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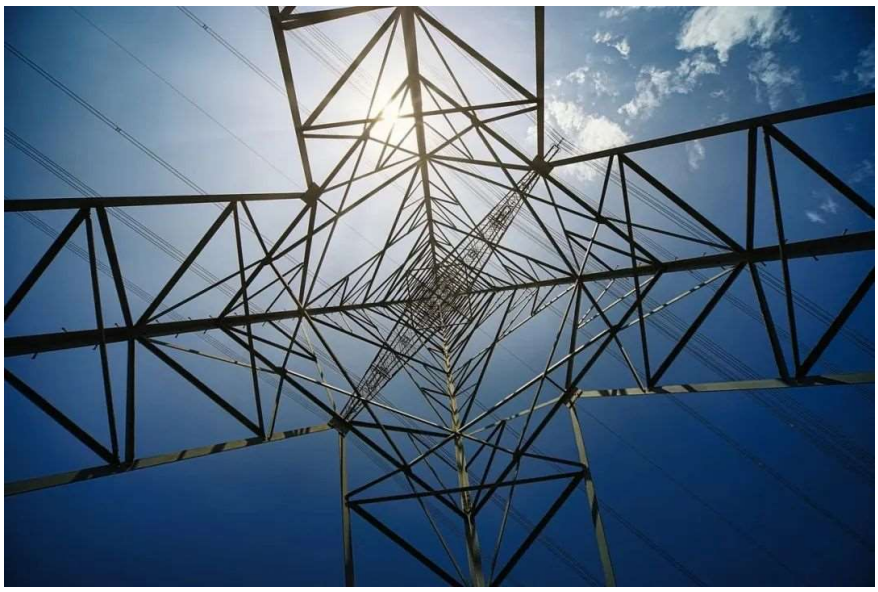
The Big Test for New Energy Consumption: Electricity Grid's Challenges and Opportunities



In 2023, China's installed capacity of renewable energy power generation will reach 1.45 billion kilowatts (including 1 billion kilowatts of wind power and photovoltaic power generation), accounting for over half of the total installed capacity, and finally surpassing thermal power generation.

This figure is only a stone's throw away from the target of "the total installed capacity of wind power and photovoltaic power generation reaches 1.2 billion kilowatts by 2030" proposed by the State Council in 2021. According to the current construction speed, AFRY estimates that it may be achieved ahead of schedule by the end of 2025.

The upstream installation heat has not diminished, but the downstream consumption problems have emerged. Research from IEA shows that bottlenecks in consumption will be reflected when the share of renewable energy reaches 15%. Data from the energy bureau shows that in 2023 the proportion of wind and photovoltaic power generation in total social electricity consumption has exceeded 15%, triggering the critical threshold.

In the power industry, if the electric power generated by the production side of electricity cannot be stored in time, it must be used in real time; when the electricity demand of an area is less than the generation of power plants, the surplus electricity needs to be stored, converted, or scheduled to other places with demand, this process is consumption. If there are bottlenecks in consumption, it will face the situation of "not being able to use it all and not being able to send it out", which can only stop power generation, which is known as "power abandonment".

In 2015, the three northern provinces suffered from serious "wind abandonment" due to lagging consumption capacity. Subsequently, UHV construction experienced its peak, and eight inter-provincial UHV lines eased the pain points of power transmission. However, with the continuous increase of new energy installation, consumption is facing new challenges again. In 2023, the wind abandonment rates in Inner Mongolia, Qinghai and Gansu were still as high as 6.8%, 5.8% and 5% respectively, while the light abandonment rates in Qinghai and Tibet were still as high as 8.6% and 22%.

After the peak of new energy installation, the main conflict of the new power system has quietly shifted from the supply side to the grid side. How to draw a "new power grid" for new energy is a common problem facing the world. What are the difficulties in new energy consumption? How to solve the status of "eastern shortage and western wastage"? During the upward cycle of global power grid positioning, which links have greater global advantages?

1. The Silk Road of Electricity

In the vast northwest region of China, the daylight time is long, the land costs are low, and it has unparalleled advantages in wind and solar power installation. Statistics show that renewable energy power generation installed capacity in this region will account for more than 50% of the national installed capacity in 2023, making it the pioneer of the new round of new energy construction wave. At the same time, the northwest region typically has little local demand and large export needs, with power supply installed capacity far exceeding demand on the use end.

Taking Qinghai Province as an example, the total installed capacity of power supply in the whole province will exceed 54 million kilowatts in 2023, of which renewable energy installed capacity accounts for more than 90%, with photovoltaic accounting for over 40%. At the same time, the largest electricity load of the whole network is only 13 million kilowatts, thus a large amount of surplus green electricity urgently needs to be stored or transported. If green electricity cannot be smoothly transmitted online for consumption in a timely manner, the utilization rate of wind and solar power in the local area will be greatly limited.

There are huge differences between the resource-rich Western regions and consumption-heavy Eastern regions. During the rapid development of renewable energy, the stress between energy production centers and load centers is becoming more prominent.

"West-to-East Power Transmission", as a representative engineering project of large-scale development in Western China, has become an important channel for consumption of Northwestern green electricity. However, in the past two years, the progress of construction on the energy supply side and grid side has not been synchronized.

Against the background of carbon neutrality, the high-speed growth of installed wind and solar power capacity is self-evident, with investment growth rates on the energy supply side reaching 30.3% and 30.1%

in 2022 and 2023 respectively, and wind and solar power investment is expected to exceed 60%. However, grid investment completions in 2022 and 2023 grew only 1.2% and 5.4% respectively, much slower than investment on the energy supply side.

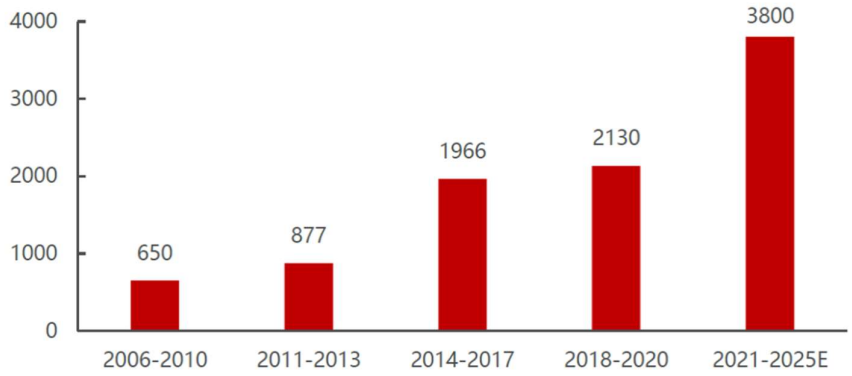
Source: National Energy Bureau, Rosefinch. Blue is electricity grid investment; orange is generator investment.

The main difference between the two lies in the mismatch of construction periods. Investment in the power supply side is mainly driven by the market. New energy projects require one year of preliminary preparation and half a year of construction, with an overall project cycle of about 2 years. Investment on the grid side is mainly driven by planning. Grid construction projects must first be included in the national energy administration's power plan, then from the State Grid's development plan to being included in the local company's annual plan, before processes such as budgeting, design and construction can begin. The

average project cycle is three to five years, resulting in the construction progress of the grid side often lagging behind that of the power supply side.

In order to keep up with the development of the power supply side, grid construction planning is accelerating. Compared with the 13th Five-Year Plan period, the number of Ultra-High Voltage Direct Current lines planned and built during the 14th Five-Year Plan period will reach 12, an increase of 50%. According to Changjiang Securities' estimates, if a single UHVDC line investment is estimated at 20-30 billion yuan, the 14th Five-Year Plan UHVDC investment amount will increase by about 100 billion yuan compared with the 13th Five-Year Plan.

China's ultra-high voltage investment size (100mmCNY)



Source: Minsheng Securities research.

During the 15th Five-Year Plan period, major projects such as wind and solar power bases and the southwest hydropower base will be successively implemented. The "Green Channel of Electricity Transfer" project, which undertakes the major responsibility of "West Electricity East Transfer", urgently needs to be completed. At the same time, with the decline in the price of photovoltaic modules, the expected IRR of downstream power stations is expected to increase. The concern about relaxing the "minimum of 95% absorption" red line is gradually rising. If indeed relaxed, it will highly likely further expand the upper limit of installed capacity for wind and light resources and increase the urgency of new energy absorption in the power grid. **Compared with the uncertain factors such as absorption and overseas policies facing photovoltaic installation, the future construction demand of the power grid may have higher certainty.**

At a recent meeting of the Political Bureau, the General Secretary pointed out that further construction of new energy infrastructure network, promotion of intelligent upgrading and reconstruction of power grid infrastructure and construction of intelligent microgrid will improve the power grid's ability to accept, configure and regulate clean energy.

The latest issued by the Energy Bureau "Guiding Opinions on High-quality Development of Distribution Grid under New Situation" proposed that by 2025, the distribution grid will have distributed new energy

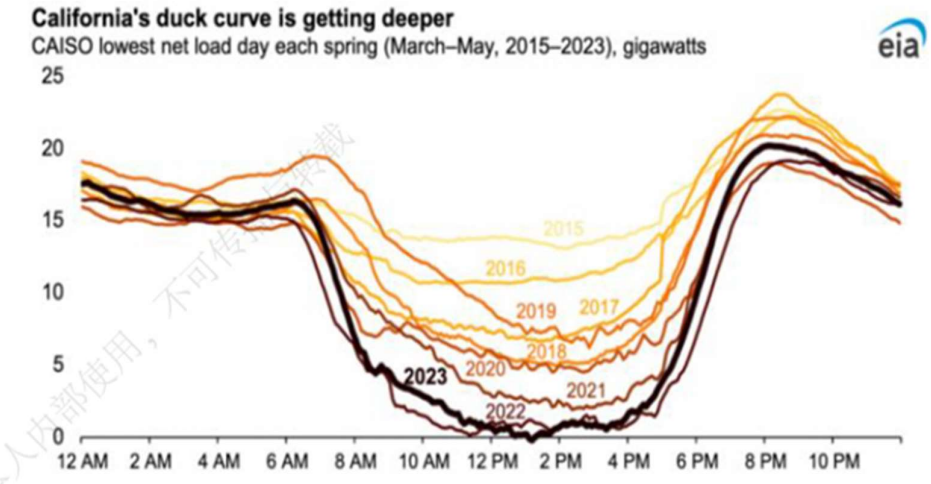
absorption capacity of 500GW and charging pile access capacity of about 12 million units. At the end of 2023, distributed PV installation reached 254GW (an increase of 96.3GW in 2023), with a cumulative 8.6 million charging facilities. That is to say, excluding the access scale of distributed wind power, the access space for distributed PV in the next two years will be about 200GW, exceeding market expectations. Considering the large access pressure of distributed new energy currently, it is expected that the investment in distribution grid will likely increase to improve the access capacity of distributed new energy.

2. The Big Test for New Energy Consumption

Unlike traditional coal-fired power, renewable energy such as wind and solar power represented by renewable energy have high volatility and intermittency, which puts higher requirements on the regulation ability of the power system.

Taking photovoltaic as an example, the following figure is the daily net load distribution by time published by the grid operator in California. The left axis is the demand side net load (the remaining power demand after deducting the wind power and photovoltaic power generation from the grid). The net load reaches the bottom at noon. When the photovoltaic output decreases in the evening, the net load rises sharply, forming fixed peaks and troughs. In addition, with the continuous increase of the proportion of new energy access, the fluctuation of the net load curve from 2015 to 2023 becomes greater and greater, and the "dual peak" characteristic of power load is more prominent.

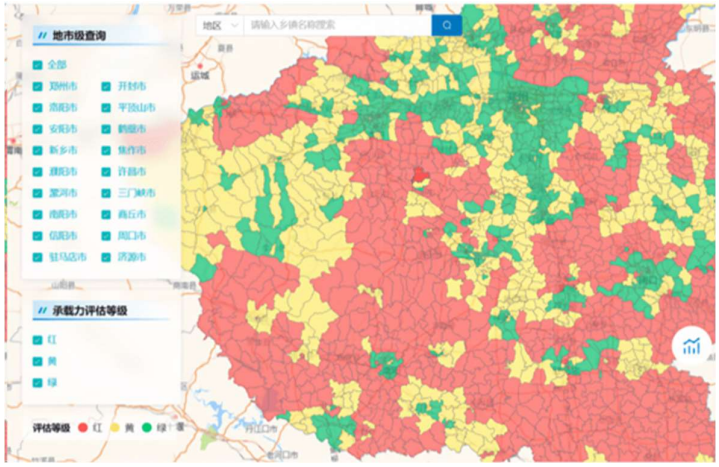
The fluctuation of the "duck curve" of net load increases year by year.



Source: EIA, CAISO, Minsheng Securities research.

To accommodate the unstable output of renewable energy, traditional supporting energy sources led by coal-fired power have undertaken the task of regulation by producing less or no power during renewable energy output peaks and producing more power during troughs, thereby achieving peak shaving and valley filling for frequency modulation.

The rapid increase in the penetration rate of renewable energy is consuming the existing regulation resources in the power system. Data released by Henan Province shows that more and more prefecture-level cities in the province have reached the carrying capacity limit for distributed photovoltaic power generation, and limits on grid access have resulted in installed solar PV that cannot generate income through power generation, constraining the future installation progress.



Source: Henan Province platform.

The regulation capability and regulation cost of the power system largely determine the absorption limit of renewable energy. From the perspective of regulation path, hydropower has high demands on the natural environment on the power supply side, nuclear power attaches more importance to production safety, and gas power is limited by resources. From multiple perspectives such as existing scale, reconstruction convenience, safety and economy, coal-fired power is still one of the priority choices for flexible transformation on the power supply side.

调节方向	调节路径	优势	劣势
电源侧	煤电	装机量高、灵活性挖潜空间大	调峰补偿机制有待完善，深度调峰增加发电煤耗，提升爬坡速度影响使用寿命
	水电	开停机迅速、负荷调节快等灵活特点	调节能力受来水条件影响较大；调节速率过快会加剧电网频率波动
	核电	调节范围为 30%-100%，低功率运行水平可超过 12h	调节频率过快会降低设备可靠性，安全裕度下降；存在核废料处理问题
	气电	调峰能力强（30%-100%），相应速度快，爬坡速度快，是较为有效的灵活性电源	我国气电对外依存度高、气源供应不足；燃料成本高、设备造价与维修费高

Source: Yuan Jiahai, Cinda Securities research center.

The three northern regions of China have abundant renewable energy resources, with wind power and solar power installations accounting for 72% and 61% of the country's total, respectively, while flexible regulation power sources account for less than 3%. Although the proportion of flexible regulation power sources and regulation capacity still have room for improvement, the initiative of coal-fired power plants

to carry out flexible transformation is highly dependent on whether the income from peak shifting compensation can offset the costs of flexible transformation. Only after the commercial model's economics are validated will coal-fired power enterprises have sufficient motivation to actively promote flexible transformation.

The main costs of flexible transformation consist of three parts: fixed transformation costs, increased operating costs due to peak shifting, and opportunity costs from reduced electricity generation. The combination of these three factors makes the cost of coal-fired power plants to carry out flexible transformation relatively high.

On the one hand, flexible transformation increases the operating pressure on power plants, the self-motivation for transformation is insufficient, and the high transformation costs lead to the progress of coal-fired power flexible transformation during the "13th Five-Year Plan" period being less than expected.

On the other hand, although most provinces implement staggered compensation for different peak shifting depths, a peak shifting price of 0.6-1 yuan/kWh is still not uncommon, while the grid price for green power is 0.2 yuan/kWh. The high consumption costs to a certain extent erode the long-term returns of new energy power generation projects and also suppress the enthusiasm for upstream renewable energy installation and grid connection.

机组类型	改造路线	达成效果	成本分析
纯凝机组改造	锅炉本体改造：燃烧、制粉系统改造、宽负荷脱硝改造	最低负载率可达 20%	总费用 1000~2000 万元/台
热电机组改造	热水蓄热:实现“热电解耦”	最低负载率从 60%～70%降至 30%～50% 额定负荷调峰能力提升 10%~30%	蓄热罐单位改造成本 1800～2800 元/m3 平均改造成本约 1000 元/kW（新增调峰能力）
	固体电蓄热锅炉：实现“热电解耦”	最低负载率可降为 0%	蓄热锅炉单位改造成本约 1000~1200 元/kW 平均改造成本约 879 元/kW（新增调峰能力）
	电极式锅炉+热水蓄热调峰	最低负载率可降为 0%	电极式锅炉单位改造成本 700 元/kW，热水蓄热单位改造成本 1800~2800 元/m3 平均改造成本约 1383 元/kW

Source: Yuan Jiahai, Cinda Securities Research center.

With the gradual improvement of the mechanism of electricity trading market, the auxiliary service market mainly composed of peak regulation, frequency regulation and reserve has turned from planning to market. Statistics show that the auxiliary service costs in the domestic market reached 27.8 billion yuan in the first half of 2023, nearly 3 times the figure in the same period of 2018, and coal-fired power enterprises accounted for 91.4% of the compensation. At the same time, more and more traditional power generation enterprises have explored renewable energy industries, and the motivation for flexible transformation of coal-fired power is expected to be further enhanced in the future.

In addition to coal-fired power regulation, energy storage is another important means of absorbing new energy. It can maintain the stability of power generation frequency while assisting coal-fired power in peak

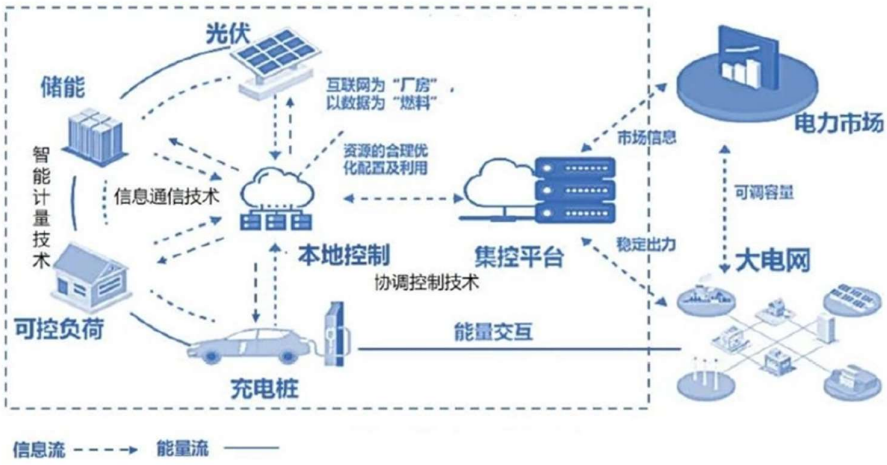
shifting and frequency regulation. Under the policy guidance of mandatory storage matching, the matching storage ratio of new energy installations has gradually increased from the original 10-20% to 15-30%. However, mandatory storage matching has low utilization and insufficient economy due to low utilization rates. While promoting energy storage installation, it has also become a major factor restricting the healthy and sustainable development of industry.

Independent energy storage is gradually becoming the main way of building energy storage power stations and has economic viability in Shandong, Ningxia, and Hunan. Independent energy storage projects with relatively high-capacity leasing rates have initially achieved economic viability, but the industry still needs to clarify the profit model of independent energy storage power stations and provide more profit channels and certainty.

The establishment of a new power system also requires a combination of "soft" and "hard" approaches. During the 14th Five-Year Plan period, State Grid plans to invest 2.23 trillion yuan in grid construction, with informatization investment as an important part. The Southern Grid plans to invest about 670 billion yuan during the 14th Five-Year Plan period to accelerate the construction of the digital grid and modern grid process.

An important carrier of power informatization is the virtual power plant. The operating principle of a virtual power plant is to intelligently and orderly integrate scattered adjustable electric loads in the power grid through information technology to reduce grid impact, optimize generation costs and reduce losses. Technology providers access the grid through ancillary power units to complete power transactions and obtain corresponding service fees, or extract profits from premiums.

According to the calculation of State Grid, the investment to offset peaks & valleys for traditional thermal power plants to meet 5% peak load is about 400 billion yuan. While using virtual power plants, the estimated investment to achieve the same goal is 40-57 billion yuan, which has a higher cost-effectiveness.



Source: 36Kr research, Great Wall Securities.

3. New Cycle of Global Electricity Grid Positioning

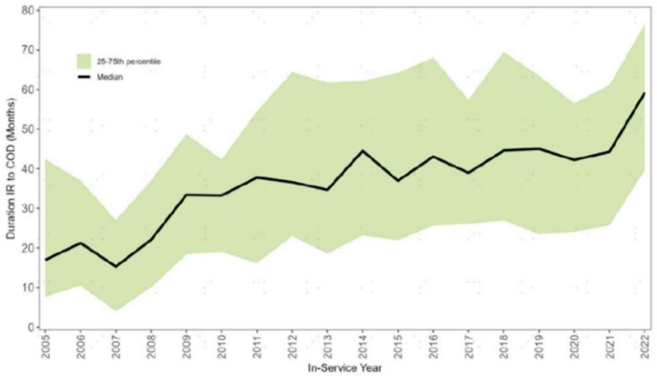
Compared with domestic grids, the infrastructure of power grids in developed overseas economies is relatively complete, but some existing lines are facing aging and gradually entering the reconstruction period. At the same time, with the significant increase in renewable energy installation in recent years, the ratio of power investment and grid investment has increased from 1.6:1 in 2015 to 2.5:1 in 2023. Grid investment has therefore lagged severely behind power investment, and a large number of supporting facilities need to be upgraded to achieve the balance and flexibility of the power system.

BNEF predicts that the annualized growth rate of global grid investment from 2022 to 2030 will reach 12%, and the total investment during the period will reach USD 21.4 trillion, of which 20% is used to replace aging assets, 40% is used for system upgrading, and 40% is used for new access and interconnection.

Taking the United States as an example, most of the existing transmission lines in the United States were built in the 1960s and 1970s. The 2021 report by the U.S. Department of Commerce shows that the average service life of transformers in the U.S. power grid has reached 38 years, 70% of transformers have exceeded 25 years of service life, and transformers are generally designed for a service life of 30-40 years, and the actual service life in areas with high loads and frequent extreme weather is even shorter, and the relevant power equipment urgently needs to be updated.

Secondly, the grid has become one of the main bottlenecks for the large-scale expansion of renewable energy. By the end of 2021, the United States had nearly 900GW of wind and photovoltaic installation capacity waiting for grid connection, while the annual installation of wind and photovoltaic power was still increasing sharply. The average waiting time for renewable energy projects from filing an application for grid connection to actual operation has increased from less than 20 months in 2005 to nearly 60 months by the end of 2022.

Delay in US Solar project time from application to online status:



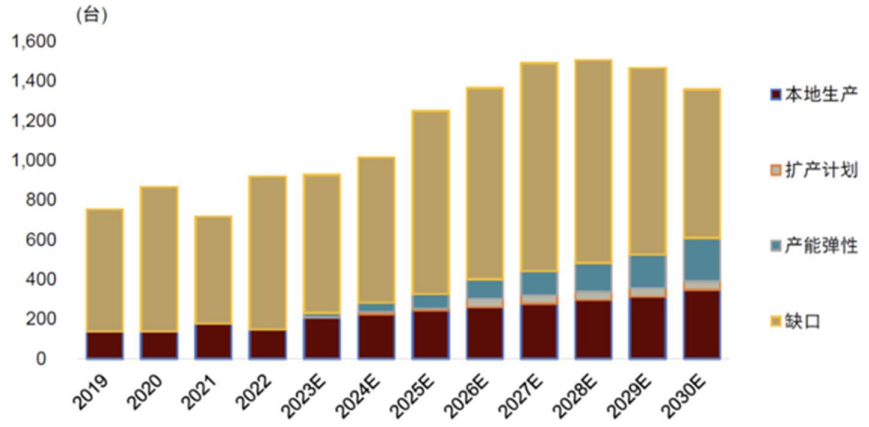
Source: Berkeley LAB, CICC Research.

It's not just the United States, grid connection of renewable energy has become a global challenge. According to IEA statistics, at least 3000GW of renewable power generation projects worldwide are currently queued waiting for grid connection, equivalent to 5 times the added capacity of photovoltaics and wind power in 2022. Assuming delays in grid investment, the share of wind and solar power generation in the global electricity mix will drop from the predicted 59% to 44% by 2050.

The need for grid investment to connect renewable energy and transform aging equipment is growing rapidly, but the short-term elasticity on the supply side is limited, leading to a periodic expansion of gaps in overseas domestic supply. Taking transformers as an example, delivery times from European and American suppliers continue to lengthen. According to BNEF data, the transformer delivery cycle in the United States has expanded from 15 months in 2014 to 4 years in the third quarter of 2023.

From the supply side, overseas suppliers will find it difficult to release large production capacities in the short term. For example, the normal cycle to expand transformer production is generally 2-3 years, and the supporting supply chain is also incomplete. Relative lack of competitive advantages in terms of production costs and product quality has also made overseas domestic suppliers more cautious in decisions to expand production.

The United States faces serious gaps in domestic supply of power transformers.



Source: BNEF, CICC Research (transformer larger than 100MVA)

According to the estimations of CICC Research Department, the market share of China's power equipment in overseas markets is less than 10%. The temporary expansion of overseas supply gaps and relatively dispersed competitive landscape have provided broad development opportunities for Chinese power equipment enterprises to go abroad.

A batch of power equipment companies with strong product strength, high performance-to-cost ratio, and obvious competitive advantages have emerged in the domestic fast-growing new energy industry chain upstream and downstream. Comprehensively considering factors such as overseas demand growth rate,

construction cycle, and supply landscape, sub-sectors such as transformers and smart electricity meters are expected to become the first echelon of power equipment exports, replicating the successful case of inverter exports abroad.

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