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# The EU's China challenge: Rethinking offshore wind and electrolysis strategy

## The current and future role of China in the wind energy and electrolyser supply chains

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# Summary

A fast energy transition is essential for Europe to meet its ambitious climate targets. China has a crucial role in many of the key technologies that are essential for the energy transition (like solar photovoltaics). Rising geopolitical tensions have highlighted the need to achieve a better understanding of the position of China in key value chains and the geoeconomic risks stemming from China in strategic value chains. The knowledge about the role of China in wind energy and electrolyser value chains is limited in the Netherlands and in the EU. As a result, it is hard to assess the level of risks associated with the central role of China and to formulate policy to mitigate these risks.

The aim of this study is to:
- provide a thorough understanding of the past, current and possible future supply chains of offshore wind energy and electrolysis, with a specific focus on China;
- provide policy recommendations on international cooperation and future organisation of international competition for the supply chains of offshore wind energy and electrolysis.

For this study TNO has conducted desk research on the supply chains for offshore wind and electrolysis in the Netherlands, the EU and China in 2020 and 2023. Expected developments for the coming 5 years have also been analysed. The study focused on key components and suppliers. For offshore wind these are the key components for the wind turbine (the blades, nacelle and tower), the foundation and electrical components (Figure 1). Key suppliers also include Original Equipment Manufacturers (OEM's) that design and assemble final products from the various components. For electrolysis the focus was on key components for the stack (e.g. membranes and electrodes, see Figure 2) and the electrolysis plant. Other relevant players are the assemblers of stacks from separate components and system integrators for the whole electrolyser plant. While dependencies on critical raw materials were not the core focus of the study, they have been included where relevant. The desk research has been supplemented by 15 interviews with researchers, civil servants and professionals active in the offshore wind and electrolysis supply chains in the EU and in China.

HCSS has conducted an assessment of the geo-economic risks. TNO and HCSS jointly used the HCSS Strategic Dependence Risk Framework to assess the impact and the probability of supply chain disruptions. (Teer, A. De Ruijter, & Rademaker, 2024) They applied this framework to assess the geopolitical risk levels of dependence on China in the offshore wind and electrolysis value chains. The findings of the HCSS geo-economic risk assessment (in chapter 3) are based on a combination of sources. First, the chapter leverages the value chain analysis and projections for 2028 presented in the previous chapter. In addition, it draws on past HCSS research and additional desk research of primary sources, namely CCP leadership speeches and industrial strategies, and secondary sources, such as thinktank reports on China's macro-economic goals. In addition, it cites a previously conducted HCSS-quantitative discourse analysis on CCP leadership's perceptions on the degree of international opposition to its rise. The probability assessment on how likely the latter five risks are to occur in the next five years was arrived at on the basis of two workshops with TNO-researchers. During a third HCSS internal workshop,

participants used the HCSS Strategic Dependence Risk Framework to reach their conclusions.[1] The same framework was used in the TNO chapter to assess the impact of disruptions in the supply of wind energy and electrolysis components and end-products from China to the Netherlands and the EU.

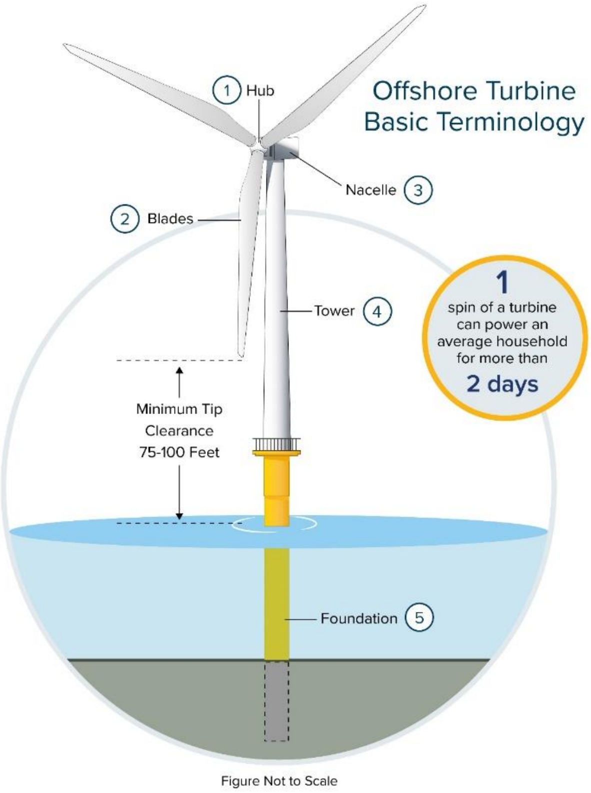



Figure 1: Schematic overview of an offshore wind turbine (Nyserda, 2024)

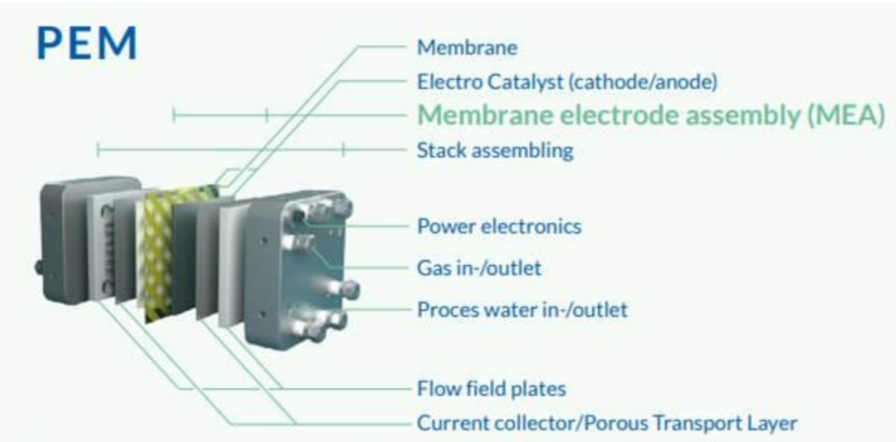



Figure 2 A schematic overview of PEM, showing the stack components (incl. the membrane and electrodes) and the stack assembly. (TNO, 2023)

[1] The development of this risk assessment framework was commissioned by the Netherlands Ministry of Economic Affairs and Climate (MinEZK). The risk assessment framework was designed by Joris Teer, Abe de Ruijter and Michel Rademaker (HCSS). (Teer, A. De Ruijter, & Rademaker, 2024)

### Main findings market dynamics

In the past few years China has become a world leader in offshore wind and alkaline water electrolyser technology, one of the two main electrolyser technologies. The leading position is developed to achieve greater autonomy in what China's government considers key strategic technologies. Currently, the dependence in the Netherlands and the EU on Chinese suppliers in the value chain is limited, except for a near-total dependence on China for specific critical raw materials for offshore wind. It is likely that Chinese companies will continue to develop a key position in the global offshore wind and (alkaline) electrolysis value chains in the next 5 years. As a result, the dependence of the Netherlands and the EU on China for these two key technologies can increase in the coming years, especially if European wind turbine and electrolyser producers cannot maintain their competitive position in Europe. A risk that gained attention in 2023 when the two main wind turbine manufacturers in Europe faced significant financial losses, showing the vulnerability of the offshore wind supply chain in Europe.

European players can be protected from unfair competition from Chinese manufacturers by excluding or limiting Chinese companies from European offshore wind and electrolysis markets, but there will be a cost. Excluding the significant production capacities in China can strain European supply chains and limit the speed at which the energy transition can be realised. It is important to navigate strategically, fostering collaboration where we responsibly can and, at the same time, maintaining strategic independence.

### Market dynamics offshore wind – past & future

In recent years China has become a world leader in the development of offshore wind technology, producing high capacity wind turbines and low-cost components. There is no consensus on the quality, but we expect it to be equal to or not far behind the quality of Western turbines. China is expected to become even more dominant in the global offshore wind market in the next 5 years.

Both the EU and China have strong local supply chains for offshore wind, but China is dominant in global supply chains for many key components. Currently, the EU's main area of dependence on China is in permanent magnets and on the rare earth mining, refining and processing and permanent magnet-making required to make these magnets. China's wind energy sector is mostly self-sufficient, but also still imports some key components (e.g. roller bearings, some power electronics and equipment for offshore installation). China's strategy is to also reduce these dependencies and strengthen their autonomy.

At the same time, Chinese companies are looking to expand their presence in Europe, all across the offshore wind value chain, which leads to unfair economic competition and subsequently to economic security risks. There are only two main offshore wind turbine suppliers in the EU: Vestas MHI and Siemens Gamesa. These companies have faced financial troubles in recent years. Yet offshore wind will already be an important part of the energy mix in the Netherlands by 2030. In addition, offshore wind will be of great importance for the energy transition throughout the EU. China's growing focus on exporting turbines and components poses an economic security challenge. The EU and the Netherlands' overall dependence on China is likely to greatly increase if the European wind turbine suppliers do not survive their current financial issues. The only other offshore wind turbine producing country (albeit with far less capacity) is the US, limiting options for diversification away from Chinese suppliers in such a scenario.

### Market dynamics electrolysers – past & future

In recent years, the global electrolyser market has grown fast due to ambitious government plans anticipating a large increase in global demand for renewable hydrogen and electrolysis to produce the hydrogen. However, the future of the electrolyser supplier market is uncertain, as the global supply chain is still in an early stage of development. It is not yet clear if there will be a limited number of dominant global player(s) or more regional players, and if so, who these might be. The market landscape is evolving rapidly. China, currently world leading in expanding electrolyser manufacturing capacity, followed by Europe, is taking big steps in terms of business and innovation.

Out of the two main electrolyser types included in the scope of this report (alkaline and PEM) China prefers alkaline electrolysis because of its simplicity and cost-effectiveness. In line with their national strategy to create greater self-sufficiency, China has developed the complete supply chain domestically (or in other words a completely 'vertically-integrated' supply chain). The demand for Proton Exchange Membrane (PEM) electrolysers is smaller in China due to its higher costs. Even though China is often described as a 'black box' of which it is hard to tell what is exactly going on, it is evident that both the market and research for electrolysis are developing fast.

The EU, on the other hand, embraces both PEM and alkaline technologies, valuing PEM for its technical advantages, mainly better compatibility with variable electricity input from renewable sources such as solar PV and wind energy. Europe also leads on the development of high temperature Solid Oxide Electrolysers (SOE). This type is not the focus of this report due to the lower current Technology Readiness Level (TRL). European companies are willing to pay more for the technical benefits of PEM and for more efficient electrolysers due to high electricity prices. In China low upfront costs are prioritised as lower electricity prices make increased efficiency less relevant for the overall cost of hydrogen. Moreover, Europe stands out for the safety and quality of electrolysers and their components, in accordance with European legislation. The main current external dependence in the electrolysis supply chain is in iridium, a material deemed 'critical' by the EU and used in PEM electrolysers. Iridium is mostly mined in South Africa.

There is currently some, but limited trade in electrolyser components between Europe and China. Additionally, there are some collaborations between European and Chinese companies. Chinese companies are also in the process of establishing a (manufacturing) base in Europe.

For Chinese companies to export to Europe, it is crucial to close the gap in quality, efficiency and safety. On the basis of expert interviews, it is expected that it will take 1-2 years for China to meet the quality and safety requirements that European companies are already required to meet. This will (potentially) enable Chinese companies to export to Europe on a large scale. Conversely, European companies are facing challenges in China, due to a preference for domestic companies. These trends are likely to persist, leading to an unlevel playing field, and a dominant position for China.

### Geo-economic risk assessment

Geopolitical risks associated with a dependence on China in (future) vital sectors such as wind energy and electrolysis value chains, at present and for the next five years, ought to be assessed carefully. International value chains should be seen in a geopolitical context, namely that of intensifying great power rivalry at a time of deep economic interconnectedness (see section 3.1). In addition, taking stock of Beijing's national aims and industrial policies is vital to come to a risk assessment. Specifically, concepts from weaponised interdependence theory such as *chokepoints* and *breaking points* and the study of China's key national strategies such as *Made in China 2025* and *the new development philosophy* are helpful to assess risks. After all, throughout the last decade great powers have increasingly sought to deter, compel or corrode the capabilities of rivals by leveraging control over (economic) chokepoints in the world economy. Not coincidentally, throughout the last twelve years, the Chinese Communist Party (CCP) under Xi Jinping has moved its focus from economic development and rapid integration into the world economy to fostering greater economic self-reliance. Likewise, Xi explicitly seeks to enhance dependence of other countries on China.

This report's taxonomy of ten different geo-economic risks stemming from China in electrolysis and wind energy value chains provides insight into the geopolitical risks associated with dependence on China, now and in the next five years (see Section 3.2 and Table 1.1). The taxonomy's aim is not to be exhaustive, but to outline the main geo-economic risks that materialise at different levels of escalation of EU-China tensions. Risks can be divided in two categories. First, the taxonomy presents market-distorting actions the Chinese state has resorted to structurally, such as risk 1 ("restrictions for EU companies on China's market") and risk 4 ("theft of EU intellectual property"). These measures aim to strengthen the position of domestic firms, expand China's self-reliance, and deepen dependence of the EU on China. These first five geo-economic risks have already materialised in wind energy, "new energy", "advanced energy equipment" or in another priority industry identified in Made in China 2025 and the $14^{th}$ Five-Year Plan. These measures structurally endanger the future (financial) success of EU companies (see Table 1.1). As tensions continue to rise, Beijing may well intensify its protectionist policies in the future.

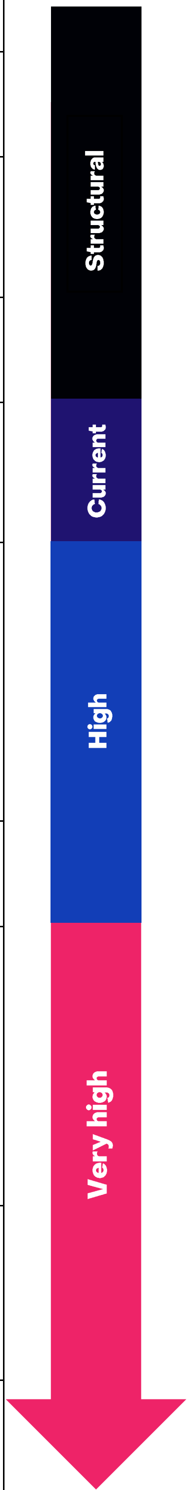
Second, the taxonomy outlines five geo-economic risks that may materialise in the (near) future. Two of these risks, namely risk 7 ("commercial monopolistic practices") and risk 9 ("a ban on exports of vital end-products to the EU") can only occur in the 2028 negative scenario, meaning a scenario when Chinese parties have become the sole remaining suppliers of important wind energy and electrolysis components and end-products (see Table 1.1). In this scenario, European OEMs have not survived their current financial difficulties by 2028. Chinese companies are left as the main competitive parties with high production capacity in global wind energy and electrolysis markets. In addition, the disruption if risk 8 ("an expansion of increasingly effective cyber-attacks against vital infrastructure") or risk 10 ("war-related disruption to China's production lines and supply routes between Europe and Asia") materialises will be far more severe if Chinese companies are the main remaining players in offshore wind and electrolysis markets. All of the latter five risks are increasingly likely to occur, when China-US and by extension China-EU tensions continue to rise (in line with the relationship's trajectory of the past decade). Especially at a time of military-strategic crisis, these risks become suddenly, possibly entirely without warning, far more likely to materialise.

The risk of becoming strategically dependent in wind energy and electrolysis value chains on China differs from the risk of becoming dependent on other third countries. In the next five years, only Chinese parties have the production capacity to become dominant in the EU wind energy sector. The future of electrolysis is more uncertain. China is likely to have become an important player by 2030, but the complexity of electrolyser systems and related transportation challenges could make it harder for China to become dominant in a short time. This is also the case for other states that are geographically far away from the EU.

Table 1.1: Taxonomy of geoeconomic risks stemming from China in strategic value chains

*(see next page)*

| Risk for the EU | China aims | Timing | Level EU-China escalation |
|---|---|---|---|
| 1. Restrictions for EU companies on China's market | Strengthen position of Chinese firms, in order to expand self-reliance and increase dependence of EU on China | Structural / Ongoing / In place for over a decade | |
| 2. State-subsidised Chinese competition on the EU market | Strengthen position of Chinese firms: increase dependence of EU on China | Structural / Ongoing | |
| 3. (State-supported) acquisition of EU companies and Intellectual Property | Strengthen position of Chinese firms: expand self-reliance and increase dependence of EU on China | Ongoing | |
| 4. Theft of EU Intellectual Property | Strengthen position of Chinese firms: expand self-reliance and increase dependence of EU on China | Structural / Ongoing | |
| 5. Export bans on technologies required to produce essential components | Strengthen position of Chinese firms: maintain dependence of EU on China; lock-in China's technological advantages | Ongoing / accelerated in 2023 | |
| 6. Ban on exports of essential materials and components | Strengthen position of Chinese firms; Disrupt production of EU-competitors (potentially fatally); Expand dependence of EU on China; Compelling and deterring the Netherlands and the EU from acting against China's "core interests"; Corroding EU abilities to act against China's "core interests" | Legislation in place to initiate export ban for some materials / Possible today; especially at moments of rising CN-EU tensions / Likely if a military crisis takes place in East Asia | |
| 7. Commercial monopolistic practices | Strengthen position of Chinese firms by increasing revenues and profits | Possible if China becomes the sole remaining dominant producer of end-products (2028 negative scenario) | |
| 8. Expansion of increasingly effective cyber-attacks against vital infrastructure | Compelling and deterring the Netherlands and the EU from acting against China's "core interests"; corroding EU abilities to act against China's "core interests"; Gathering intelligence/nesting in EU-NL systems in preparation for a large-scale attack at later moment | Possible if China becomes the sole remaining dominant producer of complex components and end-products (2028 negative scenario) / Likely at moments of high CN-EU tensions | |
| 9. Ban on export of vital end-products | Compelling and deterring the Netherlands and the EU from acting against China's "core interests"; Corroding EU abilities to act against China's "core interests" | Possible if China becomes the remaining dominant producer of end-products (2028 negative scenario) / Likely if a military crisis takes place in East Asia | |
| 10. War-related disruption to China's production lines and supply routes between Europe and Asia | Winning a regional conflict against Taiwan, Japan, the Philippines and possibly the United States. Prioritising key supplies and materials (e.g., steel) and personnel (e.g., factory workers) to defence industries and the war effort. | Especially high-impact if China becomes the remaining dominant producer of end-products (2028 negative scenario) / Possibly the direct result of a military crisis in East Asia | |



In conclusion, the current lack of a level playing field in trade relations with China (risk 1 until 5) forces a 'losing game' on the EU. Through additional subsidies, tax breaks, IP-theft and 'locking-in' technologies that China monopolises, the Chinese government aims to continue the growth of China's strategic manufacturing industries as fast as possible. Whilst China has access to the EU's open market, it keeps its own market closed. Important to note is that this is not just an economic strategy; it stems from the CCP's broader national security strategy to achieve greater self-reliance and to expand dependence of the rest of the world on China.

This leaves the EU with two unattractive options. The first is to bear the costs of raising barriers to China. That is, domestically developing wind energy and electrolysis industries to maintain an independent position. This would include deploying similar market stimulating mechanisms as China does, which are likely to be costly for taxpayers. This also means closing-off markets for cheaper Chinese alternatives that may benefit EU energy consumers and make the green transition cheaper.

The second option is to face the energy and national security risks that come with increased Chinese market dominance in another vital sector. This involves accepting new high-risk strategic dependencies, likely including for complex components and sensitive end-products supplied by Chinese companies. Considering the current financial difficulties of EU players in the wind industry already face, choosing this option may threaten their survival and hurt EU manufacturing and maritime industries, and European earning and manufacturing capacity more broadly. Finally, a dominant position of Chinese suppliers on the EU market goes hand-in-hand with four economic and national security risks (threats 6 until 10), including more severe cyber security risks (see Table 3.). In the 2028 negative scenario, if tensions in East Asia escalate, China may suddenly and without warning become unable or unwilling to supply the EU with important components and end-products for its energy security.

How to navigate these strategic challenges

Based on the analysis above, we arrive at the following policy recommendations:

- **Restrict market access in the EU for Chinese parties.** Trade with China should take place in a level-playing field. Based on China's national aims and current industrial policies it is unlikely that China will open up their market further for EU parties. Chinese companies do not face the same restrictions in the EU that EU companies face in China. A level playing-field can therefore only be achieved by restricting market access for Chinese parties
- **Consider increasing non-financial requirements in public procurement** like safety, efficiency, circularity and ESG-criteria ($CO_2$ footprint, labour conditions, circular policies). It is unlikely that EU companies can remain competitive on cost with Chinese manufacturers. Increasing non-financial requirements in procurement may improve the position of EU players as these are areas where the EU players have a stronger position. However, ESG-criteria should not lead to the blocking of the imports of raw materials for which the EU and member-states have a high level of dependence on specific non-democratic countries in the Global South, as this would be a negative side-effect and create new supply chain bottlenecks.
- **More often exclude Chinese manufacturers of complex / vital end products**, such as complete wind turbines, **from projects, based on energy and national security considerations.** As geopolitical tensions rise and the offshore wind and electrolysis become more important in the energy mix, the position of Chinese manufacturers in projects needs to be reconsidered. Particularly the operation of installations needs to be protected, as these installations are essential parts of the European energy system and energy supply. Encouraging (through financial incentives) the use of non-Chinese end-products and components can also contribute to alleviate current dependencies on China in offshore wind. For instance, rewarding the use of components and materials

produced outside of China in tenders can bring online EU or allied rare-earth mining, refining and permanent magnet making. The Netherlands and the EU can also consider introducing a list of “foreign entities of concern” as the US does.

- **Cooperation with China on technology development can accelerate the energy transition, but be aware of unwanted technology transfer.** As China takes a leading global role in offshore wind and (alkaline) electrolysis development, it is also expected to contribute more on innovation. Without collaboration, the EU could fall behind in innovation in these sectors. However, any collaboration of knowledge exchange with China should be approached carefully in order to protect European interests, innovation and intellectual property.
- **Protect and expand the European offshore wind and electrolysis industries.** In some parts of the supply chains, the number of key players in Europe is limited. If some of these players do not survive, the European value chain can quickly become strained and overly reliant on China. Existing industry needs to be protected and strengthened in order to maintain a strong position in Europe. Offshore wind and electrolysis manufacturing industries in the EU need to be expanded to maintain a strong value chain, as demand will continue to increase.
- **Keep developing alternative and next generation offshore wind and electrolysis technologies.** Dependencies on existing supply chains can be mitigated by developing alternative technologies with value chains that can more easily be localised. For example, current offshore wind designs rely on permanent magnets made with rare earth elements and therefore create a dependence on China, where most of the required rare earth materials are processed. It is possible to reduce the dependence on permanent magnets by changing the generator design by using a gearbox instead. Alternatives such as this should be developed to reduce strategic dependencies, or at least be developed to such a level that they can quickly be deployed when required.
- **Collaborate with EU member-states, other trusted partners and neutral parties to ensure the availability of sufficient alternatives to Chinese wind turbines and electrolysers.** There are currently limited alternative suppliers for offshore wind and electrolysis. The US is an important player, with a large offshore wind OEM and a key position in PEM electrolysis. Other countries, like India, are developing domestic supply chains. Collaboration with these parties creates a larger set of alternatives and makes it possible to more quickly go to alternatives if supply disruptions occur.

# Contents

# 1 Introduction

## 1.1 Context

A fast energy transition is essential for Europe to meet its ambitious climate targets as set out in the European Green Deal and to contribute to limiting global warming to 2.0 °C, ideally 1.5 °C, as set out in the Paris Agreement. The energy transition is also vital to reducing the EU's dependence on the imports of fossil energy and achieve the targets in the REPowerEU Plan (European Commission, 2022) and Net-Zero Industry Act (European Commission, 2023).

China has a crucial role in many of the key technologies that are essential for the energy transition, with over 90% of manufacturing capacity for some key technologies and components (see Figure 1.1). The EU's extreme dependence on China for solar PV and rare earth elements is well known. Yet the knowledge about the role of China in wind energy and electrolyser value chains is limited in the Netherlands and in the EU. As a result, it is hard to assess the level of risks associated with the central role of China and to formulate policy to mitigate these risks.

Rising geopolitical tensions have highlighted the need to achieve a better understanding of the position of China in key value chains and the geoeconomic risks stemming from China in strategic value chains. In a world of deep economic interdependence and where great power competition has returned, states increasingly exert political pressure by leveraging their control over chokepoints in value chains. Under Xi Jinping's New Development Philosophy, China has expanded its already ambitious industrial policies to work towards greater self-reliance, whilst making the rest of the world more dependent on China.[2]

On the short to medium term it is expected that cooperation with China will be necessary to achieve a fast and affordable energy transition, due China's low-cost manufacturing capabilities and because many materials required for the transition are either majority mined or refined in China. In order to balance speed, affordability, and strategic (in)dependencies, a better understanding of the current role of China in key energy technology value chains and expected developments in the coming years is required. In this report, as requested, we will focus on two key technologies for the Dutch and European energy transition: offshore wind energy and the water electrolyser technologies Alkaline and PEM.

Offshore wind energy is an important technology for the energy transition in the Netherlands and in Europe, both in the short and medium-term. The Netherlands aims to have 70 GW of offshore wind installed by 2050, accounting for over half of total electricity production in the country (Ministry of Economic Affairs and Climate Policy, 2023). Yet, offshore wind will already be an important part of the energy mix in the Netherlands by 2030. By that time, the government aims to already have 21 GW installed, which is equal to

[2] Specifically, Xi Jinping said: "we must tighten international production chains' dependence on China, forming powerful
countermeasures and deterrent capabilities based on artificially cutting off supply to foreigners."
Xi, 'Major Issues Concerning China's Strategies for Mid-to-Long-Term Economic and Social Development', 3.

75 percent of current electricity demand (Ministry of Economic Affairs and Climate Policy, 2022). The Netherlands' economy and vital sectors in 2030 will therefore already to some extent depend on offshore wind. The European Union aims for over 60 GW by 2030 and 300 GW in 2030 (European Commission, 2023), indicating that offshore wind is important for the whole Union.

Green hydrogen and electrolysis play a crucial role in the energy transition and the energy system of the future for several reasons. Green hydrogen acts as a transport and storage solution for electricity, especially from fluctuating sources like wind and solar. It stores excess energy during peak production times to ensure a steady supply during low renewable energy periods. Additionally, it serves as a raw material in the chemical industry and is a greener alternative to conventional gas.

The electrolyser, producing green hydrogen, holds a central role, connecting renewable energy sources (sun, wind) to various sectors (e.g. industry and transportation), as shown in Figure 1.2 (TNO & FME, 2020).

Multiple technologies exist for electrolysis, but this report concentrates only on Proton Exchange Membrane (PEM) and alkaline technologies. These two methods have reached a level of development that makes them practical for real-world applications. While other technologies, such as Solid Oxide Electrolysis Cell (SOEC), exist, they fall outside the scope of this report because of the technology's current level of maturity. Alkaline technology is technologically simpler and less expensive than PEM. On the other hand, PEM has the advantage that it is better at dealing with variable energy inputs, especially from sources like solar and wind.

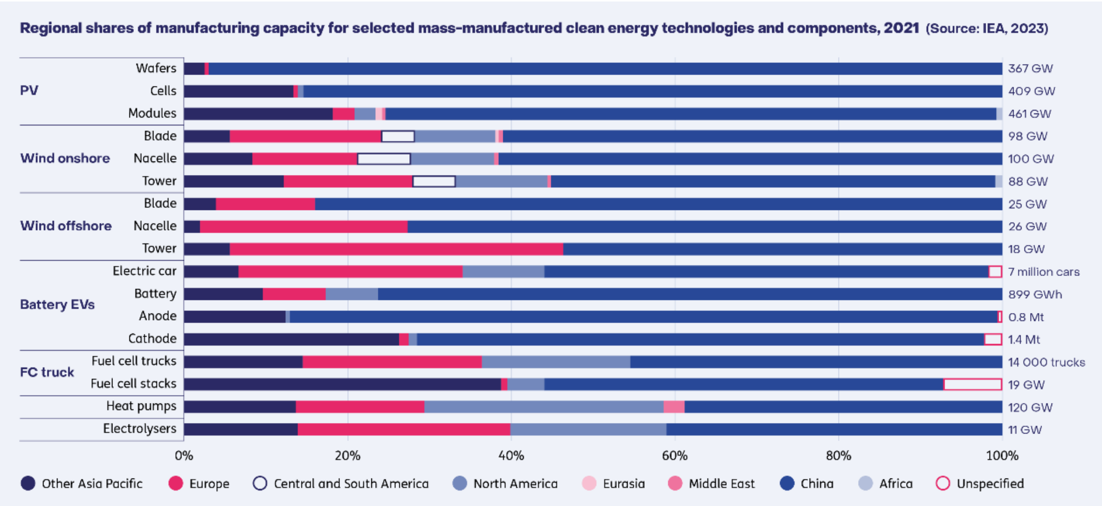



Figure 1.1: Regional shares of manufacturing capacity for selected mass-manufactured clean energy technologies and components. The European shares are indicated in pink and the Chinese shares in navy blue. Source: (IEA, 2023).

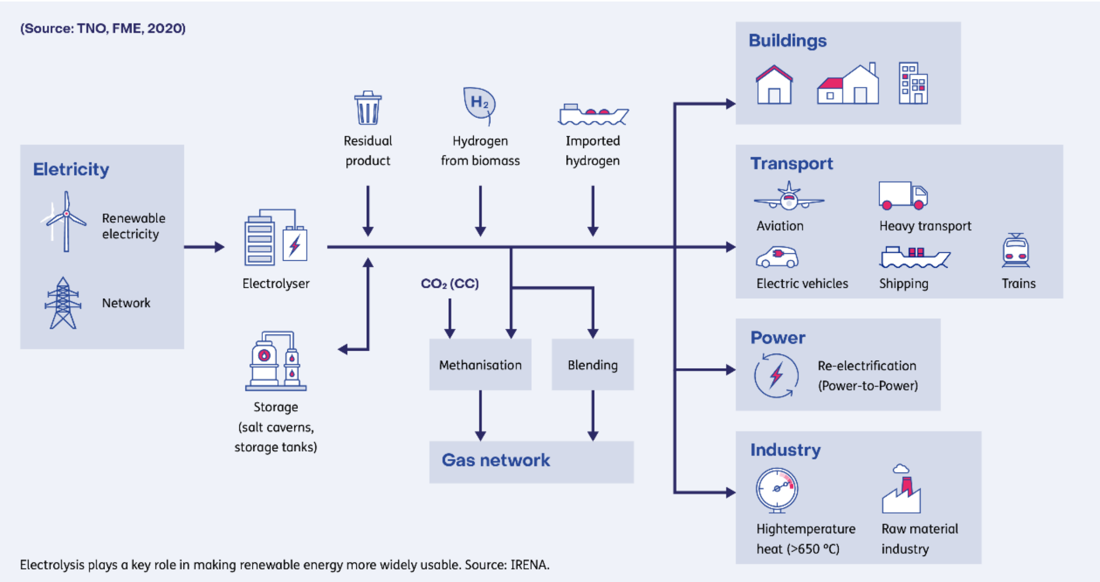



Figure 1.2: A schematic view on the role of Hydrogen in the Dutch future energy system. (TNO & FME, 2020)

## 1.2 Research aims and methodology

The knowledge about the role of China in wind energy and electrolyser value chains is limited in the Netherlands and in the EU. As a result, it is hard to assess the level of risks associated with the central role of China and to formulate policy to mitigate these risks. The aim of this study is to:

- provide a thorough understanding of the past, current and possible future of the supply chains of offshore wind energy and electrolysis, with a specific focus on China.
- provide policy advice on international cooperation and future organisation of international competition for the supply chains of offshore wind energy and electrolysis

For this study TNO has conducted desk research on the supply chains for offshore wind and electrolysis in the Netherlands, the EU and China in 2020 and 2023. Expected developments for the coming 5 years have also been analysed. The desk research has been supplemented by circa 15 interviews with researchers, civil servants and professionals active in the offshore wind and electrolysis supply chains in the EU and in China. A Strategic Dependence Risk Framework that was developed by HCSS for a previous study commissioned by the Ministry of Economic Affairs and Climate Policy was used to assess the impact of supply chain disruptions for offshore wind and electrolysis.

HCSS has conducted an assessment of the geo-economic risks. TNO and HCSS jointly used the HCSS Strategic Dependence Risk Framework to assess the impact and the probability of supply chain disruptions.[3] They applied this framework to assess the geopolitical risk levels of dependence on China in the offshore wind and electrolysis value chains. The findings of the HCSS geo-economic risk assessment (in chapter 3) are based on a combination of sources. First, the chapter leverages the value chain analysis and projections for 2028 presented in the previous

[3] Teer, Ruijter, and Rademaker, 'Navigating the Great Game of Choke Points: Assessing Geopolitical Risks and Advancing Dutch and European Strategic Indispensability in Digital Value Chains', March 2024, chaps 3, annex 1a&1b.

chapter. In addition, it draws on past HCSS research and additional desk research of primary sources, namely CCP leadership speeches and industrial strategies, and secondary sources, such as thinktank reports on China's macro-economic goals. In addition, it cites a previously conducted HCSS-quantitative discourse analysis on CCP leadership's perceptions on the degree of international opposition to its rise. The probability estimation on how likely the last five risks are to occur in the next five years was made on the basis of two workshops with TNO researchers. During a third HCSS internal workshop, participants used the HCSS Strategic Dependence Risk Framework to reach their conclusions.[4]

## 1.3 Reading guide

Chapter 2 describes market dynamics for offshore wind and electrolysis technologies for 2020, 2023 and anticipated changes by 2028. This analysis is done based on literature and interviews with multiple parties (among others governmental, research institutes, industry, consultants). In addition, this chapter contains an analysis of the impact of disruptions in the supply of wind energy and electrolysers from China, both if they occur in 2023 and 2028. Chapter 3 describes geo-economic risks that result from China's role in offshore wind energy and electrolysis for the Netherlands and the EU. Conclusions and policy recommendations are presented in Chapter 4.

[4] The development of this risk assessment framework was commissioned by the Netherlands Ministry of Economic Affairs and Climate (MinEZK). The risk assessment framework was designed by Joris Teer, Abe de Ruijter and Michel Rademaker (HCSS).Teer, Ruijter, and Rademaker, 'Navigating the Great Game of Choke Points: Assessing Geopolitical Risks and Advancing Dutch and European Strategic Indispensability in Digital Value Chains', March 2024, chaps 3, Annex 1a&1b.

# 2 Supply chain analysis and scenarios

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## 2.1 Offshore wind

### 2.1.1 Offshore wind energy supply chain

Figure 2.1 gives an overview of an offshore wind installation. Key elements are the wind turbine, of which the main three components are the tower, the nacelle and the blades. The nacelle includes the generating components such as the generator. There are two types of generator drivetrain designs: geared drivetrains and gearless direct-drives. Geared drivetrains have more components that wear down and require maintenance, but rely on lower levels of rare earth-based components. Gearless direct-drive turbines reduce the amount of wear-prone components, but require more rare earth elements for the permanent magnets for the generator.

The wind turbines are placed on a foundation and connected to the onshore energy consumers through electrical infrastructure including cables and substations. Operations and maintenance of wind turbines, including warranties, O&M know-how and spare part guarantees are important for a company to establish itself in a new market and require bankability and long-term relationships.

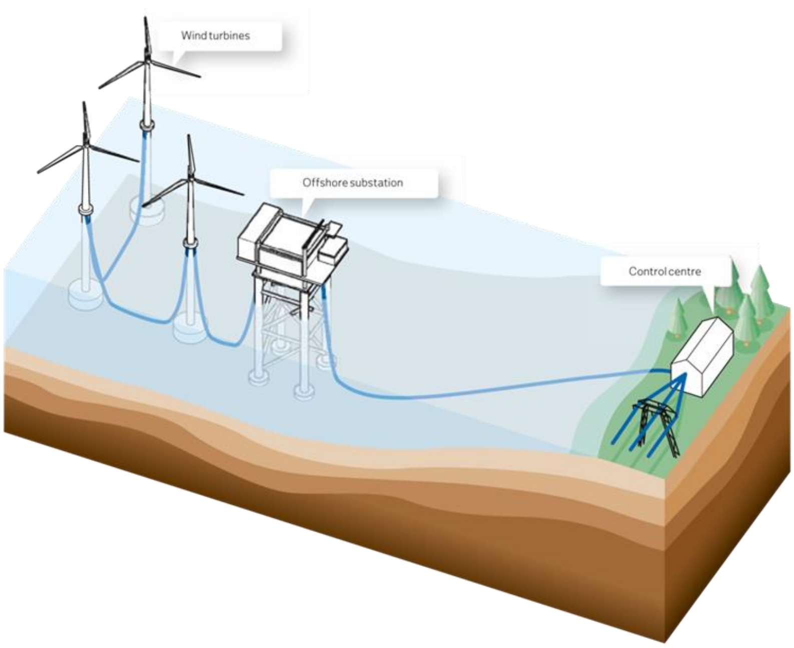


Figure 2.1: Schematic overview of an offshore wind installation.

### 2.1.2 Snapshot market dynamics offshore wind 2020

In 2020 71% of the worldwide installed offshore wind energy capacity was located in Europe (see Table 2.1), with Germany and the UK leading in the development of wind parks. The European offshore wind supply chain is described by GWEC as robust (Global Wind Energy Council, 2020). In 2021 Europe accounted for about 40% of the global manufacturing capacity for offshore wind towers, 25% of nacelles for offshore wind turbines and around 10% of offshore wind blades (IEA, 2023). Besides turbines, Europe had a strong local supply chain for foundations, cables and electrical installations and offshore installation (Wood Mackenzie, 2019).

Table 2.1: Overview cumulative installed offshore wind capacity in 2020 in Europe, China and the world. Numbers vary slightly between sources. Sources: (Wind Europe, 2021) (Global Wind Energy Council, 2020) (Global Wind Energy Council, 2023) (Guidehouse, 2023).

| Country | Cumulative installed capacity (MW) | Main turbine suppliers (including predecessors) |
|---|---|---|
| Belgium | 2,261 | Siemens Gamesa and MHI Vestas |
| Denmark | 1,703 | Siemens Gamesa and MHI Vestas |
| Germany | 7,689 | Siemens Gamesa, MHI Vestas and GE |
| The Netherlands | 2,068 | Siemens Gamesa and MHI Vestas |
| Sweden | 192 | Siemens Gamesa and MHI Vestas |
| The UK | 10,428 | Siemens Gamesa and MHI Vestas |
| Europe other | 154 | |
| Europe Total | 24,495 | |
| China | 9,490 | Siemens, Goldwind, Mingyang Smart Energy, Envision, Donfang Electric, CSIC Haizhuang, Shanghai Electric and TZ |
| World other | 458 | |
| World Total | 34,443 | |

Dutch companies had a strong competence in 2019 in foundations, electrical installations, logistics and offshore construction and installation (Wood Mackenzie, 2019). Examples of key players are SiF, Heerema, Strukton, Mammoet, Fugro, Damen, Van Oord, and Boskalis.

In 2020 China had nearly 9,5 GW offshore wind installed, 28% of the worldwide installed capacity (see Table 2.1). Europe and China were also the two fastest growing regions. The offshore wind energy supply chain in China grew rapidly in the years leading up to 2019 thanks to a robust onshore wind supply chain and rapid growth in deployments (Global Wind Energy Council, 2020). By 2019, eight Chinese turbine Original Equipment Manufacturers (OEMs) released offshore turbines greater than 5 MW, of which six are listed among the world's top ten offshore wind turbine suppliers in 2019. According to Wood Mackenzie, in 2019 China had a well-established local supply chain for offshore foundations and cables as well (Wood Mackenzie, 2019). The local supply chain for electrical equipment and installation activities was less strong according to the same study, but there were already some local capabilities.

In 2021 China accounted for around 50% of global manufacturing capacity for offshore wind towers, over 70% of nacelles for offshore wind turbines and over 80% of offshore wind blades (see Table 2.2). Most of the remaining capacity is located in Europe.

Table 2.2 Annual manufacturing capacity for wind technology components. Source: (IEA, 2023).

| | 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% |

China accounted for half of total exports in wind turbine components (both onshore and offshore) (see Figure 2.2). Due to the high costs of shipping turbine components, such as blades, nacelles, platforms, towers and vessels, only less than a fifth of the global output is traded inter-regionally (IEA, 2023).

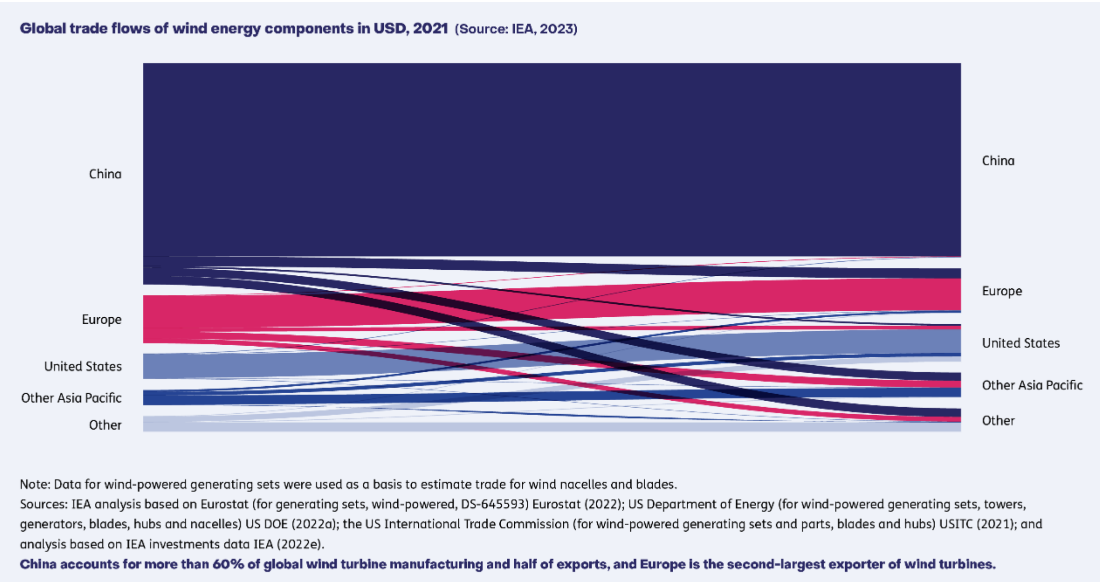


Figure 2.2: Global trade flows of onshore and offshore wind energy components in USD, 2021. Source: (IEA, 2023).

All offshore wind turbine designs in 2020 used permanent magnets for the generators. The production of these magnets requires rare earth elements (REEs). Two types of rare earth permanent magnets are used: neodymium iron boron (NdFeB) and Samarium Cobalt (SmCo) (Vekasi, 2022). In 2021 China dominated the REE supply chain, with about 60% of the global extraction and 90% of the global processing capacity (IEA, 2023) and over 90% of permanent magnet manufacturing (Teer, Bertolini, & Girardi, 2023). China is also dominant for in the mining or refining stages of other materials, such as cobalt and manganese, that are used to produce permanent magnets (Vekasi, 2022).

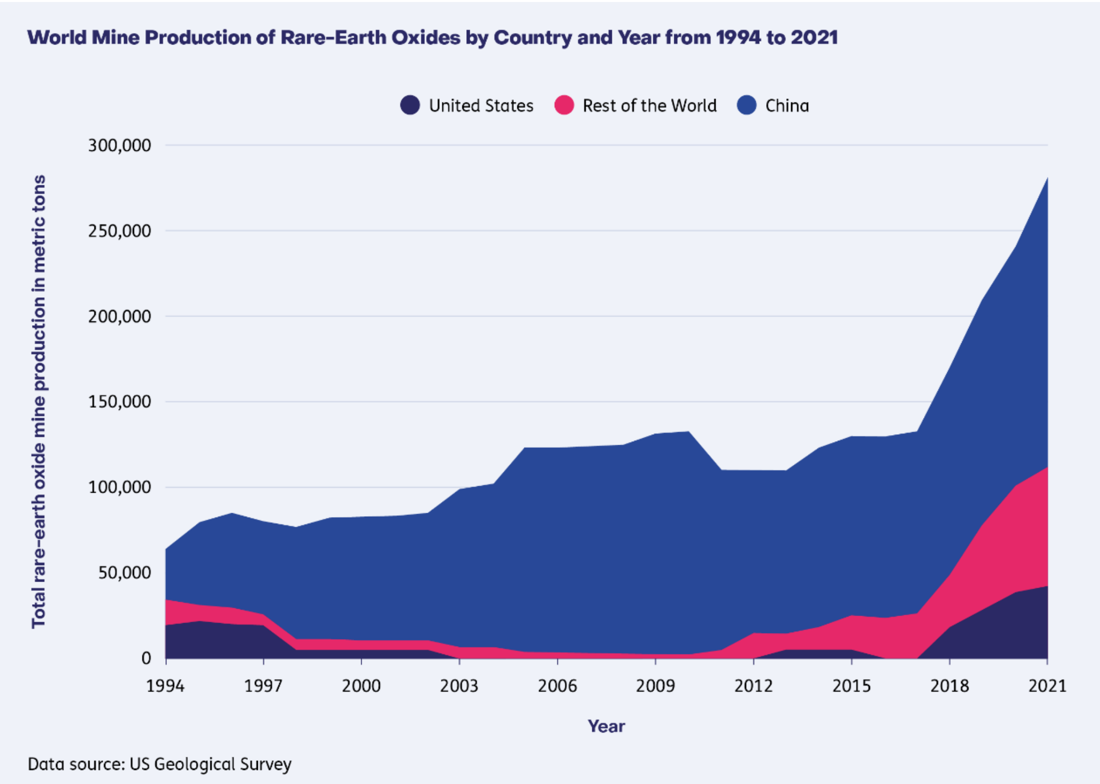


Figure 2.3: China has dominated the mining of REE since its opening up in the 1990s. Yet US companies have climbed back from 0% of rare earth mining 15 years ago to 15% of global mining in 2024. This figure was produced by Dr. Kristin Vekasi and published on the Harvard University publication Epicenter (Vekasi, 2022). Data source: US Geological Survey.

## 2.1.3 Snapshot market dynamics offshore wind 2023

Between 2020 and 2023, China led the global offshore wind development – installing over 25 GW of new capacity in three years, 17 GW of which was realized in 2021 (see Figure 2.4). The record year was driven by project developers wanting to commission projects before the ending of the national feed-in-tariff subsidy scheme in 2022. From interviews we understand that there is a preference in China to make use of local suppliers for wind energy projects. Only Siemens Gamesa has played a significant role in the Chinese offshore wind sector through technology licensed to Shanghai Electric (Waite, 2022).

In comparison, Europe installed 2.5 GW of new capacity in 2022, with France and Italy each commissioning their first commercial offshore wind projects (Global Wind Energy Council, 2023). The wind turbines for the project in Italy are supplied by Mingyang Smart Energy, making these the first 10 offshore wind turbines from a Chinese manufacturer to be installed in Europe. Mingyang has also entered a strategic agreement with a UK partner in May 2023 with the goal to drive offshore wind expansion in the UK (Varney, 2023). Another Chinese OEM, Goldwind, owns 70% of German turbine manufacturer Vensys since 2008 (Vensys, 2023). Vensys' largest turbines are 6 MW – suggesting a focus on onshore wind energy. However, the gearless design is useful for offshore turbine development as it reduces the required components and maintenance.

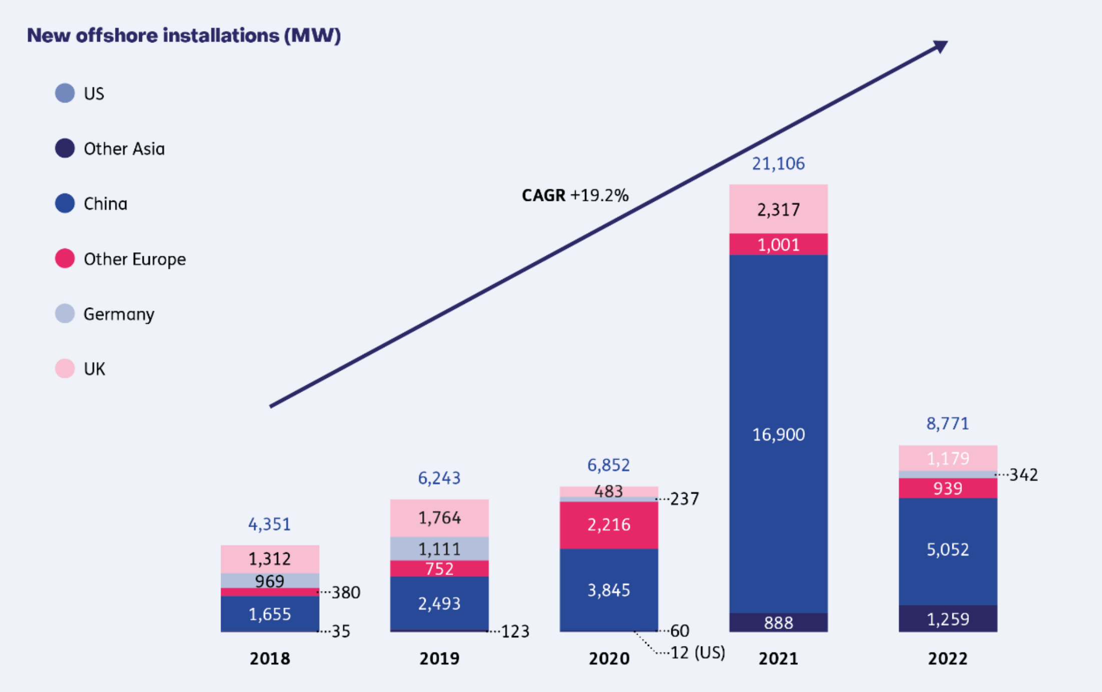


Figure 2.4: Annual commissioning of new offshore wind capacity. The large increase in China in 2021 was a consequence of a rush to realise projects before the Feed-in tariff subsidy scheme was stopped. Source: (Global Wind Energy Council, 2023).

### Chinese wind turbine manufacturers take a leading position and European manufacturers face financial hardship

More than 15 wind turbine manufacturers are active in China. Although the domestic market is large, competition has become increasingly fierce, with record-low prices being reported in the past two years. Price pressure has acted as a driver of technology innovation, as Chinese wind turbine OEMs have continued to launch new turbines with larger power rating and bigger rotors to drive the costs further down. Over the past two-to-three years Chinese turbine OEMs like Mingyang, Goldwind and Haizhuang have released offshore turbines in the 16–18 MW range, compared to 14-15 MW designs from Siemens Gamesa and Vestas MHI. The Chinese manufacturers' turbines include both designs with gearboxes and direct-drive designs. The Chinese wind power equipment industry has moved from 'following' to 'running alongside' and now 'leading' in wind technology development (Global Wind Energy Council, 2023). The top five Chinese wind turbine manufacturers are Goldwind, Envision Energy, Zhejiang Windey, Mingyang Smart Energy and Donfang Electric (DEC) (CWEA, 2022).

There was no consensus on the quality of the Chinese offshore wind turbines in the interviews conducted for this research. Views range from Chinese turbines being of lower quality resulting in higher maintenance required, to the Chinese turbines being of equal quality to the main Western OEMs. A possible explanation of the higher maintenance levels is a difference in maintenance strategy – with Chinese wind park developers accepting a higher maintenance requirement as local labour is cheaper, compared to European developers opting for more expensive turbines that require less maintenance. Based on the interviews, we conclude that even if the quality of some of the main Chinese OEMs is lower than the Western OEMs, it will not be much lower.

Meanwhile, European wind turbine manufacturers Vestas Wind Systems, Nordex SE and Siemens Gamesa reported significant operating losses in 2022 (European Commission, 2023) (Rystad, 2023). The manufacturers were particularly hit by inflation of raw material prices and component prices, as well as supply chain instability resulting from the COVID pandemic (Rystad, 2023). As EU turbine manufacturers have started to pass on costs to project developers, several offshore wind projects face delays or are being abandoned (Rystad, 2023) (Ambrose, 2023) (Reuters, 2023). In the EU, no new large offshore wind projects reached final investment decision in 2022 (Wind Europe, 2023).

#### China continues to dominate the global supply chain for crucial wind turbine components

With a global market share of more than 70%, China dominates the supply chain for components such as castings, forgings, slewing bearings, towers and flanges (Global Wind Energy Council, 2023). In addition, China dominates the fiberglass production with 60% of global production (CWEA, 2022). India, the second-largest Asia-Pacific (APAC) hub for turbine assembly and key components production, has an increasingly prominent role in the global wind supply chain (Global Wind Energy Council, 2023).

China has the largest offshore wind nacelle manufacturing capacity (16 GW/yr, 1 GW of which is owned by a western OEM) (Global Wind Energy Council, 2023). Europe has 9.5 GW/yr production capacity, expected to increase to 11.5 GW/yr next year (Global Wind Energy Council, 2023). The production capacity for larger scale offshore wind turbine blades and nacelles is expanding in Europe, with Siemens Gamesa extending its facility for >12 MW turbines in Hull (UK) and Vestas constructing a base for nacelles for 15 MW turbines in Poland (Rystad, 2023). Excluding China, the Asia-Pacific (APAC) region has 1.9 GW/yr production capacity – mainly in Taiwan and South Korea (Global Wind Energy Council, 2023). Most announced assembly facilities for offshore nacelles are in China. GE Renewable Energy, SGRE and Vestas have announced nacelle investment plans for the US in Q1 2023 (Global Wind Energy Council, 2023).

Of the Western OEMs Vestas uses a geared design for their offshore turbines, while Siemens Gamesa and GE Electric use direct-drive models. As explained in paragraph 2.1.1, the direct drive models use more permanent magnets. Vestas is therefore less dependent than Siemens Gamesa and GE Electric on rare earth elements and permanent magnets from China, as China continues to dominate the rare earth materials and permanent magnets supply chains (see Figure 2.5).

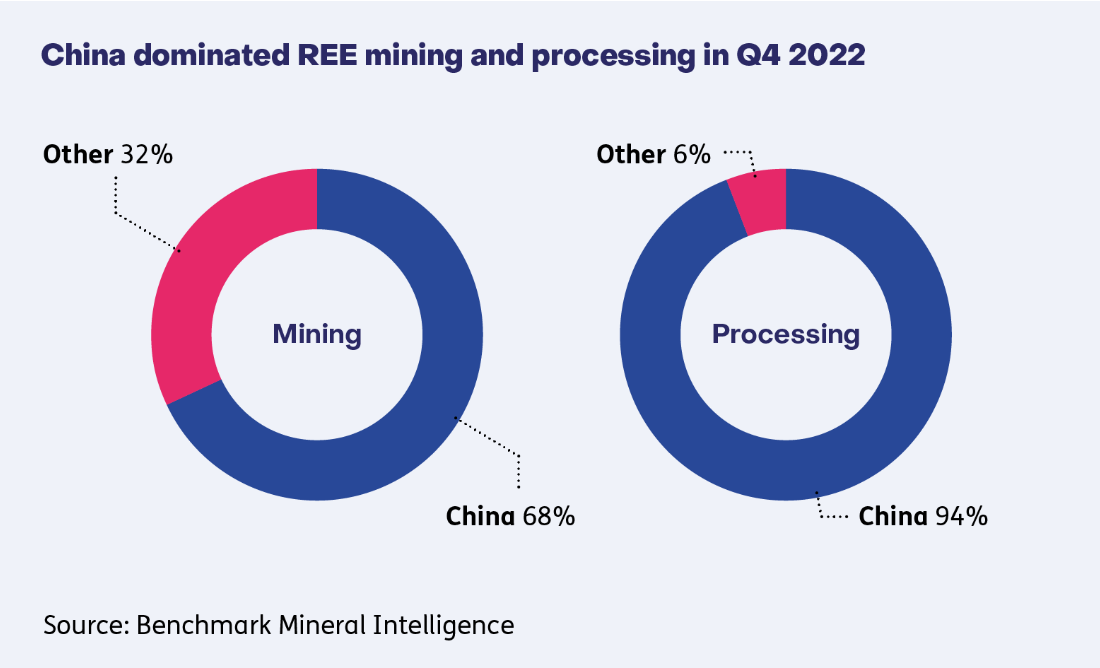


Figure 2.5: The role of China in rare earth element mining and processing. Source: (Global Wind Energy Council, 2023).

### China is not yet completely independent from Western suppliers

China lacks the capacity to produce certain bearings, most notably large diameter roller bearings, and relies on imports from the West for these bearings (CWEA, 2022). Roller bearings are used in the main shaft of the turbine and in the turbine gearbox. China also relies on the import of some blade core materials such as balsa wood (CWEA, 2022), over 90% of which is produced in and exported from Ecuador (Rodriguez Zunino, Norman, & Tenorio Fenton, 2022). China also relies on imports for largescale full power converters, IGBT transistors and main control systems from Western and Japanese suppliers such as Siemens, ABB, Infineon, Mitsubishi and Fuji (CWEA, 2022).

### China also dominates the global supply chain for towers

China has a share of more than 70% of the construction capacity for towers for onshore and offshore wind turbines (Global Wind Energy Council, 2023). Towers are predominantly made from steel. Rystad Energy estimates that there is sufficient wind tower manufacturing capacity in Europe (Rystad, 2023). In 2021, the European Commission imposed anti-dumping duties on steel towers imported from China, with tariffs ranging from 7.2% to 19.2% (Global Wind Energy Council, 2023) (European Commission, 2021).

Despite sufficient foundation manufacturing capacity in Europe, Chinese players are looking to establish a presence in Europe

Rystad Energy estimates that manufacturing capacity for offshore wind foundations in Europe is currently sufficient to meet the demand (Rystad, 2023). The Netherlands' Sif and Germany's EEW lead in monopile manufacturing capacity, the most popular foundation type. There is sufficient jacket supply due to the use in the oil and gas industry and floating wind foundation manufacturing is still in its infancy. Despite sufficient manufacturing capacity being present in Europe, Dajin Offshore Heavy Industry is delivering monopiles in the UK (Moray West). It has won contracts for French (Iles D'Yeu et Noirmoutier), German (Nordseecluster) and Danish (Thor) offshore wind projects. Dajin also plans to open a manufacturing facility in Europe for foundations for both fixed and floating offshore wind projects (Buljan, 2022). Since 2013, China International Marine Containers Group (CIMC) Offshore owns Bassoe Technology, a company in Sweden that develops floating offshore wind foundations (Bassoe Technology, 2023). China does not have a leading position in innovative foundations, such as suction piles and gravity foundations developed by Dutch companies SPT Offshore and Monobase Wind (CWEA, 2022). The first SPT Offshore suction pile foundation was installed in China in 2022 (Dutch Enterprise Agency (RVO), 2023).

Installation vessels are available in Europe and China and some European specialists are still active in the Chinese market

China and Europe own most of the offshore wind turbine installation vessels (Global Wind Energy Council, 2023). Dutch companies such as CAPE Holland, Dieseko Group, and Verschoor Trading & Sourcing are active in providing equipment for the installation of offshore wind foundations in China (NL International, 2022). Chinese companies are also active in providing these types of equipment, but there is still business with foreign companies, especially when products are of better quality than the Chinese companies can deliver. Netherlands based SMST has been awarded a contract in 2022 to deliver equipment for an offshore wind turbine maintenance vessel for the Shanghai ZMPC shipyard (Dutch Enterprise Agency (RVO), 2023).

Production and installation of cables and substations in Europe is mostly completed by EU companies, but also here Chinese players are looking to enter the European market

There are various companies active in production and installation of the cables and substations to connect offshore wind parks to shore. In 2023 TenneT selected European firms NKT and Prysmian to provide the cables for five Dutch 2 GW offshore wind projects (IJmuiden Ver Alpha, IJmuiden Ver Beta, IJmuiden Ver Gamma, Nederwiek 1 and Nederwiek 2) (TenneT, 2023). In 2022 TenneT awarded the contract for the Hollandse Kust West Beta export cable to a consortium of Boskalis and Orient Cable (NBO), a main Chinese player in the submarine cable market (TenneT, 2022). After questions from parliament to the Dutch Government about the role of Chinese companies in the electrical infrastructure, the offshore electricity infrastructure was branded as “critical infrastructure” and TenneT excluded Chinese companies from a tender for offshore substations (Energeia, 2023).

### 2.1.4 Expected developments offshore wind in the next 5 years

In order to meet the EU target of 42.5% renewables by 2030, the European Commission expects the offshore wind installed capacity needs to increase from 204 GW in 2022 to 500 GW in 2030 (European Commission, 2023). In order to meet the growing demand for offshore wind turbines, the European production capacity needs to be expanded in the second half of this decade. According to GWEC, without actions there will be shortages in offshore nacelle assembly capacity, manufacturing capacity for blades and generators, and for vessels used for offshore installations (Global Wind Energy Council, 2023). Rystad foresees shortages particularly for the manufacturing and supply of large offshore wind turbines (>12 MW) (Rystad, 2023).

With the large European wind turbine manufacturing currently facing financial hardship, expanding the European production capacity will be a challenge (see 2.1.3). In order to strengthen the supply chain, the European Commission has proposed the Net-Zero Industry Act (NZIA) and the European Wind Power Action Plan (WPAP) (European Commission, 2023). The NZIA proposes measures for faster permitting of manufacturing capacity, defining strategic projects and requires non-financial criteria such as sustainability and resilience contributions to be taken into account in public procurement. These measures can enable companies to invest in EU-based supply chains (Global Wind Energy Council, 2023). The WPAP proposes similar measures for the wind sector specifically and additional measures to ensure the European demand for offshore wind turbines, access to finance and skilled workers, and creating a fair and competitive international environment – including protecting the internal market against trade distortions and threats.

In addition, the European Investment Bank (EIB) has announced €5 billion in support for the EU's wind manufacturers (European Investment Bank, 2023). The success of the EU-policy and the future position of the European wind turbine manufacturers will be crucial factors in determining to what extent the EU can meet the local demand with local supply. How the dependency on China will develop if the local demand cannot be met with local supply is currently unclear.

The EU has also presented a Critical Raw Materials Act (CRMA) to ensure the sustainable supply of critical raw materials. The regulation aims to achieve 10% of extraction and 40% of processing of total EU annual consumption of strategic materials to be done domestically by 2030 (European Commission, 2023). Despite the CRMA and early efforts to indigenize critical raw materials processing and permanent magnet making in North America, Australia, Japan and Europe, it is expected that there will still be a reliance on China for rare earth permanent magnets in the short, medium and even long-term (Global Wind Energy Council, 2023) (IEA, 2023).

Meanwhile the Chinese offshore wind sector is expected to continue to grow rapidly, with an initiative from the Chinese wind sector calling for 100 GW by 2020, 200 GW by 2030 and 1000 GW by 2050 (Global Wind Energy Council, 2023). Based on interviews the general expectation is that the continued growth of the Chinese offshore wind sector will go paired with further strengthening of the local supply chain.

In the US the Inflation Reduction Act (IRA) has led to announcements for the development of offshore wind production facilities in the US. GWEC is unsure whether enough capacity will be built to supply the demand for offshore wind turbines in the US (Global Wind Energy Council, 2023).

# 2.2 Electrolysis

## 2.2.1 Electrolysis supply chain

The electrolysis value chain for both alkaline and PEM electrolysis is large and complex. Figure 2.6 shows a simplified version of the supply chain, including three key elements:

1. **Stack-components:** parts of the electrolysis installation, a.o. membranes, electrodes, catalysts and coating. This study will focus in particular on membranes and electrodes as these are considered to be the most important.
2. **Stack design and assembly:** companies that can assemble from the individual components the electrolyser stack itself and also the balance of stack and balance of plant components which forms the core of an electrolysis plant.
3. **System integrator:** companies that can assemble complete electrolysis plants. These parties play an important role in organizing the suppliers in the production chain.

The hydrogen production supply would be step 4 and but falls out of the scope of this study. Studying the raw materials supply is also beyond the scope of this study, so only major and well-known critical material supply chain dependencies are highlighted in the report.

For electrolysis, the supply chain is not very transparent, especially with regard to China which is often described as a 'black box'. Through literature examination and insights gathered from interviews, this study strives to clarify the main dynamics of the supply chain. However, the description of the market dynamics in the following sections does not always follow the clear division in supply chain steps as described here. The analysis aims to capture the essence of the supply chain and corresponding market dynamics.

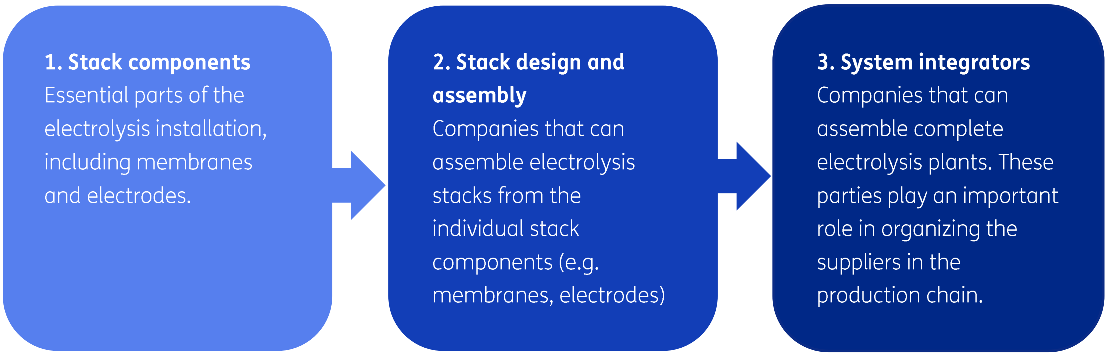


Figure 2.6: The simplified value chain of PEM and Alkaline electrolysis, including 1) stack components, 2) stack design and assembly and 3) system integrators. Source: TNO.

## 2.2.2 Snapshot market dynamics electrolysis 2020

In 2020, the electrolyser landscape looked quite different than it does in 2023. There were fewer active companies and the supply chain was less developed for both alkaline and PEM technologies. Both technologies were applied on a smaller scale than today. The potential global electrolysis annual manufacturing capacity was 3 GW in 2020, whereas the global installed electrolyser capacity was 0.3 GW (IEA, IEA analysis based on IEA (2021g), Hydrogen Projects Database, Licence: CC BY 4.0, 2021). The majority of this installed capacity is alkaline (85%), whilst PEM takes up a minor part (<15%). The remainder part consisted of other technologies, which are not considered in this report. Europe was world-leading in terms of global manufacturing capacity (60%), followed by China with 35%. (IEA, 2021)

Large system integrators are listed in Table 2.3 together with the corresponding country and technology (TNO & FME, 2020). Note that Europe is quite well represented in this list. None of the large system integrators is located in the Netherlands. Companies with growing interest are Thyssenkrupp, Nel Hydrogen, Cummins and John Cockerill. All of these companies have already announced plans in 2020 for upscaling electrolyser manufacturing capacity (IEA, 2021).

Due to significant changes in the market since then, this report places a greater emphasis on the market dynamics in 2023 and beyond.

Table 2.3: Large system integrators worldwide (not a complete list) (TNO & FME, 2020)

| Company | Country | Technology |
|---|---|---|
| Asahi Kasei | Japan | Alkaline |
| Accelera (formerly Cummins / Hydrogenics) | US & Belgium | PEM & Alkaline |
| HydrogenPro / Tianjin H2 Equipment | Norway & China | Alkaline |
| ITM Power (Linde Engineering) | UK | PEM |
| Nel | Norway and USA | Alkaline & PEM |
| Siemens | Germany | PEM |

### 2.2.3 Snapshot market dynamics electrolysis 2023

The supply chains and technology of PEM and alkaline electrolysis are developing fast. Many new companies have entered the market in the past year and the electrolyser manufacturing capacity increased globally. China is considered world-leading in this aspect. In 2023, it is approximated that China holds a 34% share of the worldwide electrolyser manufacturing capacity, followed by Europe (27%) and North America (15%), as presented in Table 2.4. The large growth in Europe and China is mostly led by ambitious governmental plans for future electrolyser capacity (BNEF, 2022).

China and Europe, both key players worldwide, have different preferences and strategies in the field of electrolysers, based on interviews. China focuses on alkaline technology due to its cost-effectiveness and simplicity. The country possesses all the necessary raw materials and all parts of the value chain domestically, aligning with its national strategy for self-sufficiency. In Europe, the focus spans both alkaline and PEM technology. The continent distinguishes itself with a commitment to quality, safety and efficiency of both components and the complete electrolyser installation, surpassing standards in China. As a result, European electrolysers have a higher cost. The higher upfront cost is favoured in Europe because higher efficiency is desired due to the high electricity costs. Lower cost of electricity in China means that high efficiencies are less important for overall costs.

**Substantial progress is evident in China for mostly alkaline electrolysis, even though it is challenging to precisely gauge the ongoing developments in China**
Estimates from 2022 suggest an increase in annual manufacturing capacity to 4.9 - 9.1 GW in 2023 by 2023 (IEA, 2023; BNEF, 2022) and the industry is growing fast. There are currently approximate over 150 active companies, of which mostly alkaline, compared to ~12 in 2020 and ~80 in 2022. Major electrolyser manufacturers are presented in Table 2.5. Chinese players are Longi (2.5 GW), Peric (1.5 GW) and Sungrow (1.1 GW). Longi has increased its

manufacturing capacity by 1 GW since 2022 (BNEF, 2022). The major players include companies from other sectors (e.g. LONGi and Sungrow are solar PV panel manufacturers).

There is currently approximately 0.5 GW of alkaline electrolysers installed in China, indicating that much of the production capacity is not being utilized at full capacity yet. The number of active green hydrogen projects in China is estimated to be 354, of which 35 are operational and 58 under construction. The remainder of the projects are planned for the near-term (114 projects) and long-term (147 projects) (Energy Iceberg, 2023).

In contrast, PEM electrolysers seem less popular in China, as indicated by insights obtained from interviews. The dependence on other countries for specific stack components such as membranes seems larger for PEM electrolysers than for alkaline electrolysers. It is unclear whether this is because there is less attention for PEM in China, the manufacturing capacity of Chinese components is limited or that imported components are preferred because they are of higher quality. While the technology is advanced enough for application, its higher cost compared to alkaline electrolysis poses challenges. Chinese preference for cost-effectiveness hampers the market for PEM technology, which also encounters technical obstacles related to scalability, safety, quality, and stable operation during fluctuating energy inputs. Nevertheless, there has an increase in research and development for PEM technology in 2023. Especially companies specialized in fuel cell technology show an interest in PEM electrolyser production. There are also new international collaborations established, such as a joint venture between Sinopec (China) and Cummins (US). (Energy Iceberg, 2023)

#### EU PEM and alkaline electrolyser production has shown strong growth

The electrolyser manufacturing capacity in Europe has been growing as well. Europe is currently largely self-sufficient for the main components of electrolysers. The main dependency in the value chain is on iridium for PEM electrolysers of which 93% is both mined and processed in South Africa (and a far smaller share in Russia) (European Commission, 2023). Current estimates suggest manufacturing capacities of 3.9-7.7 GW for alkaline electrolysis (including Norway and the UK) and around 4 GW for PEM. On the other hand, installed capacity of electrolysers is still limited. Major European players are presented in Table 2.5, including John Cockerill (2.5 GW), operating internationally and recently acquiring the Chinese company Jingli. John Cockerill are also developing electrolyser manufacturing capacities in France (1 GW), China (2 GW), and India. Also in Europe large players from other sectors are entering the electrolysis manufacturing market (e.g. Bosch and Schaeffler from the automotive sector). There are also many Dutch companies active in the electrolyser industry, currently around 150, of which the majority produces stack components. Electrolysers produced by Dutch companies are still below MW scale, which is smaller than systems from surrounding countries (ISPT, 2023).

Table 2.4: Electrolyser manufacturing capacity per region in GW/year and as a percentage of the global manufacturing capacity (IEA, 2023). This estimate is based on manufacturer's announcements and confidential communications.

| | Electrolyser manufactering capacity (GW/year) | Electrolyser manufactering capacity out of global capacity |
|---|---|---|
| **World** | 14.4 | 100% |
| **China** | 4.9 | 34% |
| **Europe** | 3.9 | 27% |
| **North America** | 2.1 | 15% |
| **India** | 0.5 | 3% |
| **Rest of the world** | 3.0 | 21% |

Table 2.5: Estimated annual electrolyser manufacturing capacity per company, country and technology (PEM, ALK) in 2022 and 2023 according to Hydrogen Insight (Hydrogen Insight, 2022) and (BNEF, 2022); adapted by TNO. This list shows the 22 largest electrolyser manufacturers worldwide.

| Position 2023 | Manufacturer | Country | Electrolyser type (ALK=Alkaline) | Annual Capacity 2022 | Expected Annual Capacity 2023 |
|---|---|---|---|---|---|
| 1 | Plug Power | US | PEM | 1 GW | 3 GW |
| 2= | Longi | China | ALK | 1.5 GW | 2.5 GW |
| 2= | John Cockerill | Belgium | ALK | 1 GW | 2.5 GW |
| 2= | ITM Power | UK | PEM | 1 GW | 2.5 GW |
| 5 | Ohmium | US | PEM | 1 GW | 2.0 GW |
| 6 | Accelera (formerly Cummins / Hydrogenics) | US | PEM | 0.6 GW | 1.6 GW |
| 7= | Peric | China | ALK/PEM | 1.5 GW | 1.5 GW |
| 7= | Thyssenkrupp | Germany | ALK | 1 GW | 1.5 GW |
| 9= | HydrogenPro | Norway | ALK | 0.3 GW | 1.3 GW |
| 9= | Siemens | Germany | PEM | 0.3 GW | 1.3 GW |
| 11 | Sungrow | China | ALK/PEM | 1.5 GW | 1.1 GW |
| 12= | Auyan | China | ALK | 1 GW | 1.0 GW |
| 12= | Guofu | China | ALK | 0.5 GW | 1.0 GW |
| 14 | Nel | Norway | ALK/PEM | 0.6 GW | 0.6 GW |
| 15= | SinoHy | China | ALK | 0.5 GW | 0.5 GW |
| 15= | Sunfire | Germany | ALK | 0.3 GW | 0.5 GW |
| 15= | Kohodo | China | ALK | 0.3 GW | 0.5 GW |
| 15= | CPU | China | ALK | - | 0.5 GW |
| 15= | Sunfly | China | ALK | - | 0.5 GW |
| 15= | Reliance Industries | India | ALK | - | 0.5 GW |
| 21= | Green Hydrogen Systems | Denmark | ALK | 0.1 GW | 0.4 GW |
| 21= | McPhy | France | ALK | 0.1 GW | 0.3 GW |
| | | | TOTAL | 24 GW | 27.1 GW |
| | | | of which China | 7.1 GW | 9.1 GW |

### Market dynamics between Europe and China

So far complete electrolysers have not been traded between China and Europe. Currently, in both continents, most stack components are supplied domestically. From interviews, it appears that due to the complex nature of electrolysers, companies mostly prefer local value chains unless components elsewhere provide better quality or price. Chinese companies import European components when higher quality and/or safety standards are required. There is also export from Chinese components to Europe. Currently, there are collaborations and Chinese companies establishing offices and locations in Europe.

The European standards for quality and safety create an extra challenge for Chinese companies who are looking to export to Europe, as many of them do not meet the European standards yet. Nevertheless, it is not self-evident that this will remain the case. Based on multiple interviews, some Chinese companies already meet the required quality and safety standards and others are expected to catch up in 1-2 years. This might lead to more collaboration with Chinese producers of stacks and stack components, as more Chinese companies will be able to provide the requested quality and safety standard in Europe. Currently, some companies design different electrolyser models for Europe (higher quality, efficiency, safety, costs) and China (lower quality, efficiency, safety, costs) as the demand is based on different standards.

In the past year, opportunities for European companies in China have decreased due to the large increase in number of Chinese electrolyser companies. From interviews follows that customers are state-owned and favour Chinese companies over European ones, in line with the national strategy on autonomy, unless higher quality is required. However, often low cost is preferred even if the quality and efficiency is also lower. To illustrate the price difference between European and Chinese electrolysers, Chinese electrolysers have been sold for 75% lower price than European models (Hydrogen Insight, 2022), but the exact scope of supply is not completely clear making it impossible to make a fair comparison.

Regarding maintenance and software updates, several trends are emerging, based on interviews. System integrators offer maintenance services bundled with electrolyser purchases, based on which they can guarantee the offered quality. This can be tied to a specific region, depending on where the supplier is located, and sometimes limited possibilities for (long-distance) maintenance. In addition, some companies specialize in maintenance and software. Given the sensitivity regarding data and autonomy, it may be important to invest in European companies with expertise in this field.

### 2.2.4 Expectations for electrolysis in the next 5 years

In the coming years ambitious plans drive hydrogen development globally. Many companies see the potential to succeed in a market full of future opportunities. The supply chain for PEM and alkaline electrolysers is actively undergoing development in multiple regions, including Europe. However, the uncertainties in future supply, demand and corresponding locations are large and it’s hard to give a precise prediction of what will happen. Europe currently holds a key role, and there are opportunities to sustain this position, but this requires strategic choices as the global electrolyser landscape evolves fast and the direction is unclear.

#### Predictions based on company announcements

Figure 2.7 shows that the globally announced electrolyser manufacturing capacity for 2030 exceeds 130 GW per year, constituting three-quarters of the required volume in the IEA’s Net Zero Emission 2030 scenario. Currently, China and Europe dominate the global stage as key players, with indications of further expansion towards 2030. The overall manufacturing capacity in 2030 is predicted to have a more global footprint than today. North America and India are expected to emerge as significant contributors to electrolyser manufacturing capacity.

Despite these projections, it's crucial to note that there is considerable uncertainty in these figures. Only 10% of the planned projects have progressed to a Final Investment Decision (FID), casting uncertainty over the fate of the remaining 90%. Additionally, 25% of the projects have been announced without specifying their location or region. This uncertainty underscores the ambiguity surrounding the future dominance of specific regions.

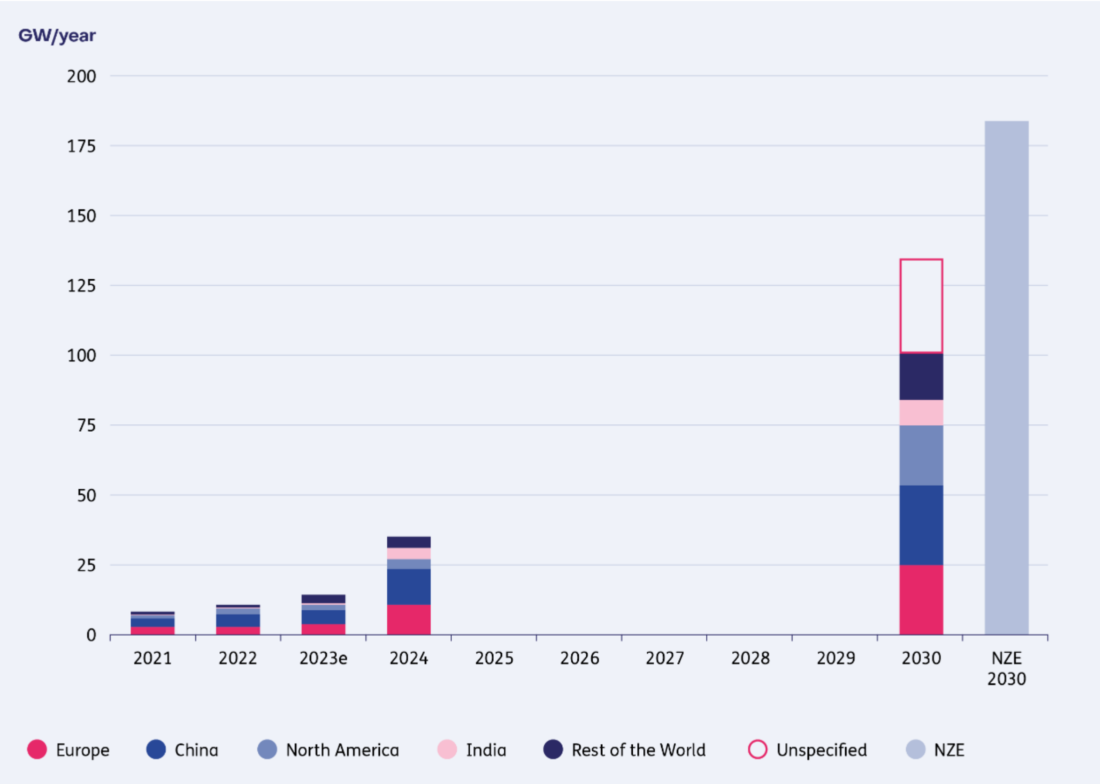


Figure 2.7: Planned global electrolyser manufacturing capacity divided per country for the years 2021-2024, 2030, compared to what's required to achieve the goals in the Net Zero Emissions 2030 scenario. This is based on company announcements and confidential communications (IEA, 2023).

### Developments & expectations

Nevertheless, by broadly assessing information from interviews and literature, it is possible to develop an understanding of how the current situation is progressing towards the future and identify key elements in this development. This will be described in a qualitative manner.

China's strategic focus most probably remains on alkaline technology due to its cost-effectiveness, simplicity and self-sufficiency. The market for PEM technology within China is expected to remain smaller in the short term, yet even a small Chinese market could provide significant export opportunities. In Europe, there will be further development in both alkaline and PEM technology and application.

Given China's goal to establish "independent" and "controllable" supply chains and its promotion of domestic businesses, the opportunities for European electrolyser companies in China may become more limited. From interviews follows that safety and quality are critical factors in this context, as currently, components are exported from Europe to China, when higher safety or quality is required by Chinese buyers that they themselves cannot produce yet. If Chinese companies meet similar standards, it is probable that Chinese consumers, often state-owned enterprises, would favour Chinese companies over their European counterparts. This situation would probably reduce export opportunities for Europe.

In contrast, when more Chinese companies are able to deliver the European quality and safety requirements, it is expected that more Chinese companies will export components to Europe or establish a presence to sell components or end-products. Particularly for suppliers of PEM electrolysers, there might a growing interest in exploring opportunities beyond China, given the lagging demand in China. But there are also opportunities for companies in the alkaline sector.

According to experts involved in the industry, China needs 1-2 years to meet the current European standards for quality and safety in alkaline electrolysers and its components. Export opportunities to Europe will be a main driver to improve standards. In addition, China has an advantage in scaling up technology due to fewer constraints on space, materials, and labour force compared to Europe. Once they meet European standards for quality and safety, transitioning to large-scale production according to European requirements could happen relatively fast. If Chinese companies can achieve large-scale production at costs lower than European counterparts, while meeting the same standards, the market position of European producers can deteriorate quickly.

There is a strategic consideration for Chinese companies of potentially exporting the entire supply chain to Europe, establishing self-sufficiency on the European continent. According to specialists, this is related to the complexity of the system. Electrolysers are composed of many different components, some of which are sensitive, making transportation complicated. Hence, a localized supply chain is the preferred option and Chinese companies might establish a local presence, which is already being pursued by some companies.

The complexity of the system and transportation challenges, sets electrolysers apart from the more straightforward solar photovoltaics scenario where China became a dominant world leader in a short time. Some say that the electrolyser market could develop towards the same scenario in the coming years (BNEF, 2022; Hydrogen Insight, 2022). However, other experts expect that such a development in the electrolyser landscape will evolve slower and that it will be less evident for China to become dominant in a short time. This is mainly related to the complexity of the system and that assembly and transport are much harder, as compared to solar panels. Local supply chains will therefore remain relevant. However, Chinese firms could establish a complete value chain on a different continent.

# 2.3 Risk assessment for the offshore wind and electrolysis supply chain

## 2.3.1 Strategic dependence risk framework

Based on the previous described findings, TNO has made an analysis on the risks related to supply chain disruptions by China. For this, the 'Strategic dependence risk framework' developed by HCSS, is used in Table 2.7 and Table 2.8.[5] The definitions are explained in Table 2.6. The analysis was shared with HCSS, Clingendael and policymakers from the ministry of Economic Affairs and Climate Policy and from the ministry of Foreign Affairs in two workshops.

Table 2.6: Definitions used in the risk-dependence framework

| Aim | | Indicator (including weight) | Main guiding question |
|---|---|---|---|
| 1. Identifying strategic dependence (impact assessment) | 1a. Assessing criticality of baseline supply | 1. Criticality – 2x | What is the effect on the security (i.e., physical or financial), safety, and health of Dutch and Europeans (level-one core interest) and on the continuation of the energy transition (level-two core interest) if the baseline supply of the good and service from one or several countries is entirely disrupted? |
| | | 2. Dependence on maintenance, updates or resupply – 1x | If the good or service is no longer supplied, when will this have an impact on level-one and/or level-two core interests? |
| | | 3. Demand projection – 1x | Total demand: Is national, regional and/or global demand for the good or service likely to outpace global supply, leading to shortages of the good or service on top of the risks of supply-related shocks? Total use of good or service to enable vital processes: Will more vital processes come to rely on the supply of the good or service in the next five years? |
| | 1b. Assessing alternatives to baseline supply | 4. Diversification - 1x | Do companies in allied, likeminded, or at least non-rival, non-EU states effectively supply the same good or service? |
| | | 5. Internal production - 1x | Can the production of the good or service be effectively moved to the Netherlands or another EU member-state? |
| | | 6. Substitution - 1x | Can the function of the good or service be performed effectively, meaning at the same level of quality, in similar quantities and at comparable prices, by a different good or service? |
| | | 7. Illicit exchange -1x | Can the good or service provided by the original suppliers still be effectively accessed, in spite of an export boycott through direct or indirect illicit flows? |

[5] For a full explanation on the working of the Strategic Dependence Risk Framework and the methodology behind it, please see: Teer, Ruijter, and Rademaker, 'Navigating the Great Game of Choke Points: Assessing Geopolitical Risks and Advancing Dutch and European Strategic Indispensability in Digital Value Chains', March 2024, Chapter 2, 22-31 & Annex 1a&1b, 65-73.

## 2.3.2 Offshore wind risk assessment

For offshore wind currently the only key dependence on China is for permanent magnets for the generators. Towards 2028 the most significant risk is the position of the European OEM's Siemens Gamesa and Vestas. In Table 2.7 the impact of supply disruptions have been sketched for the current situation and for two scenario's in 2028: 1) the baseline scenario and 2) the scenario where the European OEM's are no longer present and the dependence on Chinese OEM's for wind turbines and critical components (blades, nacelles, towers, electronics, etc.) has increased significantly (or in other words, the 2028 negative scenario). In this 2028 negative scenario, interruptions in the supply of materials, components and end-products from China will have a far more severe impact.

Table 2.7: Strategic dependence risk framework – offshore wind.

| | | Impact indica-tors (weighted) | Main guiding question | Impact level | Impact assessment |
|---|---|---|---|---|---|
| 1. Identifying strategic dependence | 1a. Assessing criticality of baseline supply | 1. Criticality 2x | How critical is the baseline supply of the good or service from one or several countries in the digital stack for the Netherlands and the EU to secure its level-one and level-two core interests? (i.e., What is the effect on the Netherlands and the EU's level-one and level-two core interests if the baseline supply of the good and service from one or several countries is entirely disrupted?) | <u>2023</u><br>2. Minor effect on security, safety and health; somewhat impedes energy transition. | In 2023 the baseline supply from China is not very critical for the security, safety and health core-interests in the EU. Disrupted supply of permanent magnets will have an impact on the speed of the energy transition. In 2028 the effect on the energy transition is larger – both due to the higher dependence on offshore wind energy for the energy transition in 2028 and in the second scenario due to the higher dependence on China. |
| | | | | <u>2028 – baseline scenario</u><br>3. Substantial effect on security, safety and health; impedes energy transition. | |
| | | | | <u>2028 – negative scenario</u><br>4. Major effect on security, safety and health; disrupts energy transition. | |
| | | 2. Dependence on maintenance, updates or resupply (1x) | If the good or service is no longer supplied, when will this have an impact on level-one and/or level-two core interests? | <u>2023</u><br>1. No maintenance, updates or resupply required for the entire lifespan of the product. Timing of the impact delayed. | In 2023 the dependence on maintenance, updates or resupply is very limited. This dependence can increase in 2028, yet we expect this dependence to remain limited. |
| | | | | <u>2028 – baseline scenario</u><br>1. No maintenance, updates or resupply required for the entire lifespan of the product. Timing of the impact delayed. | |
| | | | | <u>2028 – negative scenario</u><br>2. Maintenance, updates or resupply required every 5 years. Timing of the impact delayed, but long-term: in 5-to-10 years. | |

| | | | | |
|---|---|---|---|---|
| | 3. Demand projection (1x) | Total demand: Is national, regional and/or global demand for the good or service likely to outpace global supply, leading to shortages of the good or service on top of the risks of supply-related shocks? Total use of good or service to enable vital processes: Will more vital processes come to rely on the supply of the good or service in the next five years? | 2023, 2028 (both scenarios)<br>3-4. Total demand rising 25-to-50% in next 5 years | The global demand for offshore wind is expected to increase in the coming 5 to 10 years. The supply chain will therefore be increasingly strained for the necessary materials and prone to disruption, as the global demand also increases. Concretely, to meet the Paris Climate Agreement's goals already in 2040 demand for rare earths will have grown 7-times vis-à-vis demand in 2020. In short, China's current over 90 percent dominance in rare earth refining is growing in value each year, as growing demand for its components increases its value. |
| | 1. Criticality of baseline supply, weighted average (scale 1-5):<br>1.7 (2023), 2.1 (2028 baseline scenario), 2.7 (2028 negative scenario) | | | |
| 1b. Assessing alternatives to baseline supply | 4. Diversification (1x) | Do companies in allied, likeminded, or at least non-rival, non-EU states effectively supply the same good or service? | 2023<br>3. Partially effective, immediate diversification possible (50%); alternative suppliers offer inferior quality, half of the quantity at higher prices.<br>2028 – baseline scenario<br>3. Partially effective, immediate diversification possible (50%); alternative suppliers offer inferior quality, half of the quantity at higher prices. More competition expected than in 2023.<br>2028 – negative scenario<br>4. Limited effective, immediate diversification possible (25%); alternative suppliers offer far inferior quality, a quarter of the quantity at far higher prices. | There are currently limited diversification options for offshore wind, most notably for wind turbine suppliers, where only the US has a significant player internationally (GE Electric, with manufacturing plants in Europe and in China). Growing demand and increased pressure on GE Electric from Chinese competition, will further limit the diversification options in the next few years. |
| | 5. Internal production (1x) | Can the production of the good or service be effectively moved to the Netherlands or another EU member-state? | 2023<br>1. Complete effective internal production possible (100%); Indigenisation possible in 1-year.<br>2028 – baseline scenario<br>1. Complete effective internal production possible (100%); Indigenisation possible in 1-year.<br>2028 – negative scenario<br>3. Partial effective internal production possible (50%); Indigenisation possible in 5-to-10 years. | Internal production within the EU is currently also possible, albeit the capacity switch suppliers to meet demand is limited with only two main offshore wind turbine suppliers. In the 2028 scenario it will be more difficult to switch suppliers within the EU if the reliance on Chinese baseline supply increases. It will take at least 5-10 years to set up new manufacturing capacity for offshore wind. |

| | | | | | |
|---|---|---|---|---|---|
| | | 6. Substitution (1x) | Can the function of the good or service be performed effectively, meaning at the same level of quality, in similar quantities and at comparable prices, by a different good or service? | 2023, 2028 (both scenarios)<br>4. Limited effective substitution possible (25%); many additional technological advances are required; complete substitution possible in 11-to-15 years. | Offshore wind energy plays an important role in the future energy supply in Europe, making it difficult to substitute offshore wind for another technology. Without offshore wind, it will take technological advance and multiple years to find alternatives. |
| | | 7. Illicit exchange (1x) | Can the good or service provided by the original suppliers still be effectively accessed, in spite of an export boycott through direct or indirect illicit flows? | 2023, 2028 (both scenarios)<br>5. No continued supply through illicit exchange possible (0%); boycotting state has complete effective direct and indirect enforcement means. | Illicit exchange for a technology like wind energy is unlikely to be possible due to the size of the components. Even the possibilities for illicit exchange of permanent magnets will be limited. |
| | | Level of access to alternatives for baseline supply, weighted average of above categories (scale 1-5):<br>3.3 (2023), 3.3 (2028 baseline scenario), 4 (2028 negative scenario) | | | |
| | Impact level, weighted average of above categories (scale 1-5):<br>2.5 (2023), 2.7 (2028 baseline scenario), 3.4 (2028 negative scenario) | | | | |

## 2.3.3 Electrolysis risk assessment

Electrolysis will be an important part of the future energy system, but this is currently not yet the case, which mainly defines the difference in risk assessment between 2023 and 2028. Note that the importance of electrolysis will increase up to 2030 and beyond, which is expected to lead to a more extreme risk assessment outcome. Here only 2023 and 2028 are considered.

Table 2.8: Strategic dependence risk framework - electrolysis

| | | Impact indica-tors (weighted) | Main guiding question | Impact level | Impact assessment |
|---|---|---|---|---|---|
| 1. Identifying strategic dependence | 1a. Assessing criticality of baseline supply | 1. Criticality 2x | How critical is the baseline supply of the good or service from one or several countries in the digital stack for the Netherlands and the EU to secure its level-one and level-two core interests? (i.e., What | 2023<br>1. No effect on security, safety and health. No obstacles to energy transition. | As of now, there are no dependencies on China in the European PEM and alkaline supply chains (impact level 1). The risks associated with China interrupting the supply chain are currently minimal. Any potential disruption would primarily impact the import of components to Europe. However, these components are |

| | | | | |
|---|---|---|---|---|
| | | is the effect on the Netherlands and the EU's level-one and level-two core interests if the baseline supply of the good and service from one or several countries is entirely disrupted?) | 2028<br>2. Minor effect on security, safety and health; Somewhat impedes energy transition. | also available within Europe itself. In addition, for the main materials – iridium and platinum – the world and hence also the EU is in majority dependent on South Africa, not on China.<br><br>For 2028, it is very uncertain what the supply chain will look like, but a dependence on China is definitely possible (impact level 2). Hence, a disruption in the Chinese supply chain could impact the energy transition and functionalities connected the energy system (safety, health, security). Towards 2030-2035, the impact might be even larger (impact level 2-3), as electrolysis is expected to become a more vital part of the energy system. |
| | 2. Dependence on maintenance, updates or resupply (1x) | If the good or service is no longer supplied, when will this have an impact on level-one and/or level-two core interests? | 2023<br>1. No maintenance, updates or resupply requires for the entire lifespan of the product. Timing of impact delayed.<br><br>2028<br>2. Maintenance, updates or resupply required every 5 years. Timing of impact delayed, but long-term: in 5-to-10 years. | The replacement needs of electrolyser components purchased from other countries can lead to regular dependencies. For now, this is not an issue (impact level 1). But with an estimated lifespan of about 8 years, electrolysers require replacement of stack components, such as membranes and electrodes. Customers are likely to prefer sourcing replacement components from the same provider for ease of installation and due to a lack of standardization.<br><br>Maintenance, however, does not necessarily have to be done by the same company as the supplier. The same accounts for software (updates). For 2028, this scores an impact level of 2. |
| | 3. Demand projection (1x) | Total demand: Is national, regional and/or global demand for the good or service likely to outpace global supply, leading to shortages of the good or service on top of the risks of supply-related shocks? Total use of good or service to enable vital processes: Will more vital processes come to rely on the supply of the good or service in the next five years? | 2023 - 2028<br>5. Total demand multiplying in next 5-years. | Global demand is expected to grow tremendously towards 2030, as presented in Figure 2.7. It therefore scores 5 for both 2023 and 2028. |
| | **1. Criticality of baseline supply, weighted average (scale 1-5):**<br>2 (2023), 2.8 (2028) | | | |

| | | | | |
|---|---|---|---|---|
| 1b. Assessing alternatives to baseline supply | 4. Diversification (1x) | Do companies in allied, likeminded, or at least non-rival, non-EU states effectively supply the same good or service? | 2023<br>1. Complete effective immediate diversification possible (100%); alternative suppliers offer same quality product, in same quantities at comparable prices. | In 2023 there are many international players, e.g. the US, which could provide parts of the supply chain if needed. There are many possibilities for diversification of suppliers (impact level 1). |
| | | | 2028<br>2.5. Majority-partial effective, immediate diversification possible (50%-75%); alternative suppliers offer (slightly) inferior quality, in lower (slightly – half) quantities at higher prices. | In 2028 diversification options are expected to be more limited (impact level 2). Other partners outside Europe might be a necessity in case a dependency on China exists, and Europe is not able to provide in its growing demand. Even though there may still be many international alternatives, for instance with the US or India, there might be high competition in this due to the rising global demand. For 2030-2035 this trend continues and therefore the risk increases (to impact level 2-3). |
| | 5. Internal production (1x) | Can the production of the good or service be effectively moved to the Netherlands or another EU member-state? | 2023<br>1. Complete effective internal production possible (100%); Indigenisation possible in 1-year. | Currently there are no problems foreseen, as there are more than enough European players to cover the small scale demand (impact level 1). |
| | | | 2028<br>2. Majority effective internal production possible (75%); Indigenisation possible in 2-to-4 years. | In 2028 this might lead to problems (impact level 2), and even more so in 2030-2035 (impact level 2-3) due to the expected larger scale of the demand for electrolysers, which might be larger than the European supply. |
| | 6. Substitution (1x) | Can the function of the good or service be performed effectively, meaning at the same level of quality, in similar quantities and at comparable prices, by a different good or service? | 2023<br>1. Complete effective substitution possible (100%); no additional technological advances are required; complete substation possible in 1-year. | Currently there are no risks foreseen for substitution (impact level 1), as the required hydrogen could be replaced by blue hydrogen or biomass. |
| | | | 2028<br>3.5. Partial-limited effective substitution possible (25-50%); additional technological advances are required; complete substitution possible in ~10 years. | The amount of blue hydrogen or biomass is not sufficient anymore in 2028 (impact level 2) when electrolysis will play a larger role in the energy system. PEM and Alkaline could be used as substitutes for each other.<br><br>A problematic part is iridium, which is required for PEM and is only mined in a few countries (mostly South Africa, but also Russia, the US and Canada). Alternatives for iridium catalysts are being developed, a.o. by TNO, but it will take 3-7 years for the new materials to be fully applicable in PEM electrolysis. |

| | | | | | |
|---|---|---|---|---|---|
| | | 7. Illicit exchange (1x) | Can the good or service provided by the original suppliers still be effectively accessed, in spite of an export boycott through direct or indirect illicit flows? | 2023 - 2028<br>3. Partial continued supply through illicit exchange possible (50%); boycotting state has some effective direct and indirect enforcement means. | This is considered to be the same for both years. Regarding small components, illicit exchange is technically feasible. However, sanctions are expected. Hence, impact level is estimated at 3 for both years. |
| | | **Level of access to alternatives for baseline supply, weighted average of above categories (scale 1-5):**<br>1.5 (2023), 2.8 (2028) | | | |
| | **Impact level, weighted average of above categories (scale 1-5):**<br>1.8 (2023), 2.8 (2028) | | | | |

# 3 Assessment of geo-economic risks

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This chapter assesses the geo-economic risks associated with dependence on China in the wind energy and electrolysis value chains, at present and for the next five years. Section 3.1 puts the risks in the wind energy and electrolysis value chains into a geopolitical context, namely that of intensifying great power rivalry at a time of deep economic interconnectedness. In addition, it pays specific attention to Beijing's national aims and industrial policies. Specifically, it delves into concepts from weaponised interdependence theory such as *chokepoints* and *breaking points* and China's key national strategies such as *Made in China 2025* and *the new development philosophy*. It finds that great powers have increasingly sought to deter, compel or corrode the capabilities of rivals by leveraging control over (economic) chokepoints in the world economy. Not coincidentally, throughout the last twelve years, the Chinese Communist Party (CCP) under Xi Jinping has moved its focus from economic development and rapid integration into the world economy to fostering greater economic self-reliance. Xi likewise explicitly seeks to enhance dependence of other countries on China.

Section 3.2 presents a taxonomy of ten different geo-economic risks stemming from China in electrolysis and wind energy value chains, now and in the next five years (see Section 3.2). The goal is not to be exhaustive, but to outline the main geo-economic risks that materialise at different levels of escalation of EU-China tensions. These risks can be divided in two categories. First, the taxonomy presents market-distorting actions the Chinese state has resorted to structurally, such as risk 1 ("restrictions for EU companies on China's market") and risk 4 ("theft of EU intellectual property"). Beijing's measures aim to strengthen the position of domestic firms, expand China's self-reliance, and deepen dependence of the EU on China. These first five geo-economic risks have already materialised in wind energy, new energy & energy-saving vehicles, (advanced) energy equipment or in another priority industry identified in Made in China 2025 and the 14th Five-Year Plan. These measures structurally endanger the future (financial) success of EU companies (see Table 3.). As tensions continue to rise, Beijing's protectionist policies may well be intensified in the future.

Second, the taxonomy outlines five geo-economic risks that may materialise in the (near) future. Two of these risks, namely risk 7 ("commercial monopolistic practices") and risk 9 ("a ban on exports of vital end-products to the EU") can only occur in the previous chapter's 2028 negative scenario. This is the scenario in which European OEMs do not survive their current financial difficulties. The EU becomes almost entirely dependent on China for critical components and end-products, as a result. In this scenario, Chinese companies are left as the only competitive parties with high production capacity in global wind energy and electrolysis markets. In addition, the disruption if risk 8 ("an expansion of increasingly effective cyber-attacks against vital infrastructure") or risk 10 ("War-related disruption to China's production lines and supply routes between Europe and Asia") materialises will be far more severe if Chinese companies are the only remaining players in offshore wind and electrolysis markets than in the present situation. All of the latter five risks are increasingly likely to occur, when

China-US and by extension China-EU tensions continue to rise (in line with the relationship's trajectory of the past decade). Especially at a time of military-strategic crisis, these risks become suddenly, possibly entirely without warning, far more likely to materialise.

Section 3.3 presents differences in geopolitical risk levels of EU strategic dependencies on China and other third countries that play an important role in the offshore wind and electrolysis value chains (now and in the next five years). It shows that in the next five years, only Chinese parties have the production capacity to become dominant in the EU wind energy sector. The future of electrolysis is more uncertain. China is likely to have become an important player by 2030, but the complexity of electrolyser systems and related transportation challenges could make it harder for China to become dominant in a short time. This is also the case for other states that are geographically far away from the EU.

The findings are based on a combination of sources. First, the chapter leverages the value chain analysis and projections for 2028 presented in the previous chapter. In addition, it draws on past HCSS research and additional desk research of primary sources, namely CCP leadership speeches and industrial strategies, and secondary sources, such as thinktank reports on China's macro-economic goals. In addition, it cites a previously conducted HCSS-quantitative discourse analysis on CCP leadership's perceptions on the degree of international opposition to its rise. The probability assessment on how likely the latter five risks are to occur in the next five years was arrived at on the basis of two workshops with TNO-researchers. During a third HCSS internal workshop, participants used the HCSS Strategic Dependence Risk Framework to reach their conclusions.[6] The previous chapter used the same framework to assess the impact of disruptions in the supply of wind energy and electrolysis components and end-products from China to the Netherlands and the EU.

# 3.1 Context: China's national goals at a time of great power rivalry

## 3.1.1 Great power rivalry at a time of deep economic interdependence

In the post-Cold War era, the world economy grew more interconnected than ever before (Altman & Bastian, 2023). China's *reform and opening-up* (starting in the 1980s) added an unprecedented labour population to the world economy (Goodhart & Pradhan, 2020). The thirty years that followed saw materials production and manufacturing processes rapidly moved from the West to East Asia in general, and to China in particular. Today, China produces roughly 35 percent of all goods worldwide. This is more than the subsequent nine countries combined and three times more than the United States, the world's second largest manufacturer (Baldwin, 2024; Teer, Elisson, et al., 2024a, pp. 23–24). Looking for low-wage labour, more permissible environmental regulations and new sales, many international firms benefited enormously from China's integration into the world economy. Their production chains today criss-cross the entire globe.

However, these companies also grew highly dependent on China. This is even the case for the production of essential materials, components, goods and services that underpin vital

[6] The development of this risk assessment framework was commissioned by the Netherlands Ministry of Economic Affairs and Climate (MinEZK). The risk assessment framework was designed by Joris Teer, Abe de Ruijter and Michel Rademaker (HCSS).(Teer, de Ruijter, et al., 2024b, Chapters 3, Annex 1a&1b)

sectors, such as the defence, communications, green energy, and medical sectors of the Netherlands and the EU (Zenglein, 2020, pp. 2, 7; Teer et al., 2023; Teer, de Ruijter, et al., 2024c). More broadly, great powers would develop deep strategic dependencies on states they later came to see as rivals (again). For illustration, “the US and EU source the raw materials for medicine from China and India; China[‘s mass production of electronics relies on] imports of semiconductors from Taiwan, South Korea and the United States (US); and the EU and US import raw materials and components on a large-scale from China for the production of electric vehicles, drones [and wind turbines].” (Teer et al., 2023, p. I).[7]

With the US-China trade and technology war, the intensification of military competition in East Asia between the US and its Asian allies on the one hand and China on the other, and Russia’s invasion of Ukraine, the era of carefree economic reliance on other great powers has definitively come to an end (Teer, Elisson, et al., 2024b, p. 1). The return of competition between them accelerated the transformation of globalised value chain networks from a web that supposedly would decentralise power into a sequence of chokepoints controlled by powerful states (Farrell & Newman, 2023). States today can make use of “political authority over these [chokepoints, meaning the] central nodes in the international networked structures through which money, goods, and information travel” (Farrell & Newman, 2019, pp. 45-46) to “compel and deter” other states or to “corrode” their capabilities (Teer, de Ruijter, et al., 2024c, pp. 9–21).

Examples of the use of chokepoints throughout the last ten years are plentiful. The Trump Administration slowed the development of Huawei, a Chinese telecommunications company, by cutting it off from the supply of semiconductors from the US and US allies and partners. The Biden Administration, nudging its allies in East Asia and the EU, vastly expanded the curbs on exports of semiconductors and related technology to an increasing number of Chinese firms throughout 2022 and 2023 (Reva Goujon et al., 2022). China played its own trump card: access to its gigantic market and its dominant position in the production of critical raw materials. At different moments during the last fifteen years, Beijing punished South Korean, Australian, Lithuanian, Swedish, Norwegian, and American firms by limiting market access and encouraging consumer boycotts (Bohman & Pårup, 2022; Joris Teer & Mattia Bertolini, 2022, p. 47). In the summer of 2023, China imposed an export license requirement on gallium and germanium, two minerals needed to produce electronics and hence essential for vital sectors and the broader economy, and graphite, a key material for the energy transition (Cash et al., 2023).

At a time of great power competition, geopolitical rivals may become unwilling to continue the supply of a key resource, good or service to one another. Perhaps the most extreme case of rival states resorting to weaponised interdependence strategies came following Russia’s invasion of Ukraine. In the face of a professedly comprehensive semiconductor ban by the EU, US, Taiwan, South Korea, and Japan (aimed at destroying Russia’s arms industry) (Ursula von der Leyen, 2022; Sullivan, 2022), as well as cutting access of Russian banks from the Society for Worldwide Interbank Financial Telecommunications (SWIFT), President Putin limited gas supply to the EU by about 80 percent. This sent gas prices soaring throughout the EU and required governments to enact energy compensation schemes for industry and citizens that far exceed the financial costs of their involvement in aiding Ukraine. In fact, in 2022 EU countries mobilised ten times more funds for “domestic energy agencies” than on aid to Ukraine, finds (Trebesch et al., 2023, p. 51). Until today, this extreme curtailment of

[7] For a good overview of the PRC’s dependence on semiconductor imports and of where China’s drive to indigenise semiconductor production stands today, please see: (Lee, 2024)

Russian gas exports greatly damages the Union's competitiveness, as energy in the EU has become far more expensive than in the US and China.[8]

Likewise, conflict between great powers can lead to war-related disruption, putting even more production and trade at risk. For example, the Azovstal, a steel factory in Mariupol that together with factories in Odessa produced 50 percent of the world's neon gas for semiconductor production, was destroyed by Russia's armed forces in the first half of 2022 (Alper, 2022). The invasion of Ukraine and its aftermath shows that when tensions reach breaking point, both economic boycotts and war-related disruption can upend the supply of vital materials, components and end-products to the EU (Joris Teer & Mattia Bertolini, 2022, p. 27).

Great power competition between China and the US and by extension US allies will very likely continue to be a central feature of geopolitics in the upcoming decades (Rudd, 2022). The economic fall-out of the war in Ukraine shows that the EU faces (at least) two new risks. First, China may no longer be willing or able to supply essential materials, components, goods and services if tensions escalate. Second, war-related disruption may make it impossible for China to continue supply. Fear of falling victim to the weaponization of interdependence between great powers is only growing. This will again incentivise a proliferation of great power protectionist measures to increase economic security. Fear of a crisis comparable to the Ukraine War, which led to economic boycotts and sanctions, has driven China to accelerate policies to expand self-reliance in vital sectors and disruptive industries (Ni, 2022a). In response, the US and to a lesser extent the EU have adopted industrial policies, including state subsidies, to achieve greater self-reliance in specific strategic industries such as semiconductors and CRM (Teer et al., 2024).

### 3.1.2 China's aims and industrial policies

Throughout the last twelve years, the Chinese Communist Party (CCP) has moved its focus from economic development and rapid integration into the world economy to fostering economic self-reliance (Zenglein & Gunter, 2023). The primary means were import substitution and incentivising domestic technological and industrial development. Specifically, President Xi has called on the Party to replace China's export-oriented growth model from the *reform-and-open-up*-era (starting in the 1980s) with "the new development philosophy" (Xi Jinping, 2022, p. 34; Dikötter, 2022). This new model first and foremost relies on leveraging internal consumption to maintain, expand and (technologically) advance *domestic* manufacturing capabilities. The goal is to be able to domestically produce anything that Xi considers vital for China's economic and national security (Rennie, 2020). In recent years, Xi has urged the Party to accelerate these efforts, as he perceives important players in the global economy, in particular the United States, as increasingly hostile to China's rise. In the face of perceived extreme situations that are increasingly likely to occur, Xi fears that China's access to foreign-produced products and international sales markets is at risk of suddenly being cut-off. Following the outbreak of COVID-19, President Xi also explicitly called for expanding the reliance of the rest of the world on China. China's large-scale support for domestic industries and curtailment of access to its market that flow from these national goals increasingly put European firms at risk.

[8] Throughout 2022, EU natural gas prices were six times higher than in the U.S. and more than 2.5 times higher than in China. Even though prices dropped throughout the EU in 2023, the energy price difference between the EU and other economic great powers is still substantial (International Energy Agency (IEA), 2023, p. 96). The total cost of compensating energy bills for industry and citizens in the EU is estimated to have exceeded 1.000bn euros. (van den Beukel & van Geuns, 2023, p. 21; Bloomberg News, 2022)

Textbox 1: *Xi's role in formulating China's national goals and industrial policy*

Xi's pronouncements are becoming an ever more important source to assess China's intentions for three reasons. First, he has greatly centralised power since his ascent to China's Presidency and the position of Secretary-General of the Chinese Communist Party in 2012. Xi effectively ended the era during which China was governed by CCP collective leadership. At a very early stage in his first term, he assumed the Chairmanship of the Central Military Commission, the highest national defence organisation of the PRC. In addition, Xi abolished Presidential term-limits. Now, in his third term, he has become China's most powerful leader since Chairman Mao (Wong, 2023). Second, President Xi has again made the role of the Party in the economy more central, aiming to "align economic actors with China's strategic goals" (Zenglein & Gunter, 2023, p.1). With this more centralised approach to China's economy, Xi seeks to achieve strategic objectives such as making China less-reliant on the world and the world more reliant on China (see section below). Third, Xi has transformed China's foreign policy. According to Xi, China has "stood up, grown rich [and is now] becoming strong" (Xi Jinping, 2017). Whereas Deng Xiaoping, China's paramount leader in the 1980s, advised China to "hide your strengths and bide your time", Xi's assessment is that the international order is experiencing "great changes unseen in a century" and that China should "lead the reform of the global governance system" (Doshi, 2021, p.280, 281 ). China's foreign policy has become much more assertive, as a result.

As term-limits were abolished, nobody knows when Xi's governance of China will end (McGregor & Blanchette, 2021). Therefore, it is prudent for European policy-makers to assume that the changes Xi initiated will last.

***From reliance on "the great international circulation" to "dual circulation", self-reliance and creating dependencies on China***

Over the past 12 years, China's economic policy has shifted focus from relying on exports of materials and relatively simple components and goods to stimulating domestic consumption and more advanced production. In Xi-speak, whilst China's growth used to rely on "the great international circulation" it should come to rely on "domestic circulation" instead. Xi seeks to direct the power of "China [as the] world's largest potential consumer market" internally (Xi, 2020, p. 2). The ultimate aim is to generate the local production for anything that China needs to maintain its national and economic security (Rennie, 2020). In fact, Xi calls moving to this internal demand expansion strategy "a necessity for maintaining the long-term, sustainable and healthy development of China's economy" (Xi, 2022, p. 34).[9] Following the derailment of the global economy due to COVID-19, Xi argued that China's development path had to be revised.[10] In an April 2020 speech, he called on China to establish supply chains "that are independently controllable, secure and reliable, and strive for important products and supply channels to all have at least one alternative source."[11] China, hence, attempts to strengthen the vertical integration of strategic manufacturing industries inside its borders. As a result, China's industrial policies, including large-scale subsidies, aim to ensure that vital components

[9] In 2022, President Xi was most explicit about the need for China to step away from its export-driven growth model. He stated: "We must fully and faithfully apply the new development philosophy [...] and accelerate efforts to foster a new pattern of development that is focused on the domestic economy and features positive interplay between domestic and international economic flows" (Xi, 2022, p. 34; Murphy, 2020; Zenglein & Gunter, 2023).

[10] He argues that from the 1980s onwards, Beijing fully betted on entering "the international great circulation", meaning the global economy, in order to "seize [...] globalisation opportunities" and achieve a "rapid increase in economic strength" (Xi, 2020; Murphy, 2020, p. 2).

[11] When in April 2020 China was coming out of its first lockdowns whilst the rest of the world was going into them, Xi signals that this international emergency "is a stress test under actual combat conditions" (Xi, 2020; Murphy, 2020, p. 3).

such as semiconductors and permanent magnets and end-products such as airplanes and wind turbines are produced domestically.

In this new era, export (or "international circulation") still serves two purposes. First, selling Chinese-produced components and end-products abroad can help expand China's domestic production capacity. Excess capacity ought to be exported to the world to invest in more manufacturing. As domestic consumption has tethered following China's post-Covid opening up, exporting excess capacity has become increasingly important again in the short-term (Rosen & Wright, 2024). Second, dominance of industries through below-market price exports helps Beijing to make the world more dependent on China. After all, the goal of China's policies is not limited to expanding self-reliance through import substitution. In the same April 2020 speech, Xi calls on the Party and economy to "tighten international production chains' dependence on China, forming powerful countermeasures and deterrent capabilities against foreigners who would artificially cut off supply [to China]" (Xi, 2020, p. 3). In other words, fearing hostile acts against China, Xi seeks control over more chokepoints. The goal of doing this is to deter, and if need be take "countermeasures", against rivals. Both the export of below global market price products and the intentional creation of new dependencies put China in the crosshairs of European firms, governments and the EU.

These national goals take shape in gigantic state-directed industrial policies, most importantly Made in China 2025 (announced in 2015) and the 14th Five-Year Plan (2021-2025). Both policies aim to catapult China into a leading position in ten sectors that are expected to revolutionise national and defence industries in the upcoming decades. These policies also explicitly seek to expand China's self-reliance. "New energy & energy-saving vehicles" and "(advanced) energy equipment" are two priority sectors in both policy initiatives (Rabinovitch, 2021; Central Commission for Cybersecurity and Informatization, 2021; Creemers et al., 2022; PRC State Council, n.d.). Priority sectors receive large-scale state support to avoid strategic dependence on others, while attempting to make the world dependent on China's excess capacity.

*From an international environment of "peace" and "development" to "external attempts to suppress and contain China"*

The perceived urgency and importance for China's leadership to implement this "dual-circulation strategy" has been further strengthened over the last five years. Xi perceives the international environment as increasingly hostile to China's rise (see Figure 3.1). In fact, he fears that during a crisis (or in "extreme situations") the US and its allies may try to cut China off from parts of the global economy. Without naming the US, in his latest report to the National People's Congress in 2022 Xi lamented recent attempts to "contain, blockade, and exert maximum pressure" against China. He goes on to warn that such attempts "may escalate at any time" (Xi Jinping, 2022, p. 21). Mentions of words like "trade", "growth" and "economic development" in National People's Congress Reports have structurally made way for mentions of "national security" and words that relate to the fear of a geopolitical crisis occurring (see Figure 3.1).[12] Similar to how Russia's war in Ukraine led EU-Russia trade relations to finally reach breaking point, a crisis in East Asia may lead to the large-scale disruption of US and US-allied trade with China that Xi fears. In fact, already in the first months of the US-led attempt to cut-off Russia from the global economy, Beijing initiated large-scale sanction stress-testing. The goal of these public-private exercises was to investigate how its economy would perform under US-led sanctions (Ni, 2022a).

[12] During the National Congress of the Communist Party of China, the General-Secretary of the Chinese Communist Party sets out the general direction for the government and party for the next five years.

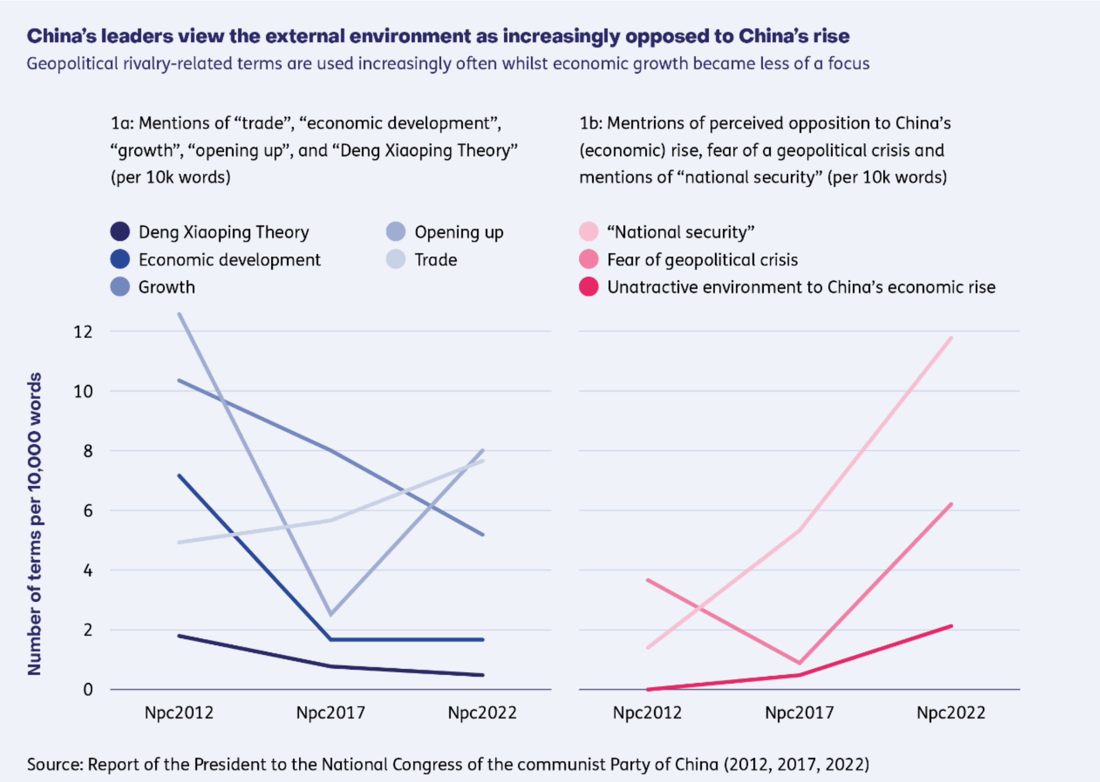


Figure 3.1: CCP leaders view the external environment as increasingly opposed to China's rise[13]

Xi's warnings followed a period of rapid intensification of US-China competition, including on China's "core interests" and related to military-strategic flashpoints in East Asia. In addition to tech-containment, the US has undertaken efforts to again move the balance of military power in the East China Sea, South China Sea and around Taiwan in its favour. Since assuming office, President Biden has made at least four explicit verbal commitments to defend Taiwan in case of a People's Liberation Army (PLA) attack and intensified US military alliances and partnerships in the region.[14] US actions came in response to increased efforts by China to achieve "reunification" on its terms. China has rapidly modernised its military throughout the last decade and a half, enabling Beijing to put more pressure on US alliances and partnerships in East Asia (Teer et al., 2021). Since 2016, China has taken a growing number of actions against Taiwan in the hybrid domain, including larger and more frequent military exercises around the island (Cheung, 2023; Hass et al., 2023; Jestrab, 2023; Lewis, 2023). The Democratic Progressive Party's candidate, according to China the choice for "war" and "recession", won the January 2024 Presidential Elections in Taiwan.[15] As a result, the probability of a China-US crisis in East Asia, most dangerously of a military-strategic crisis over Taiwan, has increased throughout the last decade.[16] The likelihood of China's relations with

[13] The full discourse analysis will be published in H1-2024, as part of the research by Joris Teer, Abe de Ruijter, and Anna Sophie den Ouden, 'Blocs and Barriers: Are There Limits to Great Power Decoupling in the next Five Years?' (The Hague: The Hague Centre for Strategic Studies, Q2 (upcoming 2024).
[14] The US introduced a trilateral military cooperation framework (AUKUS) with the United Kingdom and Australia and expanded access to military bases in the Philippines (Ni, 2022b; United States Department of Defense (DoD), 2023).
[15] "Zhang Zhijun, president of the Association for Relations Across the Taiwan Straits, a quasi-official body that handles ties with Taiwan" cited in (Zhang, 2024).
[16] For a more extensive account on why the risk of war over Taiwan has increased, please find: (Teer, Elisson, et al., 2024b, p. Chapter 1).

the US (and by extension likely the EU) reaching breaking point therefore have increased as well.

## 3.2 China-related risks in off-shore wind energy and electrolysis value chains

The section below presents a taxonomy of ten different geo-economic risks stemming from China in electrolysis and wind energy value chains (now and in the next five years). The goal is not to be exhaustive, but to outline the main geo-economic risks that may materialise at different levels of escalation of EU-China tensions. These risks can be divided in two categories. First, the taxonomy presents market-distorting actions the Chinese state has resorted to already. These measures aim to strengthen the position of domestic firms, expand China's self-reliance, and deepen dependence of the EU on China. These protectionist policies may well be intensified in the future. These first five geo-economic risks have already materialised in wind energy, new energy & energy-saving vehicles, (advanced) energy equipment or in another priority industry identified in Made in China 2025 and the 14$^{th}$ Five-Year Plan. These measures pose challenges to the future (financial) success of EU companies (see Table 3.).

Second, the taxonomy outlines five geo-economic risks that may materialise in the (near) future. Two of these risks, namely risks 7 and 9, can only occur in the previous chapter's 2028 negative scenario, meaning the scenario in which European OEMs do not survive their current financial difficulties and the EU becomes almost entirely dependent on China for critical components and end-products. After all, in this scenario, Chinese companies are left as the only competitive parties with high production capacity in global wind energy and electrolysis markets.[17] In addition, the disruption if risk 8 or 10 materialises will be far more severe if Chinese companies are the only remaining players in offshore wind and electrolysis markets than in the present situation. All of the latter five risks are increasingly likely to occur, when China-US and by extension China-EU tensions continue to rise (in line with the relationship's current trajectory). Especially at a time of military-strategic crisis, these risks become suddenly, possibly entirely without warning, far more likely to materialise.

[17] As EU companies in this scenario have not been able to withstand Chinese competition.

**Table 3.1:** Taxonomy of geoeconomic risks stemming from China in strategic value chains

| Risk for the EU | China aims | Timing | Level EU-China escalation |
|---|---|---|---|
| 1. Restrictions for EU companies on China's market | Strengthen position of Chinese firms, in order to expand self-reliance and increase dependence of EU on China | Structural / Ongoing / In place for over a decade | Structural |
| 2. State-subsidised Chinese competition on the EU market | Strengthen position of Chinese firms: increase dependence of EU on China | Structural / Ongoing | Structural |
| 3. (State-supported) acquisition of EU companies and Intellectual Property | Strengthen position of Chinese firms: expand self-reliance and increase dependence of EU on China | Ongoing | Structural |
| 4. Theft of EU Intellectual Property | Strengthen position of Chinese firms: expand self-reliance and increase dependence of EU on China | Structural / Ongoing | Structural |
| 5. Export bans on technologies required to produce essential components | Strengthen position of Chinese firms: maintain dependence of EU on China; lock-in China's technological advantages | Ongoing / accelerated in 2023 | Current |
| 6. Ban on exports of essential materials and components | Strengthen position of Chinese firms; Disrupt production of EU-competitors (potentially fatally); Expand dependence of EU on China; Compelling and deterring the Netherlands and the EU from acting against China's "core interests"; Corroding EU abilities to act against China's "core interests" | Legislation in place to initiate export ban for some materials / Possible today; especially at moments of rising CN-EU tensions / Likely if a military crisis takes place in East Asia | High |
| 7. Commercial monopolistic practices | Strengthen position of Chinese firms by increasing revenues and profits | Possible if China becomes the sole remaining dominant producer of end-products (2028 negative scenario) | High |
| 8. Expansion of increasingly effective cyber-attacks against vital infrastructure | Compelling and deterring the Netherlands and the EU from acting against China's "core interests"; corroding EU abilities to act against China's "core interests"; Gathering intelligence/nesting in EU-NL systems in preparation for a large-scale attack at later moment | Possible if China becomes the sole remaining dominant producer of complex components and end-products (2028 negative scenario) / Likely at moments of high CN-EU tensions | Very high |
| 9. Ban on export of vital end-products | Compelling and deterring the Netherlands and the EU from acting against China's "core interests"; Corroding EU abilities to act against China's "core interests" | Possible if China becomes the remaining dominant producer of end-products (2028 negative scenario) / Likely if a military crisis takes place in East Asia | Very high |
| 10. War-related disruption to China's | Winning a regional conflict against Taiwan, Japan, the Philippines and | Especially high-impact if China becomes the remaining dominant producer of end-products (2028 | |

| | | | |
|---|---|---|---|
| production lines and supply routes between Europe and Asia | possibly the United States. Prioritising key supplies and materials (e.g., steel) and personnel (e.g., factory workers) to defence industries and the war effort. | negative scenario) / Possibly the direct result of a military crisis in East Asia | |

### 3.2.1 Structural and ongoing geoeconomic risks

In order to strengthen the position of Chinese firms, the Chinese government has taken measures to expand self-reliance, increase dependence of the EU on China, and to "lock-in" China's comparative advantages vis-à-vis the EU. These measures are geo-economic risks that have already materialised. These are 1. restrictions for EU companies on China's market, 2. state-subsidised Chinese competition on the EU market, 3. (state-supported) acquisition of EU companies and Intellectual Property, 4. theft of intellectual property, and 5. export bans on technologies required to produce essential components. Considering Xi's growing focus on achieving self-reliance and expanding dependence of the EU on China through an expansion of China's manufacturing industries, these protectionist measures may well be intensified in the near future (Rosen & Wright, 2024).

1. Restrictions for EU companies on China's market

Obstacles for EU companies to sell goods on China's giant domestic market are commonplace. These formal and informal restrictions help the CCP to expand self-reliance and increase the dependence of the EU on China, as Chinese firms can make use of revenue generated domestically to compete below-market prices in specific foreign markets. Concretely, EU firms face compulsory joint venture requirements to enter China's market, local production requirements, onerous regulatory frameworks and preferential treatment of local competitors in government tenders and by China's SOEs (The European Union Chamber of Commerce in China, 2023; Korteweg et al., 2022; Koty, 2022).

The EU wind energy industry has faced these obstacles firsthand. From 1996 to 2005, Denmark's Vestas, US' GE Energy and Spain's Gamesa "dominated China's domestic wind turbine market, holding a 75 percent market share" (Oh, 2015, p. 1120). Gamesa controlled more than one third of the Chinese market alone in the early 2000s. However, in 2005 Beijing obliged Gamesa to achieve a 70 percent local production target for wind turbines. Practically, this meant it had to train 500+ suppliers to manufacture practically every part in its turbines, as well as establish a local manufacturing plant (Bradsher, 2010; Bradsher, 2020). The European Union Chamber of Commerce (EUCC) accused China of including requirements that only Chinese parties could meet in government tenders, pointing out that of the 500bn+ dollar stimulus package, none of the 25 largest contracts had been awarded to foreign companies (Moore, 2019; cited in Oh, 2015, pp. 1135–1137). By 2009, Chinese enterprises owned almost 90 percent of the market (Greenpeace, cited in Oh, 2015, p. 1122). Reciprocity is lacking, as Chinese firms do not face such restrictions in the EU (European Commission, 2023).

2. State-subsidised Chinese competition on the EU market

State subsidies for Chinese firms operating on the EU market likewise present a structural and ongoing geo-economic risk, across strategic industries. Europe, with its high energy costs following the invasion of Ukraine, high interest rates and high material prices, already faces financial challenges in offshore wind (Van den Beukel & Van Geuns, 2023).[18] Although China

[18] Fitzpatrick, K. explained the same costs during the BMI Research webinar "Subsidy Wars and the Energy Transition, the Race To Develop Low Carbon Energy Manufacturing" (Parker, 2023).

stopped providing national-level offshore wind subsidies earlier in 2023, local governments are seemingly stepping in to fill this gap (Xiaying & Xuan, 2023). China's industry also benefits from "state-backed loans" and "long-term deferred payments", says a BloombergNEF analyst. These perks contribute to the fact that China's production costs of wind energy turbines are about half of the cost that EU and US producers face (Jack, 2023). Siemens Gamesa has already called on the EU to protects its internal market against competition from China on price, by imposing quota for domestic manufacturing. One of its executives accused Chinese manufacturers of gaining market share in Europe on the basis of financial Chinese government support at several levels (Tani, 2022). In response, European policymakers have called on the EU to provide competitive subsidies for its own industries to remain competitive.[19] If current trends persist, China may be able to drive its EU competitors out of markets globally.

3. (State-supported) acquisition of EU companies and Intellectual Property

In line with Made in China 2025's objectives, China seeks to acquire EU companies and intellectual property to build on its lead in wind energy. Chinese SOEs and private companies have already acquired full or majority stakes in several European renewable energy firms. Examples of this are the acquisition of solar photovoltaic manufacturers Avancis and CTF Solar by the China National Building Materials Group Corporation (CNBM) in 2012 and the purchase of German Solibro by Hanergy in 2014. As mentioned in Chapter 2, "Xinjiang Goldwind bought a 70% stake in the German wind-turbine manufacturer Vensys in 2008" (Conrad & Kostka, 2017). At present, many European offshore wind companies face financial issues. As a result of rising material costs and high energy prices, EU firms became far more vulnerable to takeovers throughout 2023 (Jacobs, 2022; Millard, 2023).

4. Theft of EU Intellectual Property

Across the board, China's industrial espionage and theft of intellectual property (IP) poses another structural and ongoing geo-economic risk (Bradsher, 2020b). Dutch intelligence agencies, the *General Intelligence and Security Service* (AIVD) and the *Military Intelligence and Security Service* (MIVD), have regularly warned about China's large-scale targeting of Dutch companies and universities to acquire technology. Both agencies identify China as a very severe threat to Dutch economic security. The AIVD even labels China the greatest threat to economic security (AIVD, 2023; Ministry of Defence of the Netherlands, 2023). German intelligence has asserted that Chinese practices "jeopardise Germany's competitiveness [...] and undermine the laws of the market economy" . These acts risk undercutting the EU's competitive edge and R&D investments (Bradsher, 2020b). Newspaper reports revealed that a Chinese hacking-group was inside NXP Semiconductors networks for over two years, resulting in IP theft (Hijink, 2023). There are more examples of IP-theft from the Dutch semiconductor industry (Sebastian Moss, 2022). Just like semiconductor manufacturing, new energy and advanced energy equipment are priority sectors in China's industrial policies.

5. Export bans on technologies required to produce essential components

Imposing export bans on the technologies required to produce essential components for wind turbines and electrolysers is another way in which China can maintain or even expand the EU's dependence on China. Effectively, these bans aim to "lock-in" China's (near-)monopolisation of specific parts of the value chain. Late December 2023, China banned the export of permanent magnet-making technology and machinery altogether. Bans on the export of technologies for extraction and separation of rare earths were already in place (Liu

[19] The Vice-chair of the European Parliament's Committee on Industry, Research and Energy, M. Petersen has stated that these market uncertainties and unfair Chinese competitiveness have increasingly jeopardised the EU's position in the wind energy industry *after* the 2022 EU Offshore Renewables Energy Stategy was announced (Petersen, 2023).

& Patton, 2023; Baskaran, 2024). Rare earth-based permanent magnets, of which China produces approximately 85-90 percent globally, are essential components in both types of both the main current offshore wind turbine designs (outlined in chapter 2). The US and the EU hope to open two permanent magnet production sites each in the near future (Price, 2024). The introduction of these export bans are formidable obstacles for any other state to build up a complete permanent magnet-production chain outside of China.

### Geo-economic risks at times of high and very high geopolitical escalation

Five additional geo-economic risks stemming from reliance on China may materialise in the (near) future. The first four are all concrete examples of the risk that China's government may become unwilling to continue the supply of quality goods, at reasonable prices at scale. China's government already has the means to implement a painful ban on exports of essential materials and components such as permanent magnets (risk 6). In contrast, commercial monopolist practices (risk 7) and a ban on the export of vital end-products to the EU (risk 9) will only have a high negative impact in the 2028 negative scenario. In the 2028 negative scenario, if Chinese firms become dominant suppliers of complex products, then the threat stemming from China's ongoing offensive cyber programme (risk 8) to Dutch vital infrastructure increases. After all, legislation (e.g., National Intelligence Law 2017) obliges Chinese firms to assist China's intelligence services. The final geo-economic risk, namely war-related disruption of China's production lines and supply routes to the EU (risk 10), is an example of China becoming unable to continue supply.

In Chapter 2, the impact of disruptions in the supply of offshore wind turbines and electrolysers from China has been assessed. The risk level of a strategic dependence is both determined by the *impact* if supply of the good or service is disrupted and the *probability* that a supplier or supplier country-of-origin becomes unwilling or unable to continue supply. This report makes use of the HCSS strategic dependence risk framework, originally developed to compare the risk levels of six EU dependencies in the digital domain.[20]

The section below completes this assessment by making a preliminary assessment of the likelihood that China will become unwilling or unable to continue supply (see Figure 3.2 and Figure 3.3 below). It does so, by leveraging the *probability*-assessment part of the framework. *Unwillingness* to supply can be gauged by scoring strategic dependence on three indicators. Namely, the relationship with the supplier country, the state influence on the supplier, and the cost of weaponization to the supplier.[21] The section below starts with scoring the dependence on these indicators. Then, it outlines the concrete shape that an unwillingness to continue supply of quality products, at reasonable prices at scale may take (i.e., risk 6, 7, 8 and 9). Finally, the section is concluded with a brief assessment on whether China may become unable to supply (see "10. War-related disruption to China's production lines and supply routes to the EU"). Inability to supply is the result of either threats to the supplier country or threats to its supply lines materializing.

- The EU's *1. relationship with supplier country*, in this case China, has deteriorated in the years leading up to 2023. Despite some cooperation in fields such as climate change and high bilateral trade levels, the EU and China have competing and opposing interests and policies with regards to their core interests, primarily Russia's war against Ukraine and the status of Taiwan. The EU has also imposed sanctions on China

[20] For a full explanation on how the framework works, please find (Teer, Ruijter, et al., 2024c, Chapters 3 & annex 1a and 1b).

[21] The likelihood that a supply-related disruption takes place is the result of 2a. unwillingness by the supplier-state to continue supply, and 2b. inability by the supplier and/or the supplier state to continue supply. The probability of the supplier-country being *unable* to supply a good is based on two indicators, the (military) threats to the supplier country and the threats to supply lines. Please find: (Teer, Ruijter, et al., 2024c, Chapters 3 & annex 1a and 1b).

over human rights concerns in 2021, which China retaliated against with its own sanctions. As a result, the parties have halted negotiations for the Comprehensive Agreement on Investment (CAI) between them. Both parties imposed additional export controls for strategic goods.[22] Moreover, the EU is increasingly wary of China's ambition to become more self-reliant in the realm of trade and technology. For instance, Germany's China strategy notes that China's economic strategy "aims to make it less dependent on other countries, while making international production chains more dependent on China" (The Federal German Government, 2023).

Finally, the EU is becoming increasingly vocal about the severe imbalance in the EU-China trade relationship (European Council, 2023). Trade friction may soon lead to an actual conflict. The 2023 probe into China's EV subsidies is just one example. Cases in other sectors, such as medical devices, may well follow (European Parliament Think Tank, 2023). The EU's de-risking agenda, as exemplified by the European Chips Act and the EU Critical Raw Materials Act, underlines European efforts to enhance its autonomy in its relations with China in the years to come. Therefore, whilst the EU and China are not engaged in a direct proxy war, relations are poor and deteriorating and Chinese core-interests are increasingly opposed to those of the Netherlands and EU (see Figure 3.2).

- Once a breaking point does occur, such a process of "sudden and extreme" decoupling may lead Beijing to leverage its *2. state influence over suppliers*. In general, a trend can be observed over the past few years towards greater state influence in the Chinese economy, with state-owned companies and mixed ownership firms gaining greater prominence under Xi's increasingly state-led economic vision (Huang & Véron, 2023; The Economist, 2023). Moreover, Beijing can "indirectly" exert influence on "private" wind energy and electrolysis companies. This can be done by making use of export controls and legislation, like the 2017 National Intelligence Law.[23] In short, Beijing has the ability to and a history of leveraging export controls, which gives it the ability to disrupt wind energy and electrolysis supplies to the Netherlands and the EU.
- The *3. cost of weaponization* for China grows as its market-dominance grows. In 2023, the financial-economic cost of weaponization would be relatively low, given that China is hardly supplying any offshore wind energy or electrolysis end-products to Europe. Henceforth, the Chinese domestic economy would not suffer, especially given the vast potential still to develop wind energy and electrolysis within China. Moreover, as Chinese wind energy and electrolysis are not yet of high criticality to the Netherlands, this move would be unlikely to hurt Dutch and European economic security in the short-term.

However, in the 2028 negative scenario in which China has achieved dominance and is the primary wind energy exporter to the Netherlands and the EU, the cost of weaponization grows substantially. This is the case for two reasons. First, the criticality for the Netherlands of China's supplies has in that scenario increased, with Chinese offshore wind turbines becoming an increasingly important pillar of the Dutch energy mix. As a result, the pain inflicted on the

[22] The Netherlands limited the export of advanced semiconductor technology to China in 2019 and 2023 (The Economist, 2022) China introduced a licensing regime for the export of gallium and germanium on August 1, 2023 and a licensing regime on graphite from December 1, 2023.
[23] Private companies have many obligations towards the state. Under the 2017 National Intelligence Law, articles 7 and 14 explicitly mandate all citizens and commercial entities to support intelligence services (*PRC National Intelligence Law (as Amended in 2018)*, 2017).

Netherlands in case of an embargo increases. This subsequentially raises the diplomatic and political costs for China of becoming unwilling to continue supply, as China will be perceived as unreliable trading partner, damaging its international standing. Simultaneously, this increased criticality to the Netherlands makes retaliation more likely. Secondly, in this scenario the Chinese wind energy sector is much more export-oriented, and henceforth the economic costs for China increase substantially in the case of an embargo. In sum, while the cost of weaponization is still low in 2023, this increases to a medium or high level in the 2028 negative scenario, thereby lowering the probability of this dependence being weaponised.

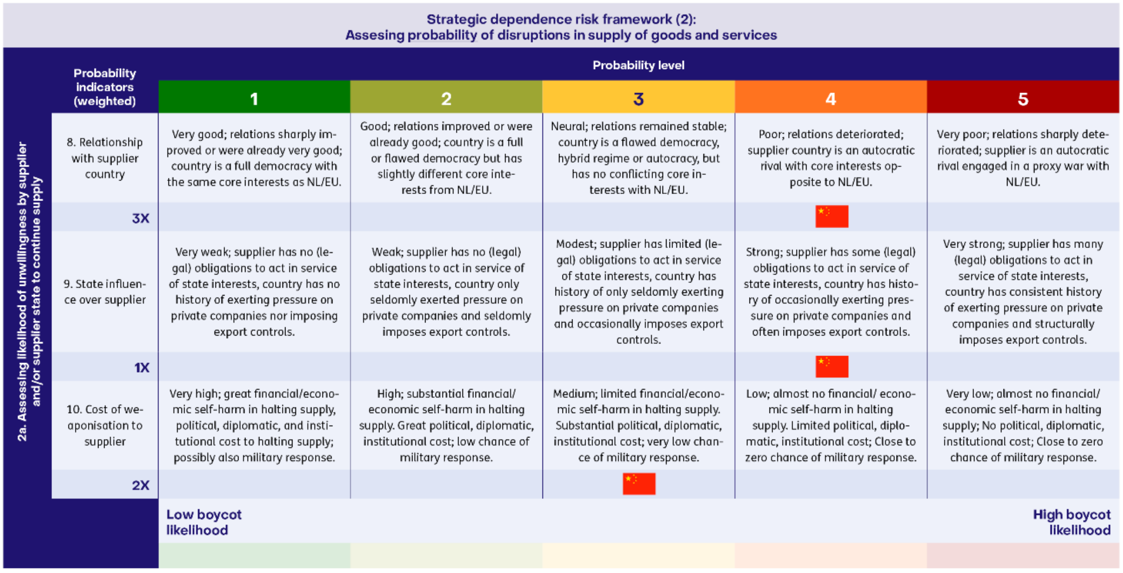


Figure 3.2 Probability assessment of future unwillingness of China to continue supply

An unwillingness to continue supply can take different shapes, depending on the level of escalation between the Netherlands and the EU on the one hand and China on the other. Risk 6 to 9 outlined below are all examples of an unwillingness by China to continue supply, albeit at increasing levels of escalation.

### 6. Ban on exports of essential components

Despite its ban on exporting permanent magnet-making technologies to rivals, today Chinese firms still uninterruptedly supply EU wind turbine manufacturers with China-produced vital permanent magnets. However, if tensions rise, Beijing may make use of export licensing requirements it already introduced in 2023 to block the exports of critical materials to rivals. In fact, China already requires exporters of gallium and germanium, materials for the production of electronics, and graphite, needed for the green transition, to obtain a license from its Ministry of Commerce (Benson & Denamiel, 2023). The complete cessation of gallium and germanium exports in August 2023 (when the new measure was introduced) can rightly be seen as a warning shot fired in the EU's direction.[24] In fact, China introduced these measures directly after the US, the Netherlands and Japan announced additional semiconductor manufacturing equipment export curbs against China. In order to acquire the intelligence that is necessary to eventually enforce an effective export ban, China today also obliges its firms that export rare earths to report on both the types of rare earths they export and the export destinations (Tabeta, 2023). A subsequent refusal by China's government to

[24] The measures came after the US, the Netherlands and Japan introduced additional semiconductor manufacturing equipment export curbs against China (Cash et al., 2023; Lv & Patton, 2023).

allow its companies to sell permanent magnets to EU and US turbine manufacturers would force EU developers to buy Chinese turbines instead. In short, already today the danger that China may become unwilling to supply key components for wind turbine production poses a severe geo-economic risk to EU turbine producers (Nieuwsuur, 2022).

7. Commercial monopolist practices

In case EU wind energy companies become financially insolvent (like in the previous chapter's 2028 negative scenario), the EU and its member-states may fall prey to commercial monopolistic practices. As a result, the EU runs the risk of China becoming unwilling to offer reasonable prices. Relying heavily on a single vendor or on a variety of firms that all are obliged to follow one country's national objectives can cause multiple issues, such as lock-in effects and unilateral market distorting decisions. These decisions may include arbitrarily raising prices for maintenance, spare parts, replacements, or expansions of capacity (European Commission, 2021, p. 94). In addition, these lock-in effects can lead to high switching costs, making it difficult for new EU companies to recapture market-share once this is lost to Chinese firms.

8. Expansion of increasingly effective cyber-attacks

If Chinese companies become the dominant supplier of wind turbines and electrolysers in the Netherlands and the EU, then this will go hand in hand with greater cyber security risks. Dependence on Chinese firms for complex components and end-products may make cyber-attacks by the Chinese state, both more likely and effective. First, Chinese private parties have obligations to aid state intelligence agencies. Legislation, for instance the 2017 National Intelligence Law, obliges Chinese firms to support, assist and cooperate with state intelligence efforts (PRC National Intelligence Law (as Amended in 2018), 2017). This makes even private firms subject to the Chinese government's geopolitical aims and methods. China-supplied equipment and software might have vulnerabilities, either intentionally embedded or inadvertently present, which companies are obligated to share with state agencies upon request. Second, the Chinese state has had an offensive cyber programme for a long time. This proramme includes an active search for such vulnerabilities in the critical infrastructure of rivals. In fact, “China has been probing U.S. critical infrastructure networks for vulnerabilities since the Obama Administration, if not before” (CSIS, 2023). As a result, embedding complex products into the Dutch energy system provides Chinese intelligence greater opportunities to find vulnerabilities in Dutch and EU energy systems to execute attacks at a later point.

Statements by the Netherlands General Intelligence Agency (AIVD) underline the risks of China's offensive cyber programme and the vulnerability of national infrastructure. Specifically, in its annual report it states that “in 2022 the Netherlands was continuously targeted with digital attacks, by countries with offensive cyber programmes”, naming China and Russia first. Such programmes are a “massive threat”, the AIVD finds (AIVD, 2023, p. 29). The AIVD specifically warns about the possibility that an “attacker builds in the possibility to destroy vital infrastructure,” for instance in “energy systems” (AIVD, 2023, p. 29). Third, reliance on energy generators from China can go hand in hand with the dependence on Chinese companies supplying updates, maintenance and technical support. This provides renewed points of entry that may be exploited to introduce malicious software at a later point (Dragos Inc., 2023; Braw, 2023). In 2022, the AIVD noted an uptick in the use by countries of “software for management and maintenance” to lay the groundwork for cyber-attacks. The agency specifically warned about these kinds of “living-off-the-land-attacks”, which avoid the use of malware (i.e., attack software) by instead penetrating networks systems via seemingly innocent management and maintenance software (AIVD, 2023, p. 29).

At moments of high tensions, for instance because of a crisis over Taiwan, the Chinese state can make use of its preparation in rival energy systems to (threaten to) initiate cyber-attacks to compel and deter the Netherlands and the EU from acting against China's core interests. If a sanction spiral occurs (e.g., due to a crisis in East Asia), these dependencies can be used to corrode, meaning to destroy or degrade, EU and Netherlands' capabilities such as its energy production (Teer, Ruijter, et al., 2024c, pp. 10–13).

9. Ban on export of vital end-products

In a scenario in which Chinese firms become the sole suppliers of wind turbines and electrolysers (2028 negative scenario), the impact of a ban on the export of these end-products is severe. In this scenario in the case of wind energy, this may even pose challenges to energy security of the Netherlands and the EU by 2030. The Netherlands and part of the EU plan to give a large role to wind energy in the future energy mix (see paragraph 1.1), with wind energy already making up a substantial part of the energy mix in 2030. The government aims to install 21GW of offshore wind around 2030. This production is equivalent to 75% of the current electricity demand (Ministry of Economic Affairs and Climate of the Netherlands, 2022). Even if the government falls short of that target, the Netherlands' economy and vital sectors in 2030 will still partially depend on offshore wind. A failure to replace turbines at sea at the end of their lifecycles or execute repairs threatens that capacity. The risk of a ban on exports of vital end-products, in a 2028 negative scenario meaning that EU wind energy companies have gone bankrupt and Chinese parties dominate the market, may be mitigated somewhat by the fact that skilled labour for repairs may still be present in the EU. In 2028, the effect of China banning the export of electrolysers will be limited, since hydrogen will not yet make up a large part of the Dutch energy mix by then. As hydrogen takes up a growing role in our economy towards 2050, however, a Chinese monopoly on the production of electrolysers becomes increasingly risky.

Why would China go as far as banning the exports of end-products such as electrolysers and wind turbines to the EU? This would require EU-China relations to reach breaking point.[25] One example of such an extreme situation could be a military conflict over Taiwan, in which the US and potentially its allies in East Asia are a direct party. If a war occurs, US' allies in Europe are likely to impose severe sanctions on China (even if they are not a direct military parties to the conflict). They would do so either of their own accord or under severe US pressure. Great power wars are bad for trade between rivals. During World War I and World War II, trade between direct belligerents dropped by respectively 96 and 97 percent (Glick & Taylor, 2010, p. 109). Is a military-strategic crisis occurs, a ban on wind turbines or electrolysers export from China could be a part of a far broader sanctions spiral. The tit-for-tat escalation of sanctions in 2022 that ended with Russia limiting gas exports to the EU by 80 percent may provide lessons, if not for one essential difference. Whereas the Biden Administration was clear from the start that the US would not put boots on the ground in Ukraine, the President's verbal guarantees to Taiwan have only become more explicit. A crisis in the East China Sea is even more likely to draw in the US, due to its defence pact with Japan. If the US is involved in a conflict in East Asia, the pressure on the EU to hit China as hard as possible economically will be enormous. In turn, the goal of Beijing's large-scale sanctioning of the EU would be to compel and deter the Netherlands and the EU from acting against China's core interests. In other words, Beijing would try to get the EU and its member-states to change policy, by peeling them off from the US-led sanctions effort. An additional goal would be to degrade and

[25] Meaning the moment when "friction in an interstate relationship, often related to military-strategic tensions, becomes so overwhelming that states are no longer willing to supply all or some vital resources on which the economies of their rivals depend." (Joris Teer & Mattia Bertolini, 2022, p. 3).

weaken EU abilities in order to punish the EU for its acts against China's core interests, such as its sanctions.

### 10. War-related disruption to China's production lines and supply routes

If a war in East Asia does occur, then the EU also runs the risk of China becoming unable to continue the supply of wind turbines and electrolysers (in the 2028 negative scenario) and the supply of essential components such as permanent magnets. As outlined above, that situation is likely to lead to an increased unwillingness by the Chinese government to provide wind energy and electrolysis to its EU customers. Yet, a conflict seems less likely to lead to the destruction of wind energy or electrolysis manufacturing sites altogether, either through cyber or kinetic attacks. Nonetheless, war-related disruption may still occur as key supplies (e.g., energy) and materials (e.g., steel and rare earths) and personnel (e.g., factory workers) will be prioritised to defence industries and the broader war effort. In short, a war in East Asia will very likely lead to some war-related disruption to production, but may stop short of destroying manufacturing capacity altogether.

The *threats to the supply lines* from China to the EU are gauged to be at medium risk of disruption, both in the short and medium term. Bulk products such as wind turbines are predominantly transported via sea, the water highways via which the majority of international trade is conducted. Electrolysis products are currently not being transported on a scale worth noting, partially as a result of high quantity of complex components. However, in the 2028 negative scenario China's electrolyser (components) would likely be transported by ship to the EU, due to their size. If a conflict occurs in East Asia involving China, this will very likely have spill-over effects to the South China Sea and possibly to the Malacca Strait, given China's artificial island building in the South China Sea and the US Navy ability to blockade the Malacca Strait to choke China's oil and LNG supply. Trade may be disrupted for days, weeks, or months, if trade is not halted altogether through boycotts.

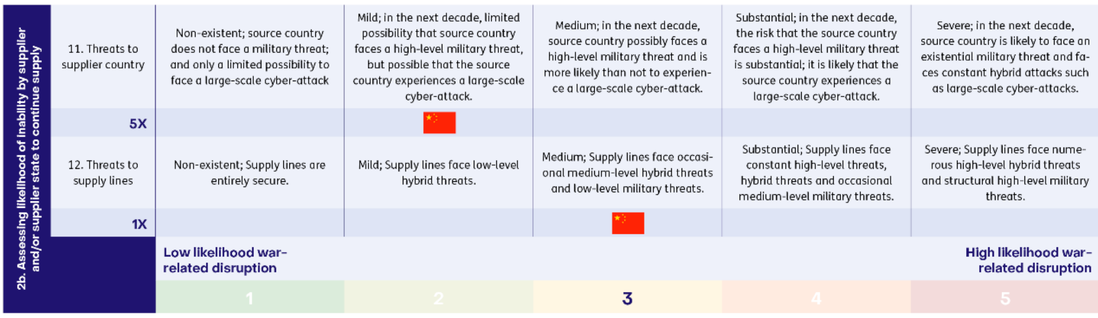


Figure 3.3: Likelihood of inability by China to continue supply

## 3.3 US-China comparison: all strategic dependencies are equal, but some more than others

At present and in the next five years, Europe has to consider only the geoeconomic risks from one other country than China in the wind energy value chain, namely the US. Except for China and the EU, only the US is home to a substantial player in the manufacturing of wind turbines (GE) (see Figure 2.10 1b.4., in Chapter 2). It is important to note, however, that US wind energy industry is far less well-positioned to gain a large-scale market share in the

EU than China's industry. The US has a technologically-advanced wind energy industry. However, due to a lack of production capacity in the industry, the likelihood is far lower that the EU will become strategically dependent on the US in this field than on China's domestic industry. The US is the third biggest player in the global trade of wind nacelles and blades (see Table 2.4, Chapter 2.2.1), behind China and Europe. China holds a 28% and Europe a 71% share of worldwide installed offshore wind energy capacity. They hold similar shares of offshore wind energy production capacity (see Figure 2.3, Chapter 2.2.1). Therefore, US industry is in no position to soon develop a position of dominance that leads to strategic dependencies of EU member-states on US companies. In the absence of a possible near future strategic dependence, strategic dependence-related threats do not apply to the US and US wind energy companies (at least in the foreseeable future).

Likewise, it is unlikely that the EU will develop a large-scale strategic dependence on US electrolysis companies in the next five years, as the electrolysis industry around the globe is in early stages of technological development. Important to note, however, is that Europe's share of global production capacity for electrolysers has dropped from 60% in 2020 to 27% in 2023, whilst China's share remained around 35% (see chapter 2.2.2 and Table 2.3, Chapter 2.3.2). North American companies show strong growth, as they achieved a 15% share in global production capacity anno 2023 (see Table 2.3, Chapter 2.3.2). However, US installed production capacity is low and most other electrolyser projects are currently still in early and feasibility assessment phases (IEA, 2023). It does not show the increasing presence that China's industry shows – which has most projects under construction already (IEA, 2023), as well as a larger production capacity (see Table 2.4, Chapter 2.3.2.). As a result, the risk of large-scale dependence on the US for electrolysers in the next five years is marginal.[26] Currently, the EU is able to cover its own small-scale demand.[27]

Today, in wind energy and to a lesser extent in electrolysis, the position of Chinese industry vis-à-vis the EU is much stronger than that of the US. As a result, the risks of near-future large-scale strategic dependence on China (if no additional policies are enacted in the EU) is much greater than a large-scale strategic dependence on the US in these industries.

## 3.4 Conclusion

The lack of a level playing field in trade relations with China (threat 1 until 5) forces a losing game on the EU. Through additional subsidies, tax breaks, IP-theft and 'locking-in' technologies that China monopolizes, the Chinese government aims to grow China's strategic industries as fast as possible. Whilst China has access to the EU's open market, it keeps its own market closed. Important to note is that this is not just an economic strategy; it stems from the CCP's broader national security strategy to achieve greater self-reliance and to expand dependence of the rest of the world on China.

This leaves the EU with two unattractive options. The first is to bear the costs of raising barriers to China. That is, domestically developing wind energy and electrolysis industries to maintain an independent position. This would include deploying similar market stimulating mechanisms as China does, which are likely to be costly for taxpayers. This also means closing off

[26] Leading up to 2030, however, global demand will increase significantly and the EU's demand might exceed its own capacity. US parties active in the development of electrolysis could capture more market share beyond that timeframe. An expansion of green policies, such as the Inflation Reduction Act (IRA), and protectionist clauses may accelerate this process. Then again, the market is more diversified as many parties, including India, the EU, China, and the US are increasingly developing electrolysis as well (see Table 2.3 and 2.4, Chapter 2.3.2 and the global market is still small-scale).

[27] Leading up to 2030, however, global demand will increase significantly and the EU's demand might exceed its own capacity. US parties active in the development of electrolysis could capture more market share beyond that timeframe (TNO & FME, 2020).

markets for cheaper Chinese alternatives that may benefit EU energy consumers and make the green transition cheaper.

The second option is to bear the economic and national security costs of an increased Chinese market dominance, including in the EU. This involves accepting new high risk strategic dependencies, likely including for complex components and end-products. Considering the current financial difficulties of EU players in the wind industry already face, choosing this option may threaten their survival and hurt EU manufacturing and maritime industries, and European earning and manufacturing capacity more broadly. Finally, a dominant position of Chinese suppliers on the EU market goes hand-in-hand with four economic and national security risks (threats 6 until 10). At a time of escalation in East Asia, China may suddenly and without warning become unable or unwilling to supply the EU with important components and end-products for its energy security.

# 4 Conclusions and policy recommendations

### 4.1.1 Conclusions

Based on the literature review, interviews, two TNO-HCSS workshops, one workshop with representatives from the Ministries of Foreign Affairs and Economic Affairs and Climate Policy, the assessment of geo-economic risks, and the impact of supply disruptions we come to the following conclusions for this study:

**China is rapidly becoming more dominant in both offshore wind and alkaline electrolysis**
In the past few years China has become a world leader in offshore wind and alkaline electrolysis technology. This leading position is developed to ensure China's strategic independence for key technologies. In addition, president Xi aims to make the world more dependent on China. The large internal market in China creates significant opportunities for Chinese companies to develop  and mature. After starting in the Chinese market, companies start considering international markets as well. The current dependence in the EU on Chinese players in the value chain is limited, with the notable exception of a near complete dependence on almost the entire supply chain of rare earth-based permanent magnets for offshore wind generators. For electrolysis, the supply chain is evolving , but currently most of the stack components are sourced locally. European companies source in the EU; Chinese companies source in China.

**Chinese companies will likely achieve a key position in the global offshore wind and electrolysis value chains**
The rapid development of Chinese offshore wind and electrolysis technology is expected to continue in the next few years. Considering China's already strong position in value chains, innovation capabilities, low manufacturing costs and lack of access to China's market for foreign players, it is likely that China will expand its position in the global supply chains for both offshore wind and electrolysis. Chinese companies in both sectors are investigating how to enter the European market. Multiple companies are considering opening manufacturing facilities for key offshore wind and electrolysis components in Europe.

The energy transition offers the EU and the Netherlands a unique opportunity to rearrange its geopolitical dependencies away from untrusted suppliers, like Russia and its supplies of natural gas. Current trends, however, suggest that the transition to green energy will most likely lead to a new, extensive strategic dependence, namely on China – also beyond materials and simple components. The European offshore wind OEM's are facing significant operational losses in 2023 and will likely be outcompeted by Chinese players if the EU does not introduce new strong protective measures for its (renewable energy) market. If (one of) the European OEMs do not survive, the dependence on China for offshore wind technology will grow significantly. At a time when our electricity production is becoming largely dependent on offshore wind production, the risks associated with such a strong dependency are high.

While Europe is presently leading in terms of quality, safety and environmental footprint, it is not expected that European electrolyser manufacturers can compete with Chinese parties in terms of costs.

**Excluding Chinese players may decrease the speed and increase the immediate cost of the energy transition**
European players can be protected by excluding Chinese companies from European offshore wind and electrolysis markets (similar to how EU parties face enormous hurdles on China's market), but there will be a cost. Chinese technology is already cheaper and will likely continue to decrease in costs due to the scale of the Chinese market and the technological developments expected to take place in China. A significant scale-up of offshore wind and electrolysis is required in the next decade for the energy transition in Europe. For offshore wind energy, for example, the EU's production capacity for nacelles, blades, generators and installation vessels needs to be expanded in the second half of this decade to meet the growing demand. Excluding the significant production capacities at highly competitive prices in China can strain the European supply chains and limit the speed at which the energy transition can be realised.

## 4.2 Policy recommendations

Based on the conclusions we come to the following policy recommendations.

**Trade with China should take place in a level-playing field. Unfortunately, this can only be achieved by restricting market access for Chinese parties**
China's role in the offshore wind and electrolysis sectors will continue to grow in the coming years. In order to strengthen collaboration and make trade fairer, mutual trust and mutual gain is essential. At present, European companies are excluded from participation in the Chinese market in strategic sectors such as wind energy, unless it is in a minority stake in a joint venture. Even for international joint ventures competing in the Chinese market can be difficult, as Chinese project developers prefer Chinese suppliers. There are no such limitations for Chinese players participating in strategic European sectors. China's economic progress depends on growth, which partially relies on the exports of its manufactured goods.

In order to ensure the financial health of European OEMs, a level playing field is necessary. In an ideal world, China would open up its market to European players and undo the obstacles for EU companies to compete. Importantly, wholly-owned foreign companies are hardly possible in China. China giving access to fully foreign owned companies (like Chinese companies can set up fully China owned entities in Europe) would be an important step in levelling the playing field. Importantly, this would create the possibility for European companies to compete by making use of relatively cheap manufacturing in China. On the basis of this, European companies could compete more fairly.

However, in reality China's "new development philosophy" sets out to foster even greater self-reliance in manufacturing by steering domestic demand to domestic industries. This dual circulation policy goes beyond reducing China's dependence on the world: it actively seeks to expand the world's dependence on China (see chapter 3.1). Xi introduced this policy, in spite of decades of EU lobbying for China to open-up further. Practically, this means that a level playing field can only be achieved if the EU and the Netherlands take defensive measures, meaning policy measures that close-off the EU market to Chinese parties in similar ways. For this reason, we recommend:

- Limit the maximum participation of non-EU companies in strategic projects. Ensuring reciprocity can only be done by also limiting the participation of Chinese parties to a minority share in offshore wind and electrolysis projects.
- State aid and market access should be governed in an equal manner both in China and in Europe in order to prevent price dumping and unfair competition.
- Imported finished products from China should be held to comparable Life Cycle Assessment (LCA) requirement that EU made finished products are held to. These include social standards such as an ethical labour environment, $CO_2$ footprint over lifetime, and O&M efforts needed.

Consider increasing non-financial requirements in public procurement like safety, efficiency, circularity and ESG-criteria ($CO_2$ footprint, labour conditions, circular policies).
In light of the above lack of reciprocity, it is unlikely that European players can remain competitive on costs compared to Chinese players. Increasing non-financial requirements in procurement, such as higher quality, efficiency, safety, and environmental standards, will improve the position of European players – as these are areas where the European players have a stronger position. However, ESG-criteria should not lead to the blocking of the imports of raw materials for which the EU and member-states have a high level of dependence on specific non-democratic countries in the Global South, as this would be a negative side-effect and create new supply chain bottlenecks.

More often exclude Chinese manufacturers of complex / vital end products, such as wind turbines, from projects on the basis of energy and national security considerations.
As geopolitical tensions rise and renewable energy, especially offshore wind, is becoming an ever more important part of the Dutch energy mix, the position of Chinese manufacturers in these projects need to be considered.

Particularly the operation of installations needs to be protected, as these installations are essential parts of the European energy system and energy supply. This pertains to the software used for installations, data that is extracted and stored and other day-to-day operations. In the event EU countries do make use of Chinese vendors, they should ensure that the software updates and maintenance can be done by EU firms independently. TenneT already specifically excluded Chinese manufacturers from tender for offshore substations.

Expand access to materials and components that are currently dominated by China.
By rewarding the use of low-risk (preferably domestic or friend-shored) components and materials in wind energy and electrolyser tenders, European governments can help undo China's near-monopoly on the production of rare earths and permanent magnets. The EU could make more haste with the development of the mining, refining and processing of rare earths and the manufacturing of permanent magnets outside of China to reduce its dependency on China. In order to achieve this, the EU could encourage member-states to include clauses in state-tenders for wind parks and electrolysers that financially incentivise the use of non-Chinese manufactured permanent magnets in wind turbines. Considering that the wind energy ambitions of the North Sea nations are enormous, including such clauses will help bring online EU or allied rare earth mining, refining, processing and permanent magnet-making. The Netherlands and the EU should assess whether introducing a list of "foreign entities of concern", like the US does, will achieve greater independence from China in these crucial sectors.

### Cooperation with China on technology development can accelerate the energy transition, but be aware of unwanted technology transfer

With increasing presence in the sectors, we expect more innovation to also take place in China. Currently already Chinese manufacturers are launching the largest offshore wind turbines available on the market to date. China is also leading in the deployment of electrolysers, gaining valuable knowledge for the development of future projects faster than is currently happening in the EU. To keep up with the technological developments in China it is important for Europe to maintain collaboration efforts with China. Without collaboration, Europe could fall behind in innovation in the sectors, which could lead to an increased dependence on China. Knowledge is an important factor for China to seek out collaboration with European players.

However, any collaboration of knowledge exchange with China should be approached carefully in order to protect European interests, innovation and intellectual property. European companies should be careful in sharing IP and R&D with Chinese parties on the components in wind energy and electrolysers it is leading in, such as rolling bearings and full power converters for offshore wind and PEM electrolysers. China's ban on the export of rare earth extraction, refining and permanent magnet making technologies effectively seeks to give Beijing continuous control over a chokepoint in the wind energy value chain. These action seek to help Beijing effectively 'lock-in' its dominance over this part of the value chain (see threat 5 in Chapter 3). To ensure that the EU, European companies and EU governments maintain leverage in the value chain, the export to China of unique wind energy and electrolyser production technologies should be avoided (and therefore restricted).

TNO has experience collaborating with Chinese parties in both the wind energy sector and developers of electrolyser technology. These collaborations have yielded TNO relevant insights on technology development and operational data. These insights help TNO with further research and development activities that can both contribute to accelerating the energy transition and lower costs. In these collaborations steps were taken to ensure TNO IP was not transferred to China. These examples illustrate that we can learn from collaboration with China and, if done correctly, can be done without unwanted IP transfer to China.

### Protect and expand the European offshore wind and electrolysis industries

Europe currently has relatively strong local supply chains for offshore wind and electrolysis. Competition by Chinese players is expected to increase very rapidly in the next few years. First existing industry needs to be protected and strengthened, in order to maintain a strong position in Europe. In some parts of the supply chains, the amount of key players in Europe is limited. If some of these players do not survive, the European value chain can quickly become strained and overly reliant on China. Second, offshore wind and electrolysis manufacturing industries in the EU need to be expanded in order to maintain a strong value chain, as demand will continue to increase.

### Keep developing alternative technologies

Dependencies on existing supply chains can be mitigated by developing alternative technologies with value chains that can more easily be localised. For example, current offshore wind designs rely on permanent magnets made with rare earth elements and therefore create a dependence on China, where most of the required rare earth materials are processed. It is possible to reduce the dependence on permanent magnets by changing the generator design by using a gearbox instead. Alternatives such as this should be developed to reduce strategic dependencies, or at least be developed to such a level that they can quickly be deployed when required.

Also accelerate the learning we can create from the first pilot and demo electrolyser project in Europe with European technologies and use this to develop the next generation electrolyser technology.

Collaborate with other countries to ensure the availability of sufficient alternatives
If disruptions occur in the supply chain with China, there are currently limited alternative suppliers for offshore wind and electrolysis. The US is an important other player, with a large offshore wind OEM and a key position in PEM electrolysis. Other countries, like India, are developing domestic supply chains. These parties will also face increasing competition from Chinese players in these sectors. Collaboration with these parties creates a larger set of alternatives and makes it possible to more quickly go to alternatives if supply disruptions occur.

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Appendix A

# Assessing geopolitical risk-levels of strategic dependencies: an HCSS assessment framework[28]

Table A.1: Strategic dependence risk framework (1): Assessing impact of disruptions in supply of goods and services

| | | Impact indicators (weighted) | Main guiding question | Impact level 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| Identifying strategic dependence | 1a. Assessing criticality of baseline supply | 1. Criticality – 2x | How critical is the baseline supply of the good or service from one or several countries in the digital stack for the Netherlands and the EU to secure its level-one and level-two core interests? (i.e., What is the effect on the Netherlands and the EU's level-one and level-two core interests if the baseline supply of the good and service from one or several countries is entirely disrupted?). | No effect on security (i.e., physical or financial), safety and health. No obstacles to digitalisation. | Minor effect on security (i.e., physical or financial), safety and health; Somewhat impedes digitalisation. | Substantial effect on security (i.e., physical or financial), safety and health; Impedes digitalisation. | Major effect on security (i.e., physical or financial), safety and health; Disrupts digitalisation. | Devastating effect on security (i.e., physical or financial), safety and health; Entirely halts digitalisation. |

[28] Joris Teer, Abe de Ruijter, and Michel Rademaker, 'Navigating the Great Game of Choke Points: Assessing Geopolitical Risks and Advancing Dutch and European Strategic Indispensability in Digital Value Chains', Report commissioned by MinEconAffairs (The Hague Center for Strategic Studies, March 2024), tbl. 5, pp. 66–68, https://hcss.nl/report/navigating-the-great-game-of-chokepoints/.

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| | | 2. Dependence on maintenance, updates or resupply – 1x | If the good or service is no longer supplied, when will this have an impact on level-one and/or level-two core interests? | No maintenance, updates or resupply required for the entire lifespan of the product. Timing of impact delayed. | Maintenance, updates or resupply required every 5 years. Timing of impact delayed, but long-term: In 5-to-10 years. | Biannual to once in four-year maintenance, updates or resupply required; Timing of impact delayed, medium term: in 6-months to 4 years. | Monthly or biannual maintenance, updates or resupply required; Timing of impact delayed, but short-term: in 1-month to 6-months. | Constant maintenance, updates or resupply required; Timing of impact immediate. |
| | | 3. Demand projection – 1x | Total demand: Is national, regional and/or global demand for the good or service likely to outpace global supply, leading to shortages of the good or service on top of the risks of supply-related shocks? Total use of good or service to enable vital processes: Will more vital processes come to rely on the supply of the good or service in the next five years? | Sharp fall in total demand (-75%-to-100%) in next 5-years. | Major fall in total demand (-50%-to—75%) in next 5-years. | Slight rise or fall in total demand (-50% or +50%) in next 5-years. | Total demand rising 50-to-100% in next 5-years. | Total demand multiplying in next 5-years . |
| | Assessing criticality of baseline supply (weighted average of indicators 1, 2 and 3): Score on 1-to-5 scale | | | | | | | |
| | 1b. Assessing alternatives to baseline supply | 4. Diversification - 1x | Do companies in allied, likeminded, or at least non-rival, non-EU states effectively supply the same good or service? | Complete effective, immediate diversification possible (100%); alternative suppliers offer same quality product, in same quantities at comparable prices. | Majority effective, immediate diversification possible (75%); alternative suppliers offer slightly inferior quality, in slightly lower quantities at slightly higher prices. | Partial effective, immediate diversification possible (50%); alternative suppliers offer inferior quality, half of the quantity at higher prices. | Limited effective, immediate diversification possible (25%); alternative suppliers offer far inferior quality, a quarter of the quantity at far higher prices. | No effective, immediate diversification possible (0%); alternative suppliers offer no quantities of the material, good or service. |

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| | | 5. Internal production - 1x | Can the production of the good or service be effectively moved to the Netherlands or another EU member-state? | Complete effective internal production possible (100%); state has immediate access to relevant skilled labour, technologies, capital, and sufficient tolerance for externalities; Indigenisation possible in 1-year. | Majority effective internal production possible (75%); state has immediate access to majority of the relevant skilled labour, technologies, capital, and high tolerance for externalities; Indigenisation possible in 2-to-4 years. | Partial effective internal production possible (50%); state has immediate access to half of the relevant skilled labour, technologies, capital, and medium tolerance for externalities; Indigenisation possible in 5-to-10 years. | Limited effective internal production possible (25%); state has immediate access to part of the relevant skilled labour, technologies, capital, and low tolerance for externalities; Indigenisation possible in 11-to-15 years. | No effective internal production possible (0%); state has no immediate access to relevant skilled labour, technologies, capital, and no tolerance for externalities; Indigenisation possible in 15-to-40 years. |
| | | 6. Substitution - 1x | Can the function of the good or service be performed effectively, meaning at the same level of quality, in similar quantities and at comparable prices, by a different good or service? | Complete effective substitution possible (100%); state has immediate access to relevant skilled labour and sufficient capital; no additional technological advances are required; complete substitution possible in 1-year. | Majority effective substitution possible (75%); state has immediate access to majority of relevant skilled labour and of sufficient capital; some additional technological advances are required; complete substitution possible in 2-to-4 years. | Partial effective substitution possible (50%); state has immediate access to half of relevant skilled labour and of capital; additional technological advances are required; complete substitution possible in 5-to-10 years. | Limited effective substitution possible (25%); state has immediate access to a quarter of relevant skilled labour and of capital; many additional technological advances are required; complete substitution possible in 11-to-15 years. | No substitutes possible (0%); state has no immediate access to a quarter of relevant skilled labour and of capital; many additional technological advances are required; complete substitution possible in 15-to-40 years. |
| | | 7. Illicit exchange - 1x | Can the good or service provided by the original suppliers still be effectively accessed, in spite of an export boycott through direct or indirect illicit flows? | Complete continued supply through illicit exchange possible (100%); boycotting state has no effective direct and indirect enforcement means. | Majority continued supply through illicit exchange possible (75%); boycotting state has limited effective direct and indirect enforcement means. | Partial continued supply through illicit exchange possible (50%); boycotting state has some effective direct and indirect enforcement means. | Minority continued supply through illicit exchange possible (25%); boycotting state has strong direct and indirect enforcement means. | No continued supply through illicit exchange possible (0%); boycotting state has complete effective direct and indirect enforcement means. |
| | Assessing alternatives to baseline supply (average of indicators 4, 5, 6 and 7): Score on 1-to-5 scale | | | | | | | |
| Negative effect on level-one and level-two core interests, if baseline supply is disrupted (weighted average of indicators 1 until 7): Score on 1-to-5 scale | | | | | | | | |

**Table A.2:** Strategic dependence risk framework (2): Assessing <u>probability</u> of disruptions in supply of goods and services

| | | Probability indicators (weighted) | Main guiding question | Probability level 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| Assessing risk level of strategic dependence | 2a. Assessing likelihood of unwillingness by supplier and/or supplier state to continue supply to continue supply | 8. Relationship with supplier country – 3x | Does the Netherlands and the EU enjoy good relations with the country of origin of the company that supplies the good or service? | Very good; relations sharply improved or were already very good previous decade; country is a full democracy with the same core interests as NL/EU. | Good; relations improved or were already good over previous decade; country is a full or flawed democracy but has slightly different core interests from NL/EU. | Neutral; relations remained stable over previous decade; country is a flawed democracy, hybrid regime or autocracy, but has no conflicting core interests with NL/EU. | Poor; relations deteriorated previous decade; supplier country is an autocratic rival with core interests opposite to NL/EU. | Very poor; relations sharply deteriorated during previous decade; supplier is an autocratic rival engaged in a proxy war with NL/EU. |
| | | 9. State influence over supplier -1x | Does the supplier state have the means to force the supplier to no longer provide the good or service? | Very weak; supplier has no (legal) obligations to act in service of state interests, both in times of peace and crisis; country has no history of exerting pressure on private companies to act in state interests; country does not impose unilateral or mini-lateral export controls. | Weak; supplier has no (legal) obligations to act in service of state interests, both in times of peace and crisis; country only seldomly exerted pressure on private companies to act in state interests; country seldomly imposes unilateral or mini-lateral export controls. | Modest; supplier has limited (legal) obligations to act in service of state interests, both in times of peace and crisis; country of origin has history of only seldomly exerting pressure on private companies to act in state interests; country occasionally imposes unilateral or mini-lateral export controls. | Strong; supplier has some (legal) obligations to act in service of state interests, especially in time of crisis; country of origin has history of occasionally exerting pressure on private companies to act in state interests; country often imposes unilateral or mini-lateral export controls. | Very strong; supplier has many (legal) obligations to act in service of state interests, both in times of peace and crisis; country of origin has consistent history of exerting pressure on private companies to act in state interests; country structurally imposes unilateral or mini-lateral export controls. |

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| | | 10. Cost of weaponization to supplier – 2x | What are the costs of halting the supply of the good or service to the state imposing the boycott?<br>. | Very high; great financial/economic self-harm in halting supply, political, diplomatic, and institutional cost to halting supply; possibly also military response. | High; substantial financial/economic self-harm in halting supply. Great political, diplomatic, institutional cost; low chance of military response. | Medium; limited financial/economic self-harm in halting supply. substantial political, diplomatic, institutional cost; very low chance of military response. | Low; almost no financial/economic self-harm in halting supply. Limited political, diplomatic, institutional cost; Close to zero chance of military response. | Very low; almost no financial/economic self-harm in halting supply; No political, diplomatic, institutional cost; Close to zero chance of military response. |
| | | | Assessing likelihood of *unwillingness* by supplier and/or supplier state to continue supply (weighted average of indicators 8, 9, 10): score on 1-to-5 scale | | | | | |
| | 2b. Assessing likelihood of inability of supplier and/or supplier state to continue supply | 11. Threats to supplier country – 5x | Does the supplier state of the good or service face a military threat? | Non-existent; source country does not face a military threat; and only a limited possibility to face a large-scale cyber-attack. | Mild; in the next decade, limited possibility that source country faces a high-level military threat (e.g., invasion/ bombardment or blockade), but possible that the source country experiences a large-scale cyber-attack. | Medium; in the next decade, source country possibly faces a high-level military threat (e.g., invasion/ bombardment or blockade) and is more likely than not to experience a large-scale cyber-attack. | Substantial; in the next decade, the risk that the source country faces a high-level military threat (e.g., invasion/ bombardment or blockade) is substantial; it is likely that the source country experiences a large-scale cyber-attack. | Severe; in the next decade, source country is likely to face an existential military threat (e.g., invasion/ bombardment or blockade) and faces constant hybrid attacks such as large-scale cyber-attacks. |
| | | 12. Threats to supply lines – 1x | Are the supply lines (e.g., maritime routes, airways, communication cables and satellite connection | Non-existent; Supply lines are entirely secure. | Mild; Supply lines face low-level hybrid threats. | Medium; Supply lines face occasional medium-level hybrid threats and low-level military threats. | Substantial; Supply lines face constant high-level hybrid threats and occasional medium-level military threats. | Severe; Supply lines face numerous high-level hybrid threats and structural high-level military threats. |

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| | | | s) via which the good or service is supplied likely to be disrupted? | | | | | |
| | 2b. Assessing likelihood of *inability* by supplier and/or supplier state to continue supply (weighted average of indicators 11 and 12): score on 1-to-5 scale | | | | | | | |
| | Assessing risk level of strategic dependence (weighted average of indicators 7 until 12): score on 1-to-5 scale | | | | | | | |

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