven by EVs lithium-ion batteries demand. In 2030, global demand for lithium is expected to surpass the 2.4 million metric tons, doubling the demand

[175] IEA (2021). "*The Role of Critical Minerals in Clean Energy Transitions"* [online]. Paris: OECD Publishing, pp. 140-144. Available at: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions (Accessed 29 June 2024).

[176] IEA (2023). "*Critical Minerals Market Review 2023"* [online]. Paris: OECD Publishing, p. 53. Available at: https://www.iea.org/reports/critical-minerals-market-review-2023 (Accessed 27 June 2024).

[177] Church, C., Crawford, A. (2018). "*Green conflict minerals: the fuels of conflict in the transition to a low-carbon economy"* [online]. Winnipeg: IISD, International Institute for Sustainable Development, p. 29. Available at: https://www.iisd.org/publications/report/green-conflict-minerals-fuels-conflict-transition-low-carbon-economy (Accessed 5 July 2024).

[178] In Brazil, for instance, the start-up Sigma Lithium was granted permission by the government to begin extracting lithium from hard rock in the Minas Gerais state, a project valued over $5 billion. Pemex, the state oil company of Mexico, is the most indebted oil corporation in the world for instance. The Brazilian oil SOE, Petrobras, has been the origin of several corruption scandals in the country, e.g. "Lava Jato". Many others could be listed but what really hinders resource nationalisation in South America is the technology differential. Cutting-edge technology is usually developed by private multinational firms which specialize and excel in mining or refining. The lack of know-how will undoubtedly make more complex mining SOE, as it was the case of Mexico's lithium SOE LitioMx. To date, the latter has been unable to produce and commercialize lithium; it is fair to say that Mexico's lithium is geographically harder to extract but LitioMx lacks the technology and investment to mine clay lithium. The Economist, (2023). *The green revolution will stall without Latin America's lithium* [online]. London: The Economist. Available at: https://www-economist-com.mutex.gmu.edu/the-americas/2023/05/02/the-green-revolution-will-stall-without-latin-americas-lithium (Accessed 12 July 2024).

forecast for 2025[179]. Australia accounted for an estimated 45% of the world's lithium supply in 2020, which made it by far the world's largest supplier. By 2030, however, Australia's share of global lithium supply is forecast to decrease to 41%. Chile, the second-leading lithium supplier, is estimated to follow a similar path as it accounted for 28% in 2020 is forecast to be responsible in 2030 for 21% of lithium production.

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[179] Statista, (2024). "*Projected total demand for lithium globally* [online]. Available at: https://www.statista.com/statistics/452025/projected-total-demand-for-lithium-globally/ (Accessed 22 July 2024).

2.5 **Nickel**

2.5.1 Characteristics

Nickel is a chemical element and a transition mineral. The latter is primarily employed in high-grade steel manufacturing and, increasingly, in green technology. Traditionally, industrial alloys have been the primary application for nickel. However, a new source of demand has just surfaced: lithium-ion batteries. In 2023 the global nickel output was estimated to be around 3.6 million metric tons. Few substitutes are used in order to reduce nickel consumption, e.g. low-nickel or ultrahigh-chromium stainless steels in construction. Nickel-free steels are also used, to a lesser extent, to substitute stainless steel in the power-generating and petrochemical industries. At the same time titanium alloys are being used to substitute nickel-based alloys. However, for what it concerns nickel's use in the EVs batteries it is harder to substitute the mineral, even though some technological progresses have been made.

2.5.2 Production by country

Nickel minerals fall into two major categories: high-purity Class 1, which contain 99.8% nickel or above, and lower-purity Class 2, which contains less than 99.8% nickel. EVs batteries require Class 1 nickel. However, the links between the various resource kinds - sulphide, saprolite and limonite - and product types - either Class 1 or Class 2 - are often complex and very technical. Nickel ores exist in two types of deposits: sulphide and laterite. Former deposits, which contain higher-grade nickel, have been the primary supply source for centuries and are mostly found in Australia, Canada, and Russia. This type of nickel is highly concentrated in ore and presents a high grade of purity. Sulphide ore is processed in high-purity Class 1 products; there are growing environmental worries about increased CO2 emissions and tailings disposal for Class 1 nickel refining but alternatives are either prohibitively expensive or emissions-intensive[180].

Laterite - saprolite and limonite - resources, on the other hand, are primarily found in the Philippines, New Caledonia, and Indonesia. They contain lower-grade nickel. Weathering in an environment with high temperatures and humidity creates these type of laterite resources. The primary use of limonite and saprolite ore is in the production of Class 2 stainless steel products. Indeed, laterite nickel needs additional energy-intensive refining for conversion into battery-grade

[180] IEA (2021). "*The Role of Critical Minerals in Clean Energy Transitions"* [online]. Paris: OECD Publishing, p. 135. Available at: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions (Accessed 29 June 2024).

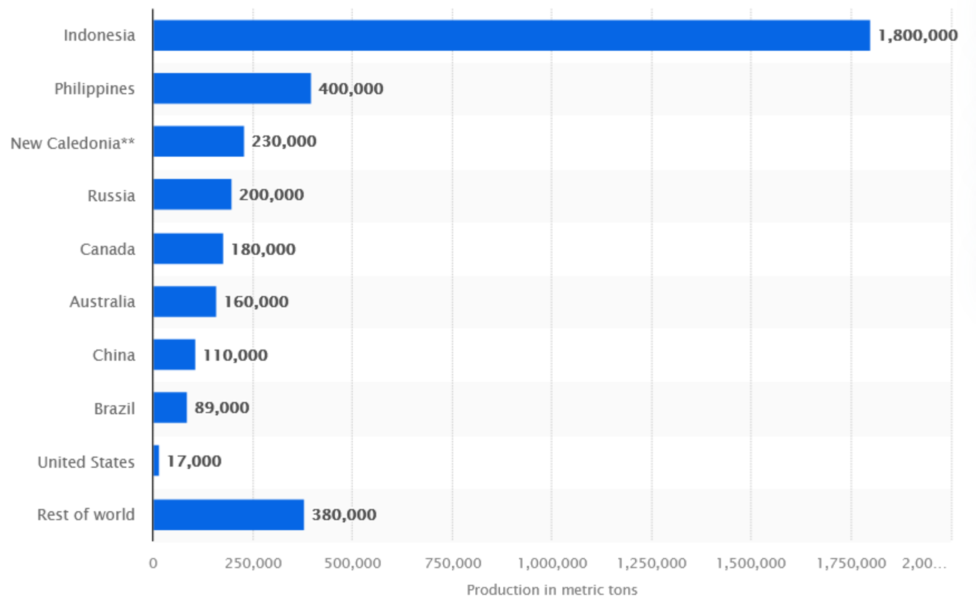
nickel, i.e. Class 2 nickel. Lower- and higher-grade nickel ores act as imperfect substitutes and compete in distinct but related markets. To date, clean energy technologies require around 10% of the nickel global supply but the estimate is expected to grow strongly in the years to come, with forecasts which predict around 60% of global nickel supply employed in the green transition and related technologies[181]. It is estimated that nickel-rich cathodes held a 60% share of the EV battery market in 2022.

Innovation in battery chemistry and recycling will definitely shape nickel's future demand. To date, global nickel output is concentrated for the 29 % in developing countries, the figure becomes 25 % if China is not taken into account. Around 3.6 million metric tonnes of nickel were produced worldwide in 2023. According to the graph below, Indonesia's mines produced an estimated 1.8 million metric tons of nickel, half of global nickel production in 2023, making it the mineral's leading producer country worldwide by a large margin. Its national production is even more impressive if we think that the South-East Asian nation produced only 130 thousand metric tonnes of nickel back in 2015, less than Australia's output in 2023. Indeed, Indonesia's production of nickel from mines has grown considerably in recent years, increasing by more than six-fold since 2010[182].

Nickel (28 Ni)	
Indonesia	48.8%
Philippines	10.1%
Russian Federation	6.7%
France (New Caledonia)	5.8%
Australia	4.9%
Canada	4.0%
China	3.3%
Brazil	2.5%
Others	13.9%

Nickel's key mining countries

Source: IRENA (2024). "*Geopolitics of the energy transition: Critical materials*". Available at: https://www.irena.org/Publications/2023/Jul/Geopolitics-of-the-Energy-Transition-Critical-Materials (Accessed 10 July 2024)



Major countries in worldwide nickel mine production in 2023 (in metric tons)

Source: Statista (2024). "*Nickel mine production by country*". Available at: https://www.statista.com/statistics/264642/nickel-mine-production-by-country/ (Accessed 26 July 2024)

[181] IEA (2021). "*The Role of Critical Minerals in Clean Energy Transitions*" [online]. Paris: OECD Publishing, pp. 145-149. Available at: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions (Accessed 29 June 2024).

[182] Statista, (2024). "*Nickel production by country*" [online]. Available at: https://www.statista.com/statistics/264642/nickel-mine-production-by-country/ (Accessed 24 July 2024).

As the second-leading nickel producer, the Philippines produced an estimated 400,000 metric tons that same year[183]. Interestingly enough Russia, which ranked as the fourth-largest nickel producer in 2023, is home to the largest nickel mines in the world in terms of production volume. The Kola MMC mine is indeed by far the leading nickel mine worldwide in terms of production. China, on the other hand, was the world's leading nickel ore importing country, followed up, distantly, by Canada. Over the last five years, there has been a 20% growth in global nickel output, mostly due to expansion projects in South-East Asia and Pacific region, namely in Indonesia and Philippines, which account for 45% of world production. Given that they account for about 70% of the increase in worldwide output from 2016 to 2025, their dominance over nickel production is expected to intensify in the years to come. Even if in the long-term several mine projects are planned outside of Indonesia, e.g. in Tanzania and Australia, in the short to medium term physical events or changes in Indonesian policies are likely to be the main drivers of nickel supply.

In 2023 the Australian multi-national mining company BHP was, by far, the largest miner of nickel worldwide, followed by the Brazilian "Vale", with the Russian "NorNickel" and the British "Anglo American" the third and fourth nickel-extracting companies. However, data are significantly different for what it concerns refining. Indeed, of the 3,6 million metric tonnes of nickel produced in 2023, the Chinese Tsingshan group appeared as the leading producer with 19% of the total output, being main refiner both in China and Indonesia, indeed, the Chinese company heavily invested in refining projects in Jakarta's territory. It was followed by the Chinese refining company Delong, with 10% of market, and the Russian Nornickel with 6%.

For what it concerns nickel reserves, developing countries hold 37 % of it, 34 % if China is not considered. Identified nickel reserves amount to, at least, 130 million tons. The latter are divided between 60% of laterites deposits and 40% of sulphide ones[184]. Of that amount, Indonesia and Australia held the world's largest shares, at 55 and 24 million metric tons, respectively[185]; Brazil came third. With a projected 1.8 million metric tonnes produced in 2023, Indonesia is the world's leading producer of nickel, which makes sense for one of the nations with the highest nickel deposits. Despite possessing the second-largest deposits, Australia is the sixth-largest producer of nickel in the world.

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[183] Despite this data may suggest the contrary, since 2017 Philippines' output has drastically decreased as a result of a government push to stop related environmental damage and land-use violations. Indeed, the government shut-down 26 mines and prohibited several future open-pit mining projects. The primary issues regarding nickel mining in the Philippines are related to the industry's track record of harming natural resource-dependent livelihoods, e.g. farming and fishing, destroying vital ecosystems and biodiversity, posing a serious threat to public health.

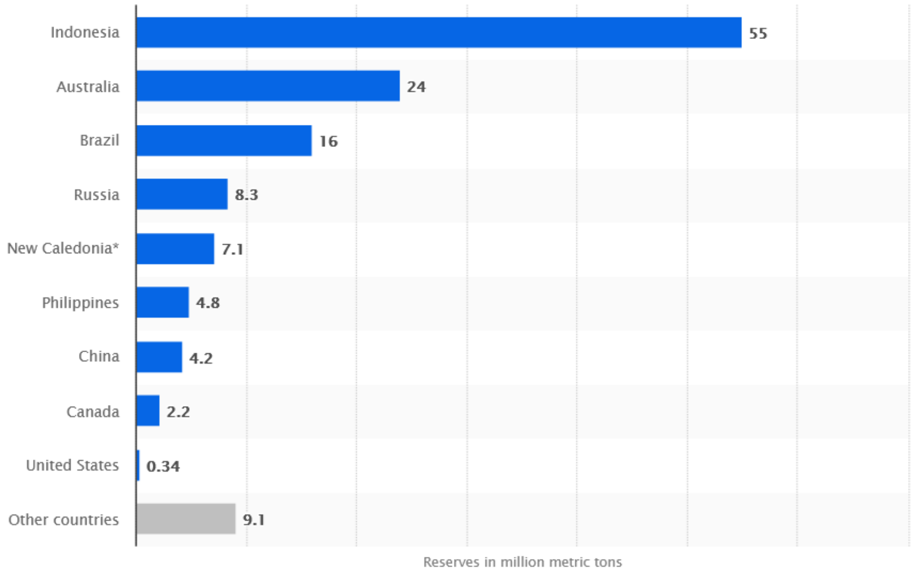
[184] Arrobas, D. L.P., Hund, L. K., Mccormick, S. M., Ningthoujam, J., Drexhage, R. J., (2017). "*The Growing Role of Minerals and Metals for a Low Carbon Future*" [online]. Washington, D.C: The World Bank/International Bank for Reconstruction and Development, p. 48. Available at: https://documents.worldbank.org/en/publication/documents-reports/documentdetail/207371500386458722/the-growing-role-of-minerals-and-metals-for-a-low-carbon-future (Accessed 6 July 2024).

[185] Statista, (2024). "*Nickel reserves worldwide by country*" [online]. Available at: https://www.statista.com/statistics/273634/nickel-reserves-worldwide-by-country/ (Accessed 24 July 2024).

Nickel	28 Ni Nickel
Indonesia	39.8%
China	23.9%
Japan	5.0%
Russian Federation	4.4%
Canada	3.7%
Australia	3.6%
Others	19.6%

Nickel's key refining countries

Source: IRENA (2024). "*Geopolitics of the energy transition: Critical materials*". Available at: https://www.irena.org/Publications/2023/Jul/Geopolitics-of-the-Energy-Transition-Critical-Materials (Accessed 10 July 2024)



Leading countries based on nickel reserves worldwide as of 2023 (in million metric tons)

Source: Statista (2024), "*Nickel reserves worldwide by country*". Available at: https://www.statista.com/statistics/273634/nickel-reserves-worldwide-by-country/ (Accessed 26 July 2024)

2.5.3 Nickel demand

The recent surge in supply, driven by Indonesia, saw a massive 50% growth in both mined and refined nickel supplies, pushing the market into surplus in the short term. Indonesia, already the world's largest nickel miner, surpassed China as the largest refined nickel producer, with many new capacities financed by Chinese companies. Although Indonesia remains the leading producer of Class 2 nickel, joint ventures with Chinese companies are enabling the processing of its natural low-purity nickel resources into Class 1 products. Nickel processing expansion in Indonesia is expected to continue, with several additional plants projected. Jakarta's amazing refining output growth is due to its national policies. Indeed, two years ahead of schedule, in 2020, the Indonesian government banned the export of nickel ore in an effort to refine it domestically - instead of shipping it to China-, so to support a downstream sector and create spill-over employment and technology know-how creation. That year nickel ore exports to China fell by about 90%. Thus, Chinese refiners were compelled to import new ore supply sources, especially from New Caledonia and the Philippines, as it was seen previously, as well as to heavily invest in the Indonesian refining sector. According to IRENA[186], about $30 billion were invested by Chinese companies in the Indonesian nickel supply chain.

[186] IRENA. (2024). "*Geopolitics of the energy transition: Critical materials*" [online]. Abu Dhabi: IRENA, International Renewable Energy Agency, p. 63. Available at: https://www.irena.org/Publications/2023/Jul/Geopolitics-of-the-Energy-Transition-Critical-Materials (Accessed 10 July 2024).

Nationalisation of the country's nickel industry held financial and political challenges especially considering that Chinese firms have a strong position in it. For instance, four of the five largest nickel mines in Indonesia are owned by private foreign companies Vale (Brazil), the Tsingshan Holding Group (China) and the Solway Investment Group (Switzerland). New nickel development projects are now underway outside Indonesia, particularly in Australia and Canada. In the Philippines, the second-largest supplier of nickel laterite, only two refining plants are currently operating, with more under consideration. Nevertheless, these projects are unlikely to challenge Indonesia's dominant position in nickel supplies. However, a key uncertainty is whether Indonesian nickel will qualify for subsidies under the US Inflation Reduction Act (IRA) and how European Union regulatory pressures on battery footprints will impact it. The outcome of these qualifications will significantly influence the competitiveness of Indonesian nickel in the global market.

Thus, Nickel supply faces mixed prospects. For what it concerns the nickel supply there should be plenty availability in the market. However, it is necessary to solve some environmental challenges, such as higher CO2 emissions due to coal-based electricity use and tailings disposal, and to convert the abundant Class 2 nickel in the more required Class 1. It may be possible to convert some of the current Class 1 products, e.g. non-battery industry, to Class 2 use, so to free up Class 1 nickel supply for batteries, although this process is both cost- and energy- intensive. Progress in Indonesia will be crucial for the future supply of nickel for batteries, at least in the near term[187].

It is evident that nickel, as cobalt, will play a critical role in the green energy transition no matter which EV battery model will dominate production in the upcoming years. Additionally, according to Hafner and Tagliapietra (2020) [188], nickel plays a key role in solar technology too, the implementation of solar technology might lead to a 300% rise in nickel demand by the year 2050. When EVs and energy storage technologies are taken into account, this number rises significantly, with a 1,200% increase in expected nickel demand.

[187] IEA (2021). "*The Role of Critical Minerals in Clean Energy Transitions"* [online]. Paris: OECD Publishing, pp. 145-149. Available at: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions (Accessed 29 June 2024).

[188] Hafner, M., Tagliapietra, S. (2020). "*The Geopolitics of the Global Energy Transition"* [online]. 1st ed. 2020. Manfred. Hafner & Simone. Tagliapietra (eds.). Cham: Springer Nature, p. 294. Available at: https://link.springer.com/book/10.1007/978-3-030-39066-2 (Accessed 4 July 2024).

2.6 **Conclusion**

The new low-carbon and low-emission technologies rely on energy resources such as sun and wind that are domestically abundant everywhere. However, the equipment needed to produce and exploit these natural sources do require minerals and materials which can only be found on the global supply chain. As it can be inferred from the graph below, the amount of critical minerals necessary for the clean energy transition and Paris' objectives achievement is expected to rise substantially and reach massive amounts, never seen before. *Ça va sans dire* that a shortage or a price spike in those minerals' supply mandatory for green technology production such as batteries or solar panels will deeply affect global *status quo*. It emerges that, in the current energy transition, a pivotal role will be played by the mining sector, not only for those minerals which have recently fell under the world's attention as nickel, lithium and cobalt due to their strategic value but base metals like copper too since it is a necessary component in renewable technologies. However, due to its key role, the mining sector should be dealt with carefully. Mines, indeed, can culminate in land disputes and harm local communities, especially in less developed countries, fuelling "Dutch disease" cases or, even worst, "Resource curse" ones, ending-up in extremists' armed groups hands, further increasing violence, as it was the case for "blood diamonds" in Sierra Leone. For instance, cobalt's mining in Congo has been linked to violence and child labour. However, to reach of the abovementioned NZE scenario based on clean energy requires a net increase in mineral extraction. The mining sector has already begun increasing investment in response to market and policy incentives. Therefore, it is anticipated that in 2030, mining capacity for all the four major minerals here analysed would have increased dramatically from today. However, this expected growth is still less than the one needed to fulfil the estimated levels of minerals' demand in the NZE scenario. Indeed, mineral demand is growing at a fast pace and is mostly concentrated in countries which are technologically advanced, e.g. EU, US, and China. To date most of these minerals necessary for the transition are directly purchased through networks of integrated Chinese firms. In addition to satisfying its demand for domestically unavailable minerals, this strategy of expanding mining operations and asset acquisitions also attempts to pre-empt markets, address China's rising environmental issues, generate more competitive resources and prevent losses in its own reserves[189]. It follows that China is ensuring, where it has not already done so, a leading role in the energy transition, becoming one of the leading producers of low-carbon energies, as well as the main supplier of the US and the world's leading consumer of minerals, primarily for its batteries and photovoltaic panels' domestic industry. China

[189] Hafner, M., Tagliapietra, S. (2020). "*The Geopolitics of the Global Energy Transition*" [online]. 1st ed. 2020. Manfred. Hafner & Simone. Tagliapietra (eds.). Cham: Springer Nature, p. 39. Available at: https://link.springer.com/book/10.1007/978-3-030-39066-2 (Accessed 4 July 2024).

has been for decades among the countries that have invested the most in the world mining industry, especially in Africa.

	2023	Stated Policies scenario 2030	2035	2040	2045	2050
Copper						
Solar PV	1208	1691	1728	1684	1773	1959
Wind	502	804	692	580	626	805
Electric vehicles	396	1645	2594	3131	3287	3470
Cobalt						
Electric vehicles	62	151	161	187	203	216
Lithium						
Electric vehicles	83	347	582	808	909	964
Nickel						
Solar PV	0	1	1	1	1	1
Wind	46	60	54	48	53	65
Electric vehicles	299	1184	1759	2081	1998	1799
Rare Earth Elements						
Wind	10	17	14	12	13	17
Electric vehicles	7	23	32	36	39	40

Demand for key energy transition minerals (in kt)

Source: IEA (2024), *"Minerals dataset"* [online]. Available at: https://www.iea.org/data-and-statistics/data-product/critical-minerals-dataset (Accessed 12 June 2024)

Therefore, it is expected that countries will increasingly favour bilateral strategies over multilateral collaboration to address the geopolitical difficulties posed by mineral shortages. Thus, mineral markets could be disrupted and fragmented by resource nationalism, government involvement, and preferential trade agreements. Even though, most minerals will still be traded through exchanges on open international markets, e.g. on the London Metal Exchange (LME). Other minerals, however, will be traded on the basis of long-term bilateral contracts' prices established between the parties. This will strengthen governments' inclination to isolate themselves and concentrate on their own interests in a multipolar world, further reducing the likelihood of cooperative and multilateral solutions to the pressure on mineral demand brought on by the switch to renewable energy sources[190].

[190] de Ridder, M., (2013). "*The geopolitics of mineral resources for renewable energy technologies*" [online]. The Hague: Centre for Strategic Studies, p. 18-19. Available at: https://hcss.nl/wp-content/uploads/2013/08/The_Geopolitics_of_Mineral_Resources_for_Renewable_Energy_Technologies.pdf (Accessed 6 July 2024).

Chapter 3

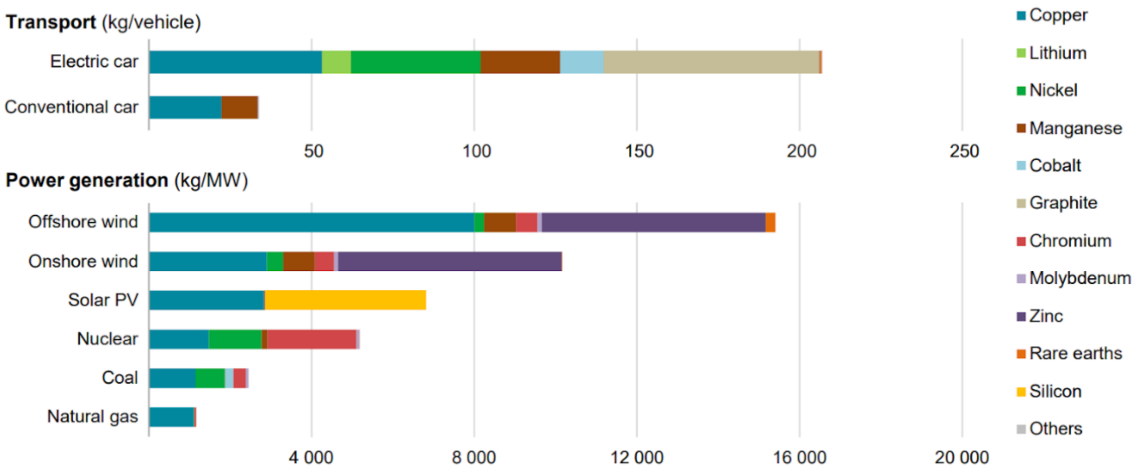
Clean energy technologies' manufacturing

3.1 Renewables' introduction

The geographical concentration of the minerals necessary for the energy transition and the few companies active in mining and processing, make the sector somewhat similar to an oligopoly. The second chapter focused on the extracting and refining processes; the third chapter will analyse the renewables' manufacturing. That is to say, the use of refined minerals as components within the low-carbon emission technologies' production chains to generate clean energy.

The rapid increase in renewables has posed new challenges to energy security which are different from fossil fuels' ones. Nowadays, as renewable technologies are developing, major concerns are expressed as the reliance on critical minerals, which may eventually replace the hitherto reliance on fossil fuels. The increasing demand for these materials, as a result of the energy transitions, highlighted the Western dependence on minerals' imports, specifically drawing the attention to issues as the geographical concentration of mining and refining, their shady trade practices and the potential overlapping with the needs of other industries, as the defence one, using the same materials. As it was seen in the previous chapter, not only critical minerals are not as geographically concentrated as fossil fuels but they nor entail a serious paralysation challenge towards societies depending on minerals' import. Indeed, there is a high degree of concentration in both mining and refining but it only mirrors the economic profitability of such activities in some countries. Moreover, minerals' supply disruption can only hinder the manufacturing of new low-carbon energy sources, it does not affect the existing ones as, instead, fossil fuels do, e.g. Electric Vehicles (EVs) vs traditional Internal Combustion Engine cars (ICE). Minerals, once extracted and refined, are an essential part of the green technologies' industrial manufacturing process. Therefore not directly employed by the public as for fuels.

The second chapter analysed four critical minerals since most renewables' technologies, among which the ones analysed in this chapter, heavily rely on those minerals for their manufacturing. It is interesting to note that the production process often constitutes just a smaller portion of the renewables' final cost. Bulk materials and critical minerals, instead, contribute to a greater extent to the total cost of EVs' batteries, photovoltaic (PV) panels and wind turbines manufacturing. In the automotive industry, for instance, critical minerals' costs for EVs far exceeds the energy costs associated with the manufacturing and assembly. Therefore, it is fair to say that minerals cover a primary role in the clean energy transition due to their irreplaceability in new green technologies *vis-à-vis* the traditional energy sources. For instance, as it is evident from the graph below, an onshore wind farm needs nine times more mineral resources than a gas-fired plant for the same capacity, whereas the average EV takes six times the mineral inputs of a conventional ICE car[191].



Minerals employed in selected clean energy technologies

Source: IEA (2021), "*The Role of Critical Minerals in Clean Energy Transitions"* [online]. Available at: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions (Accessed 29 June 2024)

While the cost for EVs' manufacturing and assembly can be affected by energy prices as well, e.g. natural gas disruptions, they are primarily susceptible to fluctuations in minerals and bulk materials' costs. For instance, lithium has almost doubled in price since 2022. A decade ago, when there were only few battery gigafactories, EV batteries' necessary components as lithium, cobalt and nickel made up less than 5% of batteries' price. Nowadays that percentage is over 20%[192]. More to that, manufacturing costs are not similar everywhere, even in the case that the same technology is adopted. Indeed, depending on the country the manufacturing company is located, materials' costs for an EV can be three to six times higher than the energy costs for the manufacturing process itself, and seven times higher than the costs of materials for an ICE vehicle. Thus, EV's manufacturing energy costs can be 10% higher than for ICE ones. Critical minerals' extraction and refining are extremely energy intensive and a significant portion of the energy used comes from fossil fuels. Therefore, rising fossil fuels' prices can seriously affect renewables' manufacturing price. Costs' increase varies significantly across regions, leading to considerable shifts in the relative competitiveness of manufacturers, with European mineral refiners being the most disadvantaged[193].

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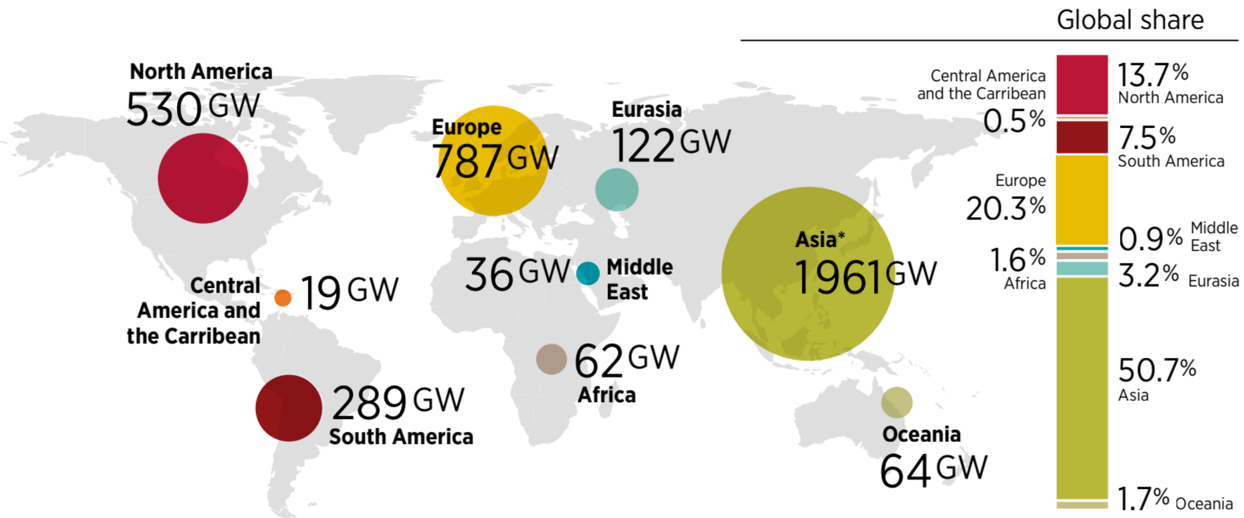
[191] IEA (2022). "*Securing Clean Energy Technology Supply Chains"* [online]. Paris: OECD Publishing, p. 26. Available at: https://www.iea.org/reports/securing-clean-energy-technology-supply-chains (Accessed 26 June 2024).

[192] IEA (2023). "*Energy Technology Perspectives 2023"* [online]. Paris: OECD Publishing, p. 28. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024).

[193] IEA (2023). "*Energy Technology Perspectives 2023"* [online]. Paris: OECD Publishing, p. 121. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024).

In 2023, the global annual renewable capacity increased by almost 50% compared to the previous year, reaching 510 GW (gigawatts) of production, the fastest recorded growth rate in the past two decades due to high public and private investment, as already seen in the previous chapter. By 2025, renewable energy are expected to overtake coal as the main source of electricity generation, with renewables accounting for 42% of world's electricity output by 2028[194]. As seen in the last chapter, minerals' mining and refining were not foreseen to meet the NZE long-term increase in minerals' expected demand by 2030 as their global supply is believed to be lower than the necessary one. However, for what it concerns technology manufacturing, the situation seems better. Indeed, according to recent IEA analysis (2023)[195], there will be a global production capacity expansion for renewables' sources that is expected to fulfil the 2030 NZE expected demand, with China expected to be the centre of production for virtually every low-carbon technology, in line with recent trends. Indeed, if in 2023 renewables' installation in the US and Europe reached all-time highs it is fair to say that China's rise in green capacity was astonishing.



Renewable power capacity by region in 2023

Source: IRENA (2024), "*Geopolitics of the energy transition: Energy security"* [online]. Available at: https://biblio.ugent.be/publication/01HYDAZA0ZH8KQNSNWYPV0D9SC (Accessed 9 July 2024)

As a matter of fact, Beijing installed as much solar PV in 2023 as the whole world did in 2022, and its wind capacity increased by 66% annually as well. To date, as it can be inferred from the graph above, China accounts for almost 40% of worldwide renewable power capacity as it generates 1457 GW. The country will be home to over 60% of the new renewable capacity predicted to be set in place

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194 IEA (2024). "*Renewables 20232* [online]. Paris: OECD Publishing, pp. 7-8. Available at: https://www.iea.org/reports/renewables-2023 (Accessed 28 June 2024).

195 IEA (2023). "*Energy Technology Perspectives 2023"* [online]. Paris: OECD Publishing, p. 55. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024).

worldwide by 2028. Even taking into account the reduction of Chinese national subsidies to renewables, the country's deployment of turbines and PV is increasing, given the investments' economic attractiveness and supportive long-term state's contract policies[196].

Not only green technology manufacturing is highly concentrated in China and few other, mostly Western, countries but for most renewables the three major producing companies collectively represent more than half of the world's manufacturing capacity. Therefore, as it was the case for minerals' extraction and refining, the mass-manufactured low-carbon technologies' market is dominated by a restricted number of companies. It is fair to say that, recently, the energy sector has been significantly affected by the green transition. As a matter of fact, while well-established energy firms are expanding into clean energy technologies through their existing know-how and experience in related industries, a large number of new companies are entering the market to satisfy the renewables' surge in demand. Therefore, competitiveness in the energy market should increase as the global manufacturing capacity is set to expand in order to meet the NZE renewables' target[197].

As for mining and refining, the supply chain's security and resilience hold a key role *in primis* for companies themselves but, more generally, for the countries and the green market as a whole. Indeed, one of the main obstacles for the clean energy transition is the duration of time required to establish and expand secure supply chains. It took decades to build the infrastructures that support the current global energy supply networks. Without a resilient supply chain, companies would be unable to rapidly increase supply to satisfy a sudden spike in demand. Furthermore, bottlenecks and higher prices would be the result of a limited manufacturing capacity unable to adapt to market demands, as it happened in 2020 with semiconductors and EV supply chain interruptions[198].

Moreover, two other recent examples of supply chain concentration's danger can be provided: Russia's invasion of Ukraine, which cut off the upstream nickel's supply, required for EV batteries and China's downstream battery and solar PV manufacture interruption due to Covid-19 lockdowns. Such disruptions in the supply chain might raise the cost of achieving NZE targets and postpone the transition to clean energy by raising the price of intermediate and final green energy technologies. In its "Energy Technology Perspectives 2023", the IEA (2023)[199] highlighted the renewables' supply chain geographical concentration in both critical minerals' mining and refining sectors, as well as in the green technologies' manufacturing.

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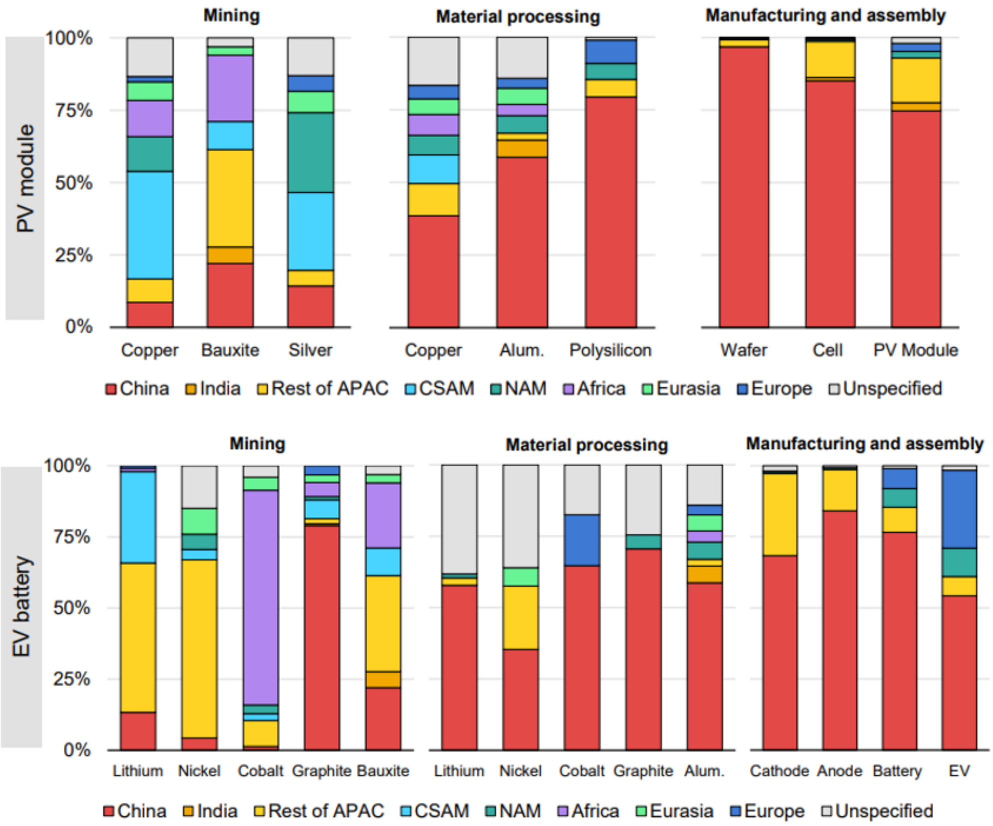
[196] IEA (2024). "*Renewables 2023"* [online]. Paris: OECD Publishing, pp. 7-8. Available at: https://www.iea.org/reports/renewables-2023 (Accessed 28 June 2024).

[197] IEA (2023). "*Energy Technology Perspectives 2023"* [online]. Paris: OECD Publishing, p. 400. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024).

[198] Ivi, p. 61.

[199] Ivi, p. 20-26.

To date, however, as previously stated, China is leader in green energy transition, holding a dominant position in all three stages of clean energy technology production, as it can be inferred, for EVs and solar PV, from the graph below.



Geographic concentration of selected clean energy technologies by supply chain stage and country in 2021

Source: IEA (2022). "*Securing Clean Energy Technology Supply Chains"* [online]. Available at: https://www.iea.org/reports/securing-clean-energy-technology-supply-chains (Accessed 26 June 2024)

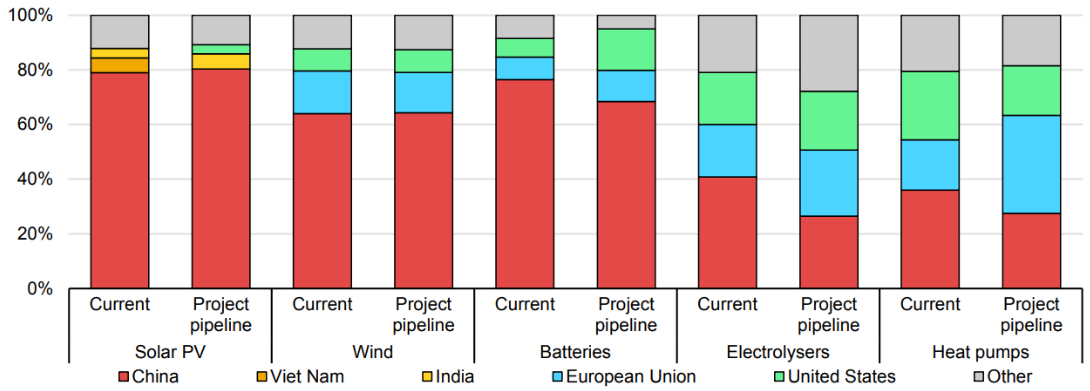
Given the high level of concentration, the possibility of supply chain disruption are particularly high for several solar PV and EVs' batteries components, while wind turbines are less exposed to this risk. The major weakness in former's technologies supply chains is their dependency on critical minerals, e.g. copper for solar PV and wind turbines or lithium and cobalt for batteries.

Nevertheless, green technologies' know-how covers a pivotal role too for what it concern renewables' manufacturing. Indeed, technological innovation is vital, for instance, to reduce mineral dependence. However, such know-how is often geographically concentrated making it difficult to spread new technologies. More to that, renewables' alternatives are still in their early phases of development and research, i.e. they do exist but have not yet attained the same level of economic viability of the dominant technology.

It is important to note that huge investments are needed to develop and install new clean energy technology capacities. Due to supply chain's fear of disruptions investments are concentrated where the risk of disruption is lower, i.e. in China. However, as investements decrease in Europe and US, in the long term, so do the the cost of capital, components and final products.

Concentration, once again, stands out as a key factor as it will affect future production. However, clean energy technologies' manufacturing factories may be built relatively fast. For instance, due to the surplus of current EVs plants' production capacity, retooling an existing facility is sometimes sufficient to enable a short-term increase in EVs' production. Since there are many machinery providers, and the technology for vehicle assembly is well-established, increasing capacity may happen quickly. Similar to this, standard equipment is frequently used for PV module assembly, which leads to comparatively low lead times. Nevertheless, concentration of production in few countries can create supply chain vulnerabilities, similar to those seen in the previous chapter with critical minerals. Disruptions originating from natural disasters or political issues in these regions can seriously impact global energy markets, leading to shortages or price fluctuations. Countries heavily dependent on imported clean energy technologies may suffer the same risks seen with fossil fuels dependence in the first chapter and face risks related to green energy technological dependence. This is mostly the case for developing nations, which cannot afford to develop these technologies because of the huge initial investment costs and the difficulty in technology transfer due to geopolitical rivalries.

Supply chains' efforts to decouple, de-risk, or friend-shore clean energy technologies risk to fragment the green technology industry along geopolitical lines. However, as indicated in the graph below, even though China holds a dominant position in several green transition's sectors, no single country, not even China, excels in every clean technology's aspect.



Top three manufacturing regions' share for key clean energy technologies in 2023 and 2030 on announced projects

Source: IEA (2023). "*Overcoming the Energy Trilemma - IEA report to G7 Leaders*" [online]. Available at: https://www.iea.org/reports/overcoming-the-energy-trilemma-secure-and-inclusive-transitions (Accessed 25 June 2024)

Countries are therefore interconnected in a web of dependencies rather than a linear chain, e.g. China is a PV panels and EV batteries leading producer but relies on other countries for mineral extraction. Ultimately, manufacturing, even though highly concentrated, is closely tied to installation and consumption. For instance, more workers are involved in installing solar panels rather than in manufacturing them. This explains why, as IRENA (2024) [200] points out, current trade protection measures as tariffs do threaten more jobs than those they actually intend to protect or create.

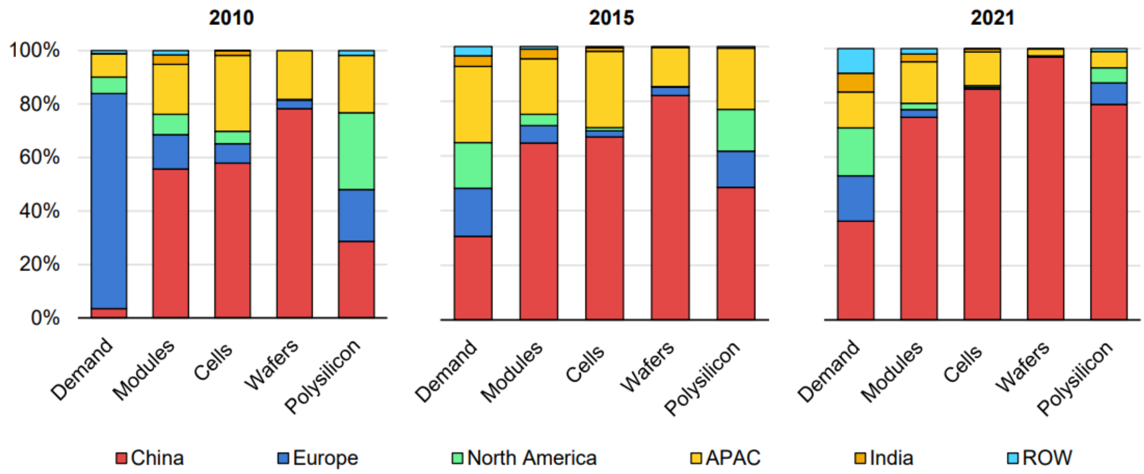
This chapter will now analyse the manufacturing sector of the green energy technologies that will play a predominant role for the achievement of the Paris agreements, i.e. solar panels, wind turbines and EV batteries.

[200] Press, E., Popkostova, Y., Van de Graaf, T., Rath, E., Tagoe, G. (2024). "*Geopolitics of the energy transition: Energy security"* [online]. Abu Dhabi: IRENA, International Renewable Energy Agency, p. 50. Available at: https://biblio.ugent.be/publication/01HYDAZA0ZH8KQNSNWYPV0D9SC (Accessed 9 July 2024).

3.2 **Solar PV**

3.2.1 *The technology*

The two most popular low-emission energy technologies now in use globally are solar PV and wind turbines, the former transform sunlight directly into electricity. The production of power using solar PV technology is one of the main drivers of the green energy transition. Indeed, according to the IEA (2023)[201], this technology will play a crucial role in the global energy mix, constituting up to 25% of the total renewable technologies' energy output by 2028. During last decade, this technology has experienced a significant growth in production and worldwide adoption. To date, PV manufacturing capacity has seen a remarkable expansion, particularly driven by advancements in technology and significant investments in manufacturing infrastructure, mostly concentrated in China. Indeed, as it can be inferred from the graph below, Beijing currently produces the greatest percentage of solar PV equipment, more than 70% - twice as much as the global demand of the country alone -, along with a reduction in Europe, Japan, and US' production shares.



Solar PV manufacturing capacity by country and region, 2010-2021

Source: IEA (2022), "*Solar PV Global Supply Chains*" [online]. Available at: https://www.iea.org/reports/solar-pv-global-supply-chains (Accessed 05 August 2024)

The ten major global PV manufacturing companies are based in China and around 25% of the world's production capacity is based in the Asia-Pacific region, not taking into account Beijing, with the remaining capacity - less than 10% - being found in Europe and North America. To better understand these percentages, just recall that in 2023 alone, producers from Asia accounted for 94%

201 IEA (2023). "*Energy Technology Perspectives 2023*" [online]. Paris: OECD Publishing, pp. 95-97. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024).

of total PV module production, China holding the lead with a share of about 86% and EU, US and Canada collectively contributing for around the 4%[202]. Even though the solar sector is experiencing an extremely rapid expansion, to achieve the NZE scenario by 2050, solar PV manufacturing must scale up even more quickly than what done so far. Announced plans to expand PV panels' manufacturing, predominantly in China, are projected to meet the capacity requirements by 2030. However, although these expansions are sufficient to meet the projected demand, actual manufacturing capacity must exceed demand, considering that producers are unlikely to operate at full capacity on a regular basis.

Before delving into PV panels' manufacture, it is important to recall that different types of panels exist and that the latter are made up of several distinct components. Indeed, modules, inverters, trackers, mounting frames, and other electrical components make up PV panels. The module type technology adopted is the main cause of the different percentage of mineral intensities employed for solar PV[203]. Significant reductions in materials intensity have been made possible by innovations. For instance, since 2008, panel's wafer thickness has significantly decreased, resulting in more than halving its silicon and copper intensity. It is anticipated that when overall efficiency increases - including with the use of new technologies - the intensities of other minerals will likewise decline. To date, as most PV panels are manufactured through the crystalline silicon (c-Si) technique, minerals' demand for solar PV will acknowledge a massive surge in order to achieve the NZE. As matter of fact, as it can be seen by the minerals employed per PV below, the c-Si technology primarily requires copper and silicon.

[202] Fraunhofer ISE (2024). "*Photovoltaics Report 2024*" [online]. Fraunhofer Institute for Solar Energy Systems ISE, p. 5. Available at: https://www.ise.fraunhofer.de/en/publications/studies/photovoltaics-report.html (Accessed 05 August 2024).

[203] The crystalline silicon (c-Si) modules are the most developed as well as the dominant PV technology, with "thin-film" (CdTe and CIGS) alternatives currently developing. Typically, c-Si PV panels are made up of less than 0.1% silver and other metals, 1% copper (interconnectors), and around 5% silicon (solar cells). Compared to c-Si, thin-film technologies use less critical minerals overall but more bulk materials. Moreover, current c-Si solar PV systems often employ components which need around 40% more copper, while the other mineral intensities in distributed and utility-scale applications are comparable. Thus, it is fair to say that each type of solar PV cell technology has its own set of benefits and drawbacks, along with varying metal content. The c-Si PVs dominate the market, accounting for approximately 85% of the existing panels. Arrobas, D. L.P., Hund, L. K., Mccormick, S. M., Ningthoujam, J., Drexhage, R. J., (2017). "*The Growing Role of Minerals and Metals for a Low Carbon Future*" [online]. Washington, D.C: The World Bank/International Bank for Reconstruction and Development, p. 9. Available at: https://documents.worldbank.org/en/publication/documents-reports/documentdetail/207371500386458722/the-growing-role-of-minerals-and-metals-for-a-low-carbon-future (Accessed 6 July 2024).

Demand	2020	2030	2040
(thousand tonnes, kt)			
Low-carbon generation	**1 692**	**2 905**	**3 343**
Solar PV	**743**	**963**	**1 491**
Cadmium	0,2	0,2	0,3
Copper	346	502	795
Gallium	0,0	0,0	2,1
Indium	0,0	0,0	0,1
Lead	0,6	0,9	1,4
Selenium	0,0	0,0	0,1
Silicon	390	452	675
Silver	2,0	2,1	2,2
Tellurium	0,2	0,2	0,3
Tin	0,6	0,9	1,5
Zinc	3,2	4,5	7,3
Arsenic	0,0	0,1	5,3
Others	0,2	0,3	0,5

Mineral demand by sector

Source: IEA (2021), "*The Role of Critical Minerals in Clean Energy Transitions"* [online]. Available at: https://www.iea.org/data-and-statistics/data-product/the-role-of-critical-minerals-in-clean-energy-transitions-2 (Accessed 11 August 2024)

In addition to the listed minerals that make up solar PV modules, other raw materials are also used during the manufacturing process, with China, as previously seen, being the main producer of most of them. As a matter of fact, as it may be recalled from last chapter, the top three producers of each of these minerals account for at least 50% of the world market. A limited number of nations are the main producers of these critical materials; China alone produces the great majority of the aluminium, silicon and REEs required in the PV sector and also controls, directly or indirectly, a stark majority of copper's refining. Even though the PV demand for these minerals accounted for less than 5% of the world's total consumption in 2021, it is expected to increase as solar PV output rises. The PV sector is therefore expected to dramatically increase its need for minerals, copper *in primis*.

3.2.2 *The supply chain*

This quick expansion raises the possibility of supply and demand mismatches, which can result in higher costs and shortages of some supplies, especially when paired with the lengthy lead times for mining operations[204]. The increased choice and use of c-Si technology panels, which require more critical minerals and materials, indirectly strengthens China's international position. Indeed, as the c-Si technology is the most globally-exploited one, China is indirectly strengthened as it is the PV technology that uses the largest amount and variety of critical minerals and bulk materials, of which Beijing is the major refining country. Thus, China emerges as an actor that will play a decisive role in the achievement of NZE by 2050 targets and international politics.

According to IEA (2024) [205], in 2022, global solar PV manufacturing capacity increased by 80% and by the end of 2024 PV manufacturing capacity is anticipated to increase by over 1,100 GW and over 1,300 GW by 2028. This rapid growth is also due to the high learning rate of solar PV technology, leading to significant reductions in production costs. However, the renewables' facilities and companies are heavily concentrated in few countries. Many of the intermediate components and minerals that make up green energy supply chains are manufactured in a limited number of nations too, with the top manufacturer occasionally controlling a sizable portion of the world market for particular inputs. From this geographic overreliance on certain technology, production, processing facilities and supply chain hazards it results countries' reduced resilience to shocks. As it has been seen in the previous chapter, all clean technology supply chains steps that are highly dependent on key technologies, components, or materials, for which the mining, refining or manufacturing is heavily concentrated in few regions, do carry significant security threats. Despite this serious short- and medium- term supply chain risk, is foreseen to persist this strong concentration, especially in China. For solar PV alternative module technologies and components that could reverse this tendency of concentration are still under development but, at the moment, their supply chain is heavily concentrated in China[206].

Most PVs' manufacturing capacity increase until 2028 is foreseen to occur in China, which will account for 85% of modules and 95% of polysilicon production. Asian companies have ramped up investments in the past two years, driven by global PV demand growth due to energy security concerns following events as Russia's invasion of Ukraine and rising clean energy ambitions in several Western countries. Even though, investments in the latter are often encouraged by policy measures to increase domestic manufacture, they are mostly concentrated in China. Moreover, the ones outside Beijing's territory, primarily located in the Indo-Pacific region, are often carried out by Chinese companies to geographically diversify their production and circumvent US's import tariffs.

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[204] IEA (2022). "*Solar PV Global Supply Chains*" [online]. Paris: OECD Publishing, p. 9. Available at: https://www.iea.org/reports/solar-pv-global-supply-chains (Accessed 10 August 2024).

[205] IEA (2024). "*Renewables 2023*" [online]. Paris: OECD Publishing, pp. 67-72. Available at: https://www.iea.org/reports/renewables-2023 (Accessed 28 June 2024).

[206] IEA (2023). "*Energy Technology Perspectives 2023*" [online]. Paris: OECD Publishing, pp. 389-390. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024).

Therefore, it is evident Beijing's stark dominant position *vis-à-vis* Western countries, even though, in the latter, policies started to incentivise investments on renewables. For instance, North America's PV manufacturing capacity is expected to cover about 35% of its domestic PV demand by 2028, which is not much, in absolute terms, compared to China but it is a great starting point for Washington. This rise in domestic manufacture was decided in the light of recent events and the acknowledged risk of dependency on China's manufactured products. Indeed, between 2022 and 2023, PV module imports in the EU and the US rose at a faster pace than PV installations on domestic soil. In the former, both the expectations in PV capacity increase and the potential import restrictions led to Chinese PV modules stockpiling. The stockpiling on a global level increased world's demand for PV modules. However, in 2023, the additional demand was not enough to offset further supply chain expansion, reducing the global average utilization rate to about 60%.

The oversupply in the solar PV market led to intense competition among manufacturing companies, which resulted in a 50% drop in PV's module spot prices between in 2023. Considering low manufacturing utilization rates and long-term trends in production cost reductions, PV module prices are expected to continue decreasing. In such a competitive market, manufacturers do focus on cost-cutting and technological innovation. Companies integrated vertically will take advantage of this since they can control costs throughout the entire value chain. Once again, Chinese companies are experts in upgrading their own manufacturing chains. However, recent manufacturing overcapacity and the PV modules' dropping prices will increase manufacturers' financial challenges, potentially leading to project cancellations and market consolidation. Established Chinese manufacturing companies, often vertically integrated and benefiting from public incentives, are responsible for PV's price drops due to their high production cost efficiencies achieved through economies of scale. The latter are expected to remain unmatched in the short and medium term by any other country, even though Western governments introduced subsidies, local-content requirements, and trade measures to hinder Chinese export and favour domestic PV manufacturing, in order to ensure a resilient and secure clean energy supply chain[207].

Interestingly enough, in 2008, the top ten producers of solar PV equipment accounted for about 90% of the worldwide PV market and were located in only four countries - Germany, US, Switzerland, and Japan. By 2021, the top ten manufacturers' market share had decreased by half, mostly as a result of a large influx of new companies that significantly diversified the industry. Furthermore, the previous top ten PV manufacturers lost their market shares so that, currently, China is home to all the top ten PV equipment manufacturers, which together own more than 45% of the world market. Thus,

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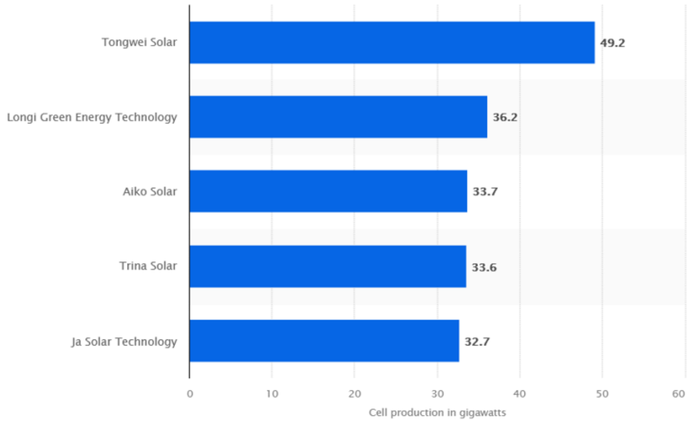
[207] IEA (2024). "*Renewables 2023"* [online]. Paris: OECD Publishing, pp. 67-72. Available at: https://www.iea.org/reports/renewables-2023 (Accessed 28 June 2024).

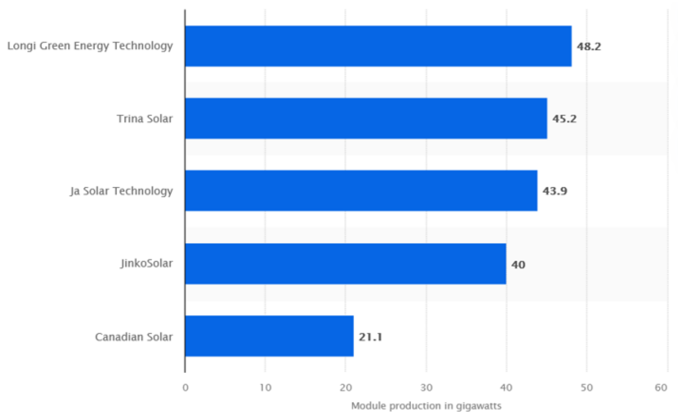
if it is fair to say that the major producing companies own a lower share of the market since more companies are active, the former are also more geographically concentrated as they are all China-based, leading to the concentration of solar PV manufacturing capacity at a company level.

The graph below shows the main PV cells and modules manufacturers, respectively on the left and on the right, in 2022. All the companies listed below are Chinese-based, the only exception is the module-producer Canadian Solar which, however, represents a percentage of total production well below the four companies preceding it. Not to mention that the Canadian company's manufacturing is mainly located in China and, to a lower extent, in Canada.



Leading solar PV manufacturers worldwide based on cell production in 2022

Source: Statista (2023) "*Major PV cell manufacturers"* [online]. Available at: https://www.statista.com/statistics/1377219/major-pv-manufacturers-cell-production-globally/ (Accessed 05 August 2024)



Production of the leading solar PV module manufacturers worldwide in 2022

Source: Statista (2023) "*Major PV module manufacturers"* [online]. Available at: https://www.statista.com/statistics/1377223/major-pv-manufacturers-module-production-globally/ (Accessed 05 August 2024)

The Chinese Tongwei, LONGi, Aiko and Trina cover about 40% of world's PV cell manufacturing capacity and a similar pattern is seen in module production, where the Chinese LONGi, Trina, Jinko Solar, and JA Solar hold roughly 40% of global output. For what it concerns wafers, are again Beijing's companies, i.e. LONGi and Zhonghuan Solar, the major global manufacturers as they contribute to around 50% of global capacity.

Chinese companies' dominance is expected to increase reaching 78% for modules, 85% for cells, and 94% for wafers by 2027, therefore strengthening their market dominant position. To understand the level of geographic concentration and how much is convenient to invest in China, a good illustration is the case of Canadian Solar which revealed a record-high $9.8 billion investment in Qinhai, China, to produce annually 200,000 tonnes of polysilicon, 250,000 tonnes of silicon metal, 50 GW of silicon ingot casting, and 10 GW each of wafers, cells, and modules. The expansion carried out by the Canadian company is a typical case of vertical integration and demonstrates the importance of the China-based PV industrial district[208].

Manufacturer	Component	Region of announced expansion	Expected completion	Billion USD
Canadian Solar	Modules, cells, silicon, crucibles	Qinghai, China	2027	9.8
LONGi	Wafers, cells and modules	Inner Mongolia, China	2024	2.4
Shangji	Wafers	Jiangsu, China	2024-2025	2
Tongwei	Cells	Sichuan, China	First phase 2023	1.9
Q Cells	Modules	South Carolina, US	2024	1.8
Jiangxi Jinko	Modules and aluminium frames	Jiangxi, China	2023-2025	1.5
Jiangxi Jinko	Monocrystalline silicon pull rods	Qinghai, China	2023-2024	1.4
Solar Space	Cells	Anhui, China	2023	1.4
Eging PV	Modules, cells and wafers	Anhui, China	N/A	1.4
First Solar	Modules	Alabama, United States	2025	1.2
JA Solar	Cells and modules	Jiangsu, China	2023	1

Announced expansion projects for manufacturing solar PV supply chain components

Source: IEA (2023), "*Energy Technology Perspectives 2023"* [online]. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024)

While the vast majority of expansion plans are concentrated in China, as it can be inferred from the graph above, significant investments have also been announced outside. One example is Enel's decision to build a 3-GW-per-year module factory in Sicily, due to come on line by 2024, supported by EU grants. ENEL's factory in Catania is currently Europe's largest solar panel manufacturing plant and is still undergoing significant expansions. Even though ENEL's plant is the biggest in Europe with an astonishing 3GW production capacity, this data is still low in comparison to Chinese companies manufacturing capacity[209]. PV manufacturing capacity are somewhat higher in North America as First Solar and Canadian Solar, the major PV companies in US and Canada, produce

[208] IEA (2023). "*Energy Technology Perspectives 2023"* [online]. Paris: OECD Publishing, pp. 219-220. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024).

[209] For instance, on April 2024, the Chinese LONGi, leading worldwide PV technologies' producer, reported an annual production capacity of 29 GW for its cell manufacturing plant in Xi'xian alone. Not to mention its 46 GW silicon ingot and wafer project in Ordos and the 30 GW cell project in the same location. As a matter of fact, with the acceleration of capacity transformation towards future technologies, the company expects to achieve a PV wafer's target of 135 GW and PV cell's production of 100 GW by the end of 2024. LONGi (2023). *LONGi 2023 Annual Report* [online]. Available at: https://www.longi.com/us/news/2023-longi-annual-report/ (Accessed 11 August 2024).

respectively 8 and 13 GW but these data are still too low to stand comparison *vis-à-vis* China's production.

The solar supply chain is so concentrated that, as foreseen by IEA (2022)[210], at least until 2025, China will provide the majority of the key components essential to produce solar panels. As a matter of fact, for instance, the Chinese 'Xinjiang' region alone currently manufactures 40% of the world's polysilicon. Any global supply chain with this degree of concentration would be extremely vulnerable, and solar photovoltaics is no exception. This is particularly evident from the graph below, which also shows the delay of Western countries in the energy transition. On the other hand, it is clear than decades of policies, market incentives and long-term approaches have made China an element of the "renewables' equation" that cannot be disregarded in the PV sector and that will be able, at least in the short- and medium- term to use its dominant position as a leverage.

	Wafers		Cells		Modules	
	Production	Capacity	Production	Capacity	Production	Capacity
World	**190**	**370**	**190**	**410**	**190**	**460**
China	96%	96%	78%	85%	73%	75%
Europe	0%	1%	1%	1%	2%	3%
North America	0%	0%	1%	1%	5%	2%
Other Asia Pacific	3%	3%	18%	13%	19%	18%
Central & South America	0%	0%	0%	0%	0%	0%
Africa	0%	0%	0%	0%	0%	1%
Eurasia	0%	0%	0%	0%	1%	1%
Middle East	0%	0%	0%	0%	0%	0%

Manufacturing capacity and production for solar PV components in GW, 2021

Source: IEA (2023), "*Energy Technology Perspectives 2023"* [online]. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024)

3.2.3 *Forecasts and policies*

In the NZE 2050 Scenario, annual average energy capacity additions is expected to quadruple over the period between 2020 and 2030, with around one-third of the total power coming from solar. By

[210] IEA (2022). "*Solar PV Global Supply Chains"* [online]. Paris: OECD Publishing, p. 9. Available at: https://www.iea.org/reports/solar-pv-global-supply-chains (Accessed 10 August 2024).

2030, the yearly installation of photovoltaic panels is expected to reach 630 GW, while in 2021 it was 151 GW, and the corresponding demand for critical minerals will rise to 4,000 kt (kilo tonnes), while in 2021 was around 1,000 kt. Growing demand for PV worldwide will mean greater opportunity to increase manufacturing capacity, the Indo-Pacific area seems especially set to take advantage of the latter. Indeed, to date, nearly all of the world's solar PV production capacity is located in the Indo-Pacific area, predominantly in China. Even though North America and Europe trying scale up manufacturing capacities domestically, it is most likely that the South Asian region will remain the PV panels' main manufacturer[211].

The Chinese dominant position in the solar PV supply chain is the result of previous decades' governmental policies. Starting with the 10th Five-Year Plan (FYP) in 2001, throughout the current 14th, Beijing has supported its national solar supply chain since the PV industry was deemed a strategic sector[212]. These policies to stimulate demand are essentially supporting domestic solar PV manufacturing as Chinese producers have showed to be able to ramp up their manufacturing production to match growing demand, especially given the short lead times of China's solar PV industry and the announced expansion plans in place.

In august 2022 the US government enacted the Inflation Reduction Act (IRA) whose main goals are to decarbonise its national energy sector, improve domestic clean energy technology manufacturing and reduce energy prices. The policy should muster around $ 370 billion in energy and climate investments, of this amount a significant share is anticipated to go towards the solar PV sector so to boost demand and in order to guarantee and fortify regional supply chains. Through the IRA policy, homeowners will be able to install rooftop solar systems so that their homes could be more energy-efficient and benefit from ten years of consumer tax credits. Additionally, over $ 60 billion will be available for the production of clean energy, including tax credits to boost domestic solar panel manufacturing and up to $ 10 billion for the construction of clean technology manufacturing facilities.

Until recently, in the European Union, a lack of policy support for domestic PV manufacturers and insufficient policies promoting EU-manufactured products led to limited PV development projects. Türkiye took advantage of this situation; the country is expected to attract most European investments due to its local incentives and low manufacturing costs. It was only in 2022 that the European Commission deployed the REPowerEU plan setting a goal of around 600 GW of solar PV by 2030 and 320 GW by 2025 to be produced domestically. The European Solar PV Industry Alliance is one

[211] IEA (2022). "*Securing Clean Energy Technology Supply Chains"* [online]. Paris: OECD Publishing, p. 7. Available at: https://www.iea.org/reports/securing-clean-energy-technology-supply-chains (Accessed 26 June 2024).

[212] Vast land availability and cheap labour prices were beneficial to the sector's developing to the extent that the 14th FYP established a target of 33% of power generation coming from renewables by 2025, with a target of 18% going primarily towards wind and solar technology, a figure which would have been unimaginable for Western countries

of the initiatives outlined in the EU Solar Energy Strategy to fortify the European solar PV supply chain. Its goal is to enable the expansion of a resilient and technology-innovative PV value chain, with a specific emphasis on domestic manufacturing. By 2025, the plan aims to increase resource efficiency and circularity, diversify the supply of critical minerals and attain manufacturing capacity equal to at least 30 GW of PV at every stage of the value chain[213]. Although its increasing domestic production plans, by 2028 Europe is expected to be only 10% self-sufficient, still being the largest PV import market, a gap likely filled by China's supply. On the other hand, PV manufacturing plans in the US and India will significantly reduce their import dependence. However, due to China's massive investment plans, global geographical diversification of PV manufacturing is not expected to improve significantly in the short and medium term[214].

[213] IEA (2023). "*Energy Technology Perspectives 2023"* [online]. Paris: OECD Publishing, pp. 221-222. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024).

[214] IEA (2024). "*Renewables 2023"* [online]. Paris: OECD Publishing, pp. 67-72. Available at: https://www.iea.org/reports/renewables-2023 (Accessed 28 June 2024).

3.3 **Wind turbines**

3.3.1 *The technology*

Wind technology is too an essential component of the energy transition. It involves the generation of electricity from wind turbines, which transform wind's strength in clean energy. Wind power is a good example to understand the dimensions of the challenges ahead since this technology is expected to become a critical component of many nations' domestic energy mix. Two distinct wind technologies may be listed: onshore and offshore. The first are located on land, while the latter in the open sea. The key difference between these two types lies in the feature of permanent magnets in offshore wind turbines while onshore turbines employ geared drives. Permanent magnets, though more costly and mineral-intensive, need less maintenance, thus are better suited to the harsh conditions of offshore environments[215].

Wind turbines are composed of three main components: a tower, a nacelle, and rotors mounted on a foundation, which require different and unique amounts of minerals and materials, which vary significantly depending on the turbine size and type. The turbines exploiting PMSG (permanent-magnet synchronous generator) technology make use of a permanent magnet and need the highest amount of REEs and copper - mineral's intensity being more than double than that for onshore turbines -, nevertheless, they represent the most common type, almost 60% of the market, of offshore wind farms. Indeed, for the latter, larger and taller turbines are required and DD (Direct Drive)-PMSG are often preferred due to their lighter design and reduced maintenance costs. As turbine power increases with taller and larger structures, the preference for light and efficient PMSG technologies increase. Onshore wind market is predominantly led by GB-DFIGs (gearbox double-fed induction generator), accounting for 70% of turbines present on the market[216]. From the graph below can be inferred the wind market's mineral requirements in 2020 and, *sic stantibus rebus*, the foreseen ones in the next decades.

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[215] Arrobas, D. L.P., Hund, L. K., Mccormick, S. M., Ningthoujam, J., Drexhage, R. J., (2017). "*The Growing Role of Minerals and Metals for a Low Carbon Future*" [online]. Washington, D.C: The World Bank/International Bank for Reconstruction and Development, p. 19. Available at: https://documents.worldbank.org/en/publication/documents-reports/documentdetail/207371500386458722/the-growing-role-of-minerals-and-metals-for-a-low-carbon-future (Accessed 6 July 2024).

[216] IEA (2021). "*The Role of Critical Minerals in Clean Energy Transitions*" [online]. Paris: OECD Publishing, p. 66. Available at: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions (Accessed 29 June 2024).

	Stated Policies Scenario		
Demand	**2020**	**2030**	**2040**
(thousand tonnes, kt)			
Low-carbon generation	**1 692**	**2 905**	**3 343**
Wind	**644**	**1 015**	**1 195**
Chromium	29	43	53
Copper	217	387	415
Manganese	46	67	84
Molybdenum	6	9	11
Nickel	21	29	38
Zinc	321	472	587
Neodymium	3,1	6,1	6,1
Dysprosium	0,3	0,6	0,7
Praseodymium	0,5	1,1	1,1
Terbium	0,1	0,2	0,3
Others	0,1	0,2	0,2

Mineral demand by sector

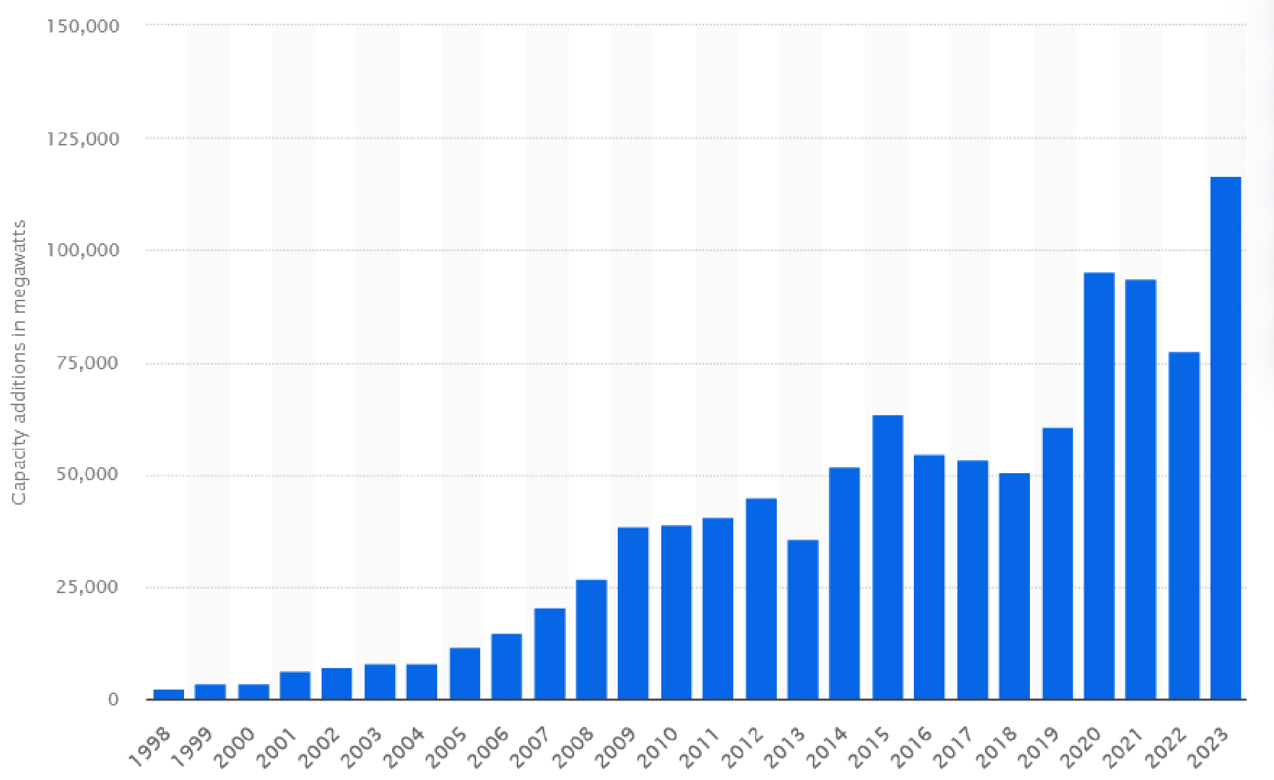
Source: IEA (2021), "*The Role of Critical Minerals in Clean Energy Transitions"* [online]. Available at: https://www.iea.org/data-and-statistics/data-product/the-role-of-critical-minerals-in-clean-energy-transitions-2 (Accessed 11 August 2024)

Over recent years, wind energy has become a competitively priced energy source and has been increasingly installed, mostly in Europe and China, the latter being the leading country in terms of turbines production, newly installed wind power and cumulative capacity.

3.3.2 *The supply chain*

Wind turbine manufacturing is highly geographically concentrated. Almost 90% of the total capacity deployed in 2021 was produced by the top 15 manufacturers, of which Chinese companies represented over half of the total, followed by European companies at around 35% and American companies at less than 10%. Chinese manufacturers have built over 95% of the domestically installed wind farms, showcasing a strong local focus. Conversely, European manufacturers operate on a global scale, with about 65% of their products' installations occurring outside their home regions; supported by local manufacturing facilities European companies have adopted a focus over international market[217]. As of 2023 the global cumulative installed wind power capacity is 1,021 GW, of which China's capacity alone is, with 476.6 GW, is almost 50%.

To date, the expansion of wind power has been remarkably successful, as suggested by the following graph, primarily driven by the development of onshore wind farms.



Annual wind power capacity installations worldwide from 1998 to 2023 (in megawatts)

Source: Statista (2024), *"New installed wind energy capacity worldwide 2023"* [online]. Available at: https://www.statista.com/statistics/268385/global-new-installed-wind-power-capacity/ (Accessed 11 August 2024)

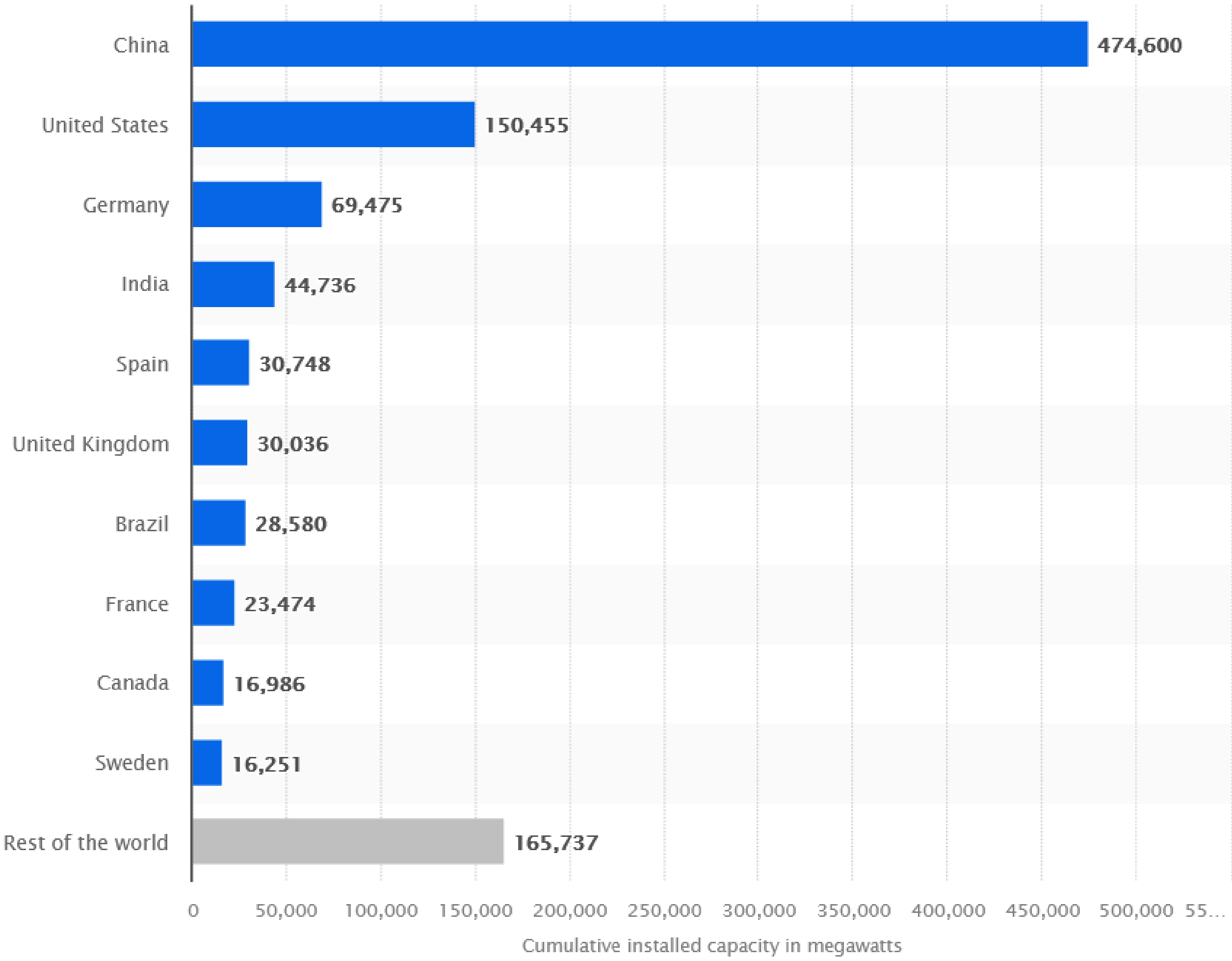
Wind power expansion and investments were boosted by governments. While in 2005 just 59 GW of clean energy were produced through onshore and offshore wind turbines, the installed wind power capacity worldwide amounted to approximately 1,021 GW in 2023 - with the onshore accounting for 946 GW of it[218].

Although offshore farms have grown at a faster rate, onshore wind energy still accounts for the majority of wind capacity. As it will be seen further on, China accounts for most global wind installations in 2023, by a significant margin. As from the graph further down, the US and Germany

[217] IEA (2023). "*Energy Technology Perspectives 2023*" [online]. Paris: OECD Publishing, pp. 95-97. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024).

[218] Statista (2023). "*Global installed wind energy capacity 2023*" [online]. Available at: https://www.statista.com/statistics/268363/installed-wind-power-capacity-worldwide/ (Accessed 08 August 2024).

follow in second and third position with a combined total that was less than Beijing's alone. Indeed, given its massive land mass, long coastline and production capacities, China possesses a unique ability to generate substantial amounts of wind power. it is, by far, the largest installer of wind power capacity in the world. As a matter of fact, as of the end of 2023, China had cumulatively installed over 464 GW of wind power *vis-à-vis* the American 150 GW.



Cumulative installed capacity of wind power worldwide in 2023, by country (in megawatts)

Source: Statista (2023), "*Cumulative installed capacity of wind power"* [online]. Available at: https://www.statista.com/statistics/217522/cumulative-installed-capacity-of-wind-power-worldwide/ (Accessed 08 August 2024)

The global wind power capacity has seen a nearly fourfold increase over last ten years, driven by decreasing costs - down by approximately 40% on average worldwide - and supportive policies. Wind power is expected to register a substantial growth in the long-term, particularly with advancements in offshore wind to keep pace with the NZE targets. By 2040, annual wind capacity installations are projected to double to over 160 GW, accounting for over 25% of new power capacity additions, mainly concentrated in China, EU and the US. The share of offshore wind in total deployments is set to increase substantially, as cost reductions and the expertise gained in the North Sea are unlocking opportunities globally.

As in the case of solar PV, technological innovations could potentially unlock new resources and markets. For instance, onshore turbine sizes have significantly increased during last decade, contributing to higher capacity factors and reduced material intensity, therefore making more resilient and secure turbines' supply chain. For instance, there has been a substantial reduction in bulk materials and critical minerals employed, i.e. less 15% concrete, 50% copper, and 60% aluminium[219]. As many turbines are still manufactured in Europe and North America, techonological innovations are extremely important as they mean less reliance on minerals and materials manufactured in China. A higher wind penetration would significantly boost demand for permanent magnets and critical minerals. The level of minerals' demand will thus hinge on the extent of offshore wind adoption, which itself is influenced by various factors[220].

When the global wind turbine deployment started to skyrocket, beginning of the 2000s, only about 5 GW of generation capacity were installed and European companies dominated 90% of the market. This technology rapid growth is attributed to economies of scale, technological advancements and robust policy support for clean energy initiatives, which made wind power one of the most cost-effective options for new generation capacity globally. Several nations, among which primarily China and other advanced economies, announced the setting of ambitious renewable energy objectives to be achieved by 2030 to reach the NZE targeet. However, the wind industry is stumbled in multiple challenges as inflation, high financing costs and long lead-times bureaucracy while scaling up manufacturing and installation capacities to meet these targets. Therefore, the initial wind energy expansionary phase has since reversed. Since 2021 the main four Western wind turbine manufacturing companies[221] - which used to supply the international market, with the exception of China, by over the 90% until 2021 - reported lower revenues, when not increasing losses, attributed to supply chain disruptions and cost pressures[222]. On the other hand, Chinese manufacturers as Goldwind performed better, even though they registered stagnant profits in 2022.

[219] IEA (2021). "*The Role of Critical Minerals in Clean Energy Transitions"* [online]. Paris: OECD Publishing, pp. 66-68. Available at: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions (Accessed 29 June 2024).

[220] Arrobas, D. L.P., Hund, L. K., Mccormick, S. M., Ningthoujam, J., Drexhage, R. J., (2017). "*The Growing Role of Minerals and Metals for a Low Carbon Future"* [online]. Washington, D.C: The World Bank/International Bank for Reconstruction and Development, p. 20. Available at: https://documents.worldbank.org/en/publication/documents-reports/documentdetail/207371500386458722/the-growing-role-of-minerals-and-metals-for-a-low-carbon-future (Accessed 6 July 2024).

[221] Vestas, Siemens Gamesa, General Electric, and Nordex.

[222] IEA (2023). "*Energy Technology Perspectives 2023"* [online]. Paris: OECD Publishing, pp. 222-226. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024).

Interestingly enough, while today the majority of wind components' manufacturing capacity is, and will be even more in the medium-term, concentrated in China, the majority of wind projects commissioned, both onshore and offshore, are primarily in Europe and North America. As a matter of fact, as it can be inferred from the graph below, the major wind companies by revenue in 2022 were Western, a similar trend is expected for the 2023 official data.

	2018	2019	2020	2021	2022
General Electric Co	97.00	95.20	75.83	74.20	76.56
Iberdrola	42.22	41.53	38.59	47.47	61.36
Mitsubishi Heavy Industries	36.60	37.48	34.65	36.15	41.08
Nextera Energy	16.73	19.20	18.00	17.07	20.96
Orsted	12.19	10.17	8.04	12.35	20.50
American Electric Power	16.20	15.56	14.92	16.79	19.68
Acciona	9.42	8.82	8.29	10.26	13.67
Avangrid	6.48	6.34	6.32	6.97	7.92
Brookfield Renewable Power Pre	2.98	3.01	3.89	4.34	4.78
Edp Renovaveis	2.23	2.14	2.04	2.83	3.25

Top wind company revenues in billion USD

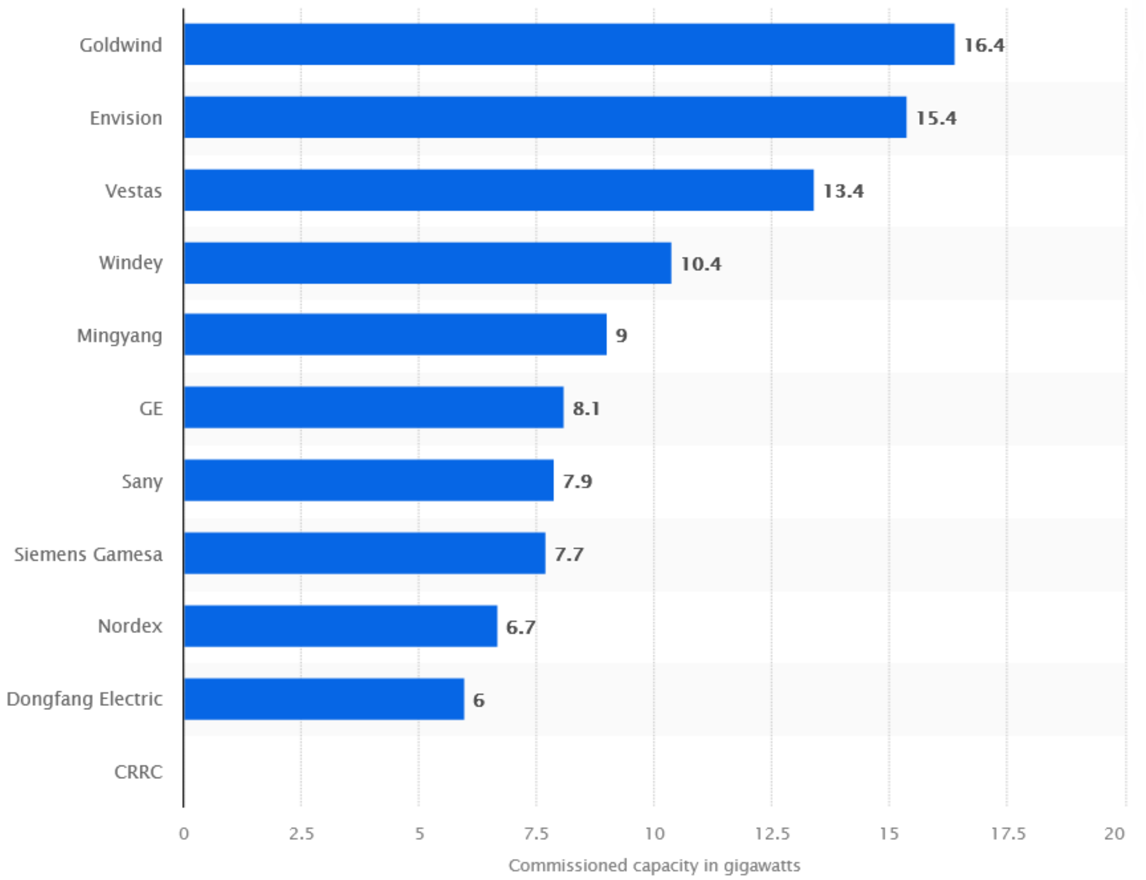
Source: Statista (2024), "*Wind Energy – Worldwide"* [online]. Available at: https://www.statista.com/outlook/io/energy/renewable-energy/wind-energy/worldwide#key-players (Accessed the 08 August 2024)

However, if major wind companies are located in Europe and North America, it is fair to wonder if the turbines employed are manufactured by Western firms too. For instance, the Spanish Iberdrola, one of the main multinational electric utility companies, seems to adopt for its offshore wind farms Siemens Gamesa turbines[223], a German firm; for onshore projects, the company operates a wide array of turbines tailored to specific project needs and local conditions, nevertheless, turbines' majority seems to be manufactured in Europe or North America. Nevertheless, Chinese companies are world's major wind turbines producers, not to mention the wind power capacity installed. China alone accounts for 50% of the latter, i.e. 476.6 GW over 1,021 GW of global wind power capacity.

If this scenario might seem confusing, a few *caveats* should be reminded. First, Iberdrola and other wind utility firms may buy from Western manufacturers, which sell the final ready-to-use good, but

[223] Offshore wind (2024). "*Iberdrola Greenlights Its Third Offshore Wind Project in German Baltic Sea"* [online]. Available at: https://www.offshorewind.biz/2024/06/27/iberdrola-greenlights-its-third-offshore-wind-project-in-german-baltic-sea/ (Accessed 08 August 2024).

turbines are made up of several components and China is currently the major producer of such components. Therefore Western companies selling final-goods may import and employ specific Chinese components not domestically manufactured - this is not the case of the previous mentioned Siemens Gamesa which entirely produce turbines with components manufactured in Germany, France or US. Moreover, it should be recalled that Western companies were pioneers of this technology. Therefore, even though they registered declining revenues and market shares, they are still essential actors of the market, not to mention that several Chinese manufacturing companies entered the game but only few became large multinationals capable to overthrow and win Western firms' internal market shares. Beijing's dominant role in wind power production as well as its companies' rapid growth may also be explained by the rapid adoption and installation of turbines on a national level. Indeed, in China, a significant share of installed turbines are not carried out by large utility companies but by privates. Therefore, there is no mystery that the most rapid growing companies in terms of potential GW exported - thus turbines - are Chinese, as it can be inferred by the graph below, even though Western ones are still active.



Leading wind turbine manufacturers based on commissioned capacity worldwide in 2023 (in gigawatts)

Source: Statista (2024), "*Capacity commissioned for the leading wind turbine manufacturers*" [online]. Available at: https://www.statista.com/statistics/516028/capacity-commissioned-for-the-leading-wind-turbine-manufacturers-worldwide/ (Accessed the 08 August 2024)

Thus, it is fair to say that world's leading wind turbine manufacturers in 2023, based on their commissioned capacity were Chinese - Goldwind and Envision - but Western companies - e.g. the Danish Vestas - are right behind. The problem lies in the long-term. Indeed, the graph above follows a longer trend of Western companies that recently started to register negative output, while Chinese ones are supported both by the extremely high internal demand - for which they provide around the 95% of turbines - and national policies. If the wind market has recently experienced a surge in its capacity, the wind industry is struggling financially. Indeed, the major Western manufacturers declared massive losses in the last two years, so that IEA (2024) [224] lowered its projection for future onshore wind by 16% given the significant increase in costs associated with offshore wind construction. Aside from China, onshore wind additions all over the world are not recording the foreseen progress. In the EU too, long wait periods for permits, difficulties in the supply chain, and increased expenses slowed down onshore wind deployment. Materials used to manufacture offshore wind components have witnessed a constant rise in prices since early 2020 due to supply chain constraints and inflation, resulting in a 20% increase in offshore wind investment costs. Therefore, currently, the capacity expansion of both onshore and offshore wind component is lagging behind the requirements outlined in the NZE Scenario.

However, this sector has historically demonstrated low lead times and its ability to swiftly increase capacity when facing high demand. For instance, between 2015 and 2020 installations grew by approximately 70% because of favourable policies and an increase in demand. Furthermore, as with solar PV, fossil fuels' cost spike led to elevated electricity prices, providing a significant boost to investments, particularly in Europe.

3.3.3 *Forecasts and policies*

The significant gap between the announced expansion projects and the ones required to comply with the NZE objective highlight the urgent need for a substantial increase in manufacturing investment in the near term. Announced expansion projects cofirm that the future of key wind components manufacturing will be predominantly concentrated in China - accounting for, with regard to onshore turbines, 64% of world's nacelles, 63% of blades and 56% of towers, with a similar scenario for offshore components reaching 80% ofblades, 70% of nacelles and 60% of towers

[224] IEA (2024). "*Renewables 2023"* [online]. Paris: OECD Publishing, pp. 19. Available at: https://www.iea.org/reports/renewables-2023 (Accessed 28 June 2024).

manufactuing[225]. Thus, around two-thirds of the 120-140 GW rise in wind turbines' capacity by 2025 should occurr in China, driven by its internal increasing demand.

Chinese manufacturers have struggled to enter international markets, where about 95% of the demand is met by European and American firms, despite the fact that turbine prices in China are roughly one-third of those in Western markets[226]. Nevertheless, these data, even though they clearly underline a future Chinese dominant position in the wind market, are promising. Indeed, if these numbers are compared to the ones of 2021, a slight increase is shown in certain European and American parameters.

	Tower (GW)		Nacelle (GW)		Blade (GW)	
	Onshore	Offshore	Onshore	Offshore	Onshore	Offshore
World	**88**	**18**	**100**	**26**	**98**	**25**
China	55%	53%	62%	73%	61%	83%
Europe	16%	41%	13%	26%	18%	12%
North America	11%	0%	10%	0%	10%	0%
Other Asia Pacific	12%	6%	8%	2%	6%	4%
Central & South America	5%	0%	6%	0%	4%	0%
Africa	1%	0%	0%	0%	0%	0%
Eurasia	0%	0%	0%	0%	0%	0%
Middle East	0%	0%	0%	0%	0%	0%

Manufacturing capacity for wind technology components in 2021

Source: IEA (2023), "*Energy Technology Perspectives 2023".* Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024)

Long-term manufacturing outlook is expected to improve as wind energy demand grows more predictable, partly due to the American IRA and the EU Wind Power Action Plan, both aimed at boosting installation rates and support local manufacturers. However, these policies actual effects on wind production capacity won't be evident until after 2025[227]. Nevertheless, several countries have

[225] IEA (2023). "*Energy Technology Perspectives 2023"* [online]. Paris: OECD Publishing, pp. 222-228. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024).

[226] IEA (2024). "*Renewables 2023"* [online]. Paris: OECD Publishing, pp. 72-74. Available at: https://www.iea.org/reports/renewables-2023 (Accessed 28 June 2024). Today, China is responsible for 80 to 90% of the expected manufacturing capacity expansion for onshore componets. It is sobering that North America and Asia Pacific collectively account for less than 50% of the announced expansion projects for offshore nacelles and the EU 25% of the announced expansion projects for offshore blades. IEA (2023). *Energy Technology Perspectives 2023* [online]. Paris: OECD Publishing, p. 222-226. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024).

[227] IEA (2024). "*Renewables 2023"* [online]. Paris: OECD Publishing, p. 72-74. Available at: https://www.iea.org/reports/renewables-2023 (Accessed 28 June 2024).

recently focused on promoting wind energy investment through a vast range of strategies such as carbon pricing, feed-in tariffs and minimum shares in the power generation mix. Policy makers are now beginning to focus more on wind equipment and components' security of supply to face recent supply chain issues.

China's 14th FYP (Five-Year Plan) prioritised wind development to improve the supply of domestic energy and move towards decarbonisation. The strategy seeks to attain 1.2 TW (terawatt) of wind and PV capacity by 2030, despite the lack of explicit objectives for further wind capacity. it is foreseen a massive increase in onshore wind farms, which will still account for the majority of wind power capacity, but additional offshore projects are on the go; coastal provinces - i.e. Guangdong, Fujian, Zhejiang, Jiangsu and Shandong - inted to build collectively over 60 GW of offshore wind farms by 2025. Governmental feed-in tariffs helped Chinese wind turbine manufacturers to exponentially grow their companies and significantly cut costs since the 2000s. However, Beijing's strong support to private companies ended in 2020 for what it concerns onshore wind and in 2021 for offshore. Rather than strengthening and bolstering supply networks, the majority of recent Chinese policy initiatives have placed emphasis on establishing deployment objectives and encouraging capacity investment. At every stage of the wind supply chain, incentives drew investment in expanded local manufacturing capacity since the nation has high import tariffs on commodities linked to wind power and access to inexpensive labour and raw materials, e.g. critical minerals[228].

The US Inflation Reduction Act extended production and investment tax credits for wind projects that started to be built before the end of 2024. Although these extensions are strictly contingent on terms pertaining wages and apprenticeships, it is projected that by 2030, American PV and onshore wind capacity will have doubled due to the production tax credits, which should lead to a levelized cost of wind capacity that is competitive with the majority of alternative producing options. By increasing developer demand for new turbines, nacelles and towers, the IRA indirectly helps wind turbine manufacturers. Moreover, for projects that fulfil specific domestic-content standards, it offers extra tax benefits. However, developers must attest that any manufactured good that is or will be a part of a facility was manufactured in the US in order to be eligible for the extra credit. To safeguard its domestic manufacturing industry, the US implemented anti-dumping and countervailing duties of up to 73% on wind towers imported, e.g. the ones from Spain, in 2021[229].

In the old continent, with the goal of achieving 45% of the EU's energy mix from renewable sources by 2030, the REPowerEU strategy seeks to increase the generation of clean energy production, with the aim to double wind energy capacity by 2030. Up to 2027, the plan calls for

[228] IEA (2023). "*Energy Technology Perspectives 2023"* [online]. Paris: OECD Publishing, pp. 226-228. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024).
[229] Ibidem.

investing over $ 94 billion on renewable energy sources. Furthermore, new laws to increase the wind farm approval process rapidity are foreseen. In a similar manner to the US, the EU Commission imposed anti-dumping duties on Chinese steel wind tower imports in 2021, with rates between 7.2% and 19.2%, following an investigation that uncovered dumped Chinese towers' imports worth approximately € 300 million[230].

230 Ibidem.

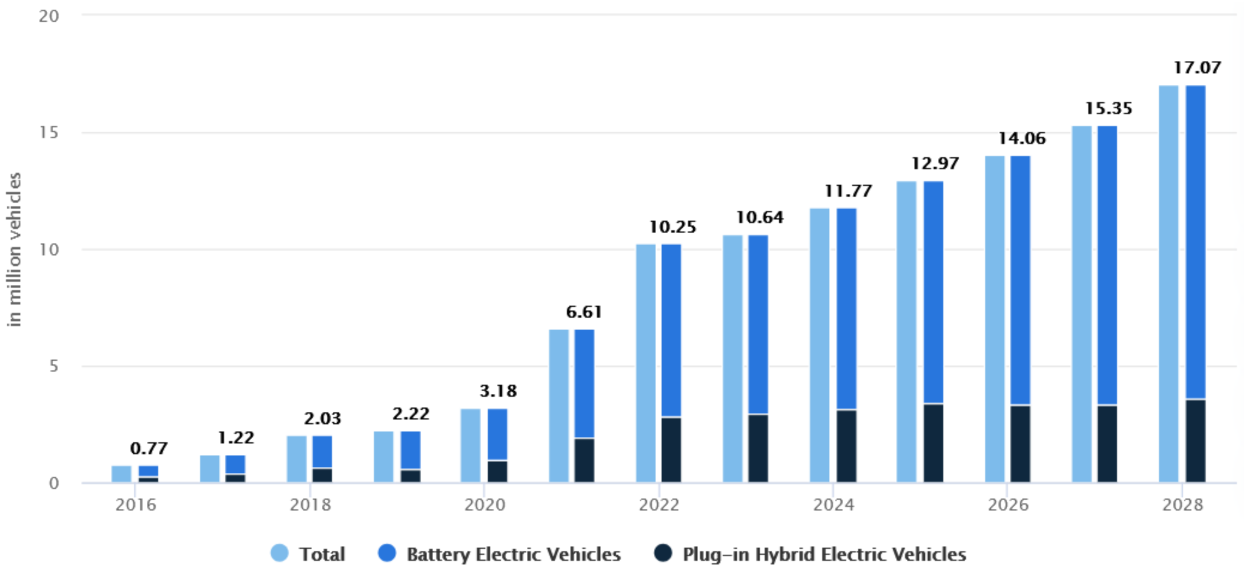
3.4 **Electric Vehicles and batteries**

3.4.1 *The technology*

This last part will focus on EVs, their value chain and their market, including their main components such as batteries. EV market is crucial to the energy transition since reduction in oil reliance strongly depends on the pace of electrification in the transport sector and because it is among the major, if not the main, green markets over which the public at large is active. Indeed, while coal and natural gas are increasingly replaced, as previously seen, by renewables in electricity generation, oil still is the main source fuelling the transport sector. It is not surprising therefore that Government are pushing public policies and incentives in the EV market aiming, on one hand, at achieving the NZE targets and, on the other hand, to support the automotive sector, historically the symbol of advanced country's economic strength and technological development. Also, as it may be recalled from last chapter, renewables are particularly important to minimize dependency on third countries. The automotive sector perfectly falls into this logic because in case of fossil fuel supply disruptions all car drivers are affected by shortages or higher prices while with EVs only the upstream production could be slowed down or interrupted, with no serious damage for the great public. So far, China has been the forerunner of domestic economic policies implementation to support the national EV automotive sector development. In terms of volumes, Asia, with China *in primis*, thanks also to national supportive policies represents the biggest market - around 4.9 million units sold in 2022, in Europe, second, just 1.5 million.

The EV market deals with vehicles powered via batteries' electricity only, in stark contrast with traditional Internal Combustion Engine (ICE) vehicles. The automotive sector accounts for over 15% of global energy-related emissions. As environmental awareness increases, EVs have gained prominence since they allow to cut greenhouse gas emissions and reduce reliance on fossil fuels. Moreover, technological improvements in batteries' chemistry contributed to make EV models more affordable, therefore, green transportation accessible to a wider share of the population.

The EVs market includes both Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs). PHEVs offer the advantages of both electric power and internal combustion engines, as they provide benefits such as an extended driving range and reduced dependence on fossil fuels. While BEVs are gaining widespread attention for their zero-emission features, PHEVs are also attracting interest due to their ability to address range anxiety and infrastructure challenges. Even though its market is not as significant as BEVs' one, PHEV remains relevant by serving as a bridge between traditional and fully electric vehicles[231]. This paper use "EVs" to refer to all electric vehicles, both BEVs and PHEVs. Even though the data are still incomplete, almost 12 million EVs are foreseen to be sold in 2024. Thus, the EV market is one of the fastest growing green markets and is expected to increase further by a 9.82% rate of growth over next decade, so that the value chain for EVs and their battery minerals is projected to account for $7,000 billion.



Unit sales in million vehicles

Source: Statista (2024), "*Electric Vehicles*" [online]. Available at: https://www.statista.com/outlook/mmo/electric-vehicles/worldwide#unit-sales (Accessed 12 August 2024)

Taking into account BEVs, the two main components of the vehicle are the motor and batteries. Several technologies have been developed for both.

For what it concern motors, two main electric technologies do exist: permanent-magnet synchronous motors and asynchronous induction motors. The former are the most efficient ones, although they are more expensive than other technologies since they require a significant amount of REEs. They additionally need bulk materials as iron and copper - around 3 to 6 kg per vehicle. Induction motors are less expensive as they do not require critical minerals but their efficiency is lower because of electrical losses and require massive amounts of copper - around 11 to 24 kg per vehicle. Therefore, permanent-magnet motors are still thought to be the most common type of EV motor[232].

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[231] Statista (2024). "*Electric Vehicles: market data & analysis*" [online]. Available at: https://www.statista.com/study/103895/electric-vehicles-report/ (Accessed 12 August 2024).

[232] IEA (2021). "*The Role of Critical Minerals in Clean Energy Transitions*" [online]. Paris: OECD Publishing, p. 90. Available at: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions (Accessed 29 June 2024).

For what it concern batteries, the matter is far more complicated as several technologies and chemistries are currently employed. This paper will take into account the macro-group of lithium-ion batteries which are the most employed in EVs. Lithium-ion batteries are mainly made up of cathodes and anodes, which employs several minerals, such as lithium, nickel, cobalt, and manganese, which make up 70 to 85 % of the overall weight. Each peculiar mineral combination result in different battery properties adopting different technologies. Cathodes' chemistry is frequently used to classify them, the two most employed technologies are: Lithium nickel cobalt aluminium oxide (NCA) and Lithium nickel manganese cobalt oxide (NMC). The former has the highest specific energy and power among current technologies, making it the preferred choice for car manufacturers - e.g. Tesla -, even though it is the most expensive techonology. NMC batteries have a lower energy density than NCA but offer a longer cycle life. Since their appearance, in early 2000s, this technology dominated BEV's market, being adopted by companies like General Motors.

3.4.2 *The supply chain*

The development of lithium-ion battery technologies is not only about energy density, durability and cost; it involves social and political challenges. Due to price fluctuations and ethical concerns related to cobalt mining, EV manufacturers have been working to reduce cobalt content, often increasing nickel and manganese as a result. This is why NCA batteries evolved into NCA+, a nickel-rich variant, with the potential to shift further towards nickel-dominant chemistries like NMC 9.5.5[233]. New technologies finally drove cost reductions in batteries spurring higher diffusion of EVs. Further cost reductions are expected[234]; battery manufacturing should continue to be dominated by China, currently holding nearly 90% of the global capacity for manufacturing cathodes and over 97% for anodes.

There is no mystery in saying that the biggest increase in critical minerals' demand was a consequence of EV batteries' market explosion. Indeed, lithium battery demand was approximately 140 kilotons (kt) in 2023, growing by more than 30% if compared to the amount requested in 2022. Similarly, cobalt battery demand increased by 15% but less significant is the increase in nickel demand due to lower battery requirements *vis-à-vis* global nickel market.

[233] This trend of reducing cobalt use significantly increased nickel demand; recent efforts to cut nickel led to increased manganese use, more available and cheaper. The Chinese-owned battery manufactor SVOLT, for instance, employ battery with a reduced nickel content and no cobalt at all by increasing manganese usage. Although manganese-rich cathodes are cheaper and safer than nickel-rich alternatives, they compromise cathode stability, potentially affecting long-term performance.

[234] Ivi, p. 93.

	Stated Policies Scenario		
Demand	**2020**	**2030**	**2040**
(thousand tonnes, kt)			
EV and battery storage	**426**	**2 992**	**3 994**
EVs	**401**	**2 809**	**3 459**
Copper	110	717	951
Cobalt	21	106	127
Graphite	141	1 065	1 027
Lithium	20	152	248
Manganese	25	102	117
Nickel	80	647	950
Silicon	0	8	26
Neodymium	2	9	11
Other REEs	0	2	3
Battery storage	**26**	**183**	**535**
Copper	8	55	133
Cobalt	0	3	9
Graphite	15	86	177
Lithium	2	12	28
Manganese	0	4	9
Nickel	0	10	36
Silicon	0	1	4
Vanadium	-	11	139

Mineral demand by sector

Source: IEA (2021), "*The Role of Critical Minerals in Clean Energy Transitions"* [online]. Available at https://www.iea.org/data-and-statistics/data-product/the-role-of-critical-minerals-in-clean-energy-transitions-2 (Accessed 11 August 2024)

Critical minerals' mining and refining should follow the past growing trend in order to meet the future long-term demand and avoid possible supply chain disruptions or bottlenecks[235] in EV market, so to ensure the past battery price trend. According to IEA (2021)[236], the overall mineral demand for EVs should reach almost 3,500 kt by 2040, that is to say a ninefold increase compared to 2020. It is noteworthy that due to significant recent technological advancements, critical minerals now make up the majority of total battery costs, ranging from 50% to 70% of the latter, compared to about 40% to 50% few years ago. The largest cost contributions come from cathode materials , which represent 25% to 30% of total price, and anode materials, which account for 8% to 12%. In contrast, labor costs contribute around 2% to 4%. As for solar PV, it can easily be deduced the importance of technological

[235] IEA (2024). "*Global EV Outlook 2024"* [online]. Paris: OECD Publishing, p. 79. Available at: https://www.iea.org/reports/global-ev-outlook-2024 (Accessed the 11 August 2024).

[236] IEA (2021). "*The Role of Critical Minerals in Clean Energy Transitions"* [online]. Paris: OECD Publishing, pp. 99-109. Available at: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions (Accessed 29 June 2024).

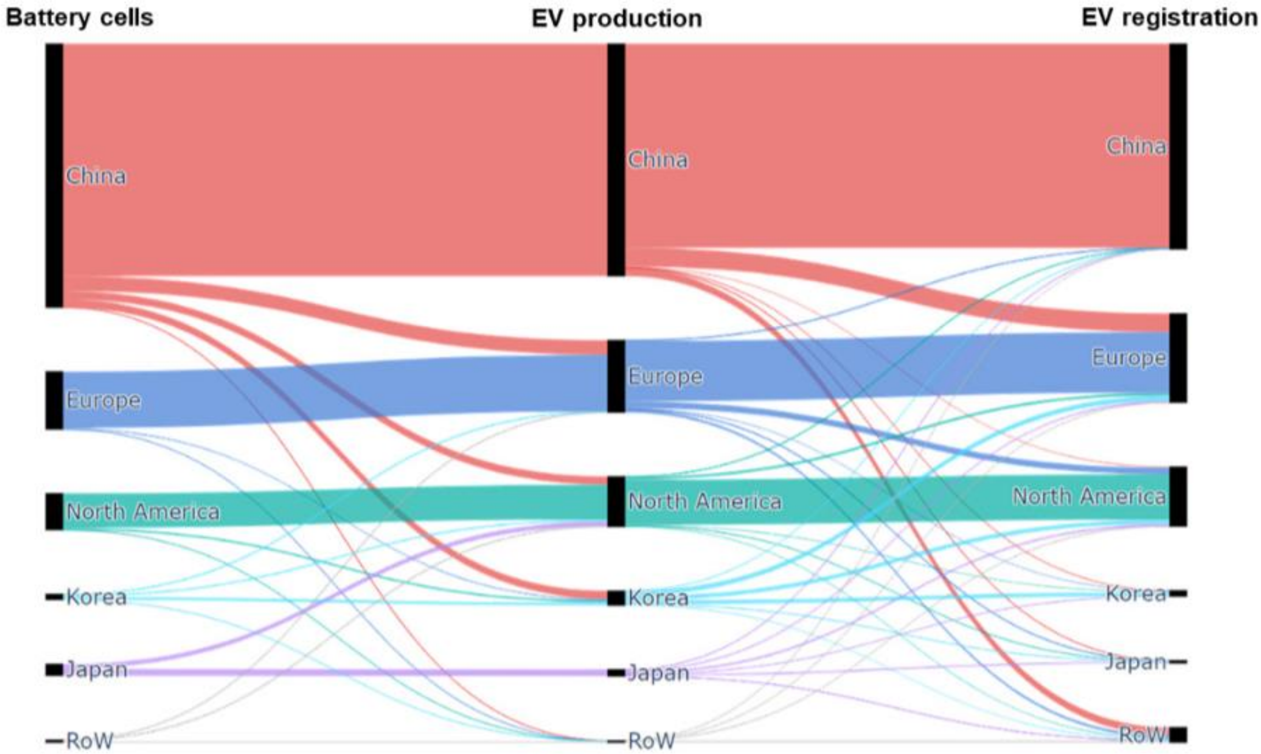
innovations for future critical minerals' demand and dependence but, above all, for the future leverage and balance of power. The following graph helps to understand the amount of minerals employed in the EV manufactuing.

The EV market is experiencing rapid growth, in 2022 alone over 10 million vehicles were sold. The majority of these were BEVs - over 70% of the sales - the remaining being hybrids; in 2022, Tesla led the BEV market[237]. However, it has to be recalled that in North America the BEV market saw more than 900,000 units sold, while in Asia sales almost reached 5 million units, with China being the leader with 4.6 million EVs sold[238]. This shows that Tesla may have the highest BEV market shares as a whole but Chinese companies produce far more EVs than the few Western ones, not to mention that among the ten major BEV manufacturers five are Chinese. Therefore, if EVs will reach a level of mass-production as ICE cars were during the '60s it is highly probable that Chinese companies will be able to effectively penetrate world's markets with low-priced EVs, acquiring those market shares historically prerogative of major Wester car manufacturing companies. Even though the BEV market does not seem concentrated within few companies, it is fair to recall that the same year the Chinese CATL and Korean LG Energy Solution were the two main producers of lithium batteries, with more than half of the global market[239]. More to that, the Chinese BYD held by far the largest market share in the PHEV sector, around 33%, far ahead of BMW and Mercedes, which had market shares of 7% and 6% respectively. Therefore, battery and PHEVs manufacturing seem far more concentrated than BEVs with a significant share in China's hands. If the EV market is in rapid expansion, considering that in 2023 sales surpassed 14 million worldwide, this growth is not evenly distributed. In China alone over 8 million new EVs, most domestic-manufactured, were registered compared to the 2.4 and 1.4 million cars registered in the EU and US respectively. The high concentration level in EVs' value chain and the batteries is well explained in the chart below.

[237] That year, Tesla led the BEV market with a 17% share, followed by BYD at 12%, Wuling at 6%, Volkswagen and Aion each at 4%, and Hyundai, Chery, and Changan each holding 3%.

[238] Statista (2024). "*Electric Vehicles: market data & analysis*" [online]. Available at: https://www.statista.com/study/103895/electric-vehicles-report/ (Accessed 12 August 2024).

[239] Statista (2024). "*Lithium global reserves top countries 2023*" [online]. Available at: https://www.statista.com/statistics/268790/countries-with-the-largest-lithium-reserves-worldwide/ (Accessed 11 August 2024).



Global trade flows for lithium-ion batteries and electric cars, 2023

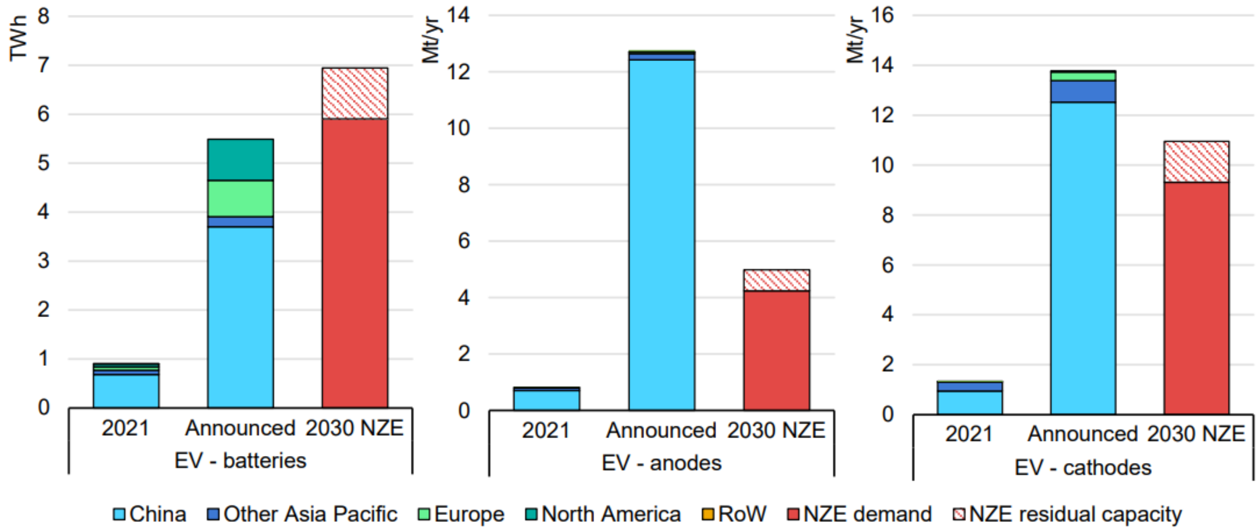
Source: IEA (2024). "*Global EV Outlook 2024"* [online]. Available at https://www.iea.org/reports/global-ev-outlook-2024 (Accessed the 11/08/2024)

More to that, it is fair to say that in 2023, for the first time in its history, China's New Energy Vehicle (NEV) sector operated without the help of governmental subsidies. The same subsidies that have enabled Chinese car manufacturers to grow and acquire considerable global market shares for over ten years. Nevertheless, the tax exemption for EV purchases and non-financial support are still in effect because the automotive sector is one of the primary engines of the country's economic growth.

As it was mentioned, in the US, 1.4 million new EVs were registered in 2023, despite its low numbers compared to China this was a 40% increase *vis-à-vis* 2022. Though there had been early worries that stricter local content standards for EV and battery manufacture may cause immediate bottlenecks or delays, it is fair to say that the additional conditions set by the IRA supported sales in 2023. The same year, 3.2 million new EVs were registered in Europe (2.4 in the EU), a 20% increase from 2022[240]. Among EV markets, the US and EU grew at the quickest rate, reaching over 40% annually; China came in second, at 35%.

[240] IEA (2024). "*Global EV Outlook 2024"* [online]. Paris: OECD Publishing, pp. 18-19. Available at: https://www.iea.org/reports/global-ev-outlook-2024 (Accessed the 11 August 2024).

The surge in EV sales and the geopolitical impact of Russia's invasion of Ukraine have tested the battery supply chain resilience, though production has kept up with demand so far. As highlighted by IEA (2023)[241], China is a dominant force in the EV battery supply chain as it produces two-thirds of the world's battery cells, around 80% of cathode materials and over 90% of anode materials.



Battery and component manufacturing capacity by country/region according to announced projects

Source: IEA (2023), "*Energy Technology Perspectives 2023"* [online]. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024)

Europe - responsible for over a quarter of EV production - holds a minor share of the supply chain, except for cobalt refining concentrated in Belgium and Finland, as seen in the previous chapter. The US has a smaller presence in the global EV battery supply chain, with only about 10% of EV and battery production capacity. Korea and Japan have significant shares in the downstream supply chain, particularly in cathode and anode material production, with Korea accounting for 13% of global cathode production and 3% of anode production, while Japan contributes respectively to 14% and 10%. Both EVs and their batteries are typically produced near their sales markets, with China being the notable exception, as it exports substantial quantities of both over long distances. Imports do supply over 20% of European EV battery demand and more than 30% of US's one. That is because the top five battery manufacturers, located in China, Korea and Japan, control well over 50% of global manufacturing capacity. Within Europe, Poland emerged as the leading battery producer, contributing to the manufacturing of 60% of the region's EV batteries in 2023, followed by Hungary at nearly

241 IEA (2023). "*Energy Technology Perspectives 2023"* [online]. Paris: OECD Publishing, pp. 95-97. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024).

30%. However, China's battery production is more vertically integrated compared to the Western ones' due to its dominant position in the supply chains' upstream stages[242].

The EV battery production capacity exceeds demand, as many factories were built larger than needed in anticipation of future growth. More to that, some companies are still scaling up to full production, a process that can take up to six years. A significant increase in battery supply is needed to speed up the adoption of EVs. According to the NZE Scenario targets, by 2030 around 20% of all vehicles on the road should be electric. Annual EV sales increase implies the simultaneous rise in critical minerals' demand, i.e. lithium's demand by 30% between 2021 and 2030 (as opposed to 6% over the previous five years), 11% for nickel (up from 5%), and 9% for cobalt (up from 8%). The Indo-Pacific area stands to gain the most from EVs' batteries increase in production and mineral requirements; Australia will cover a key position as the country is the world's largest producer of lithium, accounting for more than half of global mined production, as it was seen in the previous chapter. The same occur for Indonesia with nickel, and to a minor extent Philippines and New Caledonia[243].

As mentioned before, China is a dominant force in the EV battery supply chain and in EVs manufacturing, as it can be inferred from the graph below, due to decades of policies to encourage the development of an integrated domestic supply chain, since the sector was believed to be critical in the future. Thus, China now controls a dominant position in virtually every level of the EVs' supply chain, from downstream, i.e. mining, to manufacturing. As it can be recalled from previous chapter, Beijing dispose of more than half of the world's critical mineral refining capacity. More to that, 75% of the world's battery production capacity is found in China, as 70% of cathode and 85% of anode production capacity.

[242] For instance, China's company CATL is the world's leading company and it holds around 15% of the market.

[243] To take advantage of their natural resources' endowment, countries are exploring the idea to start or increase battery production in their countries, e.g. a SOE battery was recently established in Indonesia to increase domestic battery capacity. IEA (2022). *Securing Clean Energy Technology Supply Chains* [online]. Paris: OECD Publishing, p. 8. Available at: https://www.iea.org/reports/securing-clean-energy-technology-supply-chains (Accessed 26 June 2024).

	Cathode (kt)		Anode (kt)		Batteries (GWh)		Electric cars (Millions)
	Production a,b	Capacity a	Production a,b	Capacity a	Production b,c	Capacity c	Production b,d
World	**440**	**1400**	**250**	**810**	**340**	**910**	**6.8**
China	77%	68%	92%	87%	66%	75%	54%
Europe	1%	1%	0%	0%	21%	8%	27%
North America	16%	1%	2%	1%	11%	6%	10%
Other Asia Pacific	5%	26%	7%	13%	2%	10%	7%
Central & South America	0%	0%	0%	0%	0%	0%	0%
Africa	0%	0%	0%	0%	0%	0%	0%
Eurasia	0%	0%	0%	0%	0%	0%	0%
Middle East	0%	0%	0%	0%	0%	0%	0%
Unknown	0%	2%	0%	1%	2%	0%	2%

Manufacturing capacity and production for electric cars and battery components, 2021

Source: IEA (2023), "*Energy Technology Perspectives 2023"* [online]. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024)

However, the IEA (2022)[244] predicts that, in the upcoming years, there will likely be a decrease in the geographic concentration, at least, of the downstream EV battery supply chain. Indeed, it is believed that by the end of this decade, 25% of the world's battery production capacity will be found in Europe and the US, even though China will continue to dominate the manufacturing of anode materials and play a non-negligible role with other EVs' components. As a matter of fact, taking into account the EV battery components' production, announced plans indicate a more than tenfold increase in capacity, surpassing the requirements of the NZE Scenario.

Unlike in upstream sectors, as mining and refining, lead time to build battery manufacturing facilities is shrinking as more and more companies gain the expertise to quickly set up operations. For new entrants, it can take around four years to go from announcing a project to starting production, e.g. Northvolt's in Sweden (2017-2022). However, under optimal conditions, this timeline can be reduced to as little as six months, e.g. CATL's Shanghai plant in late 2021. Nevertheless, the current wave of new projects is largely led by established players, particularly from the Chinese CATL and BYD but the American Tesla and Korean LGES too, which collectively will account for 40% of global

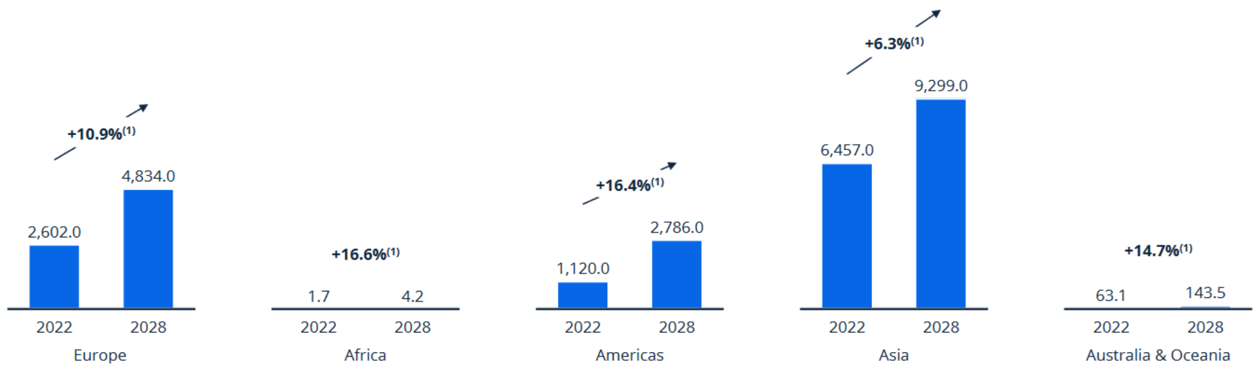
[244] IEA (2022). "*Securing Clean Energy Technology Supply Chains"* [online]. Paris: OECD Publishing, p. 25. Available at: https://www.iea.org/reports/securing-clean-energy-technology-supply-chains (Accessed 26 June 2024).

announced expansions. The geographic spread of planned EV battery manufacturing expansions is more varied than the current capacity distribution, suggesting a decrease in concentration. That is to say Europe and North America's combined share of global EV assembly capacity is expected to rise from 14% in 2021 to 24% by 2025 if all planned expansions proceed as scheduled, while Japan and Korea's share could decline from 8% to 3%.

3.4.3 *Forecasats and policies*

Despite this diversification and the reduced lead times now needed to open new production facilities, China is expected to maintain its dominant position, its global market share remaining around 70%. Europe is the only other region anticipated to increase its market share in cathode and anode production, potentially reaching about 3% of global cathode capacity and 1% for anodes. Other regions' market shares, i.e. Japan and Corea, are expected to decline except for China still foreseen to hold around 90% of the marekt[245].

Even though EV sales are expected to increase further by a 9.82% rate of annual growth, the success of electric cars worldwide will depend on how quickly they catch on in developing countries outside China. The latter accounted for 60% of sales of electric cars in 2023, followed by Europe with 25% and the US with 10%. This indicates that sales of electric models are still more regionally concentrated than those of conventional cars, as it demostrated by the data here below[246]. With a volume of 6.5 million cars, Asia had the biggest market among the selected regions in 2022 and this trend is expected to continue as it can be deduced.



Volume forecast in thousand vehicles

Source: Statista (2024), "*Electric Vehicles: market data & analysis"* [online]. Available at: https://www.statista.com/study/103895/electric-vehicles-report/ (Accessed 1 July 2024)

[245] IEA (2023). "*Energy Technology Perspectives 2023"* [online]. Paris: OECD Publishing, pp. 228-230. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024).

[246] IEA (2024). "*Global EV Outlook 2024"* [online]. Paris: OECD Publishing, p. 11. Available at: https://www.iea.org/reports/global-ev-outlook-2024 (Accessed the 11 August 2024).

A significant boost to the US EVs market was given by the Inflation Reduction Act, which offered substantial incentives for EVs and their components' production, including grants for building new manufacturing capacities, limiting EV purchase incentives to the ones domestically produced. Investments, effect of the IRA policy incentives, are expected to boost North America's battery manufacturing capacity to meet around 80% of the region's projected demand by 2030 under current pledges. North America is currently heavily reling on imports for battery components, importing almost 85% of them. Once all announced expansions for anode and cathode production are completed, North America could produce around 55 kt of anodes and cathodes, up from the 15 kt of 2021, even though this would only cover about 5% of the required capacity to meet all planned battery production[247].

In Europe, battery capacity is rapidly expanding too as automakers ramp up EV production to meet increasing demand, driven by Brussels' CO2 emissions regulations and the mandatory phaseout of ICE vehicles. For instance, Volkswagen targets 240 GWh of manufacturing capacity in the EU while other carmakers as Stellantis, Saft, and Mercedes-Benz have formed a joint venture called ACC, aiming to establish nearly 120 GWh of manufacturing capacity by 2030. Collectively, these initiatives are set to increase European battery manufacturing capacity to over 740 GWh, aligning with the projected regional demand in 2030 if current policy targets are met. The production of battery components in Europe is also on the rise, led by established chemical companies, such as Umicore and BASF. Based on current plans, total cathode manufacturing capacity in the region is expected to reach 340 kt, covering about one-third of Europe's projected demand in 2030 according to government targets[248].

China remains at the heart of the global battery supply chain, following a decade of growth fueled by strong national policies and strategic investments in EV battery value chain. Future growth's primary driver in battery and components production will be China's domestic EV market. CATL, the world's largest battery manufacturer, holds a global market share of one-third and plans to expand its production capacity to nearly 890 GWh, around six-fold increase *vis-à-vis* its 2021 level, the company would, alone, produce as much GWh as EU companies together. Component manufacturing in China is also rapidly expanding, with the country expected to account for 95% of global growth in cathode and anode manufacturing capacity under current plans, benefiting from its access to inexpensive materials and substantial domestic demand[249].

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[247] IEA (2023). "*Energy Technology Perspectives 2023"* [online]. Paris: OECD Publishing, pp. 231-232. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024).
[248] Ibidem.
[249] Ibidem.

Conclusions

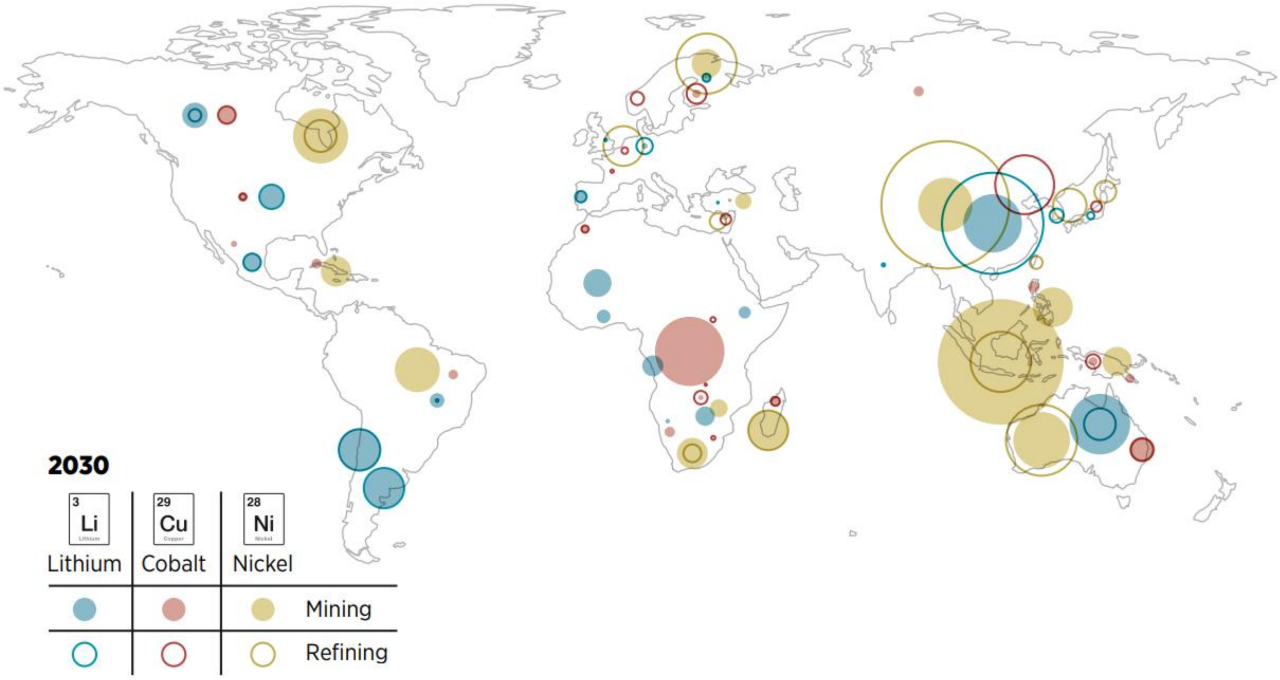
This thesis has dealt with the geopolitical implications of the energy security risks related to the green transition. It has been analysed, throughout a historical perspective, the raw materials and technologies' dependence which resulted in the current balance of power, mostly dominated by China. This thesis aim was to understand if the current concentration of minerals' mining and refining and renewables' manufacturing led to a serious case of geopolitical dependence in which a new energy weapon could be implemented by countries to influence the *status quo*.

In accordance with the IEA (2022)[250] definition, energy security is the "*uninterrupted availability of energy sources at an affordable price*". This concept is of primary importance, especially for European nations which, as highlighted in the first chapter, have seen the energy weapon - may it be with coal, oil or gas - deployed several times to threaten their national energy security. As analysed in the first chapter, the history of energy security, may it be of coal, oil or gas, has highlighted how its two main determinants - diversification of trade partners and political risks of those partners - have been changing energy security dynamics over time. Nowadays, in the 2022 gas crisis following Russian invasion of Ukraine aftermath, this concept has gained renewed prominence. Indeed, as countries, especially Western ones, try to transition away from fossils for both a geopolitical reason, given their high reliance on fuels' import from third countries, and for an ecological one, in accordance with the 2016 Paris Agreement, there are the risk to worsen their position shifting to a new type of dependency.

The rapid increase in renewable energy implementation creates new challenges for energy security. The main risk for Western countries is to shift from a situation of high oil and gas dependency on a restricted number of countries to one of higher dependence over minerals and renewable technologies on one country: China. The thesis analysed three main key aspects of the renewable transition, i.e. minerals' mining and refining and renewables' technology manufacturing, which are directly or indirectly dominated by China. The graph further down shows countries' mining and refining capacities at global level, highlighting Beijing's mining but even more its refining potential. Indeed, as it was analysed in the second and third chapter, China holds the almost totality of the renewables' supply chain. If the Chinese dominance stands around 90% in the critical minerals' global refining capacity and similar numbers are registered for EVs' (electric vehicles) batteries and PV

[250] IEA (2022). "*Securing Clean Energy Technology Supply Chains"* [online]. Paris: OECD Publishing, p.11. Available at: https://www.iea.org/reports/securing-clean-energy-technology-supply-chains (Accessed 26 June 2024).

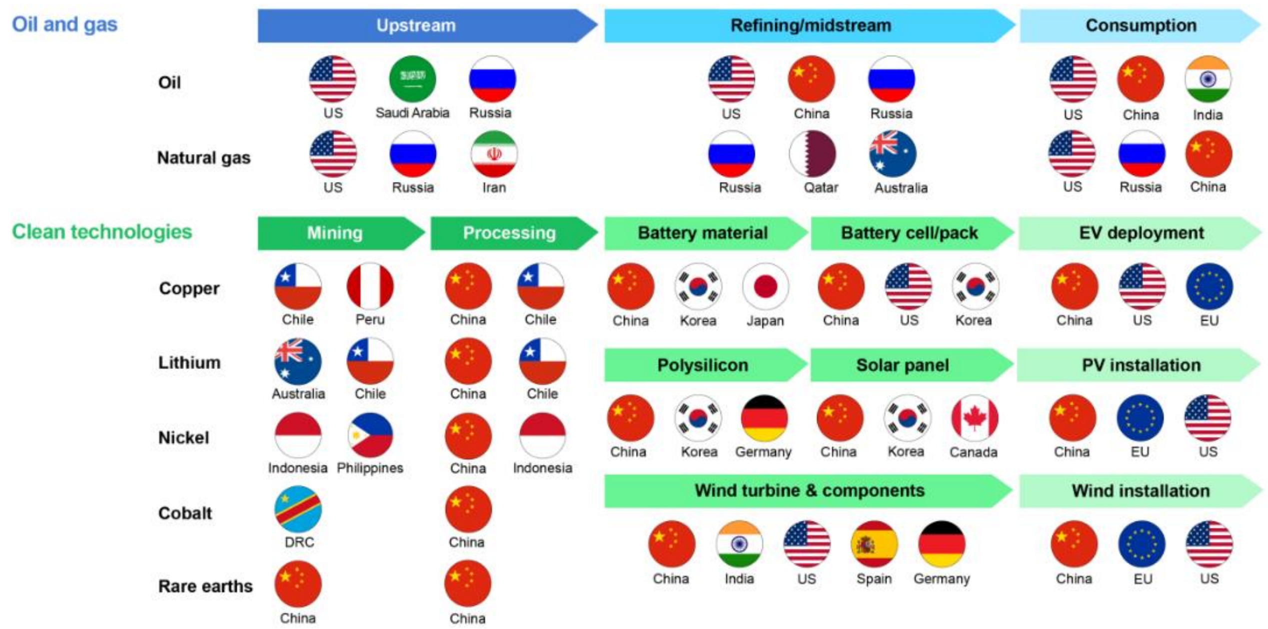
(photovoltaic) panels manufacturing, Beijing indirectly controls large shares of the mining industry, mostly located in South America and Africa, as a result of forward-looking five-year plans. Even though Western countries are seeking to diversify the market, their dependence on Beijing's components in the short and medium term is a fact that will hardly change. The thesis referred to copper, lithium, nickel and cobalt as critical minerals because of their high geographic concentration in few countries and their being essential in renewables manufacturing.



Mining and refining supply forecasts for selected critical minerals by 2030

Source: IRENA (2024), "*Geopolitics of the energy transition: Critical materials*". Available at: https://www.irena.org/Publications/2023/Jul/Geopolitics-of-the-Energy-Transition-Critical-Materials (Accessed 10 July 2024)

It can be deduced, all along the thesis, that renewable energy sources are more secure than fossil fuels by traditional energy security standards as they can access cheap, plentiful energy sources - sun and wind - that are difficult to interrupt. Dependency on imported solar PV panels is not the same as dependency on oil. As it was analysed, a disruption in the latter may cause a delay in the installation of new solar panels, but it wouldn't have an impact on how well the ones that are now in place work. Although mining is necessary for critical materials, an interruption in their supply does not cause an instantaneous scarcity or increase in energy prices, unlike in the case of fossil fuels. Nevertheless, the geopolitics of critical minerals, as it arises from the second chapter, is highly concentrated making the clean technologies' supply chain vulnerable to geopolitical risks. Indeed, currently for the key critical minerals the main three extracting countries account for 45 to 95 % of world's supply and the situation is not foreseen to change. In comparison, Russia, Saudi Arabia, and the US, the major three oil producers, each do not exceed 10% of the world's oil supply, as it can be inferred from the graph below. At the same time, international clean technology supply networks will keep nations highly interconnected. Therefore, moving energy weapons upstream, in the manufacturing of green technologies.



Indicative supply chains of oil and gas selected clean energy technologies

IEA (2021). *"The Role of Critical Minerals in Clean Energy Transitions"* [online]. Paris: OECD Publishing. Available at: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions (Accessed 29 June 2024).

4.1 Public policies to support the green transition

The rapid deployment of clean energy technologies caused an unprecedented level of high critical minerals' demand. On the one hand, recent policies, especially in Western countries, demonstrate the latter intention to diversify their domestic mineral supply, involving import or export limitations. On the other hand, countries endowed with rich mineral resources - e.g. Indonesia and Namibia - enacted legislation to prohibit the export of raw mineral ore. It is therefore evident that an almost nationalist drift has recently occurred. All states that have the opportunity have tries to grab the largest share of the clean energy supply chain. The third chapter stresses out that the achievement and pace of the energy transition, required to attain the NZE Scenario, will not be possible without long-term government policies incorporated into the planning of an overall energy and industrial policy.

It was with the 7th Five-Year Plan (FYP 1986-1990) that China recognised minerals' strategic value for its national economic development, highlighting the need for massive investments in technological research and innovation as well as to speed up production. After more than 20 years of central government financial efforts to establish a strong domestic clean energy sector - which effectively began with the 10th FYP (2001–2005) -, China now controls the vast majority of the renewables' manufacturing capacities as it was inferred by the third chapter. China is almost self-sufficient for bulk resources but it is a significant importer of fossil fuels and critical minerals. Therefore, where domestic subsoil lacked specific minerals, Beijing adopted a "going out" strategy investing in overseas projects. Indeed, as it has been seen in the second chapter, if China is hands down the major refining country worldwide, it is concerned by its dependency on mineral imports. Trying to diversify the latter, Beijing has significantly invested in mining assets and has begun to fund downstream and refining operations abroad in an effort to get strategic access to raw materials. For instance, as it arises from the second chapter, China currently owns or has influence on most Congolese cobalt production.

Beijing clearly recognized the strategic importance of minerals' industry, requiring governmental support, in 2015 with its "*Made in China 2025*" initiative. China now faces several challenges, such as low demand, high proportion of fossil fuels in the country's total energy mix and pressure on the government to maintain large subsidies - in the third chapter were stated the challenges due to the end of PV and wind government-backed supportive policies. Last Five-Year Plan (the 14th one for the 2021-2025 period) has set ambitious targets for solar and wind capacity by 2030, emphasising clean energy and innovations' importance. As it can be inferred from the previous chapters, China's dominant position along the supply chain is not in question and will not change. Major energy agencies such as IEA and IRENA expect Beijing to continue to exercise both a direct power position, such as in the refining and manufacturing of critical minerals and most renewable technologies, and indirect, as in the mining sector. Despite the progressive recent reduction of economic aid to national companies in almost all clean energy supply chain sectors, China will maintain, at least in the medium term, its technological and productive superiority.

Following the 2010 Chinese REEs export restrictions, the US released its first Critical Materials Strategy (2010), a list of the 14 key importance minerals for the country, expanded to 35 soon after. Since then, the US has made critical minerals a key component of its national security and defence plans, emphasising the connection between national and economic security. In 2017, under the Trump administration, the US raised taxes on a number of Chinese-made products in order to accelerate domestic critical mineral resource development through the construction of strong downstream supply manufacturing capabilities and the improvement of recycling. The US renewable energy industrial plan was redesigned in 2022, when the Biden administration adopted the Inflation Reduction Act (IRA), following the Mineral Security Act (2020) and the Infrastructure Investment and Jobs Act (2021) to fund the extraction, refining and research of materials needed for the EV supply chain, such as nickel, lithium, cobalt and REEs. Indeed, as it arises from chapter two, US is a net importer of refined minerals and green technologies. However, as it is showed in chapter three, the US is a net exporter of EVs, making up around 20% of all interregional shipments, mostly due to Tesla. The IRA came into place in this scenario, giving the priority to materials sourced - that is to say extracted, processed or recycled - domestically or from partner countries, creating a context for an acceleration of bilateral trade agreements, facilitating cross-investment in new mines and processing facilities. With a total investment of around $433 billion, the IRA is a historic down payment on deficit reduction to fight inflation and invest in domestic clean energy manufacturing. These strong investments and incentives policies to bring back the manufacturing, in this specific case the production and assembly of renewable technologies, in the US respond to an economy which has re-discovered the relevance of the secondary sector, breaking down that process begun at the end of the 20th century which led industries to move their production facilities to countries where the labour force was cheaper. The US has a great potential in renewable energy manufacturing, as it was previously seen they are among the fastest-growing EV markets, and even more now that promising policies gathered huge investments that will bring back in the country the production of several green technologies.

As it was seen in the second chapter, the EU has been pursuing a critical mineral diplomacy since 2011 when the Raw Materials Strategy was issued through bilateral strategic alliances in the domain of mineral extraction and renewable energy supply chains. These approaches were intensified as a consequence of the 2020 Critical Raw Materials Action Plan (CRMAP). The latter calls for the building of strategic alliances with resource-rich third countries. The same year, the European Commission released proposals to strengthen the security and sustainability of raw material supplies by increasing the number of critical minerals at risk from 14 to 30. Moreover, with the CRMAP, Brussels intends to take advantage of opportunities in European post-mining zones in order to obtain minerals locally; it was foreseen that mines located in the continent, Portugal *in primis*, could satisfy 80% of European lithium needs. Since Brussels is a major importer of renewable energy products such as EV batteries, PV, fossil fuels and minerals, the EU Commission proposed in 2023 the Critical Raw Materials Act, built on the previous 2008 Raw Materials Initiative and the 2020 CRMAP. The act aims to diversify and strengthen EU's capacities from extraction to recycling through the setting of key targets for minerals, i.e. at least 10% extracted, 40% refined and 15% recycled in the EU. The plans and policies outlined above denote Brussels' ambition to create "European champions", i.e. companies large enough to compete in those transition-related technologies on the international market. As it can be deduced from the previous chapters, we are indeed witnessing a fierce competition at international level for the supremacy of the renewable supply chain and, as it can be seen from the Chinese and American policies, other countries do not refrain from pursuing "Green Mercantilism" strategies.

4.2 Minerals' alternatives

There are currently several alternative sources under study and development to reduce countries' dependence on the use of critical minerals - such as lithium, cobalt and nickel . and to address both sustainability and supply's security.

On the one hand, alternative minerals are employed in renewables' technologies composition. For instance, lithium in lithium-ion batteries is being replaced with sodium and magnesium, more abundant in nature and less expensive, and there have been attempts to develop solid-state batteries that use sulphur instead of lithium. Finally, with regards to EV batteries, as mentioned in the third chapter, several companies, are developing cobalt-free LFP (lithium iron phosphate) and NCM (nickel-cobalt-manganese) batteries, aimed at eliminating cobalt in favour of manganese and nickel, both for costs and image reasons - child labour is still widespread in Congolese ASM mines. Despite the strong investment, however, these technologies are still in their early stages.

On the other hand, to increase the supply of raw materials, states are heavily stimulating minerals' recycling through national policies. The latter would, at the same time, allow to tackle pollution and, more importantly, recover those minerals vital for energy transition by reducing imports, therefore geopolitical and geoeconomic dependence from third countries. Despite this, recycling capacity of lithium-ion batteries is still in its nascent stages and mostly concentrated in China, whose capacity is 1.5 times larger than the European one.

Last alternative to limit mineral imports' dependence from third countries is stockpiling. The accumulation of critical minerals acquired on the market is useful to face a crisis and sudden supply chain disruptions but it poses important challenges too. The US has the largest public stockpiles, collected just for defence purposes. Although no reliable data is available on Chinese reserves, it is well known that when prices are low Beijing buys and stores huge quantities of minerals, releasing them when market price increases, making it a powerful influence on global markets. The Critical Raw Material Act does not require stockpiling, even though it promotes national voluntary actions.

Companies frown upon stockpiling obligations as they fear this would put pressure on the already tight supply chains. This was the case in 2010, when Japan built up stocks of REEs amid a crisis that widened them after the embargo, raising the price bubble. Indeed, if not carefully managed, stockpiling can exacerbate market constraints, raise prices and create an uneven energy transition that marginalises the poorest countries and delays climate action.

Nowadays, roughly 80 to 90 % of the world's manufacturing capacity for solar PV, wind, and battery production is shared, although very unevenly as seen in chapter three, by China, US and EU, with the former holding by far the largest share (ranging from 60 to 90 % depending on the component manufacturing); forecasts predict that this concentration is not likely to change until 2030. With the current situation there will be fewer fingers on the trigger as less countries are endowed with a high enough supply chain share to influence other countries. However, China's present leading position in the clean energy market will be hardly overcome by Western countries as the former was developed over decades of governmental support and protectionist policies, which came from a strong basis consisting of a well-established consumer electronics battery sector and a strong regulatory push, with official backing going all the way back to the 10th Five-Year Plan in 2001. Starting in the 2000s, European companies were early movers in many renewable technologies such as PV and wind, as inferred from chapter three, holding almost 90% of these two markets. Western free market was highly beneficial to development of renewable technologies, still in their infant state, but a protected market largely supported by the central government as the Chinese one allowed its dizzying growth. Therefore, it seems that western democracies policymakers acted in a short-sighted manner which led to the current, and future, level of dependence on Beijing even higher than the current one for fossil fuels. It was indeed witnessed a massive transfer of know-how, e.g. in PV manufacturing, from Germany - pioneer investor - to China, whose companies, thanks to massive state funding, have increased mass-production at the expense of their German counterparts. However, the latter established a competitive advantage in specialised productions, Siemens-Gamesa, mentioned in the third chapter with reference to Iberdrola, being an example of those "renewable champions" that the EU aims to create.

Thus, as the first chapter historical examples may show, it is deduced the need of breaking-up the economic and geographic energy sources concentration. There is no mystery saying that Western countries are dependent for the energy transition on China and are now presented with the need to diversify their national energy mix or ending up in the same vicious circle as before with fossil fuels. In this diversification attempt a primary role will be carried out by technological innovations, which, as seen all along the thesis, have the capacity to revolutionise the national energy mix by reducing dependencies over third parties. Disruptive innovation has historically been sparked by resource disruptions and vulnerabilities as a means of "engineering the way out" of geopolitical dependencies or scarcities.

Looking back to past and recent history, it is inferred from the first chapter, which analysed fossil fuels' energy security through coal, oil and gas, that the energy weapon is a very effective tool in the short term. However, it proves to be very damaging for the country enforcing it in the long run, especially if the country lacks a clear monopoly over the resource, as it was for Welsh coal, and a grand strategy. Only if implemented in a tight market a supply production cut could cause prices to substantially increase and hinder importing countries. Indeed, as it was from historical lessons such as the Arab oil blockade or the ban on Russian gas exports, a future embargo of minerals or renewables on the behalf of China would be, in the long term, more detrimental to Beijing than to Western countries. China, even though it has a strong domestic growth and the largest production capacity of renewable energy, as shown in the third chapter, is exhausting its domestic market. The latter is now almost saturated, so the country needs the profitable foreign market, the Western ones' *in primis*. Therefore, even assuming a Chinese embargo this could be successful in the short-term but would irrevocably hinder Beijing's international position. Mineral or renewable technology weapons would harm Western countries, however, the latter would find somewhere else to import minerals, although at a higher price, and upgrade their infrastructures where existing. Therefore, among the challenges which Western democracies will face is access to natural resources. Always from an historical standpoint, the pursuit of critical materials has been a major reason for states seeking territorial expansion, as it was for the British with the Sykes-Picot. Now, global demand for critical materials could lead to increased competition especially in deposit-rich areas, potentially sparking geopolitical tensions in still untapped areas such as the Arctic. The latter, for instance, is known to have vast reserves of critical materials such as nickel and REEs and new deposits are being discovered. Since the Arctic Sea ice is melting at a faster rate than ever before, previously unreachable resources have become available, increasing international competitiveness for the latter. In the struggle for essential resources are emerging as new fronts also the outer space and ocean seabeds, thought to house among the world's greatest mineral reserves, hence the scramble for minerals might potentially lead to geopolitical disputes over these resources.

As it was seen in the first chapter, great powers have strived for fossil fuels control, oil being the predominant example, they will do the same for critical minerals in the future. In the same manner, the resource curse that has been associated with oil - and the other fossils - will be repeated with regard to critical minerals and renewables energy; nations disrupted gas and oil supply as geopolitical weapon to leverage their power, as China did in 2010 with its REEs export ban on Japan, and they will now, with all likelihood, begin to disrupt the supply of electricity, may it be upstream, hindering mineral supply, or downstream, restricting manufactured green technology exports or targeting the domestic infrastructure as the energy grid.

Bibliography

Arrobas, D. L.P., Hund, L. K., Mccormick, S. M., Ningthoujam, J., Drexhage, R. J., (2017). "*The Growing Role of Minerals and Metals for a Low Carbon Future"* [online]. Washington, D.C: The World Bank/International Bank for Reconstruction and Development. Available at: https://documents.worldbank.org/en/publication/documents-reports/documentdetail/207371500386458722/the-growing-role-of-minerals-and-metals-for-a-low-carbon-future (Accessed 6 July 2024).

Barak, O. (2015). "*Outsourcing: Energy and Empire in the age of Coal, 1820–1911"* [online]. International Journal of Middle East Studies. 47(3), 425–445. Available at: doi: 10.1017/s0020743815000483 (Accessed 30 April 2024).

Barak, O. (2020). "*Powering empire: how coal made the Middle East and sparked global carbonization"* [online]. Oakland, California: University of California Press. Available at: https://www.perlego.com/book/1343319/powering-empire-how-coal-made-the-middle-east-and-sparked-global-carbonization-pdf (Accessed 24 April 2024).

Bergquist, A.K., Lindmark, M., (2023). "*Economic history and the political economy of energy transitions: A research overview"* [online]. Uppsala Papers in Economic History, p. 2. Available at: doi: 10.33063/upeh.v2i.576 (Accessed 24 April 2024).

Birol, F., (2023). *"Where things stand in the global energy crisis - one year on"* [online]. Linkedin, February 24th. Available at: https://www.linkedin.com/pulse/where-things-stand-global-energy-crisis-one-year-fatih-birol/ (Accessed 28 May 2024).

Blackburne, A. (2023). "*EU's war response shows Russia can 'never use energy as a weapon' – Ukraine exec"*. Charlottesville: SNL Financial LC.

BP Statistical Review of World Energy 2021 edition [online]. Available at: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf (Accessed 28 May 2024).

Chandler, D. G. (1966). "*The campaigns of Napoleon"*. New York: Macmillan.

Church, C., Crawford, A. (2018). "*Green conflict minerals: the fuels of conflict in the transition to a low-carbon economy"* [online]. Winnipeg: IISD, International Institute for Sustainable Development. Available at: https://www.iisd.org/publications/report/green-conflict-minerals-fuels-conflict-transition-low-carbon-economy (Accessed 5 July 2024).

Chyong, C. K., Henderson, J. (2024). *"Quantifying the economic value of Russian gas in Europe in the aftermath of the 2022 war in Ukraine"*. Energy (Oxford).

de Ridder, M., (2013). "*The geopolitics of mineral resources for renewable energy technologies"* [online]. The Hague: Centre for Strategic Studies. Available at: https://hcss.nl/wp-content/uploads/2013/08/The_Geopolitics_of_Mineral_Resources_for_Renewable_Energy_Technologies.pdf (Accessed 6 July 2024).

DeNovo, J. A. (1955). "*Petroleum and the United States Navy before World War I"*. The Mississippi Valley Historical Review, 41 (4), pp. 641–656.

Ediger, V.Ş., Bowlus, J.V. (2019). *"A Farewell to King Coal: Geopolitics, Energy Security, and the Transition to Oil, 1898–1917"* [online]. The Historical Journal, 62(2), p. 443. doi:10.1017/S0018246x18000109.

ESMAP (2003). "*Removing Obstacles to Cross-Border Oil and Gas Pipelines: Problems and Prospects"*. Washington, DC: UNDP/World Bank, p. 130

European Council (2023). "*EU sanctions against Russia explained"* [WWW online Document]. Available at: https://www.consilium.europa.eu/en/policies/sanctions/restrictive-measures-against-russia-over-ukraine/sanctions-against-russia-explained/ (Accessed 28 May 2024).

Evigail N. (2020), "*5 charts that explain the Saudi Arabia-Russia oil price war so far*" [online], CNBC, 1 April 2020. Available at: https://www.cnbc.com/2020/04/01/5-charts-that-explain-the-saudi-arabia-russia-oil-price-war-so-far.html (Accessed 24 May 2024).

Fischer, C. (2010). "*The Ruhr Crisis 1923-1924"* [online]. Oxford, 2003; Oxford Academic, 1 Jan. 2010, chapter 5. Available at https://doi.org/10.1093/acprof:oso/9780198208006.001.0001 (Accessed 16 April 2024).

FISR 6. *'Material relating to the Oil Commission, The Papers of 1st Lord Fisher of Kilverstone'* [online]. Churchill Archives Centre. Available at https://archivesearch.lib.cam.ac.uk/repositories/9/resources/1562 (Accessed 27 May 2024).

Fraunhofer ISE (2024). "*Photovoltaics Report 2024"* [online]. Fraunhofer Institute for Solar Energy Systems ISE. Available at: https://www.ise.fraunhofer.de/en/publications/studies/photovoltaics-report.html (Accessed 05 August 2024).

Friedman, T. L., (2014). *"A Pump War?"* [online]. The New York Times, October 14, 2014. Available at: https://www.nytimes.com/2014/10/15/opinion/thomas-friedman-a-pump-war.html (Accessed 29 May 2024).

Fulwood M., Sharples J., Stern J., Yafimava K. (2022). "*The curious incident of the Nord Stream gas turbine"*. Oxford Energy Comment.

Gerbet, P. (1956). *La Genèse du Plan Schuman: Des origines à la déclaration du 9 mai 1950*. Revue française de science politique, 6 (3).

Gillingham, J. (1991). "*Coal, Steel, and the Rebirth of Europe, 1945–1955: The Germans and French from Ruhr Conflict to Economic Community"*. Cambridge: Cambridge University Press.

Gray, S. (2017). *"Steam Power and Sea Power"* [online]. Palgrave Macmillan UK. Available at: https://www.perlego.com/book/3482992/steam-power-and-sea-power-coal-the-royal-navy-and-the-british-empire-c-18701914-pdf (Accessed 23 April 2024).

Hafner, M., Tagliapietra, S. (2020). "*The Geopolitics of the Global Energy Transition"* [online]. 1st ed. 2020. Manfred. Hafner & Simone. Tagliapietra (eds.). Cham: Springer Nature. Available at: https://link.springer.com/book/10.1007/978-3-030-39066-2 (Accessed 4 July 2024).

Hartvig, Á. D. (2024). *"The economic and energy security implications of the Russian energy weapon"*. Energy (Oxford).

Henderson, J., (2016). "*Does Russia have a potent gas weapon?".* In: Van de Graaf T., Sovacool B. K., Ghosh A., Kern F., Klare M.T., (2016). "*The palgrave handbook of the international political economy of energy"* [online]. Palgrave handbooks in IPE, London: Palgrave Macmillan UK; 2016, pp. 461–86. http://dx.doi.org/10.1057/978-1-137-55631-8_19 (Accessed 28 May 2024).

Högselius, P. (2013). "*Red gas: Russia and the origins of European energy dependence", 1st edition*. Palgrave Macmillan transnational history series. New York: Palgrave Macmillan.

Holland, J. (1835). "*The history and description of fossil fuel, the collieries, and coal trade of Great Britain"*. London: Whittaker.

Hughes, L., Long, A. (2014). "*Is There an Oil Weapon? Security Implications of Changes in the Structure of the International Oil Market"*. International security, 39 (3).

Hurd, S. A, (1898). *'Coal, Trade, and the Empire'*, in "The Nineteenth Century", November 1898.

IEA (2004). "*World Energy Outlook"* (WEO). Paris: International Energy Agency.

IEA (2005). *"Renewables Information 2005"* [online]. 2005th edn. OECD Publishing, Paris. Available at https://www.oecd-ilibrary.org/energy/renewables-information-2005_renew-2005-en (Accessed 24 August 2024).

IEA (2021). "*The Role of Critical Minerals in Clean Energy Transitions"* [online]. Paris: OECD Publishing. Available at: https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions (Accessed 29 June 2024).

IEA (2022). "*Securing Clean Energy Technology Supply Chains"* [online]. Paris: OECD Publishing. Available at: https://www.iea.org/reports/securing-clean-energy-technology-supply-chains (Accessed 26 June 2024).

IEA (2022). "*Solar PV Global Supply Chains"* [online]. Paris: OECD Publishing. Available at: https://www.iea.org/reports/solar-pv-global-supply-chains (Accessed 10 August 2024).

IEA (2023). "*Critical Minerals Market Review 2023"* [online]. Paris: OECD Publishing. Available at: https://www.iea.org/reports/critical-minerals-market-review-2023 (Accessed 27 June 2024).

IEA (2023). "*Energy Technology Perspectives 2023"* [online]. Paris: OECD Publishing. Available at: https://www.iea.org/reports/energy-technology-perspectives-2023 (Accessed 1 July 2024).

IEA (2024). "*Global EV Outlook 2024"* [online]. Paris: OECD Publishing. Available at: https://www.iea.org/reports/global-ev-outlook-2024 (Accessed the 11 August 2024).

IEA (2024). "*Renewables 2023"* [online]. Paris: OECD Publishing. Available at: https://www.iea.org/reports/renewables-2023 (Accessed 28 June 2024).

IEA (2024). *"Minerals dataset"* [online]. Paris: OECD Publishing. Available at: https://www.iea.org/data-and-statistics/data-product/critical-minerals-dataset (Accessed 12 June 2024).

IEA/Scott R. (2004). "*The History of the International Energy Agency - The First 20 Years: Origins and Structure Volume 1"* [online]. OECD Publishing, Paris. Available at: https://doi.org/10.1787/9789264020931-en (accessed 23 April 2024).

IRENA. (2024). "*Geopolitics of the energy transition: Critical materials"* [online]. Abu Dhabi: IRENA, International Renewable Energy Agency. Available at: https://www.irena.org/Publications/2023/Jul/Geopolitics-of-the-Energy-Transition-Critical-Materials (Accessed 10 July 2024).

Johnson, K. (2014). *"Digging Themselves in Deeper"* [online]. Foreign Policy. Available at: http://www.foreignpolicy.com/articles/2014/04/22/digging-themselves-in-deeper-big-oil-putin-russia (Accessed 22 April 2024).

Joshua R., Itzkowitz S., Miranda P. (2011). *"A Crude Threat: The Limits of an Iranian Missile Campaign against Saudi Arabian Oil",* International Security, Vol. 36, No. 1.

Keohane, R. O., (2001). "*Power and interdependence"*. 3a ed. New York: Longman.

Kissinger, H. (1976). "*The future of America's foreign policy"*, speech, July 6, 1976, Chicago, Illinois. (Washington): U.S. Dept. of State, Bureau of Public Affairs, Office of Media Services.

LaBelle, M.C. (2020). "*Energy cultures: technology, justice, and geo-politics in Eastern Europe"*. Cheltenham, UK: Edward Elgar Publishing, Chapters 3 and 5.

LaBelle, M.C. (2023). "*Energy as a weapon of war: Lessons from 50 years of energy interdependence*". 14 (3).

Lambert, A. (1995). "*The Shield of Empire (1815–1895)*," in Hill, J. R. & Ranft, B. (1995). *"The Oxford illustrated history of the Royal Navy"*. Oxford [England]; Oxford University Press.

Mabro, R. (2007). "*The Oil Weapon: Can It Be Used Today?"* [online]. Harvard International Review, 29(3). Available at: http://www.jstor.org/stable/43650216 (Accessed 1 May 2024).

Maclay to Hankey, (1917). TNA, ADM 116/1804. Cited in Brown, W. M. (2003). "*The Royal Navy's fuel supplies 1898-1939 : the transition from coal to oil*".

Mahan, A. T. (1975). "*Letters and papers of Alfred Thayer Mahan"*. Annapolis: Naval Institute Press.

Mikulska, A., Finley, M. (2024). *"Asymmetric Interdependence and Wielding the Energy Weapon: Russia and the EU post Russian Invasion of Ukraine",* Current sustainable/renewable energy reports.

Mills R. (2020). *"The Geopolitics of the Global Energy Transition in MENA",* in Lecture Notes in Energy book series (LNEN), volume 73.

Nastassia, A., Neil., H., (2022). *"Gas prices soar after Gazprom halts supplies to Poland and Bulgaria"* [online]. Financial Times 2022. Available at: https://www.ft.com/content/f7945d42-9cbc-401c-939b-c331f4f359a2 (Accessed 23 May 2024).

Newbolt, S. H. J. (1921). "*Poems New and Old: By Henry Newbolt"*. London: John Murray.

Offshore wind (2024). "*Iberdrola Greenlights Its Third Offshore Wind Project in German Baltic Sea"* [online]. Available at: https://www.offshorewind.biz/2024/06/27/iberdrola-greenlights-its-third-offshore-wind-project-in-german-baltic-sea/ (Accessed 08 August 2024).

Ostrowski, W. (2022). "*The twenty Years' crisis of European energy security: central and Eastern Europe and the US*. Geopolitics" [online]. 27, pp. 875–897. Available at: https://doi.org/10.1080/14650045.2020.1835863, (Accessed 28 May 2024).

Paust, J. J., Blaustein, A. P. (1974). *“The Arab Oil Weapon-A Threat to International Peace”* [online]. The American Journal of International Law, 68(3). Available at: https://doi.org/10.2307/2200513 (Accessed 29 May 2024).

Podobnik, B. (2006). “*Global energy shifts: Fostering sustainability in a turbulent age”*. Philadelphia, PA: Temple University Press.

Posen, B. R., (2003). *“Command of the Commons: The Military Foundation of U.S. Hegemony”,* International Security, Vol. 28, No. 1 (Summer 2003).

Press, E., Popkostova, Y., Van de Graaf, T., Rath, E., Tagoe, G. (2024). “*Geopolitics of the energy transition: Energy security”* [online]. Abu Dhabi: IRENA, International Renewable Energy Agency. Available at: https://biblio.ugent.be/publication/01HYDAZA0ZH8KQNSNWYPV0D9SC (Accessed 9 July 2024).

Press, E., Popkostova, Y., Van de Graaf, T., Rath, E., Tagoe, G. (2024). “*Geopolitics of the energy transition: Energy security”* [online]. Abu Dhabi: IRENA, International Renewable Energy Agency. Available at: https://biblio.ugent.be/publication/01HYDAZA0ZH8KQNSNWYPV0D9SC (Accessed 9 July 2024).

Reuters (2022). *“Gazprom to cut gas supplies to Denmark’s Orsted, Germany via Shell deal”*. Reuters 2022. Available at : URL-https://www.reuters.com/business/energy/gazprom-cut-gas-supplies-denmarks-orsted-germany-under-shell-deal-2022-05-31/ (Accessed 29 April 2024).

Reuters (2023). “*Turkey’s ruling party presents gas reform in step towards trading hub”*. Reuters.

Rjean, R. J. (2020) *“Continental Resources’ Harold Hamm leads effort to pursue anti-dumping case against Saudia Arabia, Russia”* [online]. Wilson Harold, March 11, 2020. Available at: https://www.willistonherald.com/news/oil_and_energy/continental-resources-harold-hamm-leads-effort-to-pursue-anti-dumping/article_5afe9df6-63ea-11ea-a4ff-a7a2717b6339.html (Accessed 29 April 2024).

Singer, C. (2008). “*Energy And International War: From Babylon To Baghdad And Beyond”* [online]. World Scientific Publishing Company. Available at: https://www.perlego.com/book/847027/energy-and-international-war-from-babylon-to-baghdad-and-beyond-from-babylon-to-baghdad-and-beyond-pdf (Accessed 27 April 2024).

Singh, A. K. (2020). “*The “Oil War” of 2020 Between Saudi Arabia and Russia: Examining the Underlying Geopolitical and Geoeconomic Compulsions*”. Indian journal of Asian affairs. 33 (1/2).

Squier, G. O. (1901). “*The Influence of Submarine Cables upon Military and Naval Supremacy*”. Vol. XII.

Statista (2023). “*Global installed wind energy capacity 2023”* [online]. Available at: https://www.statista.com/statistics/268363/installed-wind-power-capacity-worldwide/ (Accessed 08 August 2024).

Statista (2024). “*Electric Vehicles: market data & analysis”* [online]. Available at: https://www.statista.com/study/103895/electric-vehicles-report/ (Accessed 12 August 2024).

Statista (2024). “*Lithium global reserves top countries 2023”* [online]. Available at: https://www.statista.com/statistics/268790/countries-with-the-largest-lithium-reserves-worldwide/ (Accessed 11 August 2024).

Statista, (2024). “*Annual cobalt refinery capacity by country”* [online]. Available at: https://www.statista.com/statistics/339798/annual-cobalt-refinery-capacity-by-country/ (Accessed 21 July 2024).

Statista, (2024). “C*obalt mine production by country”* [online]. Available at: https://www.statista.com/statistics/264928/cobalt-mine-production-by-country/ (Accessed 21 July 2024).

Statista, (2024). “C*opper mining industry worldwide”* [online]. Available at: https://www.statista.com/topics/1409/copper/#editorsPicks (Accessed 20 July 2024).

Statista, (2024). "*Countries with the largest production output of lithium*" [online]. Available at: https://www.statista.com/statistics/268789/countries-with-the-largest-production-output-of-lithium/ (Accessed 22 July 2024).

Statista, (2024). "*Distribution of world lithium mineral production by producer*" [online]. Available at: https://www.statista.com/statistics/606799/distribution-of-world-lithiuim-mineral-production-by-producer/ (Accessed 22 July 2024).

Statista, (2024). "*Global cobalt reserves*" [online]. Available at: https://www.statista.com/statistics/264930/global-cobalt-reserves/ (Accessed 21 July 2024).

Statista, (2024). "*Global lithium outlook*" [online]. Available at: https://www.statista.com/topics/3217/lithium/#topicOverview (Accessed 22 July 2024).

Statista, (2024). "*Nickel production by country*" [online]. Available at: https://www.statista.com/statistics/264642/nickel-mine-production-by-country/ (Accessed 24 July 2024).

Statista, (2024). "*Nickel reserves worldwide by country*" [online]. Available at: https://www.statista.com/statistics/273634/nickel-reserves-worldwide-by-country/ (Accessed 24 July 2024).

Statista, (2024). "*Projected total demand for lithium globally* [online]. Available at: https://www.statista.com/statistics/452025/projected-total-demand-for-lithium-globally/ (Accessed 22 July 2024).

Stulberg, A. N. (2015). *"Out of Gas?: Russia, Ukraine, Europe, and the Changing Geopolitics of Natural Gas. Problems of post-communism"*. 62 (2).

Sudakov (2014). *"Obama wants Saudi Arabia to destroy Russian economy"* [online]. Pravda, 3 April 2014. Available at: https://www.pravdareport.com/world/127254-saudi_arabia_russia_obama/# (accessed 9 May 2024).

The Economist, (2021). "*People may one day drill for copper as they now drill for oil*" [online]. London: The Economist. Available at: https://www.economist.com/science-and-technology/2021/07/07/people-may-one-day-drill-for-copper-as-they-now-drill-for-oil (Accessed 11 July 2024).

The Economist, (2022). "*How the world depends on small cobalt miners*" [online]. London: The Economist. Available at: https://www-economist-com.mutex.gmu.edu/middle-east-and-africa/2022/07/05/how-the-world-depends-on-small-cobalt-miners (Accessed 11 July 2024).

The Economist, (2023). "*Cobalt, a crucial battery material, is suddenly superabundant*" [online]. London: The Economist. Available at: https://www-economist-com.mutex.gmu.edu/finance-and-economics/2023/02/16/cobalt-a-crucial-battery-material-is-suddenly-superabundant (Accessed 12 July 2024).

The Economist, (2023). "*Copper is the missing ingredient of the energy transition* [online]". London: The Economist. Available at: https://www-economist-com.mutex.gmu.edu/business/2023/03/30/copper-is-the-missing-ingredient-of-the-energy-transition (Accessed 11 July 2024).

The Economist, (2023). "*The green revolution will stall without Latin America's lithium*" [online]. London: The Economist. Available at: https://www-economist-com.mutex.gmu.edu/the-americas/2023/05/02/the-green-revolution-will-stall-without-latin-americas-lithium (Accessed 12 July 2024).

Van de Graaf, T., Colgan, J. D., (2017). "*Russian gas games or well-oiled conflict? Energy security and the 2014 Ukraine crisis*" [online]. Energy Res. Soc. Sci. 2017. Available at: https://www.sciencedirect.com/science/article/pii/S2214629616303218 (Accessed 28 May 2024).

Victor, D.G., Jaffe, A.M. and Hayes, M.H. (2006). "*Natural Gas and Geopolitics: From 1970 to 2040*". Cambridge: Cambridge University Press.

Wilson, A. (2005). "*Ukraine's Orange Revolution*". (New Haven): Yale University Press.

Xiao, A. (2015). "*The Geopolitics of Oil Prices: Analyzing the Effects of Production and Invesment on Global Oil Prices"* [online]. Harvard International Review, 36(4). Available at: http://www.jstor.org/stable/43649315 (Accessed 6 May 2024).

Yergin, D. (1991). "*The prize: the epic quest for oil, money, and power"*. New York: Simon and Schuster.

Zurcher, A. (2014). *"Is the oil crash a secret US war on Russia?"* [online]. BBC, October 16, 2014. Available at: https://www.bbc.com/news/blogs-echochambers-29651742 (Accessed 3 May 2024).