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Rosefinch Research | 2024 Series # 2

Hydrogen and Wind Power

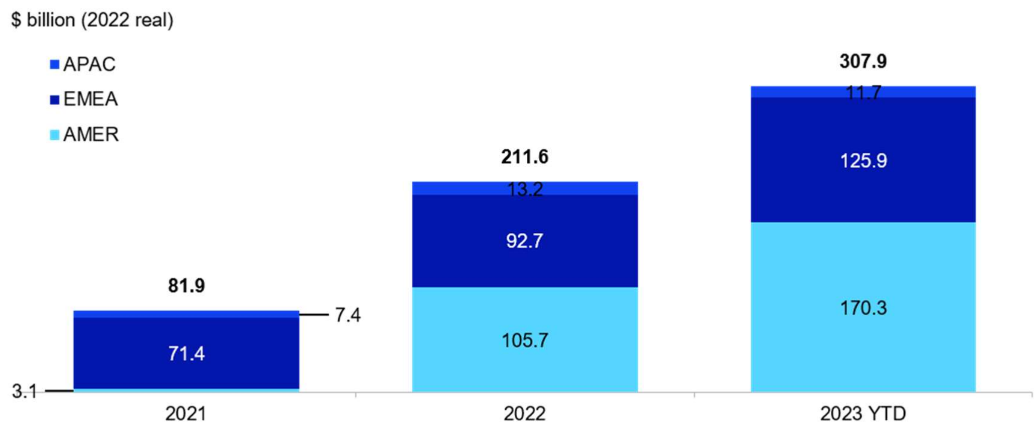
Academician Ding Zhongli predicted that in the future, photovoltaics and wind power can meet around 70% of energy demand, but some areas like steel, cement, aviation transportation and ocean-going bulk carriers still rely on fossil fuels. Hydrogen power can not only solve the problem of renewable energy absorption, but also become the ultimate decarbonization solution in areas where green electricity cannot cover. However, the current cost of green hydrogen is still high. How can we lower the cost? Which links are worth focusing on?

Onshore wind power remains one of the cheapest power generation technologies, followed by photovoltaics and offshore wind power, with costs lower than new coal-fired power. As offshore wind projects are gradually opening up in various places, demand for offshore wind is warming up. Which links will benefit the most? The following is a sharing from Rosefinch's annual strategy meeting in Dec.

We believe that the driving force behind hydrogen's future development will come from the process of achieving carbon neutrality, where green electricity plus green hydrogen can solve energy security, economic and green sustainable issues. Hydrogen can solve deep decarbonization in industries like steel, cement and aviation shipping that wind and solar cannot fully cover. Wind, solar and hydrogen are indeed complementary and mutually reinforcing.

From various countries' planning and layout, by this year more than 50 countries have released their own hydrogen strategies. Judging by the planned electrolyzer installation capacity and related investment funds in these strategies, the whole hydrogen industry involves hundreds of billions USD in investment scale.

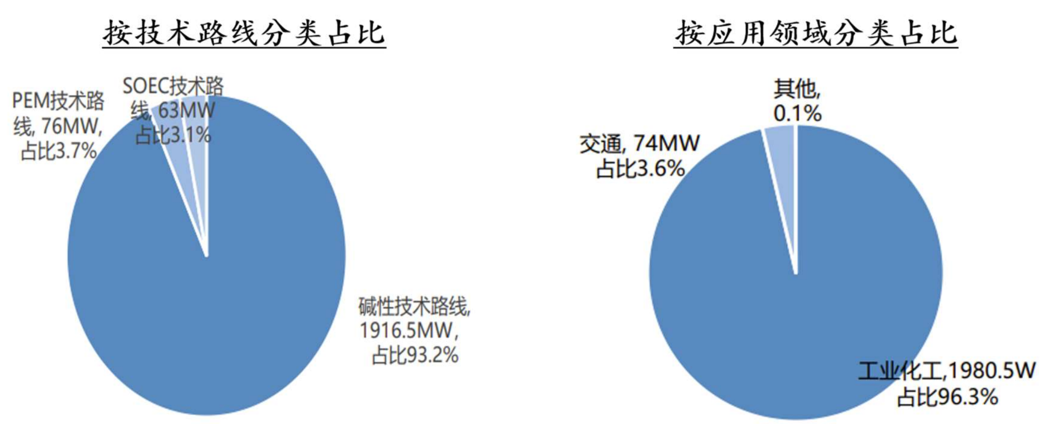
Publicly announced hydrogen investment funds situation



Source: BNEF, Rosefinch.

In China, green hydrogen projects performed very well in 2023. Ku'erqi in Xinjiang was China's first 10,000-ton-level green hydrogen project. It has been fully built and put into production, marking a breakthrough of China's green hydrogen scaled application. Additionally, Da'an project in Jilin this year is one of the world's largest green ammonia projects.

From an industrial perspective, the development of electrolytic hydrogen production is quite rapid. According to industry statistics, the scale of electrolyzer project tenders in China this year has accumulated to over 2GW, approaching 3 times the electrolyzer output in 2022. The proportion of alkaline electrolysis exceeds 90%.



Source: International Hydrogen Energy, Solarbe, Rosefinch.

1. The Four Challenges of Green Hydrogen.

From an industrial stage perspective, while some demonstration projects have already started operation, the whole industry is still at the initial stage. Whether it is electrolyzers, system optimization and configuration, or downstream application matching, there is still much room for improvement. In addition,

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the current cost of green hydrogen is relatively high, while downstream application scenarios, future absorption terminals, policies and other factors are likely still insufficient to support large-scale commercial applications of green hydrogen. Some of the current issues are:

First, the cost of hydrogen production is still relatively high. The hydrogen production cost of the Ku'erqi project in the early stage was 28 yuan/kg, twice the current cost of coal-based hydrogen production. Electricity accounts for more than 70% of the cost. In the future, with the improvement of renewable energy utilization efficiency, including performance improvement of electrolyzers, there is still great potential to further reduce hydrogen production costs.

Second, hydrogen management faces certain constraints as a hazardous chemical. For a long time, hydrogen has been managed as a hazardous chemical. Its production and use need to be carried out in chemical industrial parks. In addition, road transportation of hydrogen gas is also regulated by different jurisdictions and rules, and cross-regional transportation is also greatly restricted, which limits the development of the hydrogen energy industry and expansion of application scenarios to some extent.

However, we also see that after China clarified the energy attributes of hydrogen, local governments have also made positive adjustments to hydrogen energy management policies. Places like Guangdong, Hebei and Jilin have introduced policy optimization and relaxation for the hydrogen production process. They now allow the construction of electrolytic green hydrogen projects outside chemical industrial parks, which is conducive to reducing future green hydrogen production, storage, and transportation costs.

Provinces relaxing restrictions on hydrogen production

危化品管理	2023.6.26	河北省人民政府	河北省氢能产业安全管理办法（试行）	办法规定：“氢能企业按行业类别归口监督管理。化工企业的氢能生产，应取得危险化学品安全生产许可。绿氢生产不需取得危险化学品安全生产许可。”
	2023.6.28	广东省住房城乡建设厅、发展改革委等 12 部门	广东省燃料电池汽车加氢站建设管理暂行办法	规定允许在非化工园区建设制加氢一体化站，自 7 月 1 日起实施。
	2023.7.20	上海交通委	《上海交通领域氢能推广应用方案（2023-2025 年）》	本次《政策》强调氢气的燃料属性，有望进一步推动将氢气按照能源属性（不单单是危化品属性）管理，放宽管制力度，同时也有望推动氢气跨区域运输，化工园区外制氢等日常氢气场景。
	2023.11.23	吉林省人民政府	《吉林省氢能产业安全管理办法（试行）》	绿氢生产不需取得危险化学品安全生产许可。加氢站参照天然气加气站管理模式，经营性加氢站应取得燃气经营许可。氢能运输按照危险货物运输管理，应取得危险货物运输相关许可。移动式压力容器、气瓶的充装单位应取得充装许可。

Source: Government websites, Rosefinch.

Third, the domestic carbon trading price is still relatively low, which does not fully reflect the value of green hydrogen. In addition to technological factors, there are also issues of non-technical costs such as land, capital costs and taxes. Subsequently, national policies related to green hydrogen will also play a key role in promoting industry development.

Finally, with the introduction of new guidelines for the green hydrogen standards system, industry standards will gradually be established in the whole industry chain, laying a foundation for standardization of each link. In addition, the publication of standards for 70MPa Type IV hydrogen storage cylinders and valves has further enhanced the product strength of fuel cell vehicles and is expected to further achieve cost reduction in the future.

2. Future Cost-reduction Path of Green Hydrogen

Cost is a major influencing factor limiting the large-scale development of green hydrogen. What are some pathways to reduce the cost of green hydrogen? We believe that we should continue innovation with reference to the experience of photovoltaic development, such as large-scale electrolyzer tanks.

Looking at the green hydrogen industry this year, different downstream customers have put forward different demands for electrolyzer tanks for different projects, such as the conventional products of 500 cubic meters and 1000 cubic meters, and the demands for 1500 cubic meters/h and 2000 cubic meters/h electrolyzer tanks have been proposed this year. Some steel companies have even proposed 3000 cubic meters/h electrolyzer tank demands based on their own circumstances. Equipment large-scale is the future trend, with the source being technological innovation.

In addition, the large-scale development of single tanks can significantly reduce CAPEX. According to the information publicly released at the conference of a leading domestic electrolyzer tank company, for a 150MW green hydrogen project, if 2000 cubic meters products replace the original 1000 cubic meters products, it can save about 20% of hydrogen production equipment costs and 30% of land costs. We believe there is still a very large space for innovation in alkaline water electrolysis hydrogen production technology in the future.

In addition, we believe that the progress of different hydrogen production technologies will also have a more significant driving effect on cost reduction in the industry.

Looking at this year, alkaline electrolyzer tanks have occupied the main market share in China. Compared to electricity consumption between alkaline electrolyzer (ALK) and proton exchange membrane electrolysis (PEM), alkaline electrolysis tanks no longer have obvious disadvantages. However, the price of PEM electrolysis is currently 4-6 times that of ALK electrolysis, thus showing clear advantages for ALK. The future development of PEM electrolyzer tanks is more likely to reduce cost by substituting precious metals in electrodes and catalysts.

Solid oxide electrolyte (SOEC) may be a relatively optimal solution in special scenarios in the future, such as nuclear power and power plants, where there are heat sources. But SOEC's durability, manufacturing processes, etc. still need to be improved. The AEM (anion exchange membrane) method integrates the advantages of ALK and PEM, but is currently in the basic material research and development stage.

Different hydrogen production technologies are suitable for different scenarios.

	碱水电解池（ALK）	纯水电解池（PEM）	固体氧化物电解池（SOEC）
电解质	20-30%KOH	PEM（Nafion 等）	Y_2O_3/ZrO_2
工作温度℃	70-90	70-80	700-1000
电流密度 A/cm^2	0.25	1 左右	1~10
能耗 kWh/Nm^3	4.5-5.5	3.8-5.0	3.0-3.6
操作特征	启停较快	启停快	启停不便
动态响应能力 电能质量需求	较强	强	/
系统运维	有腐蚀性液体，后期运维复杂，成本高	无腐蚀性液体，运维简单，成本低	目前以技术研究为主，尚无运维需求
电堆寿命	可达到 120000h	已达到 100000h	/
技术成熟度	商业化	国外商业化	实验室研发
有无污染	碱液污染	清洁无污染	无污染

Source: Qingyunlian, Rosefinch.

Regarding alkaline electrolysis stacks, the conventional view is that relatively mature alkaline electrolysis stack technologies are not very advanced, which is one of the reasons why hundreds of companies announced entering the alkaline electrolysis stack field this year.

Firstly, from the perspective of manufacturing alone, the structure of alkaline electrolysis stacks is not very complex. However, we believe that future industry development and technological innovation need to be appropriately combined with future demand. Large-scale single-cell development brings comprehensive challenges in terms of energy efficiency, performance, stability, safety, and other aspects. This not only requires material system innovation, but also system optimization and structural design improvements.

For example, future materials need to balance current density, cost, energy efficiency, and small channel field optimization in the system structure. Adapting the end plate, support structure, fasteners, pipeline connections and other structural design for large electrolysis stacks is necessary to avoid potential safety issues such as leaks. Therefore, there is still room for innovation to improve the efficiency, safety, and reliability of electrolysis stacks.

Secondly, in addition to large-scale electrolysis stacks, cost reduction paths also include scale and standardization. Compared with last year, the shipment volume of electrolysis stacks in 2022 was only about 700MW, which is relatively small. Many key components of electrolysis stacks have not been mass-produced, which has also led to relatively high costs for this part of the components. With industry scaling up in the future, there will be more significant space for reducing overall industry costs.

In addition, standards for electrolysis stacks also need to be improved. Referring to the past experience of more than ten silicon wafer specifications for PV, which will likely gradually unify into a few in the future. Currently, each domestic project also has its own standards for electrolysis stacks, with strong customization for different project products and downstream application scenarios, with different designs for electrolysis stack components, small channel structures, etc. Industry standardization could potentially lower the difficulty of cost reduction in the supply chain and reduce wasteful resource inputs.

3. Thoughts on Green Hydrogen Positioning

In thinking about the future positioning in hydrogen energy sector, there are several links that need to be fully grasped.

The first link is hydrogen production. Electrolyzers are rather determined links with relatively high value. In the past, the overall market space was relatively small, and many links did not receive enough attention or sufficient technical investment to further upgrade. In the future, as the industrial space expands, trends of large-scale electrolyzer standardization and industrialization may bring development opportunities to links such as materials, processing, and equipment, while involving multiple scenarios such as electricity, chemicals, and steel. The redesign of related instrument parts may also bring new opportunities.

The second link is storage and transportation. As important basic infrastructure connecting the upstream hydrogen production and downstream application, storage and transportation are likely to be initiated first, while also being the bottleneck for the decline of terminal hydrogen prices. In terms of storage and transportation, gaseous hydrogen storage over short to medium distances is very likely to be widely deployed first; pipeline hydrogen transportation projects will gradually start construction; and domestic technologies such as liquid hydrogen, solid-state hydrogen storage, green methanol, and green ammonia will gradually mature.

The third link is two new bright spots on the downstream application end. With technological progress, recently a major hydrogen fuel cell company announced that system costs have dropped to RMB2,500/kW, a significant decline from RMB18,000/kW in 2017, and are expected to decrease to RMB1,000/kW by 2025. With rapidly falling costs, hydrogen applications in commercial vehicles may gradually increase, bringing long-term investment opportunities.

In addition, since this year, under the EU's decarbonization policies, the demand for green methanol and green ammonia for shipping has increased substantially. Looking at the recent 500,000-ton green methanol project signed between Maersk and Chinese enterprises, the certainty of future demand space is rather high. In addition, according to statistics from shipping association, in the first seven months of this year, the total order volume of methanol-fueled ships in Europe was 122 ships, up from 35 ships last year, which may bring tremendous future demand for green methanol and correspondingly higher demand for green hydrogen.

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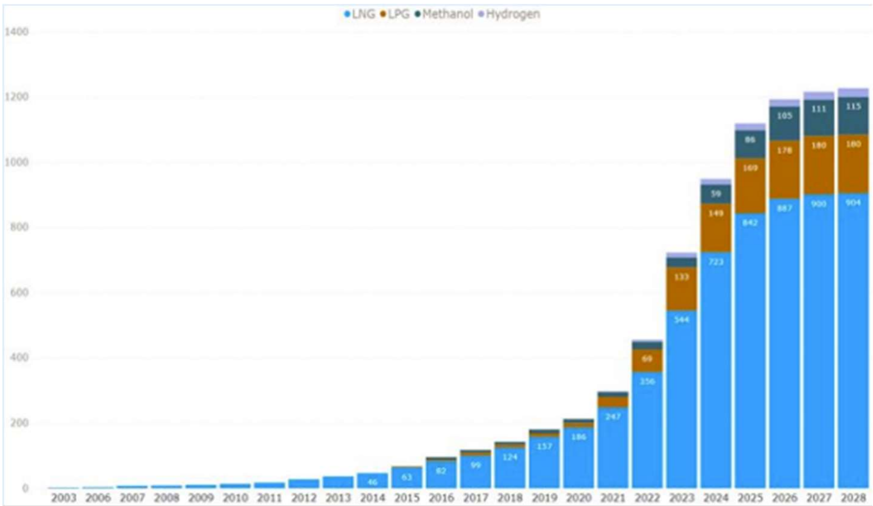
DNV estimates Methanol-fueled carrier numbers continue to rise



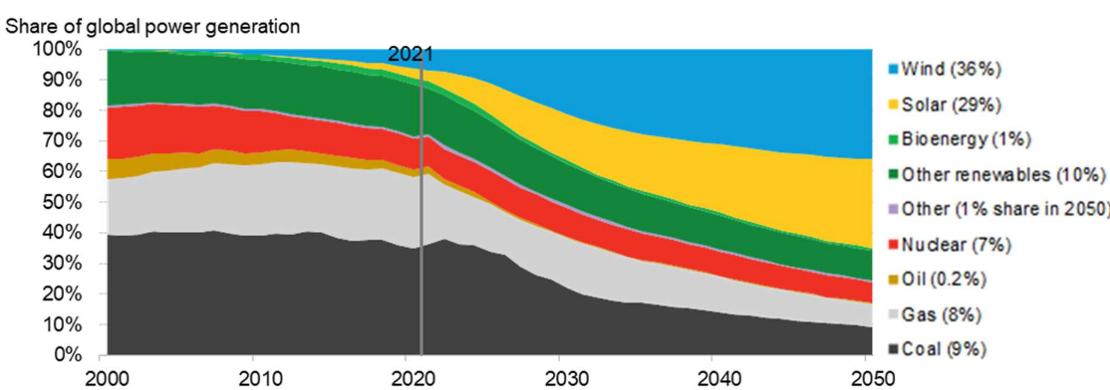
Source: DNV, Rosefinch.

4. The Bright Spot of Global Wind Power: Offshore Wind

According to BNEF statistics, after more than 10 years of technical progress, the cost of electricity for onshore wind and offshore wind power has decreased by 70%. Onshore wind power is still the cheapest power generation technology, followed by solar photovoltaics and offshore wind power. Although the cost of electricity for offshore wind power is 76% higher than that of onshore wind power, it is still lower than the construction cost of new coal-fired power.

Related data shows that to achieve global net zero emissions by 2050 and keep global warming within 2°C, renewable energy will dominate the power sector at that time, and it is estimated that wind power will account for 36%, exceeding solar photovoltaics.

2000-2050 Share of different power generation technologies in global power generation



Sources: BNEF, Rosefinch.

Looking at wind power globally, GWEC forecasts that global wind power will add 680GW from 2023 to 2027, with a compound growth rate of 15%, with China being the main contributor. Specifically, onshore wind power added globally is expected to be 550GW, with a compound growth rate of 12%, while offshore wind power should be a bigger highlight. According to relevant data statistics, global offshore wind power added is expected to be 130GW, with a compound growth rate of 32%. The proportion of offshore wind power additions from 2022 to 2027 will increase from 11% to 23%. Globally, it is expected that global wind power additions in 2023 will exceed 100GW, and global wind power will complete another 1TW in additions from 2024 to 2030.

5. Onshore Wind grows steadily while Offshore Wind demand recovers

In 2023, domestic offshore wind power, especially offshore wind power, was to some extent affected by certain restricting factors. However, with the introduction of the "single turbine over 30 MW" policy in the second half of the year and the advancement of other factors such as shipping channels, these restricting factors have gradually been resolved, and the construction of offshore wind power next year may accelerate.

Looking ahead to 2024, onshore wind power is expected to grow steadily. The wind power installation in 2023 was lower than previously expected by market, but with the resolution of restricting factors in offshore wind, wind power demand in 2024 will warm up further.

By combining the wind power tendering data statistics from various provinces and cities, including the difference between wind power bidding and installation in 2023, onshore wind installation in 2024 is expected to be around 60-70GW. Benefiting from the removal of restrictions in Jiangsu, Guangdong and other places, offshore wind power next year will exceed 10GW, with year-on-year growth of over 50%.

Sources: GWEC, Rosefinch.

Looking further ahead, China has huge potential for offshore wind development. By the end of 2023, China's cumulative offshore wind installation was only 30GW, accounting for just 1% of the available development resources, and there is still great potential for development farther offshore in the deep sea.

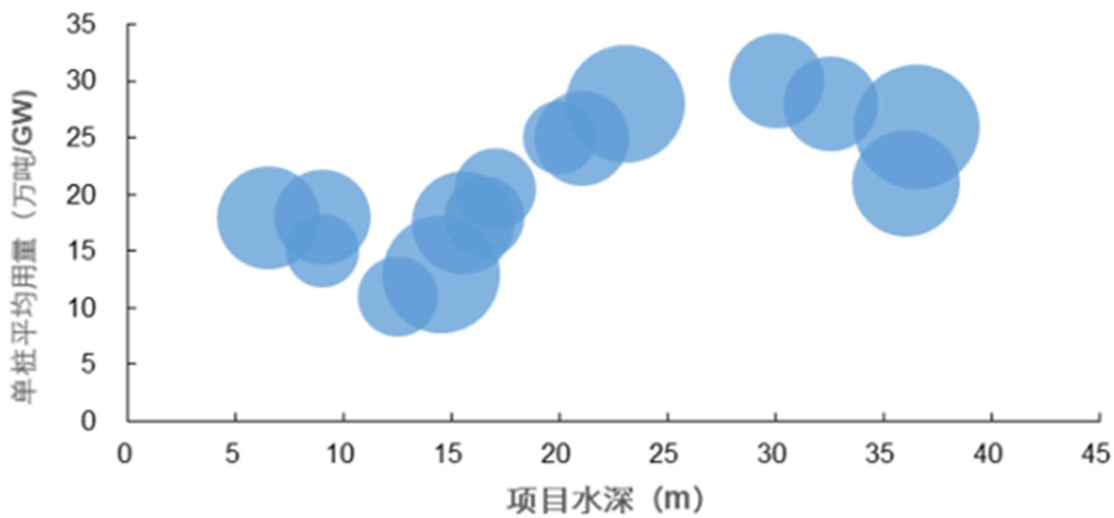
In September 2023, the National Energy Administration issued a notice on "Organizing and Conducting Renewable Energy Development Demonstration Projects", proposing to support technologies such as ±500kV and above flexible AC transmission systems, offshore wind turbines over 15MW, and new floating foundation technologies, and that the single project scale of offshore wind power demonstration projects in deep sea areas shall not be less than 1GW. With the background of offshore wind development more than 30 kilometers offshore and in waters more than 30 meters deep, the national policy has provided definitive guidance for deep-sea offshore wind technologies and evaluation demonstration projects, which is expected to promote state-controlled maritime projects.

6. Sea cable and monopiles may benefit first

Here are some thoughts on positioning in related industries benefiting from the warming offshore wind demand and development towards deeper waters:

Monopiles are the columns that support the wind turbines, and are one of the first stages to be delivered in offshore wind farm construction. They directly benefit from the warming offshore wind demand. Currently the usage of monopiles for a 1GW offshore wind farm is about 200,000 tons. As offshore wind moves towards deeper waters in the future, the usage is expected to increase with water depth.

Monopile usage increases with water depth

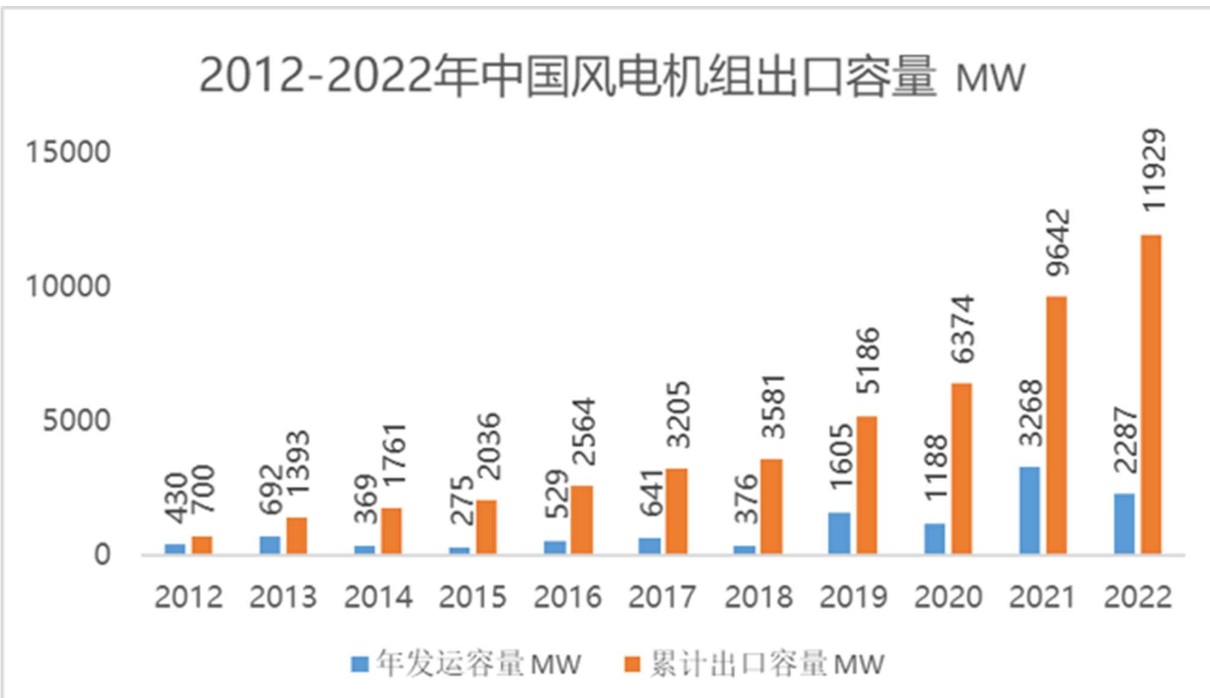


Sources: World Bank, GWEC, Rosefinch.

Because monopile production capacity is limited by suitable ports and lands, the demand should be able to take up monopile supply in the next 2-3 years. Some components like supporting structures will have favorable outlook due to production equipment constraints and few planned additions in manufacturing. Given the backdrop of warming offshore wind demand, the monopile business is expected to experience rapid development.

After power generation from wind turbines, sea cables are required to transmit the electricity from offshore wind farms to onshore substations. With the development of offshore wind towards deeper waters and larger capacity, the requirements for cable quantity and technological sophistication will increase significantly.

On the supply chain side, some domestic links that are relatively tight may have greater opportunities to go global considering the cost pressure in overseas wind power, in particular wind turbines. Looking at China's wind turbine production capacity, it accounts for nearly 60% of global capacity. However, compared to the globalized solar PV industry currently, China's wind turbine exports only account for 3% of the overseas market. Considering the impact of domestic wind turbine price wars in recent years, domestic wind turbine prices of 7500-8900 yuan/kW are much lower than overseas prices. This should accelerate Chinese wind turbine manufacturers' exploration of overseas markets with better profitability.



Sources: Woodmac, Rosefinch.

Moreover, one major overseas manufacturer experienced quality issues this year. Combined with higher delivery costs and longer delivery cycles due to high inflation abroad, this also drives oversea wind farm developers to switch to higher cost-effective and more reliable Chinese wind turbines. In the future, Chinese manufacturers with global deployment capabilities and advantages in technology R&D and cost control may benefit from overseas demand.

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With the rapid development of offshore wind power in Europe and other overseas markets, the current production capacity of cables and monopiles cannot adequately meet future development needs in Europe. These two segments are expected to accelerate into 2024.

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