GIC × MIOTECH

The Green Leap

How the Energy Transition is Transforming China's Economy

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Executive Summary

Over the past few years, China has stepped up its climate action efforts to accelerate the transition of China's economy and energy mix towards zero carbon emissions. The carbon neutrality target of 2060 is a policy target set by the Chinese government for 40 years from now, creating certainty and anchoring new investment opportunities for value investors seeking exposure to China's decarbonization transition.

The carbon neutrality target signals a major shift is on the way in how energy is supplied and consumed. MioTech Research has completed a series of studies covering China's path to reaching a carbon emissions peak, and later, falling to a target of zero carbon emissions. Visions drawn from these studies show distinctive features; namely, decoupling energy consumption from economic development, continuous improvement in energy use efficiency, accelerated evolution of energy demand patterns, continuous optimization of energy supply structures, and rapid iteration of low-carbon energy technologies.

On the energy supply side, the structure of primary energy demand will change dramatically, with fossil fuel demand dropping by more than 90% and renewable energy becoming the mainstay of energy supply. Under a scenario of renewable energy becoming the dominant energy source, we expect several outcomes: traditional thermal power assets will confront flexibility retrofit, energy storage technology will be applied on a large scale, transmission infrastructure investment will be increased, and demand-side management and other measures will improve power system flexibility. Meanwhile, digitalization will greatly improve the overall efficiency of both production and consumption.

On the demand side, several factors will reshape resource and energy use, including increased efficiency in energy consumption, large-scale electrification of the industrial, building and transportation sectors. The circular economy will also reshape the industry, which decouples economic activity from the consumption of finite resources. In the industrial sector, the recycling and recovery rates of energy-intensive materials and the energy efficiency of general electrical equipment will be significantly improved, greatly reducing energy demand. Industrial waste heat recovery technologies are also beginning to pick up steam across industries.

In the building sector, prefabricated construction will lead the decarbonization transition in building design and construction, and much room for progress remains. Heating and cooling of homes and offices with zero carbon emissions will be made possible by building-integrated photovoltaics, advanced heat pump technologies and energy-efficient building materials. Along with progress in electrification, novel applications such as virtual power plants and vehicle-to-grid technology are gaining traction as contributors to a new flexible power system.

MioTech Research conducts an extensive two-part assessment of China's ongoing transition toward a carbon emissions peak by 2030 and, eventually, Net Zero in 2060. The first part covers China's grid-side innovations with accelerating renewable transition, while the second examines the complementary energy demand side innovations, especially within the industrial and building sectors under the decarbonization trend. The study aims to reveal new trends of green investment, especially from the standpoint of 2022, and to explore the significant investment opportunities in the complex and changing macro environment in the coming years.

I. The supply side – power generation and the electricity grid

Overview: Variable Renewable Energy (VRE) Installations Maintain High Growth

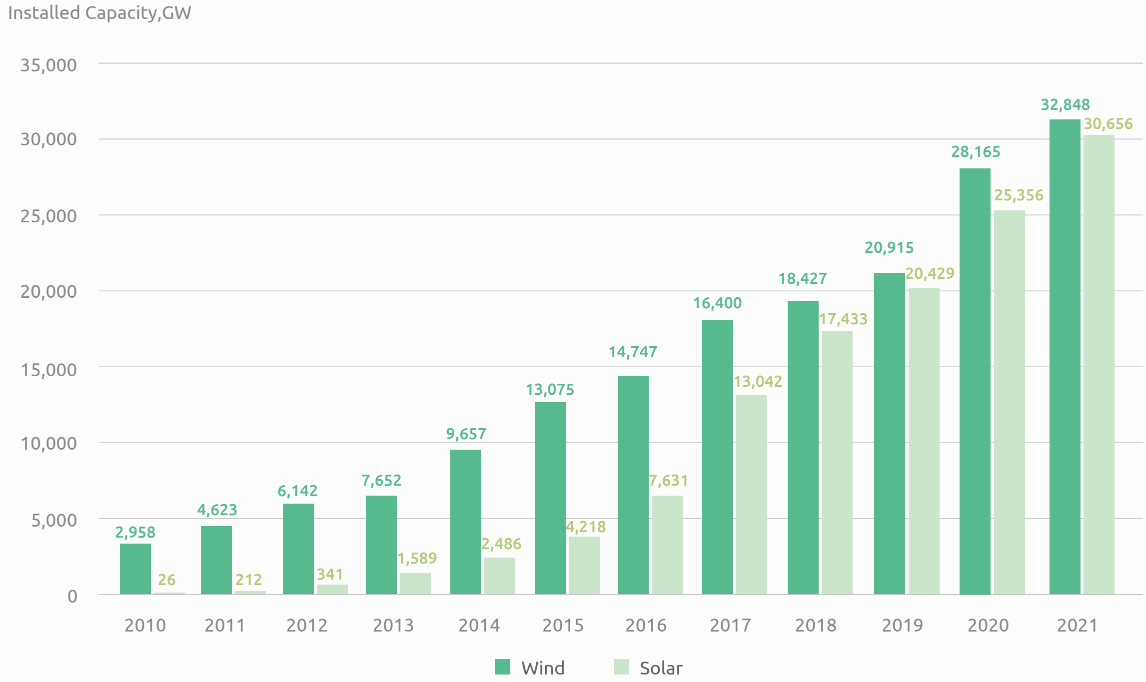
Wind and solar power account for a rising share of Variable Renewable Energy (VRE). In 2021, the duo together took almost 13.5% share of China's electricity consumption, up from just 1.6% ten years ago. Remarkably, new VRE installations are largely market-driven, as the levelized cost of energy (LCOE) of onshore wind and PV is already substantially cheaper than coal and gas. Massive financing for renewable technologies will further reduce production cost and improve efficiency. The country also announced revised targets as a part of the 14th FYP decarbonization policies, facilitating China's technological transition and steering the country towards its decarbonization goals.

In 2021, the installed capacity of wind and photovoltaic generation in China both exceeded 300 gigawatts (GW), accounting for one-fourth of the country's total installed generation capacity. The National Energy Administration released data showing that in 2021, China's installed capacity of wind power surpassed the 300 GW mark, accounting for about 12.6% of the country's total installed power supply. Wind power generation accounted for about 7.5% of total electricity consumption. Compared with 2020's data, both figures are up 0.3 and 1.3 percentage points, respectively. The newly-installed wind power capacity of 47.57 GW is about 27% of China's total new installed capacity.

China's cumulative installed capacity for photovoltaic generation reached 306 GW in 2021, accounting for 12.8% of the total installed power supply and 4.5% of the total electricity consumption; newly-installed capacity is 53 GW, accounting for 31.1% of all newly-installed capacity in China. On the global scale, China's wind power installation has made up more than two-thirds of the global wind power capacity, with China's total equaling 1.4 times the total installed wind power capacity of the European Union and 2.6 times that of the United States. China has ranked first in the world for 12 consecutive years. The installed capacity of photovoltaic power generation has also ranked first in the world for seven consecutive years.

In the first half of 2022, China installed 43.82 GW of wind and solar PV power generation, accounting for 64% of the country's new installed capacity.

Exhibit 1: Wind and photovoltaic power cumulative installed capacity (GW) in China, 2010-2021



Source: China Electricity Council, MioTech Research

Technological advancements have made wind and photovoltaic power generation highly economical. The cost of VRE power generation is actually lower than that of coal-fired power plants. According to data released by IRENA, during 2010-2019, China's onshore and offshore wind power's levelized cost of electricity (LCOE) dropped from RMB 0.91/kWh and RMB 1.15/kWh to about 0.32 /kWh and 0.53/kWh, or 65% and 54% drop in percentage. During the same period, the photovoltaic LCOE has gone down to RMB 0.36 /kWh, a reduction of more than 90%.

Various renewable innovations are accelerating the growth and opportunities within the renewable economy in the past year. In the wind power industry, leading manufacturers such as Goldwind and Mingyang have transitioned to the larger unit specifications of 4MW and 5MW units, lowering its tender price. In the PV industry chain, players such as HJT and TOPCon technology have emerged. Compared with the current 22.8% conversion efficiency of PERC (passive emitter and rear cells), the finished products of the two technologies are able to reach 24%, while the conversion efficiency could reach as high as 27% theoretically. According to the industry forecast, the LCOE of onshore wind will further decline during the 14th FYP period, which is expected to hit RMB 0.1, 0.2 and 0.3 by 2025 in high, medium and low wind speed areas, respectively. At the same time, the LCOE for Solar PV is expected to drop to between RMB 0.25 and 0.38 by 2025.

The subsidizing policies for wind and PV are being retired and the feed-in tariff (FiT) scheme has been abolished. Since 2021, no national subsidies have been provided for developing centralized or commercial/industrial distributed PV projects. Effective from 2022, no subsidies will be available for new household distributed PV projects. Wind power coincides with the PV timeline, with subsidies for newly-approved onshore projects phasing out in 2021 and newly-approved offshore power projects scheduled to phase out in 2022.

Exhibit 2: Onshore wind power tariffs (in RMB) and national policies

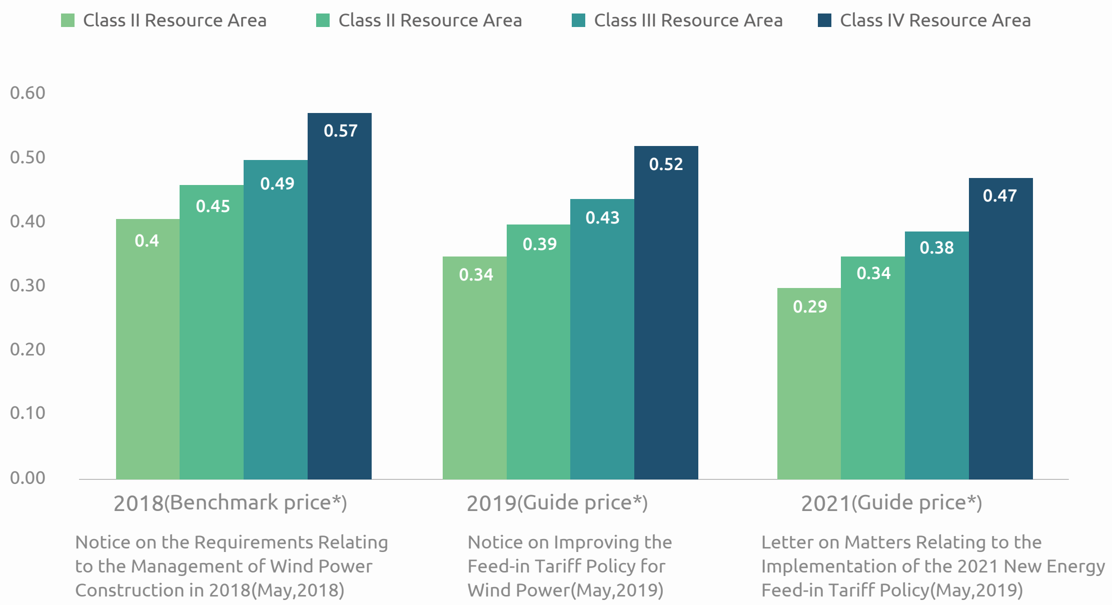
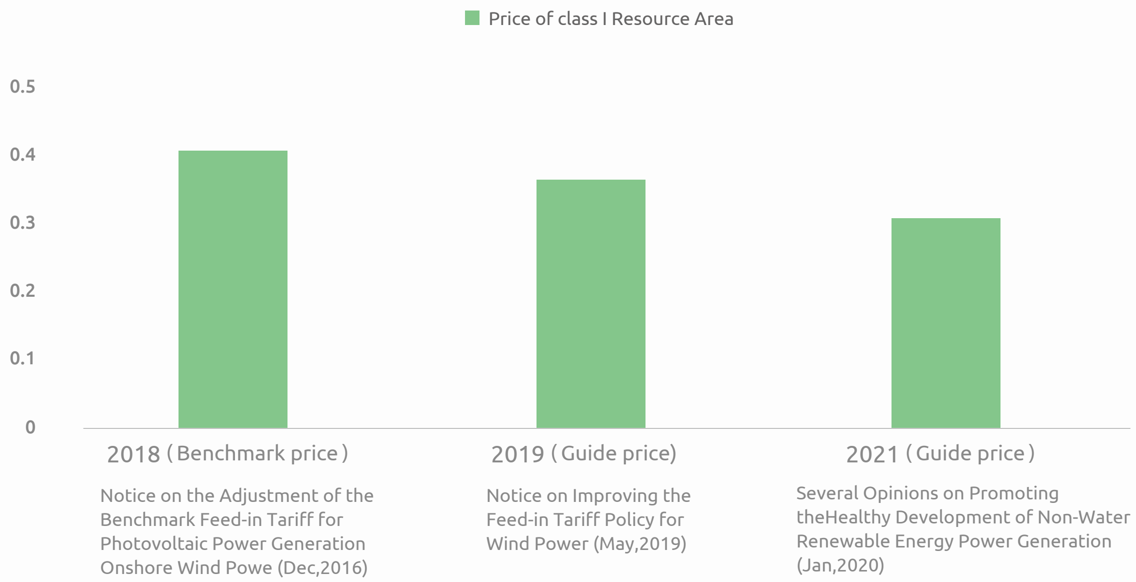
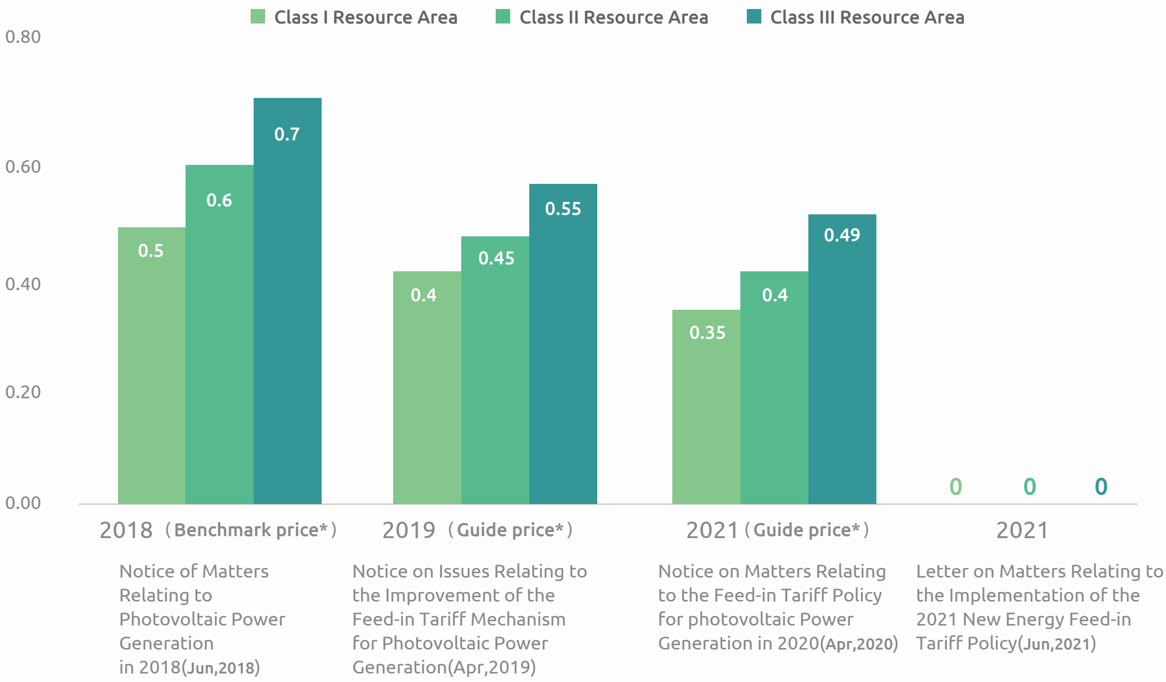


Exhibit 3: Offshore wind power tariffs (in RMB) and national policies



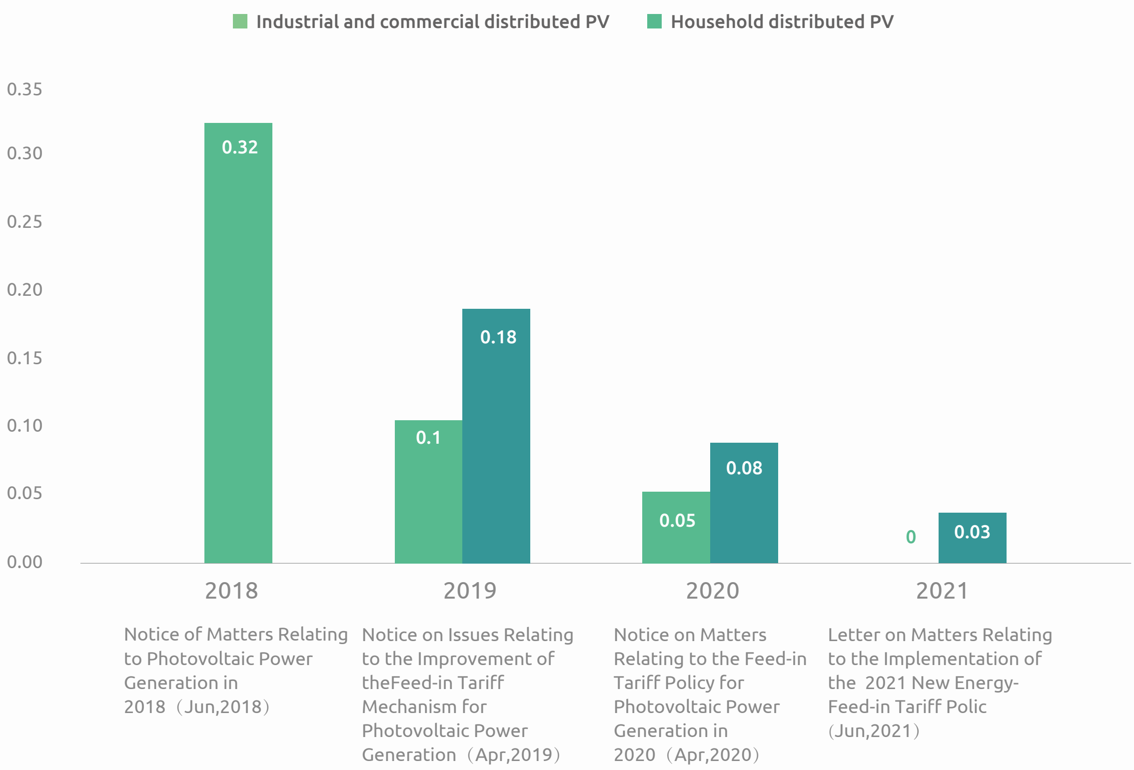
[1] Benchmark price: Nationwide unified feed-in tariff set by the national government
[2] Guide Price: ceiling price set by the national government, final tariff decided by lowest bid

Exhibit 4: Centralized PV tariffs (in RMB) and national policies



*: Guide price policy expired in 2021, which means no more subsidies were provided for centralized PV.

Exhibit 5: Distributed PV subsidies (in RMB) and national policies



Source: Public documents, MioTech Research

In 2021, the two major grid companies in China, namely the State Grid and China Southern Power Grid both rolled out their action plans for carbon peaking. Looking forward, both companies have set out ambitious targets on power mix change in line with the State Council's carbon peaking requirements by 2030. To further break down the commitments, provincial grids are also asked to set out provincial level numerical targets for grid transformation. The first of its kind report have been published by Zhejiang State Grid in May 2022.

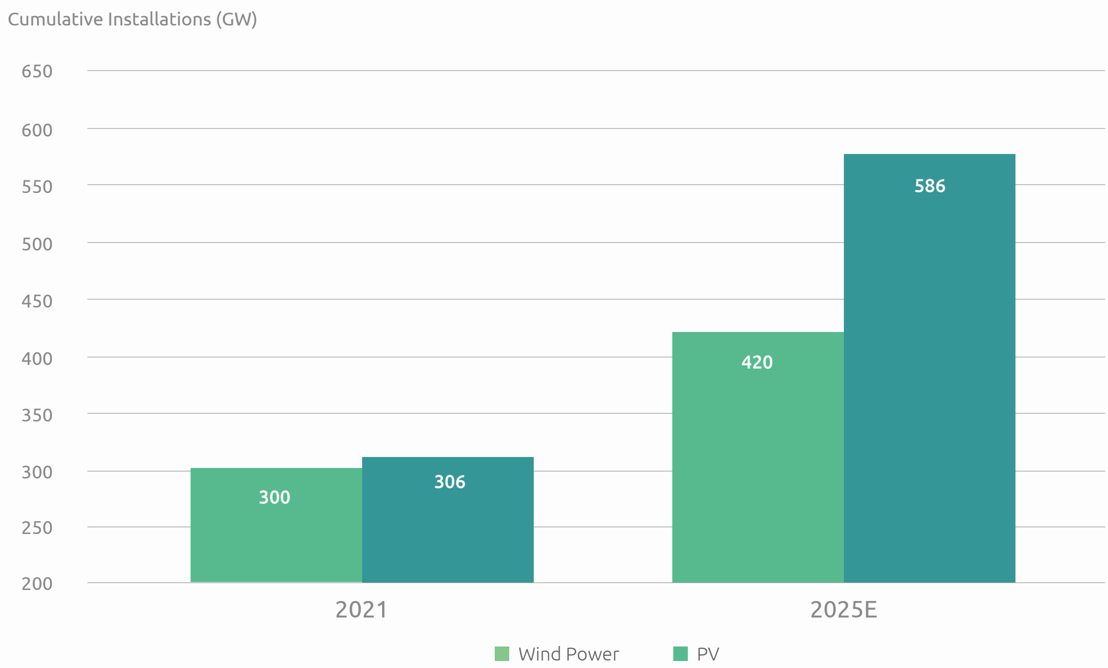
Exhibit 6: The numerical targets on power mix change set out by China's two grid companies and provincial grids

	Share of non-fossil fuel in total primary energy consumption	Share of non-fossil fuel installed capacity	Share of non-fossil fuel electricity generation	Electrification rate of total energy consumption	Wind and solar installation target
The State Council's Action Plan for Carbon Dioxide Peaking Before 2030	25%	Not mentioned	Not mentioned	Not mentioned	1.2TW
Grid Companies					
The State Grid	25%	Not mentioned	Not mentioned	38%	1TW
China Southern Power Grid	42%	65%	61%	35%	250GW
Provincial Grid					
Zhejiang	30%	60%	Not mentioned	Not mentioned	54GW

Source: Public documents, MioTech Research

The industry side also anticipates accelerating domestic renewable installation. The National Energy Agency proposed that by 2025, the national PV and wind power will account for 16.5% of the total electricity consumption. China Photovoltaic Industry Association (CPIA) expects new PV installations to reach 70GW per year during the 14th Five-Year Plan, and can be as high as 90GW per year. Wind power installations are expected to remain strong after record-setting growth driven by an installation rush for the phase-out of feed-in tariff scheme, with GWEC (Global Wind Energy Council) giving a forecast of about 40GW per year from 2022 to 2025.

Exhibit 7: China Wind Power and PV Cumulative Installations (GW), 2021-2025



Source: CPIA, GWEC, MioTech Research

Centralized and distributed renewable development are attached with equal importance. The National Energy Agency in December 2021 issued an administrative notice to promote the second round of large wind and PV project development in West China, with the first round of about 100GW of large wind power PV already under way. On the other side, the national government is pushing for the coupling of distributed wind power and development with rural revitalization action plans in South-eastern and Central-southern China. This move unlocks potential wind power of around 1000GW in the two regions. Distributed PV is expected to become the majority form of future development, reaching a 50% share in 2025.

Exhibit 8: National level policies on centralized and distributed renewable energy during the 14th FYP period (partial)

Date	Policy	Content/Objective
Dec-21	National Energy Agency, "Notice on Organizing the Second Batch of Large-scale Wind Power and Photovoltaic Projects Focusing on Deserts, Gobi and Desert Areas	Promoting the development of large-scale wind and solar energy stations
Jan-21	The State Council, "Opinions on Completely Accurately and Comprehensively Implementing the New Development Concept and Achieving Carbon Neutralization"	The total installed capacity of wind power and PV will exceed 1200GW by 2030
May-21	National Energy Agency, "Notice on Matters Related to the Development and Construction of Wind Power and Photovoltaic Power Generation in 2021"	Wind Power and PV will account for 16.5% of the total electricity consumption by 2025; initiate rural wind power and PV development scheme
Mar-21	National People's Congress, "14th Five-Year Plan and 2030 Vision Outline"	Development of Nine large-scale energy bases integrating wind, solar and energy storage and five offshore wind power bases

Source: Public documents, MioTech Research

VRE Integration Orders for Higher Grid Flexibility

Grid mode transformation becomes imperative

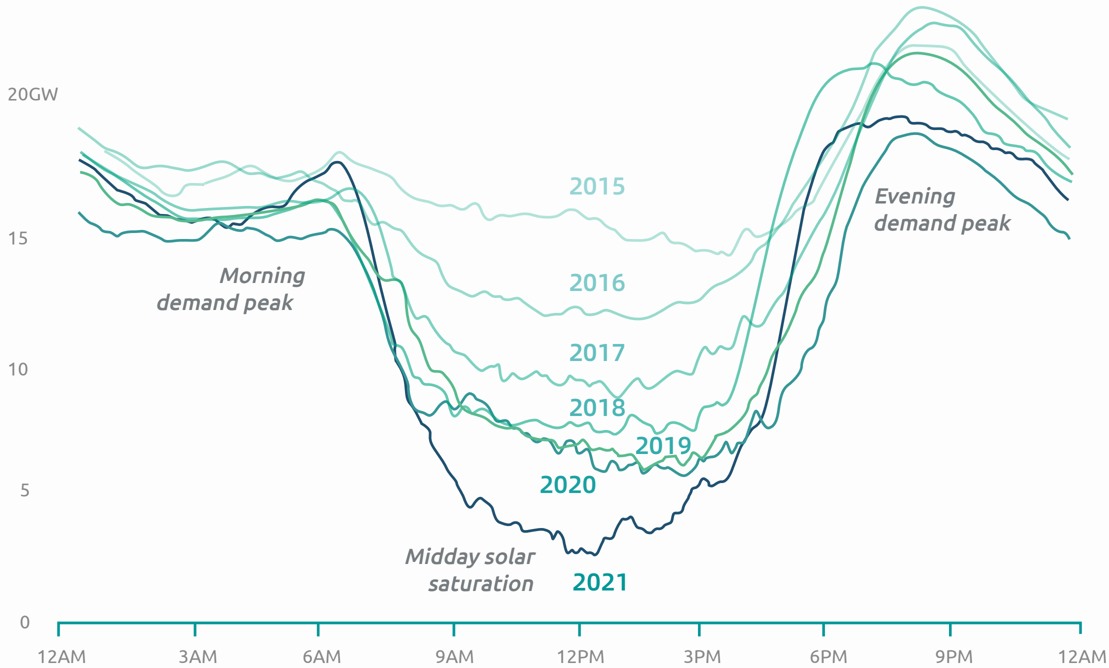
Wind energy and PV are both Variable Renewable Energy (VRE) sources, producing electricity intermittently that cannot easily be stored. Unlike stable generating capacity from thermal power plants, VRE sources cannot be simply plugged into the grid. This creates two main challenges to the traditional power system when deployed at scale:

- VREs are weather (wind and sunlight conditions) dependent, which means the power generated varies from time to time, and even at the second level, is unpredictable. Directly connecting VRE to the grid will stress the load balance, voltage and frequency, affecting the overall stability of the grid.
- Second, VREs experience a typical power generation curve throughout the day. The peak period does not necessarily coincide with periods of high power demand (Exhibit 8). In general, PV can achieve its maximum output between 9 am and 3 pm, resulting in the lowest net load (power demand subtracting the wind and PV power generation) on the grid during these hours. Between 6-9 am and 6-9 pm, however, the net load peaks as the power demand increases but the VRE generation power decreases.

Maintaining the stable operation of the grid is crucial. And therefore, auxiliary services from power generators and grid operators need to be in place to respond quickly to the net load changes in a short period of time.

Exhibit 9: Net load in California, the U.S. (Duck Curve)

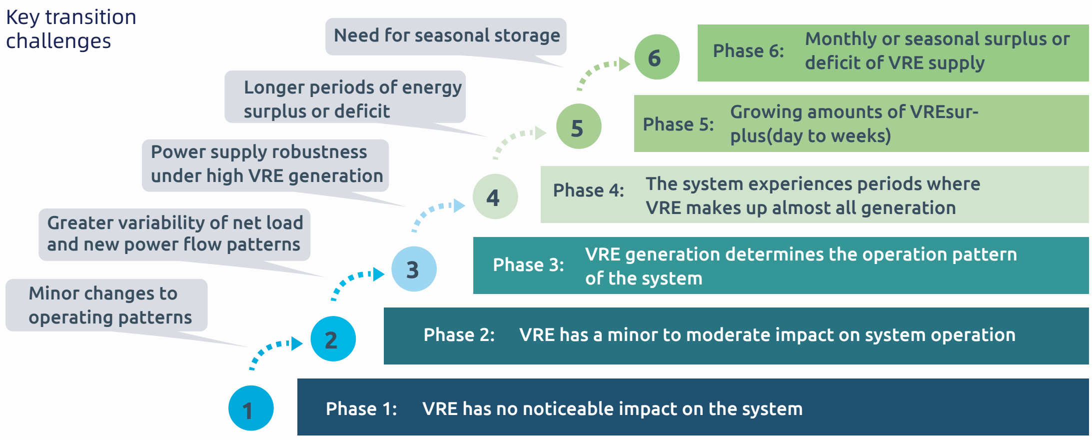
California's duck curve is dipping deeper than ever
Lowest net load day each year in CAISO, 2015-2021



Source: CAISO

Sufficient flexibility is the key for the decarbonized grid system to rise to the challenges stemming from grid integration of VRE and maintaining system stability, while meeting electricity demand. In general, the progress of the grid's decarbonization transition, i.e., the share of electricity generated from VRE, characterizes staged flexibility requirements. The grid then needs to take different actions. Six phases of VRE grid integration, as described by International Energy Agency (IEA), define the grid system impacts and identify specific flexibility requirements (Exhibit 9), with the required actions and their associated costs becoming more prominent at each phase. The issue of lack of flexibility starts to become a significant and substantial challenge in the transition from Phase 2 to Phase 3.

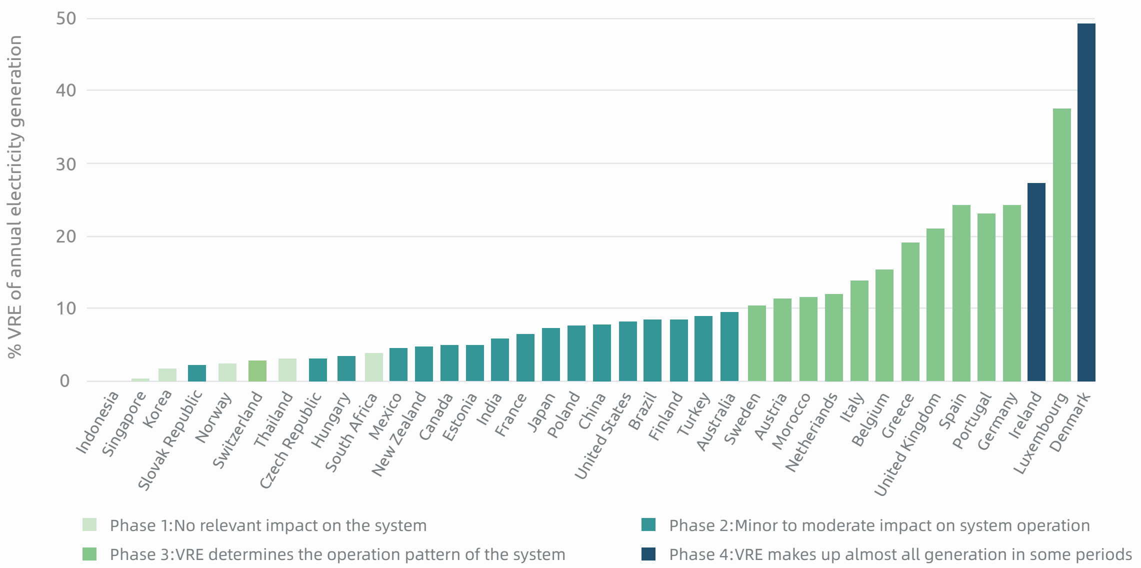
Exhibit 10: Six phases of VRE grid integration



Source: IEA

The country is rapidly approaching the stage of insufficient flexibility while shares of VRE keep rising. Following the boom in wind and PV installations in recent years, their combined share in electricity generation has increased to nearly 10%, a value close to the IEA cut-off for Phase 2 and Phase 3 (Exhibit 10). During this period, the variability of net load will increase significantly and put the traditional electricity transmission and distribution mode under stress. Without sufficient flexibility, the grid would have to either suffer system level stability issues or curtail VRE from the grid.

Exhibit 10 Stages of VRE grid integration by country



Source: IEA

Source:(IEA,2019)

There are four main available sources of grid flexibility: operational flexibility of thermal power plants, energy storage facilities, cross-border power trade, and demand-side flexibility. From the national power grid perspective, if the other three flexibility resources are lacking, cross-border power trading is not a meaningful solution at the system level. Demand-side flexibility requires in part behavioral changes of energy consumers and an electricity trading market that can assist in achieving such changes, both of which cannot be achieved overnight. **Therefore, flexible operation of thermal power plants and energy storage facilities are currently the two most feasible and effective solutions to the grid transition challenge in the coming years.**

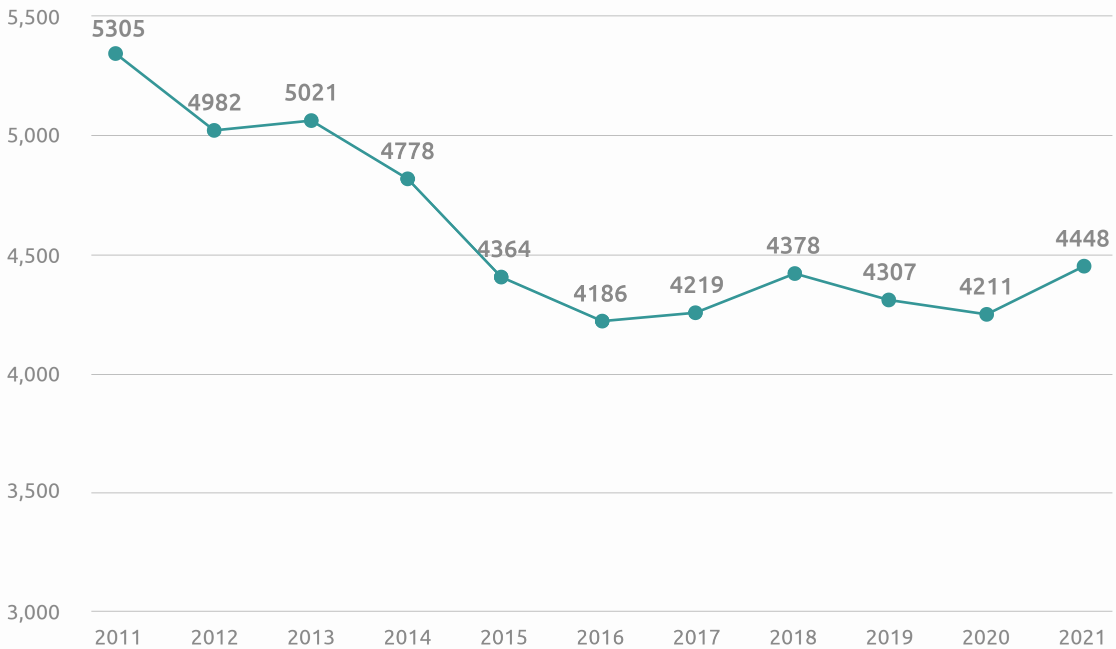
1. Flexibility Retrofits for thermal power plants – Revisiting asset values

Shifting role of coal-fired power plants

In the traditional power system, thermal power, particularly coal-fired power plants (CFPP) assume the central role of providing baseload capacity and following load changes on the demand side. With VRE taking a majority share of new installations since the 13th Five-Year Plan, CFPP gradually weakened its position as the main provider of installed capacity, but is slowly transforming into the main source of electricity generation. Furthermore, CFPPs are leaning more towards following demand throughout the day, by running during the day and early evening. They are operated in direct response to changing demand and VRE plant output.

This transition trend is best reflected by changes in CFPP's full-load hours, a statistic used to measure power plant's actual electricity output over a period of time. In China's traditional power system, the full-load hours of CFPP are about 5,000 hours per year, which is the typical number for CFPPs providing baseload capacity and following load changes. According to the data published by the National Energy Agency, the annual average full load hours of CFPPs fall by 16% from 5,305 hours in 2011 to 4,448 hours in 2021.(Exhibit 11).

Exhibit 11: Average annual utilization hours of coal-fired power plants in China, 2011-2021



Source: China Electricity Council, MioTech Research

We believe China's decarbonized power system would give more priority to the VRE capacity, and CFPP shall serve the flexibility function to peak-shave and valley-fill the power load profile, and maintain stable operation of the grid system. The predominant source of generation capacity will gradually shift from thermal power to hydro, PV and wind energy.

Commercial attributes of flexible CFPP

The demand of flexible CFPP will be proportional to the newly installed VRE capacity. In August 2021, National Development and Reform Commission (NDRC) and NEA issued a regulatory notice on encouraging renewable developers to build or purchase peak shaving and valley filling capacity. Retrofitted flexible CFPP, pumped storage, and electrochemical energy storage are encouraged as flexible resources to undertake renewable energy integration. The Notice specifies that the renewable developers should at least deploy equivalent to 15% installed VRE capacity of peak shaving and valley filling capacity, with a storage duration of 4 hours. Grid-connection priority will be given to those deployed peaking shaving and valley filling capacity at a ratio of 20% or more.

Power auxiliary service market mechanisms as sub-markets of the electricity market have also been introduced at the national level to encourage the flexibility retrofitting of existing thermal power assets. Since 2019, major regional grids have gradually adopted peak-shaving auxiliary service trading markets. As an economic incentive mechanism, flexible thermal power participating in peak-shaving auxiliary services receives reimbursement proportional to the amount of generation actually replaced by renewable energy.

On this basis, the country has started rolling out the peak-shaving capacity trading market mechanism. The peak-shaving capacity market provides qualified thermal power plants with additional reimbursement proportional to their generation capacity. The higher the flexibility of the thermal plant's output, the higher the cap on the offer. The North China electricity market has officially launched a peak-shaving capacity market on November 1, 2021, of which the VRE installed capacity share is second only to the Northwest region grid. Fujian and other provinces have also announced market operating rules, and the formal market launch is on the arrow.

In addition, the loosening of the floating range of coal-fired power electricity prices and the establishment of inter-provincial power spot trading market reflects the country's reconsideration of the commercial value of flexible thermal power assets.

Retrofitting scale to reach 200 million kW

The 13th FYP target for thermal power retrofitting was 133 GW of combined heat and power (CHP) units and 82 GW of pure condensing units in North China. However, by the end of 2019, 57.75 GW of coal power flexibility retrofitting had been completed, which is only one-fourth of the target retrofitting capacity.

In analyzing the cause for this, we believe that the unsecured return from the auxiliary service market is the main reason. Auxiliary service reimbursement is affected by the demand load and weather (hence VRE generation), coupled with illiquid market transactions. Therefore, thermal power plants did not receive economic incentives as forecasted. According to statistics, only 76 transactions were made in the peak-peaking auxiliary service market in the entire North China Power Grid between January and April 2019. The cost of flexibility retrofitting is real, but there is a large uncertainty of return, which restricts thermal power plants in carrying out flexibility transformation.

The National Energy Agency sets the goal of flexibility retrofitting during the 14th FYP period to 200 GW. In our view, strong flexibility demand from VRE grid integration and electricity market mechanisms provides sufficient driving forces for thermal power retrofitting development during the 14th FYP period, and the target of 200 GW is expected to be reached in full or even exceeded.

Market segments and leading players

The technical routes of CFPP retrofitting can be divided into two categories in general. The first category is the retrofitting of pure condensing units (power generation only without heat supply). For pure condensing units, the problem with flexibility retrofitting is how to maintain stable combustion at low load. Flexible units involved in peak-shaving service need to have the ability to adjust the load quickly and operate continuously at low loads, which deviates from the original design parameters of high load conditions.

Flexibility retrofitting for such units requires process and equipment adjustments, of which the most critical equipment is the boiler. In order to meet the requirements of stable combustion in the new operating conditions, specific improvements need to be taken, including oxygen-rich combustion, plasma combustion stabilization technology and coal dust separator modification; on the other hand, environmental system emissions are also key factors limiting the low-load operation of the boiler. The denitrification system, the dust collector and the desulfurization system must be modified to ensure efficient operation under low-load conditions.

The second category is the retrofitting of CHP units. This type of retrofitting generally does not involve changes to the boiler. The main issue here is the decoupling of electricity and heat generation, for which there are two means of retrofitting solutions. The first is turbine modification with the addition of desuperheater or low-pressure bypasses; however, part of the energy is dissipated as heat and wasted. The other, more optimal solution includes heat storage tanks, with salt or hot water. The storage tanks allow excess energy to be stored and later distributed when needed.

Exhibit 12: Retrofitting Technologies and their cos

Retrofitting technology	Applicable CFPP type	Cost
Boiler modification	Pure condensing	Medium
Turbine modification, w/ addition of desuperheater or low-pressure bypass	Combine heat and power	Low
Heat storage tank (hot water)	Combined heat and power	High
Heat storage tank (molten salt)	Combined heat and power	Very high

Source: Public documents, MioTech Research

We expect the proportion of pure condensing units and CHP units to be retrofitted in the 14th FYP and the 13th FYP to be approximately the same, totaling about 80 GW of pure condensing units and about 120 GW of CHP units. Assuming CHP units adopt the hot water storage tank technology, overall market size for flexibility retrofitting during the 14th FYP period (2020-2025) can reach RMB 25 billion, which is over 200% increase from the 13th FYP period.

At present, the flexibility retrofitting segment mainly consists of players who were power generating equipment suppliers to CFPP power stations. The essence of flexibility retrofitting is the redesign and modification of combustion, power generation and heating equipment and processes, which requires close cooperation between CFPP operators and retrofitting solution providers to develop tailored design and implementation plans according to specific conditions. Power generating equipment suppliers have a natural advantage over third-party service providers because of their rich experience and know-how in both design and equipment, and their close working relationships with thermal power operators. Major players include Xizi Clean Energy (002534.SZ), Shanghai Electric (601727.SH) and others.

Transition power generators holding flexible thermal power assets will also benefit from the trend. Affected by the above-mentioned regulatory notice, new VRE project investors will have to consider the cost of flexibility resources in the total investment cost of the project. According to our calculation on Capex and operational cost, CFPP flexibility retrofits cost about 0.14 RMB/kWh, substantially lower than the 0.55 RMB/kWh of electrochemical energy storage and 0.18 RMB/kWh of pumped storage. Therefore, Flexible CFPP is the most economical flexible resource at the moment. Transition power companies with large CFPP units will have the edge in the cost competition of VRE investment project bidding. Listed domestic thermal power companies include Huaneng Power International (600011.SH, 00902.HK), Huadian Power International (600027.SH, 01071.HK), Shanghai Electric Power (600021.SH), etc.

Company implications

Power generating equipment: Xizi Clean Energy (002534.SZ)

This company is currently the largest domestic research, development, design and manufacturing base for waste heat boilers, and has transformed from a single product manufacturer into a supplier of energy-saving and environmental protection equipment and a system solution provider of energy harvesting. The company previously provided boiler equipment for thermal power companies. In early November 2021, it announced a decision to acquire 51% of Hepu Energy, a company mainly engaged in thermal power unit flexibility retrofitting. The company's flexibility retrofitting and energy storage business will use the new acquisition to grow faster and become a market leader. The company has developed demonstration projects for molten salt energy storage.

Power generating equipment: Shanghai Electric (601727.SH)

Shanghai Electric is one of the largest power equipment manufacturing enterprise groups in China, focusing on three major fields: energy equipment, industrial equipment and integrated services. The company leads in traditional thermal and nuclear power equipment, and has a strong track record in wind power. It has the largest share of the offshore wind power market. The company has provided integrated service programs on CFPP retrofitting and upgrading based on demand for energy-saving, heat supply transformation and flexibility retrofitting of power plants.

Transition power operator: Huaneng Power International (600011.SH, 00902.HK)

Huaneng Power International Power Co., Ltd. develops, constructs, operates and manages large-scale power plants throughout China, and is one of the largest listed power generation companies in China. During the 13th Five-Year Plan period, the company's renewable energy development has been rapid, reaching first place in its domestic market share of wind power and second place in photovoltaic, based on power generation capacity.

Transition power operator: Huadian Power International (600027.SH, 01071.HK)

Huadian Power International Power Co., Ltd. is one of the largest integrated energy companies, whose main business is the construction and operation of power plants, including large and efficient coal-fired and gas-fired generating units and various renewable energy projects. The company is quickly transitioning into a renewable energy operator. The company's power generation assets are located in 14 provinces, autonomous regions and municipalities across China.

Transition power operator: Shanghai Electric Power (600021.SH)

Shanghai Electric Power Co., Ltd. is a listed company under State Power Investment Group Co, and the main power provider for Shanghai City. The company is committed to the development of clean energy, renewable energy, and circular economy. The company holds coal-fired thermal power assets with high efficiency parameters, wind power, solar power generation and distributed energy plants.

2. Energy Storage System (ESS) Scales with Rising VRE Capacity

Energy storage is reaching a critical point of development. As more supportive policies for the energy storage industry are introduced, investment in the energy storage sector will continue to flow, driving the commercialization of energy storage technologies and extending into more applications. From the sectoral micro perspective, photovoltaic and wind power are currently in the late growth and early mature phase of the business growth cycle, which means large-scale development is commercially viable. On the other side, ESS started late and is currently limited to a small range of applications, which means it has not yet reached the “outbreak” period. With ongoing large-scale development of photovoltaic and wind power, ESS will soon reach a key inflection point, allowing it to be used widely in commercial applications.

Shifting role of coal-fired power plants

The application of ESS in the power system is placed in three segments: the power generation side, the grid side and the demand side.

- On the power generation side, ESS mainly plays the role of stabilizing the output power of VRE supply and acting as a backup capacity of the grid
- On the grid side, ESS regulates power system frequency and improve the efficiency of transmission and distribution equipment
- On the demand side, ESS is a necessity for distributed VRE installations, and electricity consumers can take full advantage of peak and valley electricity price difference with ESS installed.

A rising proportion of VRE in the energy supply will give rise to ESS applications in every segment of the power system, due to its role in meeting the requirements of balancing power supply and demand, thereby stabilizing grid operation.

Policy implementation on the ground

As an important part of China's strategic emerging industries, ESS has received continuous attention from the state in recent years. Policies are rolled out to ensure sustainable development of the energy storage industry.

In March 2016, the energy storage industry was officially listed in the national development plan. In September 2017, NRDC, MoF, Ministry of Science and Technology, Ministry of Industry and Information Technology and National Energy Agency launched Guidance on Promoting the Development of Energy Storage Technology and Industry, putting forward the development goals for the next 10 years, which aims to bring the ESS industry from the early stage of development into the large-scale development stage.

Since 2020, national and local governments have continued to promulgate more specific guidance and implementation plans summarized in Exhibit 16). Overall, there are three positive signals at the policy level:

- First is the strong support for technology R&D and industry chain enterprises. The key to the rapid formation of the scale effect lies in performance improvements and cost reduction, and the vast majority of the technical route of energy storage is in the technical embryonic stage. For this, policy support is particularly important.
- Secondly, policies set out proportional allocation requirements of energy storage capacity for VRE installations. This provides a guaranteed domestic demand for larger-scale energy storage.
- Finally, further exploration of electricity market reform is encouraged, which should improve the economic feasibility of ESS on the revenue side.

Exhibit 13: Relevant national and local policies for energy storage (partial)

Department	Policy	Publish date	Content
National level policies (partial)			
National Energy Agency	Guiding Opinions on Energy Work in 2020	Jun-20	Strengthen support for energy storage industry, and study and implement policies to promote the development of energy storage technology
National Development and Reform Commission, National Energy Agency	Notice on Key Works in 2021	Dec-20	Widen time-of-use price differences, and implement these on both generation and demand sides of the electricity system.
National Development and Reform Commission, National Energy Agency	Guiding Opinions on Accelerating the Development of Novel Energy Storage System	Jul-21	By 2025, realizing the transformation of novel energy storage industry from the initial stage of commercialization to large-scale development, with an installed capacity of more than 30GW. By 2030, the target is to achieve full market-driven development of the energy storage industry.
National Development and Reform Commission	Notice on Further Improvement of Time-of-use Tariff	Jul-21	Requiring the time-of-use electricity price difference to be no less than 4:1.

Department	Policy	Publish date	Content
Provincial and local level policies (partial)			
Qinghai Provincial Development and Reform Commission	Notice on the Issuance of Certain Measures to Support the Development of Energy Storage Industry	Jan-21	In principle, the energy storage capacity of newly built renewable energy projects should not be less than 10% of the installed capacity of the project, and the duration length of energy storage should be more than 2 hours.
Datong Municipal People's Government	Implementation Opinions of Datong City on Supporting and Promoting the High-Quality Development of Energy Storage Industry	Jan-21	Energy storage industry reaches about RMB 10 billion and becomes one of the pillar industries in Datong.
Ningxia Provincial Development and Reform Commission	Guidance on Accelerating the Healthy and Orderly Development of Energy Storage in the Autonomous Region	Jan-21	Ensuring capacity of energy storage facilities to be no less than 10% of the installed capacity of new energy, and the duration length of energy storage is more than 2 hours

Source: National Energy Administration, Development and Reform Commission, local government websites, MioTech Research

Strong growth in both global and domestic markets

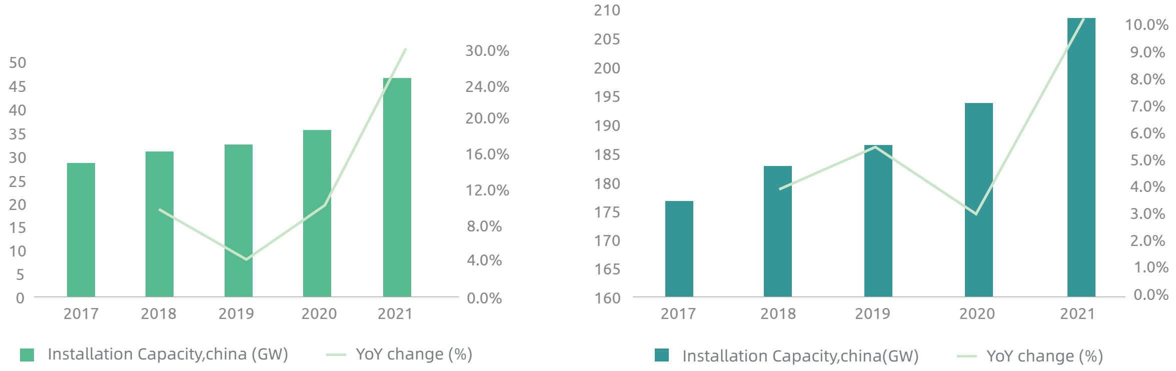
According to statistics from the China Energy Storage Committee (CNESA) of the China Energy Research Association (CERA), the cumulative global installed capacity of energy storage grew steadily from 2016 to 2020, with growth rates remaining at 2%-3.5%. By the end of 2021, the global installed capacity of energy storage projects in operation reached 209 GW.

China's energy storage installation maintained a higher growth rate, with a CAGR of 10% from 2016-2020. According to CNESA statistics, the cumulative installed capacity of energy storage in China should reach 46.1 GW by 2021, up 30% from 2020's 35.6 GW.

From the perspective of industry development, the current energy storage industry is represented by pumped storage and electrochemical energy storage. Pumped storage is the most mature technology with highest installation across the globe and in China.

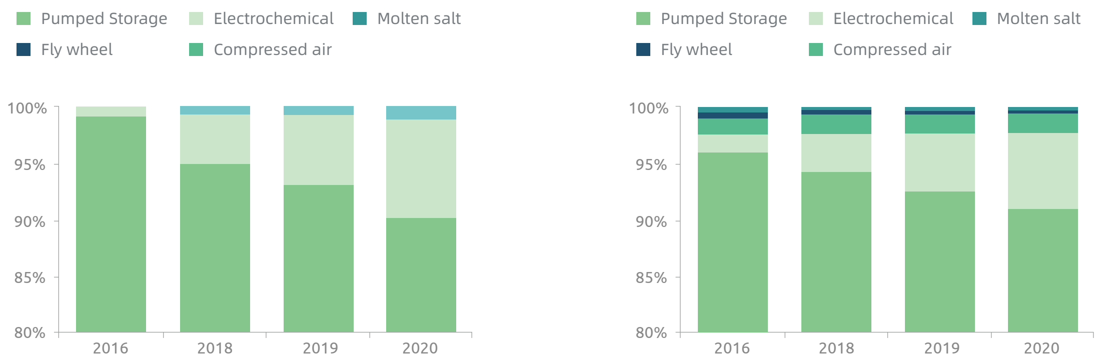
By the end of 2020, the share of pumped storage in the global energy storage capacity was 90.3%; electrochemical storage represented 7.5% with 14.2 GW installation. The share structure of China's energy storage industry is broadly similar to the global structure; however, electrochemical energy storage accounted for 9.2% of the share in 2020, corresponding to an installed capacity of 3.3 GW, which was higher than the global average level.

Exhibit 14: Installed Energy Storage Capacity in China and Worldwide (GW), 2017-2021



Source: CNESA, MioTech Research

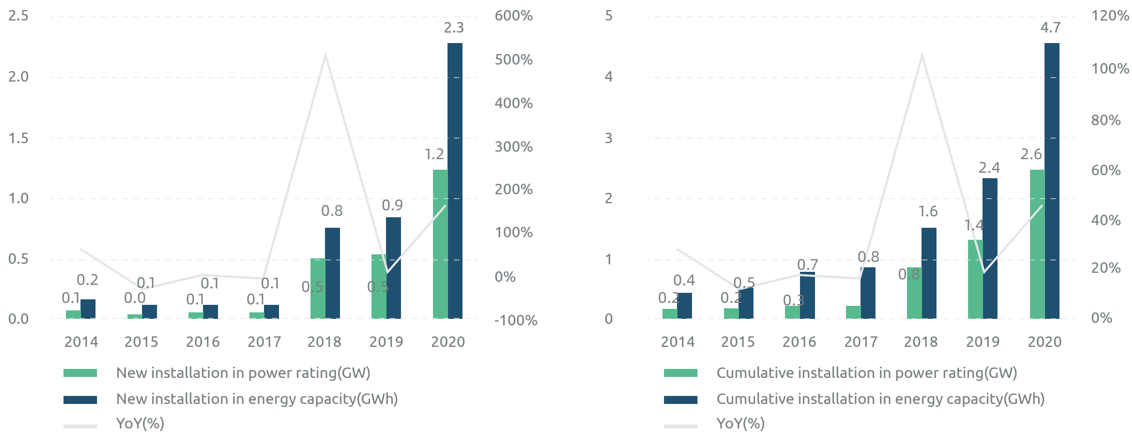
Exhibit 15: Cumulative Installed Energy Storage by Technology Type in China (left) and Worldwide (right), 2017-2020



Source: CNESA, MioTech Research

In 2019, the NDRC clarified that grid-side energy storage cannot be included in the cost of electricity transmission and distribution prices, causing ESS development to hit a trough. In 2020, the industry saw high growth due to cost reductions in ESS and the state grid's increasing investment. The installation exceeded 1 GW in power rating and 2.3 GWh in energy capacity, or a 168% YoY growth. The cumulative installed capacity reached 26 GW with huge room for development.

Exhibit 16: Electrochemical energy storage new installations and cumulative installations in China, in unit of GW and GWh, 2014-2020



Source: CNESA, MioTech Research

Pumped storage

Pumped storage is currently the most technologically mature and economically optimal ESS system, particularly suitable for large-scale development, and therefore accounts for the highest share of all energy storage types.

Pumped storage works similar to that of a reverse hydropower plant. It requires two reservoirs, upper and lower. It consumes electricity in the trough to pump the water to the upper reservoir, and releases the water from the upper reservoir at times of peak demand to generate electricity. The efficiency of pumped storage power plants is about 80 - 82%, i.e., 1 kWh of electricity consumption results in 0.8 - 0.82 kWh of electricity regeneration. Its lifespan is close to that of conventional hydropower plants, capable of operating for 80 - 100 years.

The development pace of pumped storage is guided by the government. The National Energy Agency's Medium- and Long-term Development Plan for Pumped Storage (2021-2035) states that by 2025, the total scale of pumped storage shall exceed 62 GW; by 2030, the total scale will double the number about 120 GW. Given the estimated average cost of pumped storage of RMB 5,516 per kilowatt, pumped storage investment will be about RMB 170 billion during the 14th FYP, and up to 500 billion by 2030.

Exhibit 17: Energy Storage Installations by Technology Types

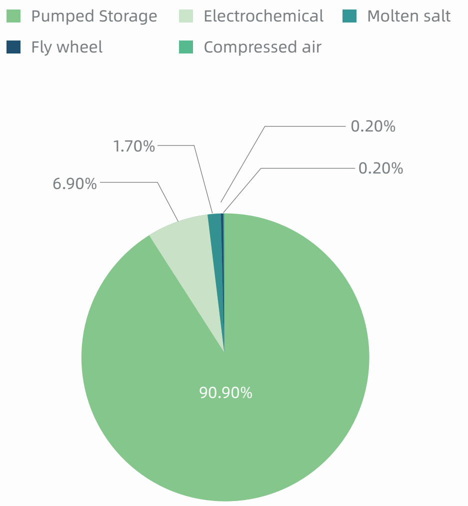
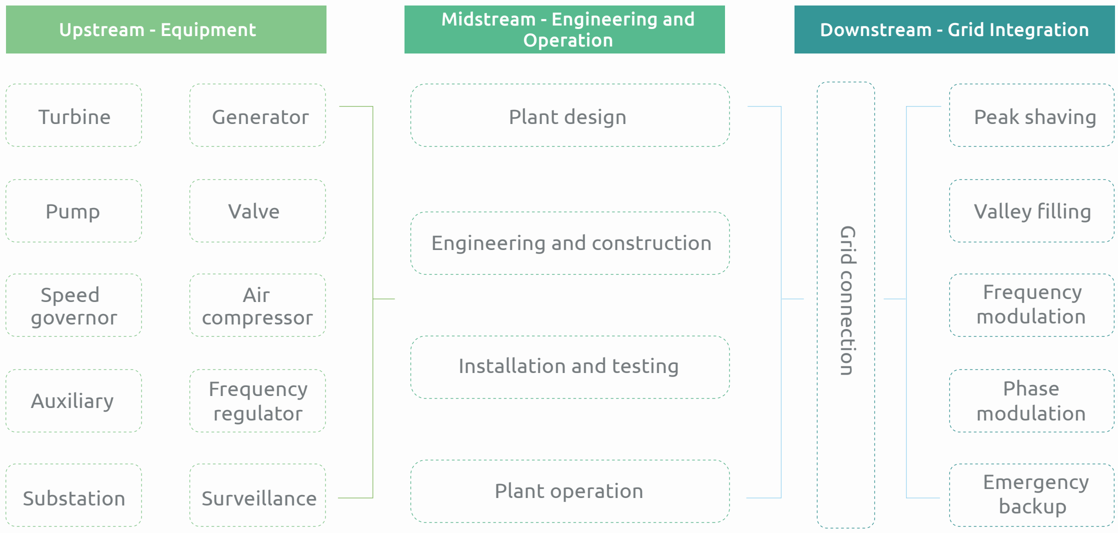


Exhibit 18: Historical Installed Capacity and Forecast of Domestic Pumped Storage (GW)

Source: CNESA, MioTech Research

The pumped storage value chain includes equipment manufacturing, engineering design and construction, and power plant operation. The upstream component is the equipment manufacturing industry, with core equipment including turbines, pumps, generators and transformers. The midstream component mainly consists of design institutes, engineering companies, and power plant operators. The downstream is mainly the auxiliary service applications of pumped storage power plants in the grid system, including peak-shaving and valley-filling functions, and frequency modulation.

Exhibit 19: Pumped storage industry chain



Source: Public information, Wind, MioTech Research

Dongfang Electric (600875.SH) and Harbin Electric (1133.HK) are the two large state-owned enterprises taking the predominant market share. Other private and foreign enterprises such as ZF Holdings (002266.SZ) and Toshiba Hydropower occupy a small percentage.

The State Grid and China Southern Power Grid are the two main pumped storage power plant operators. As of 2020, State Grid has 28 pumped storage power plants in operation with an installed capacity of 23 GW, and 35 plants under construction with an installed capacity of 48 GW. Southern Power Grid has 6 plants in operation with 7 GW capacity and 5 under construction with 5 GW capacity. The design, engineering and installations are mainly undertaken by China Power Construction (601669.SH) and China Energy Construction (601868.SH).

Exhibit 20: Number and installed capacity of pumped storage power plants

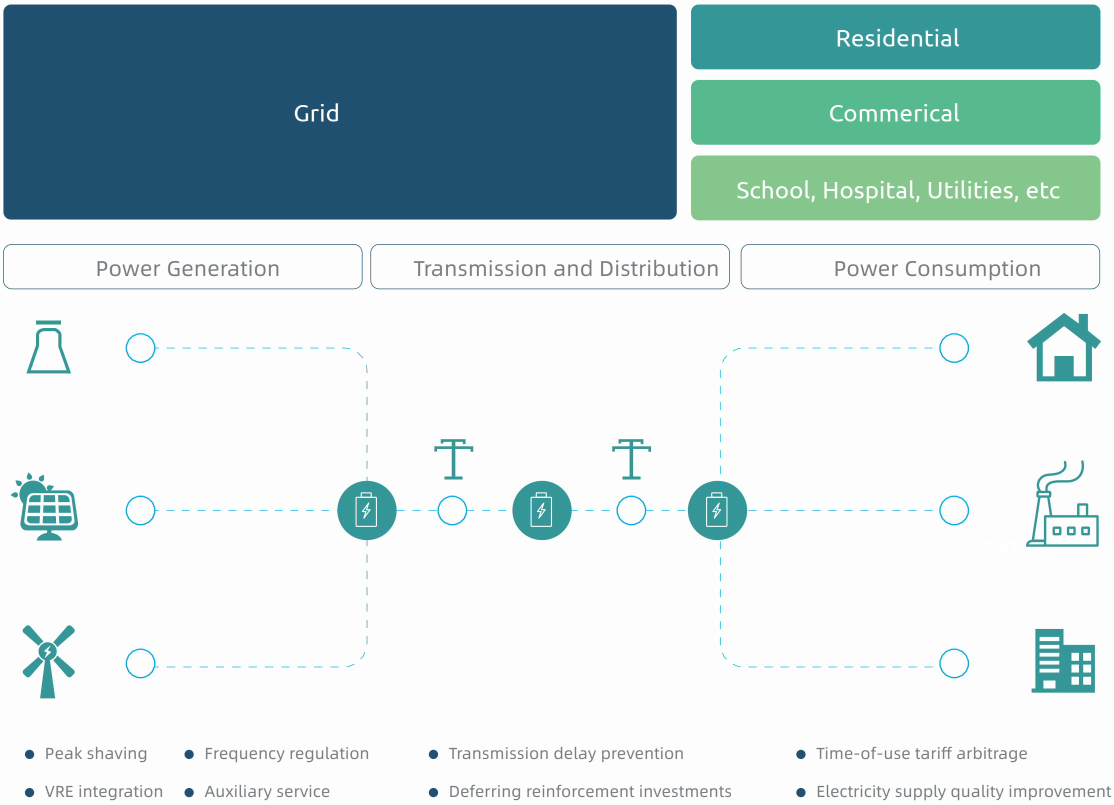
		State Grid	China Southern Power Grid
Number of pumped storage power plants	in operation	28	6
	under construction	35	5
Installed capacity of pumped storage power plants	in operation	23.41 GW	7.88 GW
	under construction	4.85 GW	5.4 GW

Source: State Grid, China Southern Power Grid, MioTech Research

Electrochemical Energy Storage

Electrochemical energy storage is being rapidly laid out. The high-power density and high-energy density property makes electrochemical energy storage the most versatile ESS type. Compared with other technologies, electrochemical ESS has the advantages of good equipment mobility, fast response, and high cycle efficiency. In addition, cost reduction has shown an accelerated trend, which provides electrochemical energy storage with a promising commercialization future. According to Rocky Mountain Institute's estimation, by 2050, electrochemical energy storage in China could reach 510 GW in installation capacity, far exceeding the scale of pumped storage of 140 GW by then, and become the most dominant form of electric energy storage.

Chart 21: Electrochemical energy storage applications



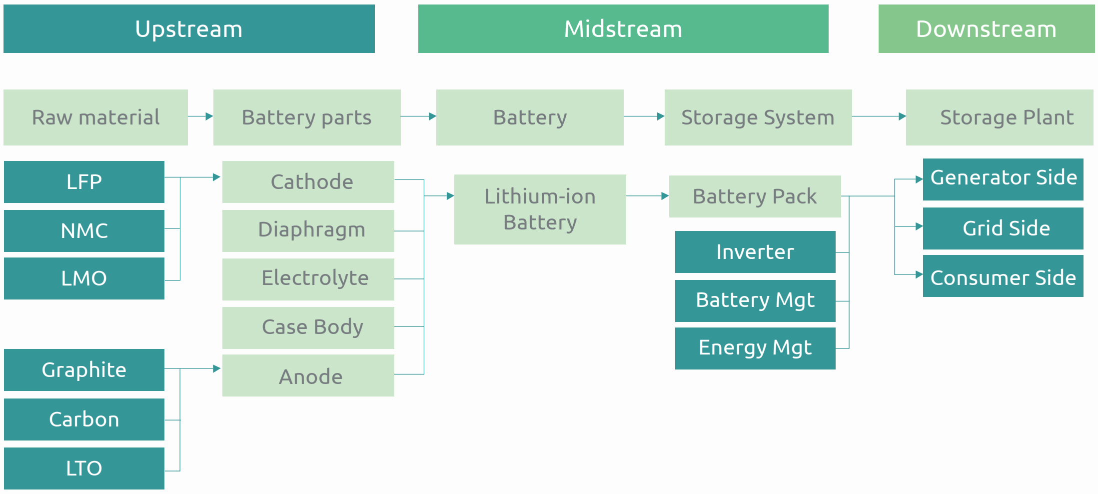
Source: Pylon Technology, MioTech Research

Electrochemical energy storage technologies mainly include lithium batteries, flow batteries, and sodium-sulfur batteries, among which lithium battery energy storage is the most mature technology at present. In the value composition of energy storage systems, the battery module and inverter are the most expensive parts.

(1) The value of the battery module is the highest, accounting for 60% of the value; the quality of the battery cells (energy density, cycle times, temperature adaptability and safety, etc.) directly affects the operation and efficiency of the entire energy storage system, and is therefore a key element in determining the return on investment of the energy storage system.

(2) The value of energy storage inverters ranks second, accounting for about 15%-20% of total value. Energy storage inverters are similar to PV inverters, but the former has more diversified functions and is the key part for intelligent control capability in the energy storage system.

Exhibit 22: Lithium-ion battery energy storage value chain



Source: Pylon Technology, MioTech Research

Compared with pumped energy storage, electrochemical energy storage is not limited to geographical resource allocations and has a shorter construction timespan, which translates to a higher degree of flexibility. In addition, it has significant advantages in discharge duration, response time and comprehensive efficiency. It therefore has a wider range of application scenarios, and is fully suitable for both power-based and energy-based applications. Overall, the development of electrochemical energy storage is still in its infancy, and it is likely that a variety of technologies will coexist in the future. Different technologies reflect their advantages in different applications.

Exhibit 23: Comparison of various types of energy storage technologies

Technology Type	Project power scale	Discharge time	Response time	Overall efficiency	Number of cycles	Power-based applications	Energy-based applications	Technology maturity
Pumped storage	More than 100MW	1-24h	min	70-80	15,000-25,000	Not suitable	Perfect fit	Mature
Compressed Air	Dozens to hundreds of MW	1-24h	min	65-75	15,000-25,000	Not suitable	Perfect fit	Mature
Flywheel energy storage	KW- tens of MW	s-30min	ms	90	100,000+	Perfect fit	Suitable	Early Commer-cialization
Lead-acid batteries	KW- tens of MW	m-h	ms	50-85	300-500	Perfect fit	Perfect fit	Mature
Lithium	KW-	m-h	ms	85-95	2,000-	Perfect fit	Perfect	Mature

Technology Type	Project power scale	Discharge time	Response time	Overall efficiency	Number of cycles	Power-based applications	Energy-based applications	Technology maturity
Battery	hundreds of MW				10,000	fit	fit	
Flow Battery	KW-100 MW	m-h	ms	65-85	5,000-15,000+	Suitable	Perfect fit	Early Commercial-ization
Sodium-sul-fur batteries	100KW-100 MW	m-h	ms	75-90	2,000-6,000	Perfectly fit	Perfect fit	Early Commercial-ization
Super Capacitor Battery	KW-hun-dreds of MW	s-m	ms	75-95	10,0000+	Perfect fit	Not suitable	Development Stage
Supercon-ducting Energy Storage	KW-tens of MW	s-m	ms	90	10,0000+	Perfect fit	Not suitable	Development Stage
Hydrogen Energy Storage	KW-GW	NA	NA	35-50	NA	NA	Perfect fit	Development Stage

Source: CCID, MioTech Research

At present, the industry is generally most optimistic about lithium-ion battery technology. With good charging and discharging performances, fast response times and high energy densities, lithium-ion batteries have technical advantages in many applications and significant cost advantages due to the scaling effect from the electric vehicle application. By the end of 2019, the cumulative installation of lithium-ion batteries accounted for more than 80% of the various types of electrochemical energy storage that have been put into operation in China. We expect that lithium-ion batteries will still represent the mainstream of the future electrochemical energy storage in China. Despite concerns around lithium-ion batteries' current safety and life cycle performance, further breakthroughs can be expected when the whole value chain starts to scale.

Market prospect of ESS

In 2020, global new electrochemical energy storage installed capacity reached 10.7 GWh, an increase of 57.4% year-on-year. According to IEA, the global new installed capacity of energy storage should reach 284 GWh in 2025, with a CAGR of 53%. By that time, new energy storage installations in China's market will reach 90 GWh, which represents 32% of the global installed capacity.

Exhibit 24: Global energy storage new installation forecast (unit: GWh)

	2021E	2022E	2023E	2024E	2025E
Global Energy Storage New Installed Capacity	51.3	87.5	125.6	187	283.8
Overseas Market (outside of China)					
Household	10.5	18.6	24.4	32	44.8
Commercial and Industrial	2.1	6.9	12.5	19.4	21.4
Power Generator side	14.2	15.2	23	48.4	106.7
Grid side	3.3	7.2	10.5	12.3	21.3
China's Market					
Commercial and Industrial	1.1	3.7	6.7	10.4	11.5
Power Generator side	18	31.4	41.8	56.6	64.3
Grid side	2.1	4.5	6.7	7.9	13.8

Source: IEA, BP, MioTech Research

Taken together, the installed capacity of electrochemical storage in China is expected to reach 66.0 GWh in 2025, corresponding to a 5-year CAGR of 88.14%, according to our research. The average price for lithium-ion battery storage in 2020 was RMB 1.8/Wh. With scaling applications bringing the cost further down, we expect that by 2025, the average price of lithium-ion battery storage systems will fall to around RMB 1.2/Wh. The overall market size of electrochemical energy storage, led by lithium-ion batteries, will then reach RMB 250 billion during the 14th FYP period.

Chart 25: Global energy storage new installations forecast (unit: GWh)

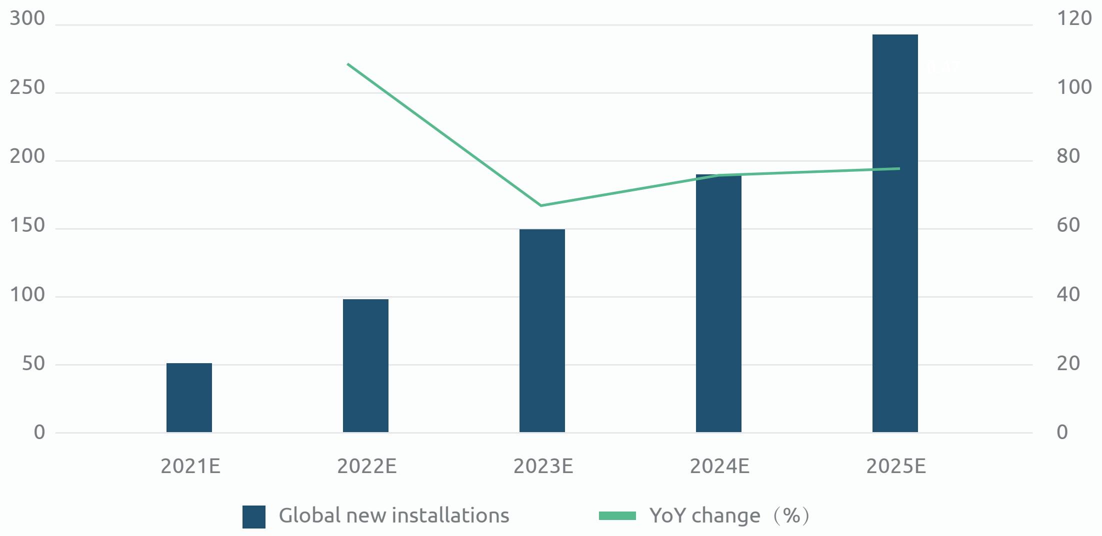
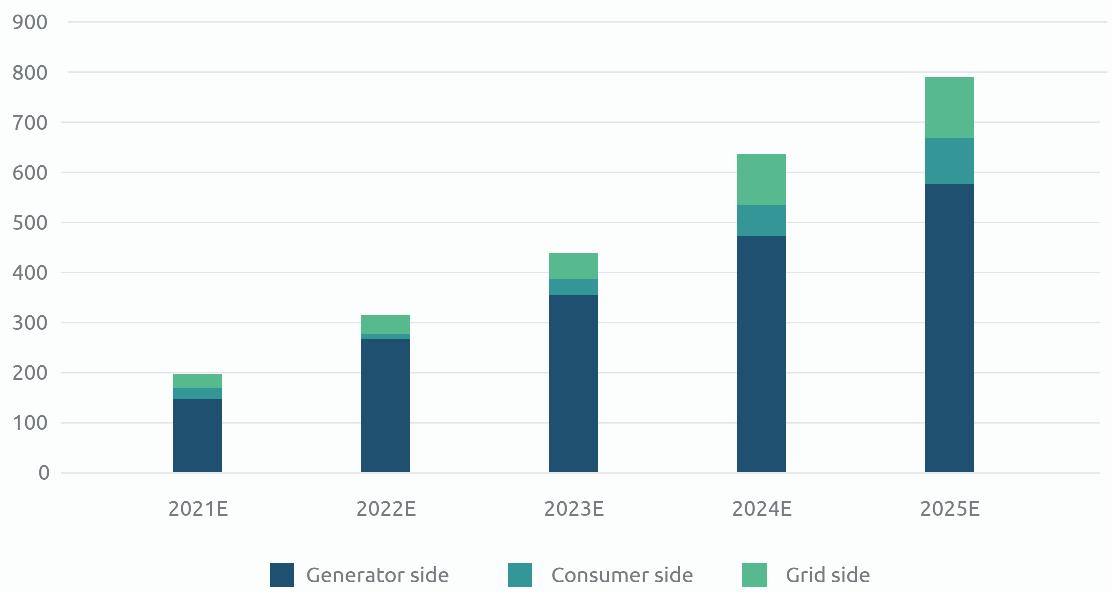


Exhibit 26: China electrochemical energy storage market size forecast (unit: RMB bn)



The forecast assumes the following for relevant indicators:

●Consumer side

(1) In 2020, China's lithium-ion battery energy storage cumulative installed capacity was 0.81 GW on the consumer side. Considering a daily discharge of 2 hours, and 350 days of operation per year, then the lithium storage user-side penetration rate was 0.04% in 2020.

(2) Considering that cost reduction is driving up penetration rates, we expect user-side penetration rates to reach 0.02% / 0.03% / 0.05% / 0.08% / 0.12% in 2021-2025.

● Grid side

(1) On the grid side, China's energy storage involved in thermal power frequency regulation capacity is generally 0.5h, and 2h on other projects, so it is assumed that grid-side energy storage experiences a daily discharge of 1.5h, running 350 days per year.

(2) Considering the cost reduction driving the penetration rate to further increase, we expect 2021-2025 grid-side penetration rates of 0.01% / 0.02% / 0.03% / 0.055% / 0.08%.

● Power generation side

(1) The PV installation forecast is taken from the China Photovoltaic Industry Association (CPIA), and the installed wind power data is taken from the forecast data of Global Wind Energy Council (GWEC).

(2) As the scale of energy storage continues to expand in the future, the penetration rate and capacity allocation steadily increases.

Based on the above assumptions, we can estimate the market size of electrochemical energy storage in China in 2021-2025. The results are shown below.

Exhibit 27: 2021-2025 Electrochemical energy storage market size forecast

	2020E	2021E	2022E	2023E	2024E	2025E
Consumer side						
Commercial and industrial electricity consumption (10^8 kWh)	50,297	52,812	5,5452	58,225	61,136	64,193
Penetration rate	0.011%	0.020%	0.030%	0.050%	0.080%	0.120%
Energy storage capacity (10^8 kWh)	5.67	10.56	16.64	29.11	48.91	77.03
Cumulative installed capacity (GW)	0.81	1.51	2.38	4.17	7.00	11.03
New Installed Capacity (GW)	0.30	0.70	0.87	1.79	2.84	4.03
Storage hours (h)	2	2	2	2	2	2
New installed capacity of energy storage (GWh)	**0.60**	**1.40**	**1.74**	**3.57**	**5.67**	**8.05**
Grid side						
Total electricity consumption (10^8 kWh)	75,110	78,866	82,809	82,809	91,297	91,297
Penetration rate	0.004%	0.010%	0.020%	0.030%	0.055%	0.080%
Energy storage capacity (10^8 kWh)	2.81	7.89	16.56	26.08	50.21	76.69

Grid side						
Cumulative installed capacity (GW)	0.67	1.88	3.95	6.22	11.97	18.29
New Installed Capacity (GW)	0.32	1.21	2.07	2.27	5.75	6.31
Storage hours (h)	1.5	1.5	1.5	1.5	1.5	1.5
New installed capacity of energy storage (GWh)	**0.40**	**1.82**	**3.10**	**3.41**	**8.63**	**9.47**
Power generation side						
PV new installations (GW)	48	60	70	80	90	100
Centralized PV share	68%	64%	62%	60%	58%	56%
Centralized PV new installations (GW)	33	38	43	48	52	56
Wind power new installations (GW)	49	30	37	40	42	45
Combined wind and centralized PV new installations (GW)	82	68	80	88	94	45
Energy storage penetration rate	7%	40%	50%	60%	70%	80%
Capacity allocation ratio	15%	16%	17%	18%	19%	20%
Installed energy storage on the power generation side (GW)	0.89	4.38	6.83	9.50	12.53	16.16
Storage hours (h)	2	2.2	2.4	2.6	2.8	3
Installed energy storage on the power generation side (GWh)	**1.80**	**9.63**	**16.40**	**24.71**	**35.08**	**48.48**
Total						
Consumer side (GWh)	0.60	1.40	1.74	3.57	5.67	8.05
Grid side (GWh)	0.40	1.82	3.10	3.41	8.63	9.47

Total						
Power generation side (GWh)	1.80	9.63	16.40	24.71	35.08	48.48
Total installed energy storage (GWh)	**2.80**	**12.85**	**21.24**	**31.69**	**49.38**	**66.00**
Average price of lithium battery energy storage system (RMB/Wh)	1.8	1.6	1.5	1.4	1.3	1.2
Electrochemical energy storage market size (RMB billion)	**50.40**	**205.56**	**318.66**	**443.66**	**641.94**	**792.05**
Total (RMB billion)	**2,452**					

Source: CPIA, GWEC, National Energy Agency, MioTech Research

The bottlenecks

1. Incentive policies are needed to further promote development of the industry. The electrochemical energy storage industry is still in its infancy. Currently, the pricing mechanism of energy storage is not clear, and therefore project investment profitability is difficult to predict. The revenue mechanism of energy storage needs to be clarified and implemented, such as: the participation of energy storage in the auxiliary service market, the establishment of pricing and trading policies and models, the improvement of payment compensation mechanisms, and the establishment of power retail market for energy storage applications in distributed energy generation. On the other hand, preferential policies need to be adopted to support the early market, such as: extending the procurement support for energy storage projects, providing financial and tax incentives for energy storage projects.

2. Rising upstream raw material cost hampers cost reduction trend. Benefiting from technological progress, the cost of electrochemical energy storage has continued to decrease in the past 10 years. But at the same time, energy storage is very sensitive to the cost of the core upstream material, including lithium, electrolyte, and nickel. The increase in upstream price will have a huge impact on the economic feasibility of energy storage projects, which then investors are reluctant to build new energy storage projects.

Company implications

Pumped storage

1. Dongfang Electric (600875.SH)

The company is one of China's major power generation equipment providers. The company's business ranges from thermal, hydro, nuclear, wind, PV and gas power plant equipment. In 2021, the company's renewable energy equipment revenue for the first time exceeds thermal power equipment. By the end of April 2021, the company's cumulative production of power generation equipment exceeded 600 GW, ranking first in the country, of which the market share of thermal power, hydropower (pumped storage), and nuclear power is more than 40%.

2. China Power Construction (601669.SH)

The company is a leading engineering enterprise in the global power plant development. With a strong technical background and rich engineering experiences, the company owns about an 80% of share in the domestic pumped storage engineering markets. In 2020 the company won RMB 10 billion of pumped storage project contracts.

Electrochemical energy storage

1. Lithium-ion Battery

CATL (300750.SZ)

The company is the world's leading lithium-ion battery provider, focusing on the research, development, production and sales of battery system products for electrical vehicle and electrochemical energy storage applications. The company's revenue from sales of battery products for energy storage system revenue increased 219% YoY in 2020, accounting for 4% of total revenue, an increase of 2.6 pct. In the past two years the company participated in a number of large-scale energy storage projects.

Pylon Technology (688063.SH)

The company is a leading energy storage battery system provider, focusing on the development, production and sales of LFP battery cells, modules and energy storage battery systems. The company's own brand household energy storage products sales in 2019 accounted for about 8.5% of the total global shipments, ranking third in the world.

2. Inverter and energy storage system integration

Goodway (688390.SH)

The company is a veteran leader in the PV and energy storage inverter markets. The company's global shipments of three-phase/single-phase string inverters is ranked 6th/5th in the world, and the market share of household energy storage inverters is 15%, the top position globally.

Sungrow Power (300274.SZ)

The company focuses on the research and development, production, and sales of solar, wind and energy storage power products. Main products include photovoltaic inverters, wind power converters, energy storage systems, EV drive systems, and intelligent energy operation and maintenance services. In 2020 the company's PV inverter shipments was 35GW, or 19% of the global market share.

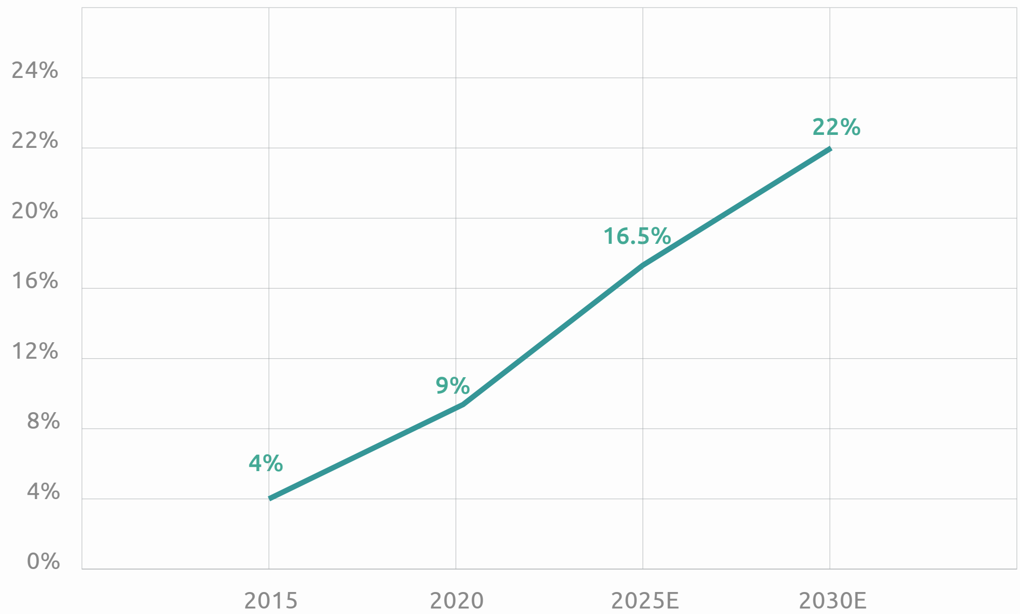
Decarbonized grid calls for broader application of energy IT

The digitalization of the power industry is not just about empowering the industry with data and information tools, but also about maximizing the potential of power reform based on data and marketization. Digitalization of the power sector has not been widely noticed by the market due to the complexity of its systems and technologies, and the monopolizing nature of the industry. The power sector, due to its own need for a large amount of real-time power generation and consumption data, has higher digitalization potential compared to traditional energy and manufacturing industries. The continued promotion of decarbonization and electricity market reform will also bring more application scenarios and market-oriented investment opportunities for the application of energy IT in the power system.

VRE integration and electricity trading market call for digital transformation of the grid

The power grid is a network system that connects power producers and consumers for the purpose of transmitting electricity. The power grid includes three core aspects of the power system: power transformation, power transmission and power distribution. At present, China's power system is in AC mode and relies on thermal power. In the context of decarbonization targets, the combined generation of wind power and PV generation rose to about 11% of total electricity consumption 2021, and this will further increase over the coming years.

Exhibit 28: Share of VRE in electricity generation in China, 2015-2030E



Source: China Electricity Council, MioTech Research

- July 2021, NDRC issued the Notice on Further Improving the Time-of-use Tariff Mechanism, which aims to form an effective market incentive mechanism to stimulate the commodity properties of electricity.

- In 2021 September, Green Electricity Trading Pilot Work Plan was officially approved. Green electricity generated from wind power and photovoltaic power plants are priced separately for online trading purposes. 259 market entities in 17 provinces participated and traded 8,000 GWh of green electricity. According to China Electricity Council's forecast, green electricity trading will account for about half of the total amount of green electricity generation in the next five years.

- In November 2021, the State Grid issued the Inter-provincial Electricity Spot Trading Rules, marking the initiation of China's inter-provincial and inter-regional electricity market, which allows large consumers and electricity sales companies to participate in trading.

- In January 2022, NDRC issued Guiding Opinion on Accelerating the Construction of a National Unified Electricity Market System, aiming at the initial completion of a national unified electricity market system by 2025. **In the future, the electricity spot market, green electricity trading, auxiliary service trading market and other forms of electricity trading markets will exist at the same time. The timeliness, accuracy and effectiveness requirements for transaction data processing will significantly increase.**

The new generation of ICT technologies, represented by cloud computing, AI, 5G, and others, provides a backbone digital transformation of the power grid. The smart grid concept allows for highly integrated power flow, information flow and business processes. Through the application of new information technologies in the grid system, it is expected that intelligent sensing and real-time monitoring within the physical grid will become possible. This will happen by mining and analyzing real-time data to dynamically optimize decision making processes and enhance the operational flexibility of the power grid.

Favorable policies to promote grid digitalization

In recent years, a number of policies have shown the determination of the government to advance the digitalization of the power grid.

- In November 2020, the Proposal of the Central Committee of the Communist Party of China on Formulating the 14th Five-Year Plan for National Economic and Social Development and the Visionary Goals for 2030 proposed the concept of "new infrastructure", the power industry is listed as one of the key areas for consideration.

- In December 2021, the Central Economic Work Conference released a document on "moderately over-investing in infrastructure", and the main direction of this round of "new infrastructure" will fall on the construction of energy storage, ultra-high voltage transmission, and smart grid.

- In January 2022, the State Council issued the 14th Five-Year Plan for the Development of Digital Economy, which includes promoting the digital transformation of the power industry.

The total investment in power grid during the 14th FYP is at a record high

According to the States Grid's general planning report, the total planned investment in the state grid from 2009 to 2020 is RMB 34.5 trillion, of which RMB 384 billion is invested in grid digitalization, accounting for 11% of the total investment. In the last three stages, the proportion of digitalization investment to total grid investment is 6%, 11% and 12% respectively, gradually increasing.

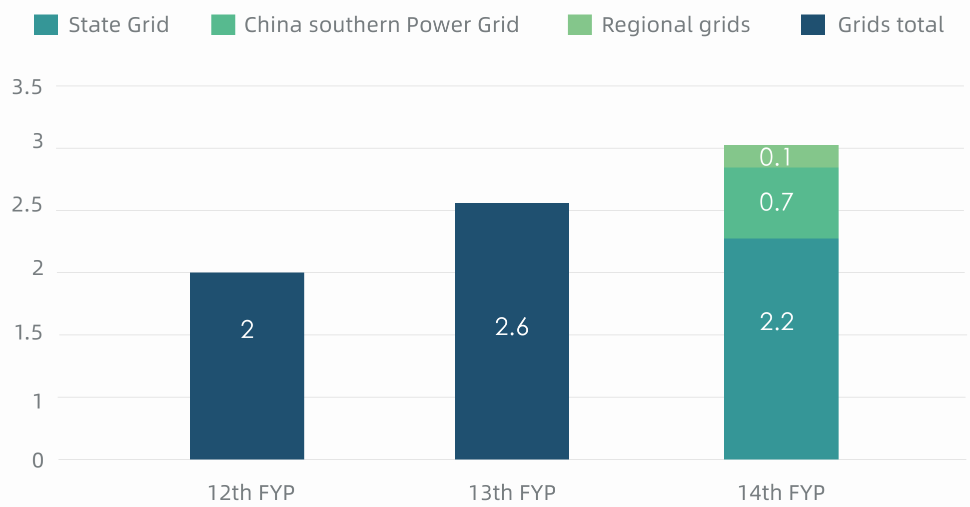
Exhibit 29: Digitalization investment by the State Grid, in RMB bn, 2009 to 2020

Segments	1st Phase（2009-2010）		2nd Phase（2011-2015）		3rd Phase（2016-2020）		Total	
	Investment (RMB bn)	Pct	Investment (RMB bn)	Pct	Investment (RMB bn)	Pct	Investment (RMB bn)	Pct
Power Generation	0.6	2%	2.8	2%	2.5	1%	5.9	2%
Power Transmission	2.2	6%	9.1	5%	12.5	7%	23.8	6%
Power Transformation	1.7	5%	36.5	21%	36.6	21%	74.8	19%
Power Distribution	5.6	16%	38	22%	45.6	26%	89.2	23%
Power Consumption	10.1	30%	57.9	33%	50.5	29%	118.5	31%
Scheduling	3.3	10%	6.2	4%	5.2	3%	14.7	4%
Communication Platform	10.6	31%	24.4	14%	22.1	13%	57.1	15%
Total	**341**	**100%**	**1,750**	**100%**	**1,750**	**100%**	**3,841**	**100%**

Source: The State Grid's Intelligent Planning General Report

During the 14th FYP period, the State Grid and the China Southern Power Grid will invest a total of more than RMB 2.9 trillion in power grids, and if regional power grid companies outside the two major power grids are included, **the total investment in the national grid during the 14th FYP is expected to reach RMB 3.0 trillion.**

Exhibit 30: Digitalization investment by the State Grid, in RMB tn, 12th FYP to 14th FYP



Source: The State Grid, China Southern Power Grid, MioTech Research

Unprecedented demand for energy IT amid fast-track transition to a smart power system

1. Grid design and software solutions

Designing is an essential part of the initial phase of grid construction. The grid designing industry will be a direct beneficiary of the growing construction of power distribution networks, while the transition to a smart power system is making the digitalization of designing works compulsory. As the need to transform the grid applies nationwide, a one-stop-shop solution will be favored. Meanwhile, as the adoption of new technologies has made grid designing much more professional and complex, turning it from original 2D designing to 3D designing, design software will need to be optimized to meet the higher requirements.

Henghua Technology (300365.SZ).

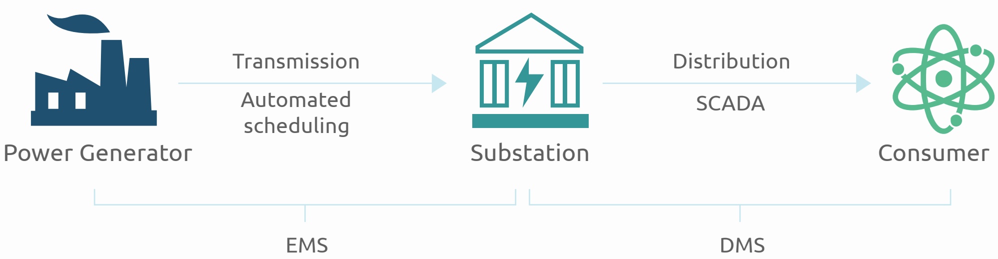
Founded in 2000, the company is equipped with strong R&D capacity, outstanding information technology capability and a wealth of engineering experiences to bring the emerging technologies like cloud computing, IoT, big data, mobile Internet, and AI to the rollout of smart grids, energy systems, water conservation and transportation. The company owns the intellectual property rights of its self-developed software to design 3D transmission lines, 3D substations, 3D cables and 3D grid distribution systems, which allows geographic information input from multiple sources, including laser point cloud and tilt measurement. The software functions meet the criterion developed by the State Grid and its outputs meet State Grid's GIM standards and can be directly referenced for construction.

2. Smart management of power transmission and distribution

With the progressing of strong smart grid and power IoT, the demands are continuously rising for automated IT systems to operate the transmission and distribution grid.

The Energy Management System (EMS) that controls power generation and transmission and the Distribution Management System (DMS) that controls power distribution and grid load are necessary IT systems to keep the grid running smoothly. Now, the two systems need to be smarter than ever. EMS performs stimulation and computation based on real-time data to derive status analysis, tide calculations, economic operation calculations, and static or dynamic safe operational analysis, and uses these to adjust grid operations for improved safety and efficiency. The SCADA system seamlessly collects real-time data, including the voltages, currents and power outputs of various components including transformers and lines, the status of each circuit breaker, and whether a breaker is open or closed. Built on the data, the system can monitor and control the substations.

Exhibit 31: Power transmission and distribution smart management



Source: Power Source Motion "The difference between DMS and EMS, EMS and DMS software relationship

Each unit of the entire process from power generation to end-users could be made smart with the integration of new smart products:

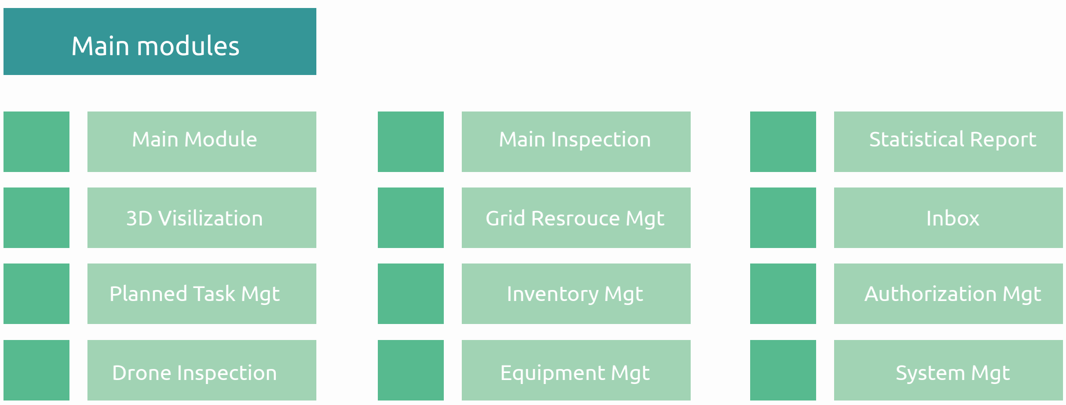
Exhibit 32: Intelligent operation and maintenance IT products for electricity transmission, transformation and distribution

Segments	Related technologies and functions
Transmission	Smart monitoring technologies, such as transmission line channel visualization and condition monitoring, image analysis, automatic identification of risks and defects, warning notifications, drone inspection, etc.
Transformation substation	Online monitoring, security, environment, and graphics system for substation equipment.
Distribution	The construction of automated distribution, with the ability to auto-correct system faults, which can effectively execute status monitoring of the distribution network, fault location, automatic fault isolation and network reconfiguration.

Source: MioTech Research

1. Intelligent transmission management system: The intelligent management system is expected to merge the different, separate procedures of task planning, data collection, data analytics and storage into a whole system. It will target the inter-connection of internal systems data for in-depth analysis and decision-making to form a complete closed loop of power distribution and operational inspection. It enables the management of transmission lines to be precise, systematic, intelligent and visualized. An example would be the system developed by Zhongfei Sunway, with modules including task allocation, drone-powered data collection, inspection result manager, fault elimination manager, statistics and alert manager, account of transmission lines, drone device manager, and drone operation monitor.

Exhibit 33: Intelligent transmission management system modules



Source: Zhongfei Sunway official website

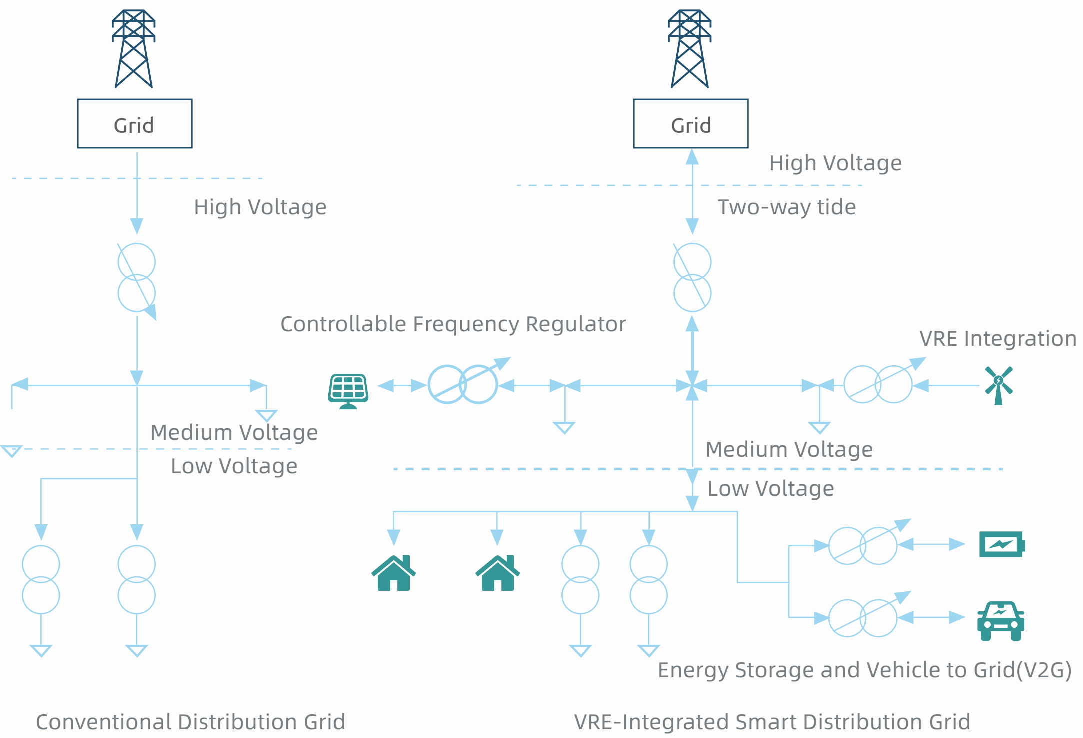
2.Intelligent transformation substation management system: The majority of the quasi-intelligent substation systems available so far are a combination of various smaller systems, each of which has a sole function. However, the core of a real intelligent substation system is web, built on data integration to break the information barriers and enable the internal and external connections of substations. It will consolidate the substations located in different cities or countries. Moreover, the all-in-one management system can identify potential risks with a toolbox of access control, indicator monitoring, data analysis and projection, and act in response to provide a safeguard for the system equipment and staff workers at substations.

3.Intelligent distribution management system: Notably, China has called for more investment in leveling up the distribution grid in the 14th FYP period running from 2021 to 2025. The State Grid has decided to spend half of its total investment planned for the five years on the distribution grid, which amounts to RMB 1.2tn. China Southern Power Grid aims to invest RMB 320bn, also close to half of its total planned investment. The increasing net load and the larger role played by renewables in the power system have prompted grid companies to improve their distribution capability.

The conventional distribution grid runs single way, where it only receives load from the grid, equipped with a standard transformer and simple protection, automation and communication devices. With VRE integration, the conventional passive style distribution grid will be replaced by an active network with small and medium-sized power sources. The distributed power supply system with two-way currents is making the distribution network more complex and leading to issues with the quality of electricity and the capacity factor on the grid side. Receivers of low-voltage electric power, like energy storage devices and electric vehicles, require the distribution network to adjust the low-voltage port and enable two-way communication posing challenges with line protection for both low-voltage and medium-voltage networks.

Such challenges have given rise to the emergence of an intelligent distribution management system. With demand-side management technologies and applications, the system can achieve the optimal economic efficiency to make the most of the load and ensure high-quality power supply. The highlight of an intelligent distribution management system is a highly-effective real-time monitor that incorporates a dynamic power curve, reverse tide, and issues with power output adjustment.

Exhibit 34: Conventional and future distribution grid modes



On the one hand, the intelligent power distribution monitor can leverage the visual "digital twin" to establish a simulation model of the distribution network to replace manual monitoring. Staff can refer to the chronological event records, waveform records, fault records to quickly analyze the faults, location and resolve the issues to minimize the time of disruption. The system can collect the data for indicators like current, voltage, power output, as well as voltage fluctuation of each circuit and device, to analyze and manage the power efficiency of the distribution system and end-using device. The intelligent distribution system can significantly reduce transmission losses at each unit and improve the overall efficiency.

On the other hand, automatic and intelligent inspection approaches to the distribution system are able to sense the status and operational environment of equipment seamlessly amid the use of increasingly complex electric devices and power sources. It manages to improve the stability of the grid and its ability for emergency response. In addition to that, if a video camera is connected, the system can retrieve the on-site graphics upon emergencies like a short circuit, and capture the object with malfunctions by turning the camera, which reduces the time to analyze and respond to the emergencies.

Company implications

Senter Electronics

Founded in 1996, the company has a variety of products developed on its independent intellectual property rights in the communications and electric power for other industries and is committed to becoming a leading provider of industry-level IoT solutions in China. In the electric power industry, it has clients like State Grid, to which it offers power substation, transmission, and distribution solutions. The main products include auxiliary monitoring systems for intelligent substations, visual inspection systems for transmission lines, intelligent active operation and maintenance systems for the power station area, and electric power mobile operation terminals, of which its transmission line visual inspector has a number of patented technologies applied.

Dongfang Electronics Corporation (000682.SZ)

The company is a hi-tech business group combining R&D, production and operation, technical services and system integration. It is one of the major suppliers of China's energy management system solutions, and also the key hi-tech enterprise.

3. Digitalized Electricity Market

Participants in the electricity market include power generation companies, grid operators, power distribution and sales companies, trading agencies, dispatching agencies, end users, and energy storage firms. They have different needs for the informatization of the electricity trading market:

- For power supply and sales firms, an auxiliary decision-making system for the market trading is needed, as well as a trade mocking system to help optimize the strategy to provide more accurate quotes.
- For trading agencies, they need to purchase more advanced electricity trading settlement and support systems.
- For electricity consumers, it is necessary to monitor electricity consumption, analyze safety real-time, and manage the consumption towards better energy efficiency, all with the presence of automatic electricity consumption systems and smart meter systems.

Company implications

YGSOFT INC (002063.SZ)

YGSOFT Inc. is a technology provider of energy inter-connection, social service information technologies, products and services in China. It has specialized in information-based management of large corporations for over 30 years. Its main products and services include group management, intelligent energy, intelligent Internet of things, digital society, etc.

NARI Technology (600406.SH)

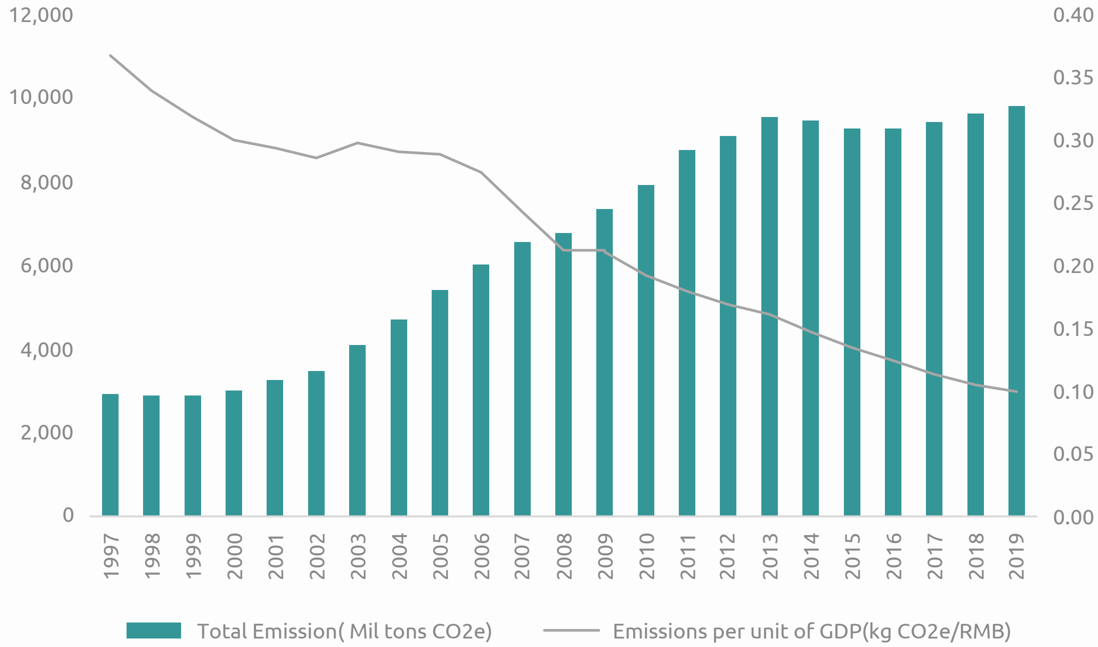
Founded in 2001, NARI Technology Co., Ltd. (abbr. as NARI-TECH) is a leading supplier of solutions for power and automation technologies in China. It has business with 222 electricity market participants across 14 provinces, covering power system automation, smart grid, renewable energy, railway automation, industrial control, energy conservation and environment protection, power plant auxiliary equipment technology, etc.

II. The demand side – sectoral use of energy

Overview: China's Commitments to Demand Side Carbon Emission Reduction

Since 1997, the total carbon emissions in China have shown a steady upward trend along with the economic growth. The trend was curbed in 2014, as the greater decrease in emissions per unit of GDP offset the economic growth rate. Along the timeline, the country rolled out total energy consumption and consumption intensity control policies in the 12th FYP documents in 2014, and supply-side structural reform in 2015. According to the latest CEADs data, as of 2019, the total carbon emission reached 9.8 billion tCO2e, meanwhile emissions per unit of GDP has decreased 72% from 1997.

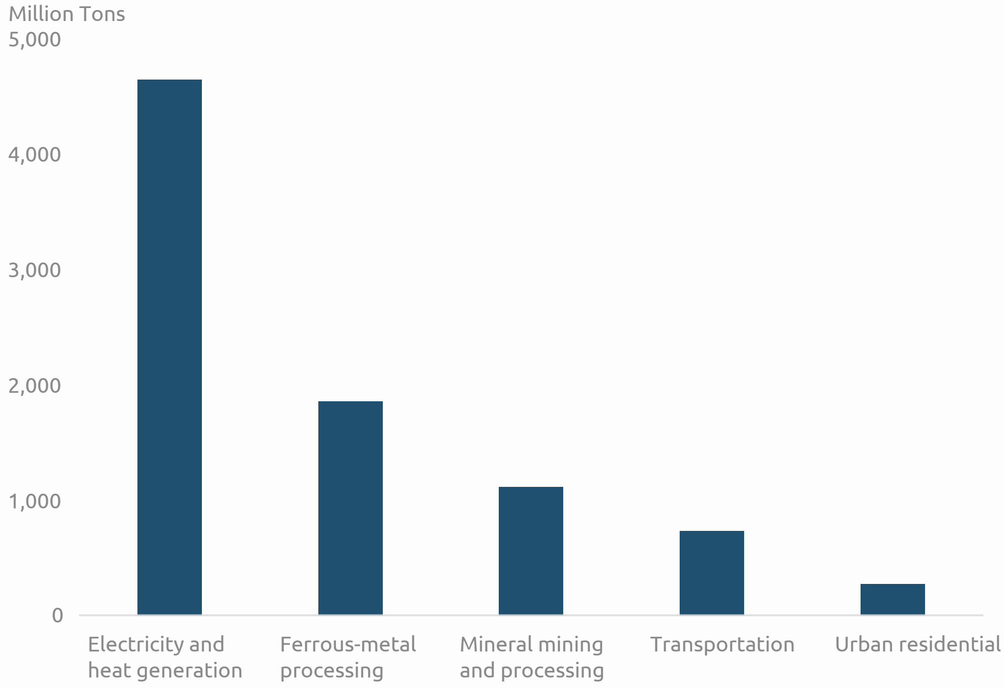
Exhibit 1: China's total carbon emissions and emissions per unit of GDP, 1997—2019(Million Tons of CO2e)



Source：CEADs、MioTech Research

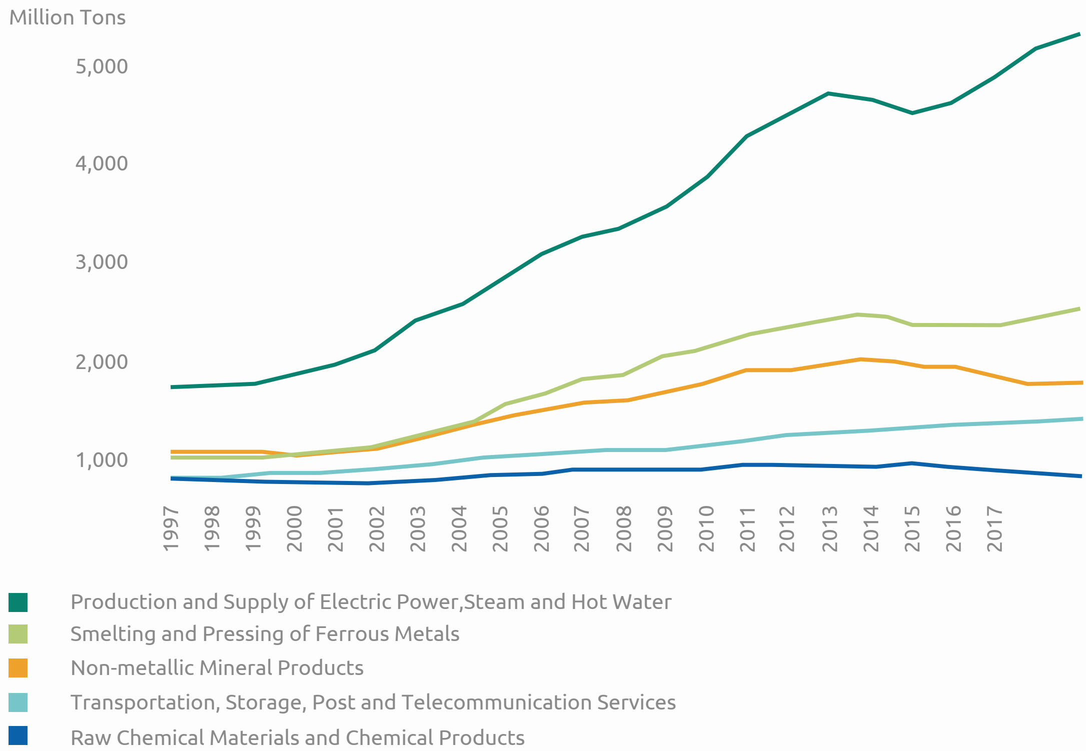
China's top three industries with the highest carbon emissions are electricity and heat generation, ferrous metal smelting, and mining, with annual carbon emissions of approximately 4.6, 1.9, and 1.1 billion tons respectively in 2019, accounting for 47%, 19% and 11 % of the country's total carbon emissions.

Exhibit 2: Carbon emissions of top five sectors in China (2019)



Source：CEADs、MioTech Research

Exhibit 3: Historical carbon emissions of the top five sectors in China, 1997—2019



Source：CEADs、MioTech Research

One important trend is that the primary policy target in focus has shifted from energy intensity to emission intensity control. The State Council and relevant Ministries have formulated high-level policies to set the agenda for energy-consumption sectors to achieve the decarbonization targets in the 2030 and 2060 timeline.

Meanwhile, bottom-up commitments from the provincial and municipal levels have collectively set long-term development targets for the carbon peaking and neutrality goals. According to our study, 17 out of 31 provincial administrations have already rolled out policy documents related to carbon peaking and neutrality, and the rest are in the progress.

Exhibit 4: Provincial level commitments on achieving "3060" carbon goals (selected)

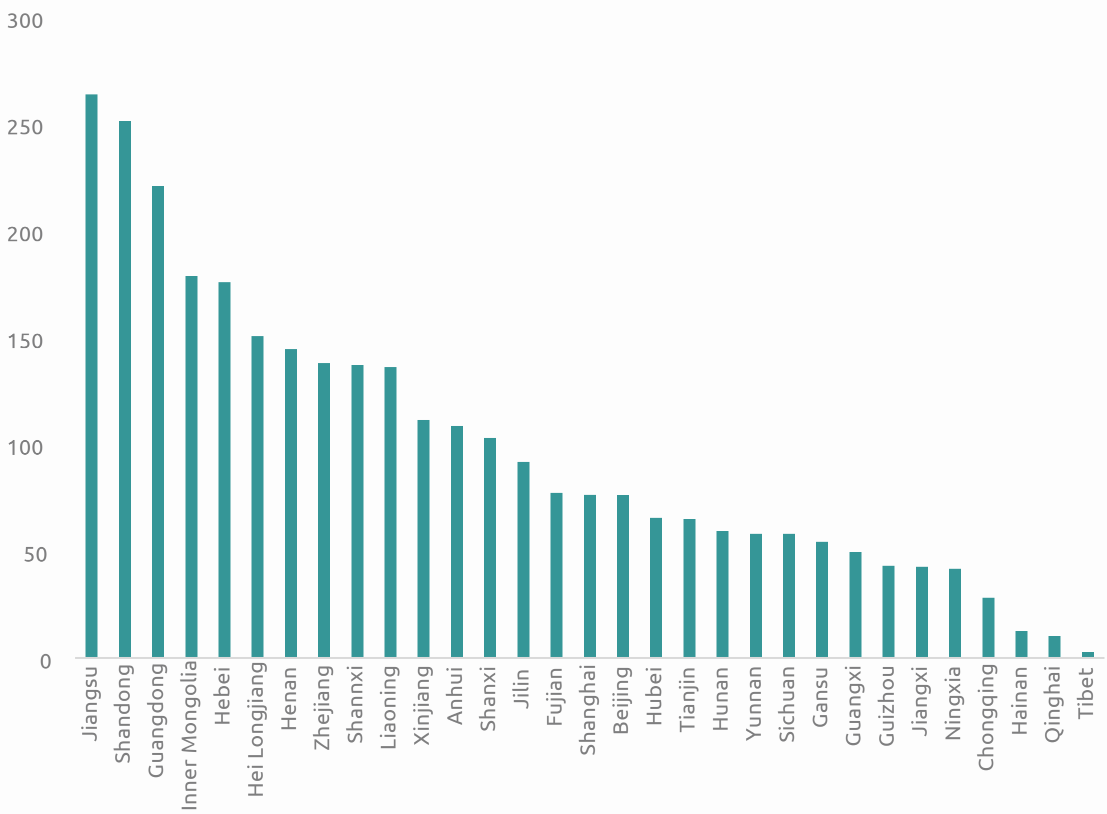
Province	Policies	Carbon goals
Beijing	The Thirty-eighth Meeting of the Standing Committee of the 15th Beijing People's Congress	Accelerate the formulation of documents on carbon peaking and carbon neutrality; Promote low-carbon transformation in energy, transporta tion, and construction sectors, etc.
Tianjin	Promotional Ordinance on Tianjin Carbon Peaking and Carbon Neutrality	Promote low-carbon transformation in energy, transportation, and construction sectors, etc.
Hebei	Implementation Opinions on the Complete and Accurate Implementation of the New Development Concept in Carbon Peaking and Carbon Neutrality Goals	By 2025, the proportion of non-fossil energy consumption will reach over 13%; the forest coverage rate will reach 36.5%; By 2030, the proportion of non-fossil energy consumption will reach over 19%; the forest coverage will reach about 38%, the goal of carbon neutrality shall be achieved by 2060.
Shanxi	Shanxi Provincial Government Work Report 2022	Formulate decarbonization work plan and the implementa tion of the carbon peaking plan
Liaoning	Accelerating the Establishment of a Sound Green Low Carbon Cycle Develop ment of Economic System Task Measures	By 2025, the value added of strategic emerging industries will account for 8.5% of the regional GDP, the proportion of installed non-fossil energy will exceed 50%, the installed wind power and photovoltaic power will strive to reach more than 30 GW, and new nuclear power installations will reach 2.24 GW.
Hei Longjiang	Implementation Plan on Promoting Carbon Peaking and Carbon Neutrality in 2021-2023	Formulate the implementation plan of carbon peaking according to the national policy

Shanghai	Public Institutions Green Low Carbon Cycle Development Action Plan in Shanghai	By 2023, the total energy consumption of public institutions in the city will be controlled within 1.71 million tons of standard coal; carbon dioxide emissions will be controlled within 3.2 million tons, and the installed solar photovoltaic will reach 50,000 kilowatts. The energy consumption per unit of floor area, comprehensive energy consumption per capita and water consumption per capita will be reduced by 3%, 3.6% and 4.2% respectively compared to 2020

Source: Government websites， MioTech Research

As a matter of fact, the current carbon emission situations are unique on provincial levels. According to MioTech's satellite data, the three provinces with the highest annual carbon emissions in 2019 are Jiangsu, Shandong, and Guangdong, with 263, 251 and 220 million tons respectively, all of which have introduced decarbonization policy documents, with Jiangsu and Shandong having formulated clear quantitative targets. The 17 provinces that have introduced carbon policy documents are home to a total of 1.7 billion tons of carbon emissions, accounting for approximately 56.7% of total annual carbon emissions.

Exhibit 5: Carbon emissions (million tons of CO2e) of 31 provinces in Mainland China



Source： AMI, MioTech Research

The Industrial Sector

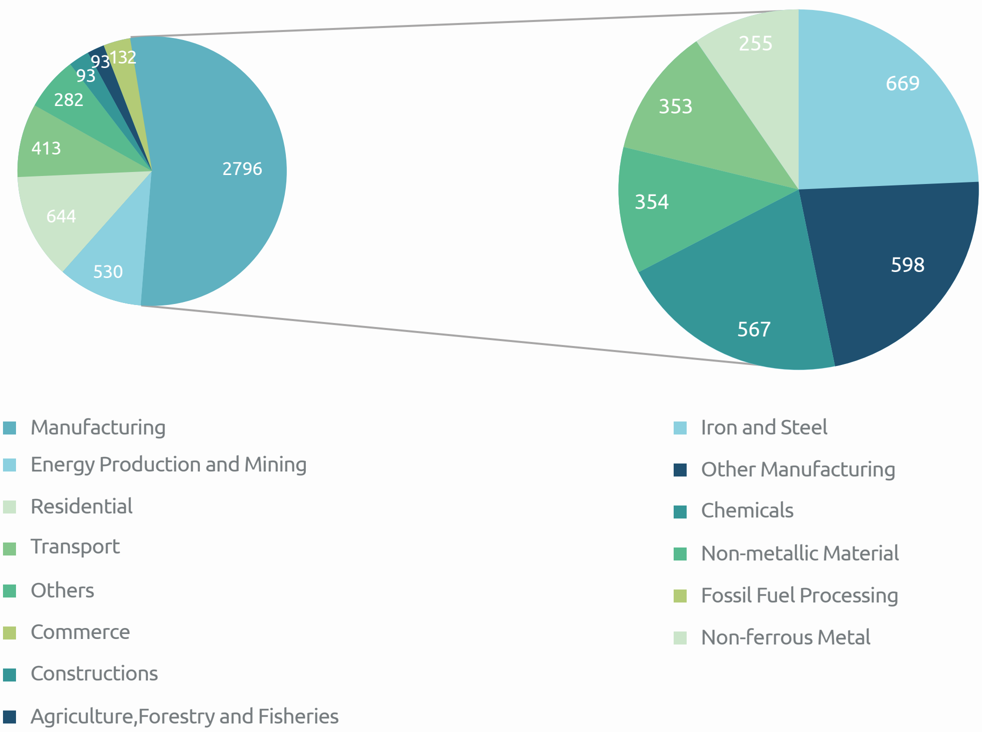
Industrial manufacturing is a fundamental sector that profoundly impacts the economy. The industrial sector has a strong demand for upstream raw materials, while the importance of the products it produces and sells, whether primary materials such as steel or end-user products such as household appliances and automobiles, is ubiquitous in everyday life. In China, the industrial sector has been the backbone of its rapid economic growth for decades. China now has the largest industrial sector in the world, as well as the most complete industrial system and sectors. With its intensive energy consumption and high greenhouse gasses (GHG) emission intensity, the industrial sector is a key area of focus for China's carbon neutrality.

GHG emissions from the industrial sector consist of three types of activities: manufacturing of products, supply of raw materials, and processing and use of the finished products sold. The majority of emissions from industrial enterprises fall into scope one and two, referring mainly to emissions from the manufacturing of their products, of which carbon dioxide accounts for more than 90% of direct emissions. Less than 10% of direct industrial emissions consist of GHG other than carbon dioxide: methane (from carbon black production), fluoride (for refrigeration) and nitrous oxide (from acetaldehyde and nitric acid production). Emissions from the use of fossil fuels 1) as raw materials for production, 2) as fuel and power, and 3) from purchased electricity together constitute the industrial sector's CO2 emissions.

In China, the industrial sector is the largest consumer of energy among all social sectors. According to the National Bureau of Statistics, total industrial energy consumption in 2020 was 3,326 million tons of coal equivalent (Mtce), accounting for two-thirds of the total energy consumption of the whole society (4,983 Mtce).

Exhibit 6: Energy consumption (Mtce) by social sectors in China in 2020

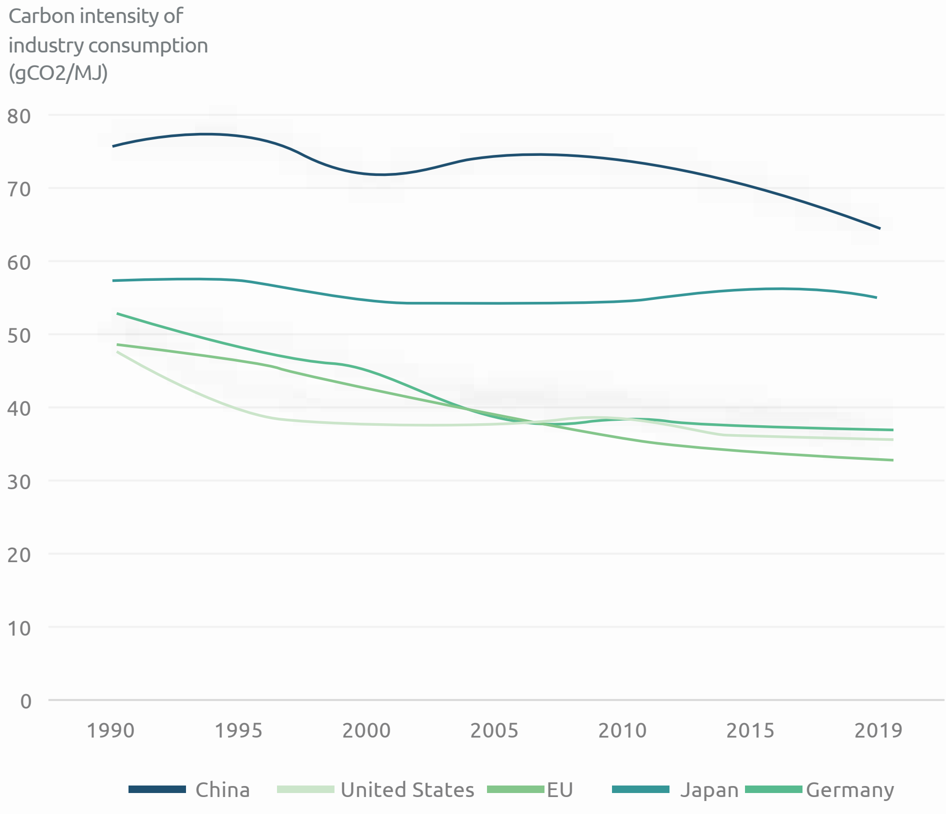
Exhibit 7: Energy consumption (Mtce) by industrial sub-sectors in China in 2020



Source: China Electricity Council, MioTech Research

Due to the government's continuous push for supply-side structural reform, transformation of energy-intensive industries and other measures, China's carbon emission intensity in the industrial sector has shown a gradual decline in the past 30 years. However, compared with the other top five economies in the world, its carbon emission intensity is relatively high, with still large potential for energy saving and emission reduction in the industrial sector.

Exhibit 8: Carbon emission intensity of industrial energy consumption for the top five economies in the world, 1990-2019



Source: IEA, MioTech Research

Challenges and Opportunities

The industrial sector has been widely recognized as a difficult area for decarbonization due to the complexity of industrial processes and the high cost of emission reduction, among other reasons. The investment in decarbonization technologies in industry has also been consistently lower than in sectors such as energy, buildings, and transportation. This makes the path to carbon neutrality in the industrial sector not as clear as in other sectors.

From the technical point of view, there are four main points of difficulty in decarbonizing the industrial sector.

- First, carbon emissions from raw materials directly consumed in processes cannot be simply replaced or removed, and can only be reduced by improving the process efficiency.
- Second, fossil fuels are mostly used in industrial production to generate high-temperature heat (typically reach 700 °C to over 1,600 °C) for processes such as smelting and high-temperature heat treatment. Reducing these emissions by switching to zero-carbon electricity will be difficult, as it will require significant changes in the process flow and equipment.
- Third, industrial processes are highly integrated, so any change to one part of the process must be accompanied by changes to other parts of that process.
- Finally, industrial plants have long life cycles, often exceeding 50 years with regular maintenance. Changing the processes in an existing plant requires extensive rebuilding or retrofitting, often expensive.

In addition, economic factors add to the challenge. Products from key industrial sectors, such as steel, oil, basic chemicals and nonferrous metals, are among bulk commodities traded globally. Buyers of these commodities are often very price sensitive and not willing to pay for so-called "greener" or "lower carbon" production processes. Companies that increase their production costs by adopting low-carbon processes will therefore find themselves at a competitive disadvantage.

In 2021, the Party Central Committee and the State Council issued Opinions on the Complete and Accurate Implementation of the New Development Concept for Carbon Neutrality and the Action Plan for Carbon Neutrality by 2030, which together constitute the top-level design document for the two phases of carbon neutrality. Regarding the decarbonization path for the industrial sector, both documents mention industrial restructuring and means to improve energy use efficiency, and provide guidance on the work of key carbon-control industries such as iron and steel, nonferrous metals, building materials and petrochemicals in the State Council's program.

It is expected that the National Development and Reform Commission (NDRC) will issue an official version of the overall carbon neutral action plan for the industrial sector during 2022, and may issue draft opinions on the implementation plan for key industries such as steel, nonferrous metals, building materials, chemicals and petrochemicals.

Even though there are many challenges mentioned above, we believe there are already technologies enabling carbon peaking paths that gradually show uptrends in development:

1. the recycling and recovery of energy-intensive products, particularly steel, aluminum, paper, and plastic;
2. the efficiency improvement of industrial general equipment such as motors, transformers and industrial control equipment;
3. waste heat recovery and utilization for energy gradient use or power generation.

1. Recycling of energy-intensive products – steel, aluminum, paper and plastic

Exhibit 9: Picture of recyclable materials

Recycling can reduce the demand for feedstock processing. Particularly in the case of energy intensive industries, recycled products can significantly reduce the carbon dioxide footprint by replacing processes of high energy consumption with lower ones.

In July 2021, the NDRC released the 14th Five-Year Plan (FYP) for the development of circular economy, which proposed to build a resource recycling industrial system, planned to recycle 60 million tons of waste paper, 320 million tons of steel scrap, 20 million tons of nonferrous metals, including 4 million tons of copper, 11.5 million tons of aluminum, and 3 million tons of lead, and the recycling industry total output value of RMB5 trillion by 2025.

The national carbon trading market is phasing in industries, and the implied carbon price of the energy-intensive products shall provide more incentive for recycled substitutes. Currently, the power industry is included in the national carbon market. Industries with highest emissions, — petrochemicals, chemicals, building materials, iron and steelmaking, nonferrous metals, and paper — will be phased in by 2025. Among them, steel, aluminum, paper and plastics are indispensable raw materials or primary products. The industries are also contributors to high energy consumption and high carbon emissions, with considerable potential for greater circularity.

High emission reduction potential of recycled products

By recycled volume and recovery value, the top four varieties are scrap steel, scrap nonferrous metal, waste paper, and waste plastics, which are all related to energy-intensive industries. To better understand in a quantitative way, we have calculated the carbon emission reduction potential of the four types in detail, as follows.

Exhibit 10: Emission reduction potential of scrap steel, aluminum, paper and plastic

	Steel	Aluminum	Paper	Plastic	Total
Recycling volume (Million ton, 2025)	320	12	60	25	**417**
Emission reduction pathway (By substituting virgin material processes with recycled material)	Blast furnace and the following processes – electric arc furnace processes	Aluminum production from mineral – from scrap aluminum	Every 1.25 tons of waste paper makes 1 ton of pulp, saving 70% of energy	Plastic production from petrochemical processes - from waste plastic	
Emission reduction efficiency (t CO_2e/t)	0.68	15.08	5.42	1.94	
Total carbon emission reduction (Million tons of CO_2e, 2025)	218	173	325	49	**765**

Source: the 14th Five-Year Plan for the Development of Circular Economy, "Quantitative Analysis of Recycling and Carbon Emission Reduction", China Products Carbon Footprint Factors Database, MioTech Research

Recycled steel: The 14th FYP's target is to recycle 320 million tons of scrap steel by 2025. After years of supply-side reform, China's crude steel production has been reduced significantly, but the overall revenue of the steel industry is still growing steadily, reaching RMB8.9 trillion. Currently, China's steelmakers predominantly adopt blast furnace ironmaking, which is a very energy-intensive metallurgical process, while scrap steel's electric arc furnace process greatly reduces carbon emission. If renewable electricity is used, the emission reduction efficiency can be further increased.

Recycled aluminum: The primary aluminum production industry is one of the most carbon-intensive industries. The electrolytic process for aluminum production consumes a huge amount of energy. On the other hand, secondary (recycled) aluminum has only 5% of the carbon emission intensity of primary aluminum. The 14th FYP proposes 11.5 million tons of domestic aluminum recycling. Combined with numbers taken from the China Products Carbon Footprint Factors Database, each ton of recycled aluminum production reduces over 15 tonnes of carbon dioxide equivalent (tCO_2e) compared to primary aluminum production, with an overall emission reduction potential of 173 million tCO_2e. In terms of emission reduction efficiency and overall potential, recycled aluminum production is the most noteworthy alternative to energy-intensive industries.

Waste paper: The Plan proposes 60 million tons of waste paper recycling during the 14th FYP. In 2020, the country's paper industry total revenue is RM1.3tn and waste pulp consumption rate is about 55%. When comparing the emission factor of waste paper pulp with that of virgin paper pulp, research has found out the emission reduction efficiency of waste paper recycling is 5.42tCO_2e per ton.

Waste plastics: According to the NDRC estimates, the plastic recycling volume will reach 25 million tons in 2025, and the recycling rate will increase from 26.7% to 30% this year. Each ton of recycled plastic can reduce

1.94 tCO2e compared to the equivalent amount of virgin plastic.

* Since different plastic types vary in their emission reduction efficiency, we combine the percentages data with the emission factor of each major type of plastic products. The results are as follows.

Exhibit 11: Carbon emission factor for various types of waste plastics

Plastic types	Percentages	Emission factor（t CO2e/t）
LDPE	27%	2.98
HDPE	21%	2.72
PP	18%	2.53
PS	16%	4.24
PVC	7%	6.74
PET	11%	3.23
Combined total	0.27*2.98 + 0.21*2.72 + 0.18*2.53 + 0.16*4.24 + 0.07*6.74 + 0.11*3.23 = 3.34	

Source: "Progress in recycling of polyethylene and polypropylene waste plastics", "Environmental footprint assessment of plastics in China", MioTech Research

Steel, aluminum, paper and plastic recycling has immense emission reduction implications. According to our calculation, the total carbon emission reduction in 2022 to 2025 could reach 2,865 million tCO2e, equivalent to the carbon sink of ~10million square kilometers of urban forest – close to the size of the whole of Europe - in one year. In 2022 alone, we forecast the recycling level of the four commodities to be 670 million tCO2e, almost three times the estimated annual carbon removal from the forests in the entire Europe.

Most value-added in upstream collection and recycling technologies

According to the data of the Ministry of Commerce, China's recycling system is characterized by high fragmentation and low barriers of entry, with about 159,600 recycling outlets, 1,837 sorting centers, 266 distribution markets and 63 sorting clusters. The policy is promoting the integration of the two networks of "waste classification" and "recycling", so that companies that integrate more recycling sites can gain more channel advantages. In addition, the circular economy has also given rise to the so-called "internet plus" recycling model. Whether it is B2B or B2C, internet plus recycling reduces the cost of recycling labor and further broadens the recycling channels. This trend is particularly evident in the boom of online flea markets, such as RERE's Aihuishou platform.

Taking a closer look at the recycling value chain, the smaller recyclers collect scrap materials with value from enterprises, government and individual dealers, produce low value-added recycling products after primary processing, and sell them to industrial enterprises that need raw materials. Profits are derived mainly from the value of the end recycled product, minus the cost of raw material collection, processing, logistics and other factors.

In the case of steel and paper recycling, the midstream primary processing has the lowest value-added from its basic processes, i.e., shredding, washing and packing, while the upstream controls the channel and flow of waste goods, and the downstream capitalizes on technical advantages to improve the added value of recycled products and increase profit margin.

The waste goods are collected from either industrial commercial channels or the municipal system, described in the Exhibit below. Among them, auto dismantling and garbage classification have much potential for improvement. Auto dismantling can recover large amounts of scrap steel and aluminum, while domestic garbage classification can improve the quality and quantity of scrap material by segregating them from municipal waste at the collection point.

Exhibit 12: Scrap material collection channels in China

Materia	Source	Collection channels
Scrap steel	Industrial	Steel scrap from steel product workshops
	Municipal	End-of-life steel scrap, mainly from scrapped automotives, ships, spent cans and furniture
Scrap aluminum	Industrial	Recycling within aluminum and aluminum product manufacturers
	Municipal	Construction aluminum scrap, automotive aluminum scrap, cans, etc.
Waste paper	Industrial	Waste paper from paper mills and paper product processing plants
	Municipal	Spent cardboards, newspaper, packaging paper, etc. from municipal waste
Waste plastics	Industrial	Waste plastic and plastic products generated in the process of plastic molding and processing
	Municipal	Plastic bottles and bags from municipal waste Including also agricultural land film and disposable plastic products from medical channels

Source: China's Waste Plastic Pollution Prevention Strategy, China Nonferrous Metals Industry Association, Miotech Research

Technological advantages can improve the added value of end products, especially in the case of recycled plastics and recycled aluminum where recycled materials have to go through mechanical, chemical and metallurgical processes. It is foreseeable that the industry will put more attention towards research and development, (R&D) in recycling technologies. In the long run, vertical integration of the industry canamplify the upstream and/or downstream advantages of respective industry players, for which the scale and profitability are expected to rise at the same time.

Scrap import and export situation

China's "Green Fence'' policy is in full force, directly affecting the import and export of recycled goods, both in quantity and prices. The policy first came into force in 2017 with harsh restrictions on importing waste material, and the country ordered a total ban on imports of solid waste from 2021, which includes waste plastics and paper, and scrap nonferrous metals iron and steel, etc. Only recycled goods, meaning those being primarily processed and no longer contain material considered as waste, are allowed to be imported, and arer still subject to strict customs inspections.

China's waste imports have plummeted, especially for the paper industry, which has a high degree of import dependence. Companies sourcing paper pulp have encountered difficulties, and the price of domestic waste paper and virgin pulp has subsequently increased. To cope with the market risk of raw material supply, the relevant domestic enterprises established plants in Southeast Asia, Northern Europe and North America. A new commercial loop of importing pulp from OECD countries to Southeast Asia for processing and export to China - has been established. Furthermore, forest - pulp - paper integration may become the new trend in response to the increasingly stringent environmental regulations and increased import costs in Southeast Asia. Taking Shandong Sun Paper as an example, the company established a manufacturing base in Laos which integrated forest-pulp-paper in the same place.

Recycled aluminum and plastic have the fastest growing market

China has a large recycling system with long chains from individuals who walk the streets and collect from door to door, to packing stations and sorting centers in scattered divisions within the city. After sorting and packing, material flows to recycling enterprises and traders, and eventually back to the manufacturing enterprises demanding raw materials.

Exhibit 13: The domestic recycling loop in a nutshell

Source: MioTech Research

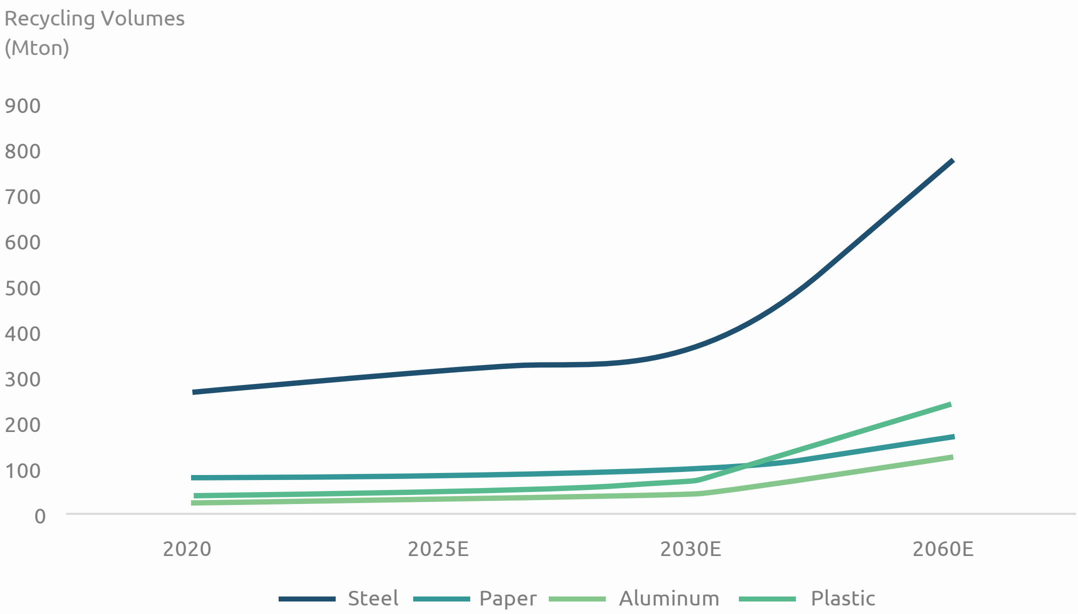
The recycling of steel and paper is relatively mature, and the added value of processing is not high, with limited potential for future recycling rate growth. The increase of recycling volume will be mainly linked to the overall economic development and the increase of per capita consumption of steel and paper. From 2025 onwards, assuming stable economic growth, we expect steel and paper recycling to maintain a growth rate of 3% between 2025 and 2030 and 2.5% between 2030 and 2060. Steel recycling will reach 780 million tons in 2060, while paper recycling will be close to 150 million tons.

The recycling of aluminum and plastic benefits from technological advances and the expansion of processing capacity. The performance quality of their processed varieties will be improved, resulting in greater value added and driving the growth of upstream aluminum and plastic scrap recycling rates and recycling volumes. On the basis of 7.4 million tons of aluminum scrap and 16 million tons of plastic scrap recycled in 2020, the aluminum/plastic recycling volume is expected to reach 11.5 million tons/25 million tons and 23 million tons/50 million tons in 2025 and 2030, respectively. Thereafter, the recycling of aluminum and plastics is expected to maintain a 5% compound annual growth rate (CAGR) from 2030 to 2060, reaching 100 million tons of aluminum and over 200 million tons of plastics by 2060.

Exhibit 14: Recycling volume and CAGR predictions of steel, paper, aluminum and plastic, 2025-2060

Varieties	Recycling Volume（Million tons）				Compound Annual Growth Rate		
	2020	2025E	2030E	2060E	2020-25	2025-30	2030-60
Steel	260	320	371	778	4.2%	3.0%	2.5%
Paper	55	60	70	146	1.8%	3.0%	2.5%
Aluminum	7.40	11.5	23.1	100	9.2%	15.0%	5%
Plastic	16	25	50	217	9.3%	15.0%	5%
Total (Million tons)	**338**	**417**	**514**	**1,241**	**4.2%**	**4.3%**	**3.0%**

Exhibit 15: Recycling volume predictions of steel, paper, aluminum, plastic (million tons，2025-2060)



Source： MioTech Research

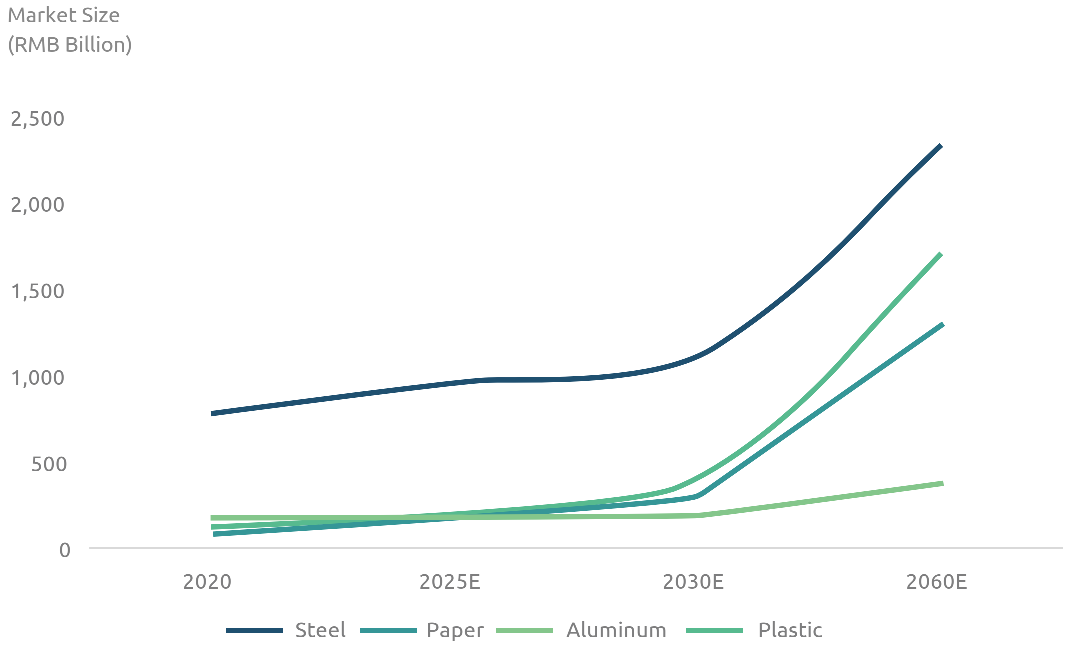
The recycling of steel, aluminum, paper and plastic will reach a combined market size of RMB1.4 trillion in 2025, with an overall average annual growth rate of 5%. The market size of aluminum and plastic recycling will grow at an average annual rate of 9.2% and 9.3%, ahead of the 4.2% of steel and 1.8% of paper. By 2030, the total recycling market size of the four varieties will reach RMB 2 trillion. By 2060, the recycling market size for both aluminum and plastics will exceed the RMB 1 trillion mark, reaching 1.7 trillion and 1.3 trillion, respectively, while the overall market size for steel, aluminum, paper and plastics will reach RMB5.7 trillion.

Exhibit 16: Market size forecast table for steel, paper, aluminum and plastic, 2025-2060

Market Size (RMB bn)	2020	2025E	2030E	2060E
Steel	780	960	1,113	2,334
Paper	132	144	167	350
Aluminum	126	196	393	1,699
Plastic	96	150	302	1,304
Total	**1,134**	**1,450**	**1,975**	**5,688**

Note: The unit price of each material is calculated at RMB 3000/ton for steel, RMB 2400/ton for paper, RMB 17000/ton for aluminum and RMB 6000/ton for plastic respectively.

Exhibit 17: Market size forecast (in RMB bn) for steel, paper, aluminum and plastic, 2025-2060



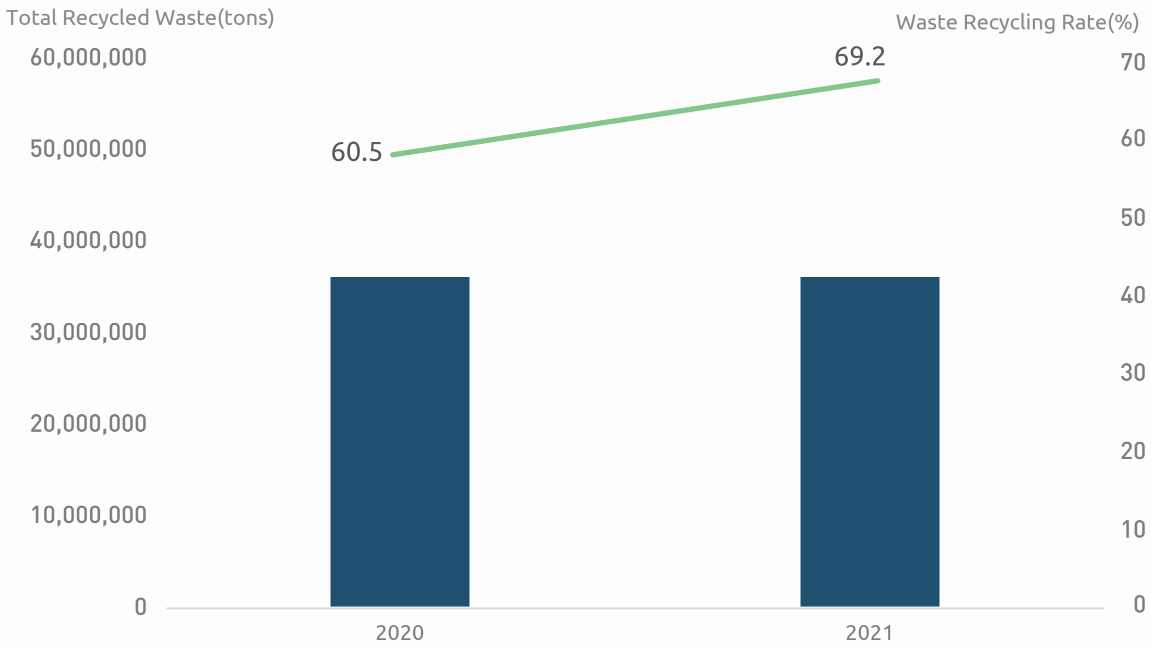
Source: MioTech Research

Evidence from MioTech's data: the increasing circularity

Corporates have stepped up their responsible waste management efforts. Based on 2020-21 data from all mainland A-share and Hong Kong-listed Chinese firms, we found a 46% YoY increase in these companies' total recycled waste volume, while the average waste recycling rate also improved significantly from 60.5% in 2020 to 69.2% in 2021.

The increased quantity comes from a higher volume of recyclable materials, including scrap steel from the steelmaking process, end-of-life waste plastics as well as paper for packaging and other uses, among other industrial and commercial waste.

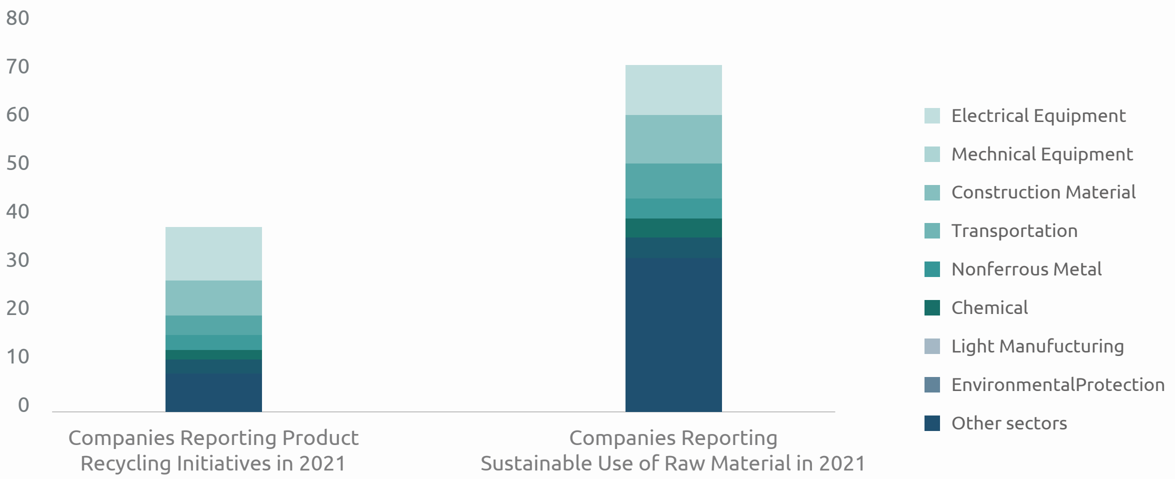
Exhibit 18: Recycling trends of all mainland A-share and Hong Kong listed Chinese firms disclosing the sets of waste recycling data in both years of 2020 and 2021



In addition, manufacturing companies are putting more emphasis on promoting the sustainable use of raw materials and the recycling of used products as part of the circular economy.

In 2020, out of all (2,675) industrial sector companies covered by MioTech (MICS), only six firms reported progress on promoting the sustainable use of raw materials and none disclosed product recycling initiatives. In 2021, by contrast, 70 companies shared about activities targeted at the sustainable use of raw materials and 37 companies reportedly established product recycling initiatives. Heavy industries showed the highest reporting rates, where they consume the most steel, aluminium, paper, and plastic products.

Exhibit 19: Companies reporting initiatives supporting circularity in 2021, by sector



Source: MioTech Research

Waste-to-energy to supplement decarbonized circularity

As the final destination of waste disposal, waste-to-energy also contributes to carbon emission reduction. As an alternative to landfill disposal, waste incineration avoids the methane generated by landfills and reduces greenhouse gas emissions by replacing fossil fuels with electricity generated by incineration. According to our calculation, incineration of 1 ton of garbage can actually achieve GHG emission reduction of 0.54 tCO_2e.

Exhibit 20: Waste-to-energy carbon emission reduction measurement

Emission reduction by avoiding waste from landfill	With 50 cubic meters of methane generated per ton of waste, an oxidation rate factor of 0.5, and an average utilization rate of 20% of landfill gas, 20 cubic meters of methane will be leaked per ton of waste. The greenhouse gas effect of methane is 21 times that of carbon dioxide, yielding a carbon emission reduction of 0.3tCO_2e per ton of waste landfill avoided.
Emission reductions from electricity generation	Waste-to-energy power generation assumes 300kWh/t. Based on the East China Power Grid emission factor of 0.7921 tCO_2/MWh published by the NDRC, waste-to-energy power generation can achieve carbon emission reduction of about 0.24tCO_2e per ton.
Emission reductions total	0.54 tCO_2e per ton

Source: MioTech Research

The certified carbon emission reduction (CCER) market is expected to restart in 2022, and CCER trading can bring additional revenue to waste-to-energy companies and improve their cash flow. The certified emission reduction of a waste-to-energy project is about 0.5Kg per kWh. Assuming the carbon quota trading price of RMB30/ton, CCER trading can bring additional revenue of RMB 4.2/ton, which is about 5% of the tipping fee.

The waste-to-energy industry also faces some challenges. First and foremost is the gradual saturation of the market. The new installations in the domestic waste-to-energy market in 2021 has dropped significantly for the second year in a row: a total of 57,500 tons/day with 69 new waste-to-energy projects were awarded in 2021. Compared to 127,000 tons/day in 2019 and 74,300 tons/day in 2020, the number has decreased for two consecutive years by 70,000 tons/day (54.72%) and 16,800 tons/day (22.61%). Further implementation of garbage classification will also lead to a decrease in the volume of admitted waste, affecting tipping fees and power generation revenue.

On another note, state subsidies for waste-to-energy have been adjusted, which affects the future cash flow of existing waste-to-energy projects. Under the current incentive program, waste-to-energy projects stop receiving state subsidy after about 17 years of operation, and for their last 13 years of project life cycle the net profit will drop by 14.3% on average. Taking an example of a medium sized waste-to-energy project with 1,000 tons/day capacity, the net profit is RMB21.7 million (project life cycle years 9-17, income tax rate 25%) and RMB18.6 million afterwards (project life cycle years 18-30, assuming complete abolition of state subsidy, income tax rate 25%).

Case Company: Shanghai Chengtou Corporation, a pioneer in urban environment protection

Shanghai Chengtou Corporation, established in July 1992, is a large investment group company authorized by Shanghai Municipal People's Government to engage in urban infrastructure investment, construction and operation. One of the main business focuses of Shanghai Chengtou Corporation is environmental services. Its subsidiary Shanghai Environment Group Co. Ltd. and Shanghai Laogang Solid Waste Comprehensive Development Co., Ltd. are mainly responsible for the transportation and disposal of municipal waste and other solid waste, as well as the investment, development and operation of environmental protection projects. Shanghai Environment Group Co. Ltd. (601200.SH) is its flagship solid waste treatment company.

Shanghai Chengtou Corporation has a waste-to-energy capacity of 28,200 tons/day in operation, and over 4,500 tons/day of projects under construction and in the pipeline. The company has also diversified its operation, with deep involvement in the construction of garbage classification terminal capacity in Shanghai, and two construction waste projects and two food waste projects in hand. In 2020, the company reached RMB7.1 billion yuan of revenue, with a CAGR of 23% from 2016 to 2021. The company also achieved net profit of RMB687 million, ROE of 8.2%, gross profit margin of 23.66%.

Outlook 1	Exclusive domination of Shanghai market and establishment of barriers of entry. The company's domestic waste disposal capacity accounts for about 80% of the total capacity in Shanghai. As the local governments tend to give priority to continue cooperation after the project expires, the company is expected to occupy a stable monopoly position in the long term.
Outlook 2	CCER will increase profits. Under the premise that waste-to-energy power generation projects can apply for CCER, for example, based on the annual generation of 2.19TWh, the company can obtain an additional revenue of RMB37.6 million through CCER transactions, accounting for 6% of the company's net profit in the same period.

Company implications

Jiangsu Huahong Technology (002645.SZ)

The company's business involves scrap steel processing and trading, comprehensive utilization of rare earth scrap, dismantling and recycling of end-of-life vehicles, as well as the research, development, production and sales of elevator parts. Starting with a scrap steel processing equipment business (the company's market share of scrap steel equipment in 2019 was nearly 40%), the company gradually integrated auto dismantling and rare earth scrap processing businesses through acquisition.

Chongqing Shunbo Aluminum (002996.SZ)

The company is mainly engaged in the recycling of aluminum and aluminum products, including the production and sales of recycled aluminum alloy ingots. The company’s product line includes various standard and non-standard grades of recycled aluminum alloy ingots for domestic automobile and motorcycle industry manufacturers, general machinery foundry enterprises and aluminum product companies.

Nine Dragons Paper (02689.HK)

The company is the second largest paper manufacturing group in the world in terms of production capacity. The company engaged in the production and sale of diversified packaging board products, including cardboard (white kraft liner board and coated kraft liner board), coated gray-backed white board, specialty paper, high-strength corrugated board, corrugated carton and pulp, and has established a number of paper packaging companies downstream to provide one-stop packaging services to customers.

Shandong SunPaper (002078.SZ)

Founded in 1982, Shandong Sun Holdings Group is a leading cross-national papermaking group integrating timberland pulping and paper making. The company has six major product lines, comprising premium coated packaging paperboard, high-class art paper, high-class cultural and office paper, specialty fiber dissolving pulp, household paper, and industrial paper. To date, Shandong Sun Paper has RMB42 billion total assets and more than 14,000 employees.

Shandong Intco (688087.SH)

Shandong Intco Recycling is a high-tech manufacturer of recycled products. Utilizing recycled resources, it has created a full supply chain with recirculated plastics. The company has the annual capacity to recycle 150,000 tons of EPS foam, and 50,000 tons of PET bottles and food-grade PET plastics.

ATRenew (RERE)

Headquartered in Shanghai, ATRenew Inc. operates a leading technology-driven pre-owned consumer electronics transactions and services platform in China under the brand ATRenew, which stands for “All Things Renew.” Since its inception in 2011, ATRenew facilitates recycling and trade-in services for electronic goods, and distributes the devices to prolong their life cycle. ATRenew’s open platform integrates C2B, B2B, and B2C capabilities to empower its online and offline services. The company is a leading player in China’s pre-owned consumer electronics industry, through its end-to-end coverage of the entire value chain and its proprietary inspection, grading, and pricing technologies.

2. Advanced electrical equipment drives energy efficiency improvement

As mentioned earlier, most GHG emissions from the industrial sector come from manufacturing, including emissions from the consumption of raw materials, the use of fossil fuels as heat sources, and the indirect emission of electricity consumption. The first two sources of carbon emissions are more difficult to abate. First, carbon emissions from raw materials consumed in the process cannot be decarbonized directly, rather only be reduced by improving the process. Second, fossil fuels are mostly used in industrial production to generate high-temperature waste heat (process temperatures typically reach 600 °C to over 1,600 °C) for processes such as smelting and high-temperature heat treatment. Reducing these emissions by switching to zero-carbon electricity would be difficult because it would require major changes in the process flow and equipment. But as a transition and emission peaking, energy efficiency could be improved by means of waste heat recovery.

The decarbonization pathway for reducing indirect emissions from the use of electricity is more explicit. Although processes vary from industry to industry, the equipment that consumes electricity is relatively common and can generally be divided into high voltage equipment (above 1000V) and low voltage equipment (below 1000V). High-voltage equipment includes compressors, rolling mills, crushers, cutting machines, transport machinery and other larger electrical equipment used in metallurgy and steel, mining, machinery and petrochemical industries. On the other hand, low-voltage equipment such as pumps, fans, compressors, are widely used within almost all industries.

The electrical system of a typical manufacturing plant includes high-voltage power, low-voltage power, power distribution and electrical control modules. The core components of these four modules are motors, transformers and inverters. Improving the energy efficiency of these core devices is key to reducing indirect emissions from the industrial use of electricity. In the following, we will focus on analyzing the availability of these three core devices for energy efficiency improvement and their future trends.

Electric motors

Electric motors are the equipment that converts electrical energy into mechanical energy and the key driver of almost all industrial electrical equipment. It is estimated that the power consumption of industrial motors accounts for 70% of the total electricity consumption in the whole industrial sector. Every one percentage point increase in motor energy efficiency can save 26 TWh of electricity per year. Phasing out low energy-efficiency motors and replacing them with high energy-efficient ones can maintain the same level of output while saving 5-10% of energy use.

In November 2021, the State Ministry of Industry and Information Technology issued the Motor Energy Efficiency Improvement Plan (2021-2023). The plan orders the phasing out of inefficient motors that do not meet the requirements of the current national energy efficiency standards, and proposes that the annual output of energy-efficient motors should reach 170GW, and the proportion of energy-efficient motors in service should exceed 20% by 2023. This could result in annual saving of 49 TWh, equivalent to 15 mtce and an emission reduction of 28 million tCO2e.

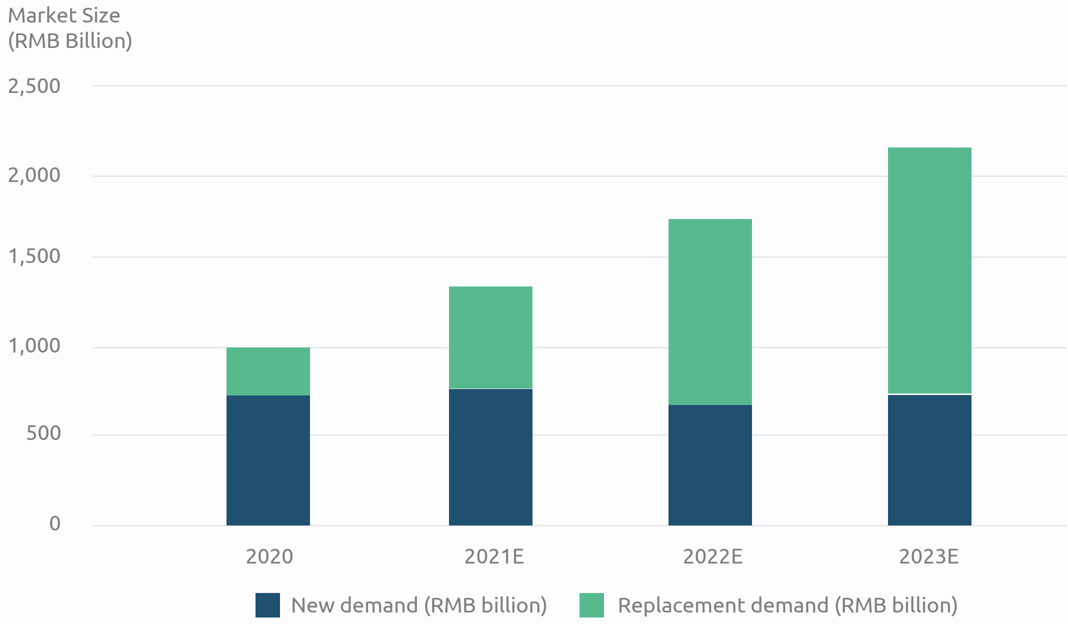
The market share of energy-efficient motors is currently less than 10% in China, and the plan sets a level of over 20% to be met by 2023. The future demand for energy-efficient motors comes mainly from the incremental demand for new motors and the replacement of old motors with new ones.

Industrial enterprises also need to reduce their carbon emission exposure through energy-efficient motor replacement. With the carbon trading market coming into effect for heavy industries by 2025, these industrial enterprises have to find a way to prepare for the rising cost of carbon. The replacement of energy-efficient motors is the most direct and cost-effective means of saving energy in their electrified processes which does not require modification to other process equipment. From information publicly disclosed by some motor manufacturers, the market growth rate of energy-efficient motors in 2021 has risen from a stable 3-4% in previous years to about 20%.

Market Size

The overall market size of industrial energy-efficient motors is around RMB100 billion per year, of which 70% is new demand and 30% is replacement demand. The value of motors currently in operation is about RMB2 trillion. The new plan will stimulate the replacement demand of low-efficient motors. In order to reach the 20% of energy-efficient motors target in 2023, we estimate the replacement rate of stock motors will reach 3%/5%/7% in 2021-2023. According to this projection, the overall size of the energy-efficient motor market can exceed RMB210 billion in 2023.

Exhibit 21: Energy-efficient motor market size forecast, 2020-2023



Source: MioTech Research

Large high-voltage installations have big emission exposure. Significant potential for replacement demand is present in the petrochemical, coal chemical and metallurgical industries. For low-voltage electronics such as fans, sump pumps, compressors, the growth opportunity for energy-efficient motors is linked to general industries, infrastructure, and real estate, etc.

In addition, permanent magnet motors, a higher cost technology with superior energy efficiency, is expected to gain traction in the high-end market, such as electric vehicles, home appliances, intelligent manufacturing and wind power. The motor industry is expected to increase in market concentration with rising barriers in energy-efficient technologies.

Company implications

Wolong Electric(600580.SH)

The company is mainly engaged in the research and development, production and sales of electric motor and electric control products. The company has a large number of independent intellectual property rights on household motors and control technology, high-power drive control technology, high-efficiency motors and permanent magnet motors. Leading in the domestic and global market, the company is joined by peers like ABB and Siemens. According to IHS Markit data, in 2020, the company's share of the global high-voltage motor market was about 11%, ranked second in the world; the share of the global low-voltage motor market is about 6.5%, ranked fourth in the world.

Transformer

The transformer is a device that changes the AC voltage with the principle of electromagnetic induction. Transmission to distribution as well as distribution to end-of-use requires gradient use of transformers for reducing the voltage. On China's AC grid system, the transmission line voltage is at least 35kV, and the ultra-high voltage can even exceed 1000kV, while the distribution line voltage is 10kV, and the end-use voltage is 220V (residential) or 380V (industrial and commercial). And therefore, transformers are the basic equipment for transmission and distribution, and are widely used in the demand side, e.g., industrial, agricultural, transportation, and residential sectors. It is estimated that China has about 17 million transformers currently operating.

The transformer losses account for about 40% of power losses on the transmission and distribution lines, or about 2.6% of total power generation, which is of great energy-saving significance. Mandatory policies have been launched to promote the application of energy-efficient transformers and the phasing out of low-efficiency transformers. In June, 2021, the Energy Efficiency Limiting Values and Energy Efficiency Grades of Power Transformers (GB 20052-2020) was officially implemented. This mandatory national standard puts forward higher requirements for transformer energy efficiency, in line with international standards. With the new standard coming into force, the Ministry of Industry and Information Technology issued the Transformer Energy Efficiency Improvement Plan (2021-2023), which emphasizes the following:

1. Increasing the use of energy-efficient transformers. Since June 2021, all new transformers shall meet the requirements of national energy efficiency standards. Energy-efficient transformers used in industrial, communications, construction, transportation sectors are particularly encouraged.
2. Phasing out of low-efficiency transformers. Special inspections will be organized to oversee key industries such as steelmaking, petrochemical, chemical, non-ferrous metal, and building materials. The enterprises will be asked to get rid of transformers that do not meet the new national standard.
3. Upgrading transformer efficiency in power grid enterprises. Power grid enterprises are asked to develop and implement low-efficiency transformer phase-out plans. By 2023, transformers that do not meet the new national energy standards should be replaced. Starting from June 2021, all new procurement should be energy-efficient transformers.

Market Size

Over the next few years, the market size for energy-efficient transformers in China could reach RMB20 billion per year, with high certainty of demand growth from new investment and replacement of existing low-efficiency transformers.

1. Replacement of low-efficiency transformers – 400,000 -700,000 units per year

   There are about 17 million transformers in operation in China, of which 65%, or more than 10 million, are Grade 3 energy-efficient transformers and below. Low-efficiency transformers, i.e., transformers below Grade 3, are estimated to be about 4-7 million units. If all of them are replaced in the next 10 years, the annual demand will be about 400-700 thousand units. Based on the average price of RMB 20,000/unit, total replacement demand is about RMB11 billion per year.

2. New investment incremental demand - 400,000 -600,000 units per year

   From the second half of 2021, all newly procured transformers for State Grid and China Southern Power Grid are energy-efficient ones. Grid companies' transformer demand is estimated to be 200,000-300,000 units, combined with a similar amount of demand from commercial and industrial sectors, the annual new investment demand is expected to be about 400,000-600,000 units worth RMB10 billion.

Company implications

TBEA (600089.SH)

TBEA Co. Ltd. mainly operates in the electric power transmission and transformation, new energy and Energy segments. Electric power transmission and Transformation is mainly engaged in R&D, manufacturing and distribution of transformers, wires and cables and other electric power transmission and transformation products. Its neweEnergy segment mainly involves in the production and sales of silicon and inverters, as well as solutions for the design, construction, debugging, operation and maintenance of photovoltaic electric and wind power plants. The company is the domestic leader in the transformer product market. In 2021 the company's transformer sales exceeded RMB 10bn and is expected to maintain high growth.

State Grid Yingda (600517.SH)

State Grid Yingda Co Ltd, formerly Shanghai Zhixin Electric Co Ltd, is a China-based company principally engaged in the manufacturing and sales of transformers. The company is a subsidiary of the State Grid Corporation. The company's main products include amorphous alloy distribution transformers, amorphous alloy modular transformers, silicon steel transformers, amorphous alloy iron cores and integrated transformer substations, among others. The company is also involved in the provision of energy saving and environmental protection equipment and services, as well as the operational and maintenance services related to smart power grids through its subsidiaries. The company is also engaged in trust, securities and futures businesses.

Variable-frequency drive (VFD)

Although the replacement of motors can improve energy efficiency, the combination of high-efficiency motors and variable-frequency drive (VFD) can achieve higher energy savings. The VFD serves to regulate the speed and torque of the motor to match the system load requirements, and ultimately to optimize operation by controlling the motor. With the right VFD, the motor will only run at the speed required by the load, resulting in significant power savings. When VFD and motors are used in combination, energy consumption can typically be reduced by at least 25%, according to ABB's estimate.

Energy savings from VFD are mainly found in the application of fans and pumps. In order to ensure the reliability of production, production machines are designed with power drives with a certain extra amount of margin. When the motor runs below full load, the unutilized excessive torque increases electricity consumption, resulting in a waste of electrical energy. When variable frequency control is installed, VFD will respond to the reduction in the load demand in real-time, and reduce the speed of the pump or fan accordingly.

The earliest VFD were developed in the early 20th century and were designed based on mechanical structures. With the development of solid-state electronics in recent decades, VFDs have become increasingly sophisticated and inexpensive. Despite this remarkable progress, the acceptance of VFD has not been as fast as desired. It is estimated that about 23% of the world's industrial motors are currently equipped with VFDs. The figure is expected to grow to 26% in the next five years, but if the rate of penetration can be accelerated, it will help save a lot of extra energy. According to the IEA, about 50% of industrial motors can save more energy when equipped with VFD.

Motors and inverters are easy to install and do not require any additional modifications to existing industrial processes, making them an attractive investment proposition for the industrial companies. Another major consideration for them is the payback cycle, as the potential return on energy efficiency investments are desired to match that on investment in other areas. The payback cycle of VFD depends heavily on energy prices. Periods of rising energy prices will make investment in energy-efficient equipment more attractive.

Leveraging Industrial IoT for advanced industrial energy management system

The industrial Internet of Things (IoT) is another technology on the rise which brings significant implications for industrial energy efficiency improvement. Traditional industrial energy management focuses on the efficient provision and use of process energy needs, such as heating, cooling, compressed air, and electricity. The IoT has a wealth of new data streams to support energy management measures. The technology stems from the digitalization and interconnectivity of industrial equipment. In a nutshell, industrial IoT offers the accessibility to the operational data through connected sensors. In a complex industrial facility, those data can include 1) operational monitoring data, such as load curve of the motor, heat meter, flow meter, and production line output, and 2) energy consumption data from individual equipment in production lines, power system, and auxiliary systems such as heating, ventilation, and air conditioning (HVAC) and firefighting.

The data provided by the sensors can be integrated and analyzed to provide the basis for real-time regulation of the equipment by an industrial control system (ICS). This allows two ways of energy management:

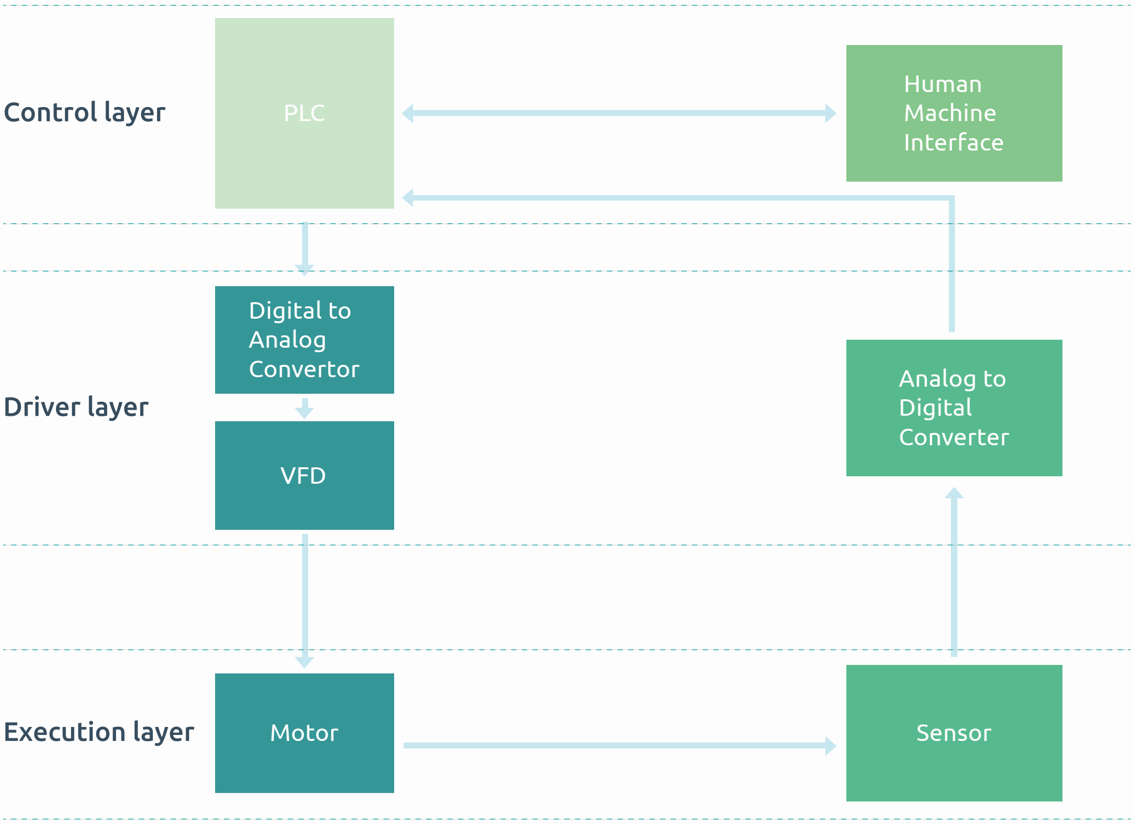
1. Open loop, where the optimal set points are indicated to the operators to manually set the optimization variables;
2. Or closed loop, where the set points are sent directly to each optimizable variable.

These implementations can typically achieve energy-consumption reductions from 3% to 8% for the open-loop model, and 6% to 15% for closed-loop applications.

A typical ICS has three layers of components:

1. The control layer, which serves as the brain of the system. The control layer is a human-machine interface in which the operator relies on a programmable logic controller (PLC) and decentralized control system (DCS) to visualize operational data and send process control instructions.
2. The driver layer, which serves as the heart of the system. VFD is the main device at this layer. It receives instructional signals from the control layer and alters power input frequency and/or voltage to the motor accordingly.
3. The execution layer, which serves as the arms and legs of the system. These are the motor-driven equipment performing as the control layer intended.

Exhibit 22: Three layers of a typical industrial control system



Source: Public information, MioTech Research

The ICS industry is a multi-billion-dollar business. Big players like Siemens, Schneider, and ABB are comprehensive automation and process automation solution providers. The business scales of these companies are over $5 billion in ICS. Panasonic, Omron and mainly other Japanese companies provide specialty factory automation. Their automation business scales are around $1 billion to $5 billion. Overall, China's domestic market size for ICS is well over RMB200 billion.

The combination of industrial control with digitalization of equipment management, process management and energy efficiency improvement can present a total solution for energy management in the industrial sector. Industrial enterprises with large carbon emission exposure have a continuous demand in the coming years. However, the successful implementation of such total solutions depends on the understanding of the industrial process flow and operational characteristics and the full matching of key equipment such as VFD. Enterprises with technical know-how for industrial applications and key equipment manufacturing capabilities will have significant competitive advantages and gain solid growth prospects.

Company Implications

Shenzhen Inovance Technology (300124.SZ)

Shenzhen Inovance Technology Co Ltd is a China-based company principally engaged in R&D, manufacture and distribution of industrial automatic control products and new energy related products. Its main products include VFD, servo systems, control systems, industrial visual systems, sensors, motor controllers, auxiliary power systems, traction converters, auxiliary converters, high voltage boxes, traction motors and train control and managementsSystems (TCMSs), among others. The company distributes its products in the domestic market and to overseas markets. After 17 years of development, it has become a leading industrial automation enterprise in China. In 2021, the company's total revenue reached RMB18 billion.

Hiconics Eco-energy Technology (300048.SZ)

Hiconics Eco-energy Technology Co Ltd formerly Hiconics Drive Technology Co Ltd is a China-based company principally engaged in R&D, manufacturing and sales of high, medium and low voltage VFDs. The company's business covers industrial automation, power quality management, energy saving and environmental protection, clean energy and other fields. In April 2020, Midea Group took control of the company, and integrated the company into Midea Group's industrial technology business group. The company is the leading in the domestic high-voltage VFD market, ranking first in market share, with a share of more than 10%.

3. Waste heat recovery technologies gain traction

Waste heat resources are widely available in the industrial sector. These resources that cannot be directly reused in the production process are recoverable in the form of thermal energy. Waste heat resources are commonly found in various industries, including metallurgical, power generation, chemical, and food industries.. Waste heat resources have quite a lot of commonalities, such as wide temperature range, complex working mediums (often corrosive and dusty), and scattered throughout the production process. Efficient harvesting and utilization of these waste heat can often be found challenging with existing technologies.

The temperature of industrial waste heat is an important parameter to measure its quality. The temperature has a decisive role in the way waste heat is recovered and utilized. Industrial waste heat is divided into three categories, according to its temperature:

Exhibit 23: Categories of industrial waste heat

High temperature waste heat	Most of the industrial waste heat with temperatures above 500°C comes from industrial furnaces, such as smelting furnaces, heating furnaces, cement kilns, etc.
Medium temperature residual heat	Industrial waste heat at temperatures between 200 and 500°C, mainly comes from gas discharged from the high-temperature medium in various thermal powered plants and furnaces after heat transfer.
Low temperature waste heat	Industrial waste heat at temperatures below 200°C mainly comes from three sources: a. The low temperature direct waste heat emissions from some equipment; b. The high and medium temperature waste heat that has been primarily recovered; c. The waste heat from the cooling agent, between 25°C and 90°C.

Source: Review of Industrial Waste Heat Recovery Technology in China, MioTech Research

At present, China's energy utilization rate is only at about 33%, which is 10% lower than that of developed countries, and at least 50% of industrial energy consumption is directly discarded as waste heat in various forms. From another perspective, waste heat resources are abundant in China's industrial sector. Widely present in the production processes of various industrial sectors, these waste heat account for about 17% to 67% of total fuel consumption, of which the recoverable portion can be as high as 60%. There is a lot of room for improvement in the utilization rate of waste heat.

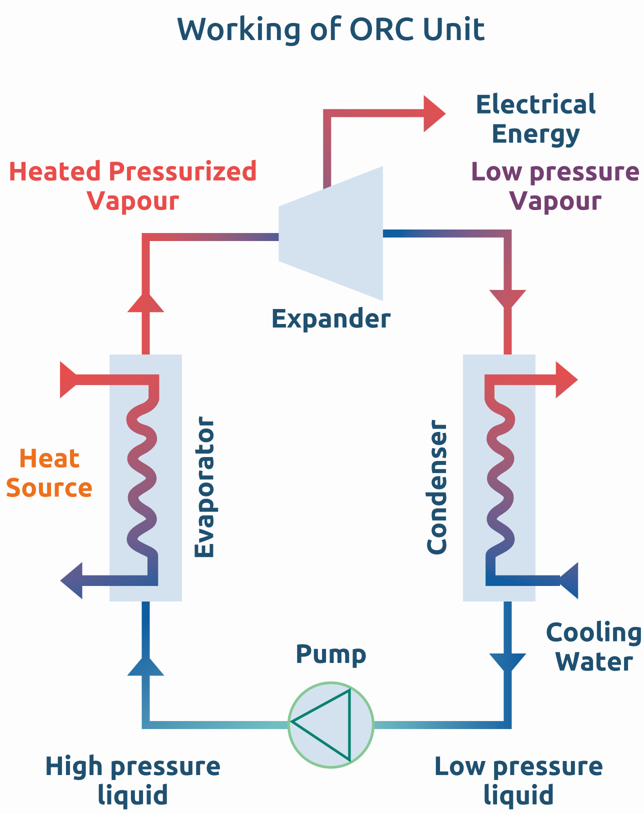
Organic Rankine Cycle and lithium bromide chillers gather momentum

High temperature waste heat recovery is a well-recognized technology, with a good economy of heat recovery for power generation. High temperature waste is generally recovered by waste heat boiler technology. Another matured technology example is the top pressure recovery turbine (TRT) generation system. The central government mandated restrictive policies on energy conservation and emission reduction over the years, and these technologies have been widely adopted by industrial companies to cope with the stringent target requirements.

On the other hand, waste heat recovery technology for medium and low temperature waste heat still has huge market potential. Medium and low temperature waste heat makes up the bigger proportion of total waste heat energy, for example in the petrochemical industry up to 80% of total waste heat resources are medium and low temperature. However, harvesting this type of waste heat has been less efficient due to technological limitations and lower grade of the waste heat, making the recovery process economically unattractive.

Organic Rankine Cycle (ORC) technology is on the rise for harvesting specifically medium and low temperature waste heat and generating electricity thereafter. Screw expansion power generation system has been developed based on ORC technology. In the process depicted below, industrial waste heat is passed through a heat exchanger that heats a process fluid with a lower boiling point than water into steam, which then enters a turbine to drive electricity generation.

Exhibit 24: The basic principle of an Organic Rankine Cycle Unit

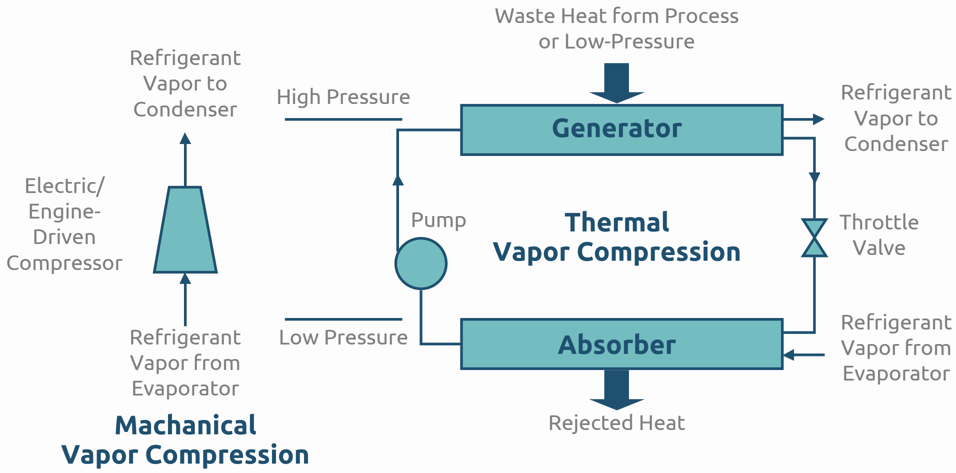


Source: Energy Education, MioTech Research

ORC systems have been successfully commercialized, and proven to be efficient and economical for recovering industrial waste heat. A number of ORC design and manufacturing manufacturers have emerged, such as Ormat in the USA, and Turboden of Italy. Big names in machinery manufacturing business such as GE and Mitsubishi have also set up new business lines for ORC generators. Besides industrial waste heat, the ORC system is also suitable for other low-grade energy sources, such as geothermal, solar and biomass.

For lower temperature waste heat resources, the lithium bromide (LiBr) absorption chiller is the niche solution, which can generally utilize low-temperature heat sources in the range of 80-250℃. In the oil and gas, chemical, metallurgical and coking industries, there are large amounts of separation water, processed wastewater and low-pressure waste steam. At the same time, these industries need a large amount of heat source in the production process. The LiBr absorption chiller can extract the heat from the low temperature waste heat and generate higher grade heating or cooling suitable for production use, saving fuel consumption in the process.

Exhibit 25: The working principle of a LiBr absorption chiller



Source: ACHR News, MioTech Research

In heavy industries, we estimate medium and low temperature waste heat suitable for ORC generator recovery totals 39.45 mtce in China. Based on recovery efficiency of 10%, the recoverable waste heat resources amounted to 3.945 mtce. Assuming annual average operational hours to be 7,000 hours, the recovery of this amount of waste heat requires an installed capacity of 4.58GW of waste heat power generation.

According to the above estimates, with the current cost of about RMB14,000 per kilowatt of ORC generator, the potential market size can reach RMB64 billion for heavy industries demand. In addition, fine chemical, building materials, oil and gas industries also have a large amount of low-temperature waste heat resources. A rough estimate shows that the potential demand for medium and low-temperature waste heat recovery in the industrial sector can reach RMB 150 bn.

Company Implications

Kaishan Group Co Ltd (300257.SZ)

Kaishan Group Co Ltd is principally engaged in the development and manufacture of air compressors, expansion generators and compressors. The company's products are widely used in mining, metallurgical, petrochemical, and machinery manufacturing industries for low-grade heat recovery and power generation. The company's proprietary screw expander is world-leading in mechanical performance, which helps the company's business venture into the development of geothermal power plants.

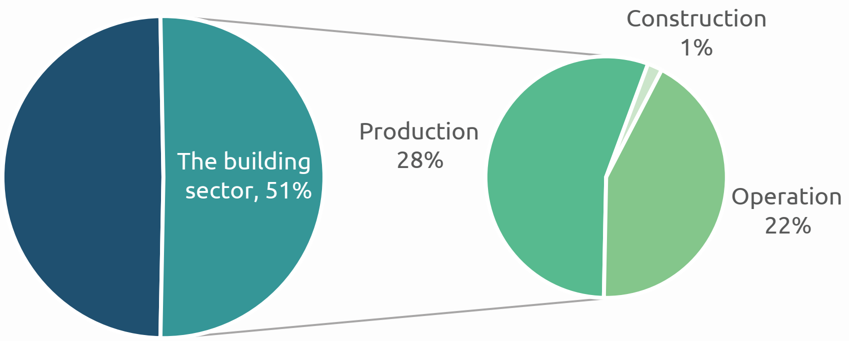
Shuangliang Eco-Energy Systems Co Ltd (600481.SH)

Shuangliang Eco-Energy Systems Co Ltd is mainly engaged in industrial waste heat recovery. The company's main products include lithium bromide cooling and heating units, heat exchangers and air cooler systems. The company ranks first in the absorption chillers industry with more than 25 years of experience in manufacturing.

The Building Sector

The decarbonization of the building sector, especially its life cycle carbon emission reduction, plays an important role in the demand side net-zero progress. The life cycle carbon emissions of the building sector mainly consist of: direct and indirect emissions 1) from the production of construction and building materials 2) from the construction process 3) during the operation period of the building. Life-cycle carbon emissions from the building sector account for about 50% of all carbon emissions in China. Among them, the production, construction, and operation phases account for 28%, 1%, and 21.6% of the national carbon emissions, respectively.

Exhibit 26: The proportion of life cycle carbon emissions of the building sector to the total emissions



Source: China Building Energy Efficiency Association, MioTech Research

We also note that there are two other relevant issues that cannot be ignored when considering the decarbonization of the building sector. One is that China is still among developing countries, for which urban and rural construction is still the most important government-led effort. Policy plans, guidelines and requirements for green buildings, construction methods, green building materials and operation management will have a significant impact on the segments. Secondly, as the level of China's economic and social development increases, the end-consumers of the building sector -- residents -- have a higher demand for better living environments. Therefore, the decarbonization of the construction sector also needs to provide residents with more livable working and living spaces.

In March 2022, the Ministry of Housing and Construction released the 14th FYP for the Development of Building Energy Efficiency and Green Buildings. This medium-term plan can be seen as the core efforts of the central government to decarbonize the building sector, with seven specific targets proposed for building energy efficiency and carbon emission reductions. For these proposed targets, we have identified the current progress for comparative analysis in the following Exhibit.

Exhibit 27: Comparison on targets for the 14th FYP and current progress for key performance indexes mentioned in the 14th FYP for Building Energy Efficiency and Green Building Development

	Targets for the 14th FYP period	Progress by the end of the 13th FYP
Energy efficiency retrofitting of existing buildings (billion m2)	3.5	5.14
Construction of ultra-low and near-zero energy floor space (billion m2)	0.5	0.1
Proportion of prefabricated construction in the new buildings	30.00%	20.50%
New installed building solar PV capacity (million kW)	50	0.716 (Yr2020)
New geothermal energy building applications (million m2)	100	17 (Yr2020)
Renewable energy replacement rate for urban buildings	8%	6%
Proportion of electricity consumption in building energy consumption	55%	44%

Source: Ministry of Housing and Construction, China Electricity Council, MioTech Research

Taking the guiding policy trends and the development of the technologies into consideration, we identify the following fields with significant upward potential during the 14th FYP (described in detail in later chapters):

1. Prefabricated construction will be an increasingly common construction method, especially for steel structure buildings. At the same time, the construction of traditional buildings should be in line with the requirements of resource conservation and as resource-efficient as possible.

2. The concept of net-zero buildings, including passive buildings and ultra-low energy consumption buildings could gain traction with the implementation of various green technologies. Among which, we believe building-integrated photovoltaics and energy-saving building materials have remarkable potential for growth.

3. Intelligent operation and maintenance should be carried out in combination with the latest building technology to realize energy saving in the operation phase of the building sector. The heating needs for Northern China buildings take up 11% of total energy consumption of the country. The electrification of space heating with air-source heat pumps can result in significant emission reduction.

1. Prefabricated construction leads the trend of low-carbon construction

Prefabricated construction (or "prefab") is a method of construction that uses components made off-site in a factory, which are then transported and put together on-site to create a structure. This transfers a large amount of on-site work from traditional construction sites to factories, where building components and accessories (such as floor slabs, wall panels, stairs and balconies.) are processed and made. These parts are then transported to the construction site, assembled and installed through reliable connections. Prefabs can be concrete, steel or wooden structures. The standardized design allows for factory mass production and refined management.

The carbon emissions of prefab are significantly lower than those of traditional construction methods. According to academic studies, prefab can achieve 51% carbon emission reduction in production, transportation, and installation construction. This is mainly due to the traditional method being difficult to finely manage, resulting in higher material and energy waste, which increases carbon emissions. In addition, prefab has greater potential for further carbon emission reduction. Thanks to the standardized design and factory production, which makes it easier to improve the prefab production process.

The industrialized construction of prefabs brings environmental benefits as well. As most of the dirty work moved to indoor factories, the method effectively reduced exhaust and wastewater emissions to the environment. Construction dust, noise pollution, as well as the construction waste are reduced consequently. More importantly, prefab requires a smaller number of construction workers on-site than traditional construction, which is widely believed to be one of the key reasons why the Chinese government spares no effort in promoting prefab - the number of construction workers will be unsustainable as the aging population becomes apparent.

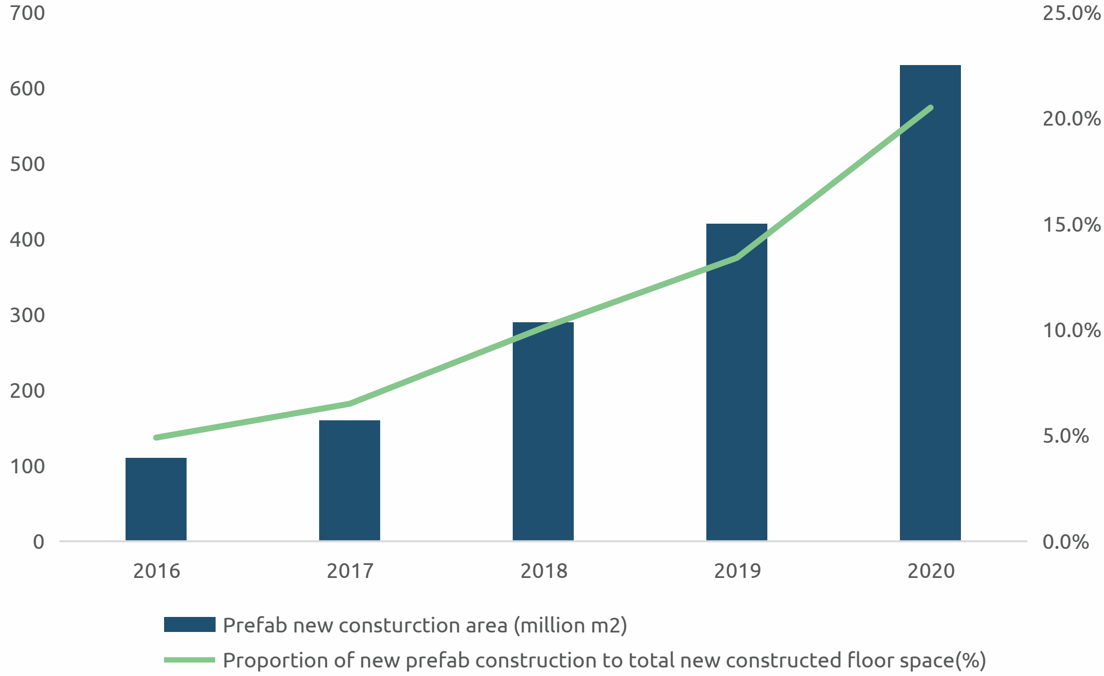
Exhibit 28: Comparison between prefab and traditional construction in terms of energy-saving and environmental performance

Performance	Prefab	Traditional Construction	Improvements prefab vs. traditional
Project Duration (Days)	160-210	250-300	20% - 45%
Number of workers required on site	40 -50	150-160	60% - 75%
Water consumption (m^3/m^2)	0.051- 0.067	0.085- 0.09	35% - 40%
Energy consumption (kwh/m^2)	7.0 - 7.1	8.9 - 9.0	20% - 25%
Construction waste volume (kg/m^2)	7.34 - 7.35	23.75 - 23.80	65% - 70%
Dust, PM10 ($\mu g/m^3$)	60 - 75	85 - 100	20% - 30%

Source: Guosheng Securities, MioTech Research

Prefab has a number of significant advantages over traditional construction. Therefore, in the early stage of its development, the Ministry of Housing and Construction strongly advocated and proposed a mandatory proportion of prefab's share in new construction. For example, in the 13th FYP action plan for prefab, the Ministry proposed the proportion to reach 15% in 2020. In fact, the ratio of prefab construction in total new construction in 2020 was 20.5%, significantly exceeding the policy target.

Exhibit 29: Proportion of new prefab construction to total new constructed floor area in China, 2016 to 2020



Source: Ministry of Housing and Construction, MioTech Research

The Ministry expected prefab's penetration rate to reach 30% in the 14th FYP. We believe that 30% target is easily achievable by 2025, and excessive penetration rate can be expected for the following reasons:

- Provincial governments have set higher penetration rate targets than the Ministry. It is being promoted by local governments for the advantages of fostering local industries and the reduction of dust, noise and waste pollution.

Exhibit 30: Recent measures to promote prefabricated construction on the local government level

Time	Province	Promotional Measures	Contents
2022/3/31	Jiangsu	Issued Highlights of the province's construction industry modernization efforts in 2022	By the end of 2022, the province's new construction of prefabricated buildings will account for 37% of new construction of floor space in the same period.
2022/3/17	Anhui	Province-wide seminar on assembly-style construction of Department of Housing and Construction	The proportion of prefabricated buildings in new buildings in the province will reach more than 25% by 2022.
2022/3/15	Tianjin	14th Five-Year Plan for the development of assembly-type buildings by Jinghai District	In 2025, the implementation ratio of prefabricated buildings for new residential buildings in the whole area of Jinghai District will reach 100%.
2022/3/7	Hunan	Provincial prefabricated building development promotion meeting	The proportion of assembled floor space in new urban buildings in the province will reach more than 32% by 2022, with Changsha, Zhuzhou and Xiangtan city reaching more than 35%.

2022/3/2	Hangzhou	Issued Implementation Opinions on Promoting High Quality Development of Construction Industry	35% implementation rate of new residential prefabricated buildings by 2022.
2022/2/25	Hainan	Issued Several Opinions on Further Promoting High-Quality Green Development of Assembled Buildings in the Province	In 2022, the proportion of new prefabricated construction to total new buildings will be 60%; by 2025, the proportion will be greater than 80%.
2022/2/25	Jiangxi	Provincial prefabricated building development promotion meeting	In 2022, the area of new prefabricated construction in Jiangxi Province will reach 30% of the total construction area.
2022/2/21	Henan	Issued The 14th Five-Year Plan for Urban Renewal and Urban and Rural Habitat in Henan Province	In 2022, the area of new prefabricated construction in Henan Province will reach 30% of the total construction area.
2022/2/8	Hubei	Issued Implementation Opinions on Promoting the Development of New Type of Building Industrialization and Intelligent Construction	By 2025, the proportion of prefabricated buildings in the province's new construction area will be no less than 30%.

Source: Public information, MioTech Research

- Preferential land concession conditions are the most powerful policy tool to promote assembled buildings. Currently, Beijing, Shanghai, Guangzhou, Shenzhen, Jiangsu, Zhejiang, Heilongjiang and Chongqing have all added prefab mandates to their land concession requirements. With the Ministry's 2022 work session on prefab deployment, we expect that further prefab penetration rate requirements will be added to land concession conditions across the country.
- The increase in the concentration of the real estate development industry is conducive to the advancement of prefab buildings. The biggest primary driver for prefab comes from large property companies. Vanke, for example, began piloting prefab in 2003 and established the Vanke Factory Center, which is dedicated to prefab assembly systems. Its first prefab built high-rise residence project was nine months ahead of the construction schedule compared to traditional construction. Large real estate developers can effectively take advantage of the benefits of prefab construction by establishing a complete set of building construction models that can be adapted to prefab construction, while amortizing the higher upfront costs of prefab factory with project replication. The construction time savings from prefab can subsequently reduce interest and financial costs, and improve capital turnover.

Considering the above factors, we expect that the penetration rate of prefab in new instructions will exceed the planning target of 30%, reaching 32-38% by 2025. Subject to the slowdown of the real estate industry and the financial constraints of real estate development enterprises, China's new construction floor area declined in 2021 and is expected to pick back up in 2022. We assume that the ratio of prefab concrete structure and steel structure is 6:4. The market size of prefab construction in China is estimated to be around RMB1.5 trillion in 2020, and is expected to reach RMB2.7 trillion in 2025, with a CAGR of 12% in five years. By 2030, the market size of prefab is expected to exceed RMB5 trillion, and by 2060, it will reach Rmb10 trillion.

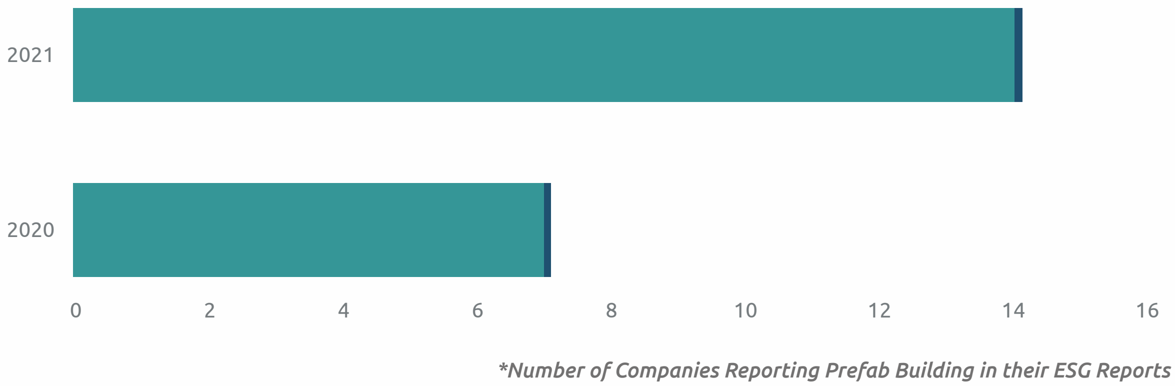
Exhibit 31: Prefab market size projections, 2022-2060

	2020A	2021E	2022E	2023E	2024E	2025E	2030E	2060E
New construction floor space (billion m2)	30.7	27.3	28.7	30.1	31.6	33.2	36.7	49.4
Prefab penetration rate	20.5%	23%	25%	27%	29%	32%	55%	80%
New construction of assemblies (billion m2)	6.3	6.3	7.2	8.1	9.2	10.6	20.2	39.5
Percentage of prefab concrete (PC)	68%	60%	60%	60%	60%	60%	60%	60%
Percentage of prefab steel (PS)	32%	40%	40%	40%	40%	40%	40%	40%
Unit cost of PC structures (RMB/m²)	2231	2264	2297	2330	2363	2396	2396	2396
Unit cost of PS structures (RMB/m²)	2776	2776	2776	2776	2776	2776	2776	2776
Market size of prefabconstruction (RMB trillion)	1.51	1.55	1.78	2.04	2.32	2.71	5.14	10.07

Source: National Bureau of Statistics, Ministry of Housing and Construction, MioTech Research

Through MioTech's ESG data, we find an increasing number of Chinese property developers and engineering companies taking on prefab. In 2020 and earlier, large property developers have reportedly implemented prefabricated technologies, while we found out that more recently in 2021, developers of smaller businesses and regional construction companies have also started reporting their engagement in prefabricated construction.

Exhibit 32: Number of property development companies reporting the use of prefab in their ESG reports



Note: The average market cap of reporting developers in 2020 is USD 4.8 bn, while the average market cap of those in 2021 is USD 2.8 bn.

Source： MioTech Research

The biggest challenge that hinders the large-scale application of prefab is its economy of scale. Current engineering practice shows that the cost of prefab concrete and steel is generally RMB300 to RMB2,500 per square meter higher than that of traditional cast-in-place structures. The higher cost is attributed to the fact that the current building structure design has not been optimized for prefab, wasting prefab's material-saving potential, while the high up-front investment of prefab factories and insufficient utilization of factory capacity driving up the cost of prefab. It is expected that as the prefab scales with the increasing penetration, the economy of scale will be further improved.

Company Implications

Changsha Broad Homes Industrial Group Co Ltd (02163.HK)

The company provides comprehensive solutions for industrialization of the construction industry. The company operates its businesses through three segments. The prefab concrete unit manufacturing segment provides customers with comprehensive solutions for prefabricated construction, including unit design, manufacturing and assembling consultation. The prefab concrete equipment manufacturing segment provides equipment specially designed to provide value-added services. The construction contracting segment performs the construction contract in accordance with designs and timetable provided by architectural design organizations and the project owner. The company has 15 self-owned factories and over 70 production lines.

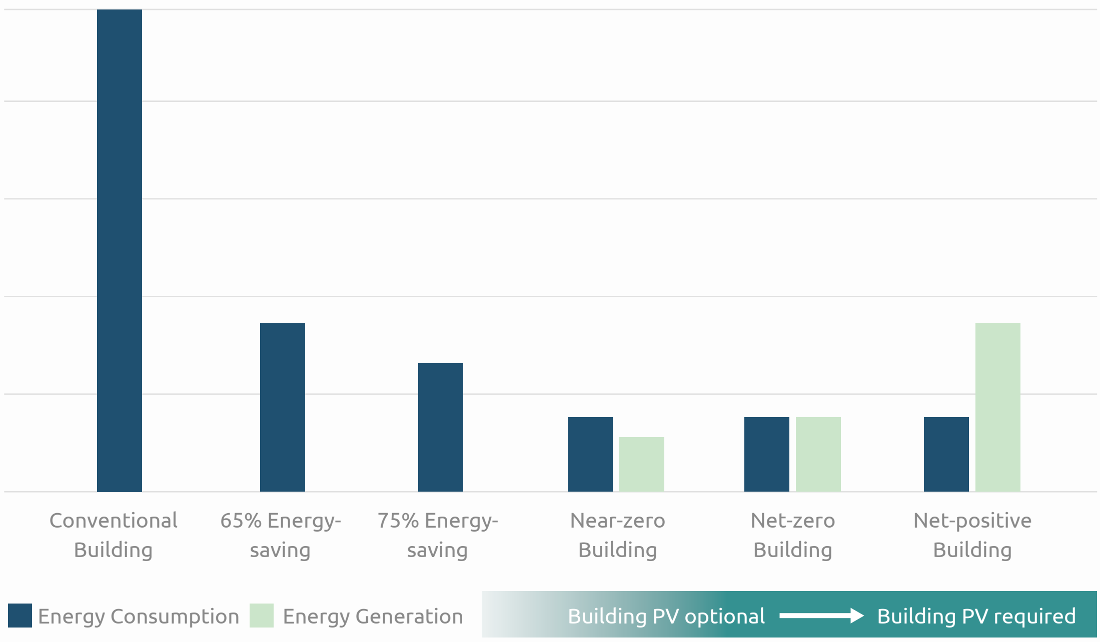
Changjiang & Jinggong Steel Building Group Co Ltd (600496.SH)

The company is a leading company in the domestic prefab steel industry. founded in 1999, The Company is principally engaged in the manufacturing of steel structure industrial buildings, commercial buildings, public buildings and curtain walls, as well as the provision of related engineering services. The company's main products include light steel structures, space large span steel structures, high-rise steel structures, envelope systems and fasteners, as well as curtain wall systems. It mainly operates its businesses in the domestic and overseas markets.

2. BIPV and energy-saving materials empower passive buildings

The passive building system can be used in the design of the building to maximize its energy saving and emission reduction performance during its operation phase. Ultra-low energy buildings and near-zero energy buildings can be considered "passive buildings", which are constructed by combining various passive energy-saving measures such as natural ventilation, natural lighting, solar radiation heating with improved facade heat insulation. Near-zero energy buildings are a higher level of ultra-low energy buildings. Furthermore, if a building consumes an equal or smaller amount of energy than its energy generation, it can be considered a net-zero building.

Exhibit 33: Energy consumption and supply of various types of buildings



Source: Public information, MioTech Research

The passive building concept is considered one of the important directions of future building development. In September 2019, China's national technical standard for near-zero energy buildings was officially published. This is the first time that near-zero energy buildings are clearly defined in the form of a national standard in the world, and it is also the first guiding national standard for building energy efficiency in China.

At present, Beijing and provinces such as Shandong, Henan and Jilin have introduced incentives and technical guidelines for the demonstration of ultra-low energy consumption buildings. As ultra-low energy consumption building technologies continuously evolve, relevant applications for civil, public and high-rise buildings have broad space for development.

Building Integrated Photovoltaic (BIPV) market explodes with energy transition and passive building development

Building Integrated Photovoltaic (BIPV) is the integration of photovoltaics (PV) into the building envelope. The technology is expected to become an important application scenario for distributed PV, which is developing rapidly and gradually becoming the mainstream of PV new installations. According to the National Energy Agency data, in 2021, China's total distributed PV reached 107.5 GW, about one-third of all installed PV power generation capacity. In terms of new installations, distributed PV contributes 29 GW, accounting for about 55% of all new installed PV capacity. For comparison, the number was only 6% in 2013.

Exhibit 34: Photo of BIPV roof

Source： solarpowerportal.co.uk

Supported by favorable policies, photovoltaic facilities have gradually broadened their application in the building sector. In 2021, the central government started to roll out guiding policies for building PV applications, and set targets for rooftop PV installations. Local governments have also introduced subsidy programs for BIPV from 2021 onwards.

Exhibit 35: Policy documents on BIPV and their key takeaways

Date	Central government policies	Key takeaways
Oct-21	State Council's Action Plan for Carbon Peaking by 2030	Promote the integration of photovoltaic power generation and building applications. By 2025, the urban building renewable energy replacement rate of 8%, new public institutions buildings, new factory roof PV coverage rate to reach 50%.

Date	Central government policies	Key takeaways
Jun-21	the National Energy Agency's Notice of on the Submission of Pilot Program of Rooftop Distributed Photovoltaic Development for the Whole County (City, District)	For demonstration projects, it requires the ratio of the total roof area suitable for PV installation generation not less than 50% in public institutions; 40% for schools, hospitals, and other public buildings; 30% for industrial and commercial plants; and 20% for rural residential buildings.
May-21	Ministry of Housing and Construction Opinions on Strengthening Green and Low-carbon Construction in County Cities	By raising rooftop photovoltaic applications on new factories, public buildings and other rooftops, and promoting the use of building integrated photovoltaics, it intends to build low-carbon energy systems in county cities. Decentralized wind power, distributed photovoltaic, intelligent photovoltaic and other clean energy applications are promoted.
Date	**Local government policies (selected)**	**Key takeaways**
Nov-21	Guidelines for the Declaration of Subsidy Funds for Demonstration Projects of PV Building Integration Application in Xi'an City	For new BIPV projects, after completion of the grid and acceptance, the developer is given a one-time subsidy of RMB 0.3 / watt according to the installed capacity, with a maximum of RMB 1 million for a single project.
May-21	Measures for Promoting Green Low-carbon Development in Huangpu District, Guangzhou Development Zone, Guangzhou High-tech Zone	For distributed PV generation investments, a tariff subsidy of RMB 0.15/ kWh on non-public building roofs, and RMB 0.3/ kWh on public building are provided to the developer. A single project can receive subsidies for up to 5 years.
Mar-21	Measures for the Management of Green Building Demonstration Projects in Nanjing	Provide building PV with a subsidy of no more than RMB 500/ kW. In principle, the maximum subsidy for a single demonstration project does not exceed RMB 2 million.

Source: Public information, MioTech Research

Currently, there are two main forms of building photovoltaic facilities. According to the degree of integration into the building, these can be divided into Building Attached Photovoltaic (BAPV) and BIPV. With its advantages in cost and performance, BIPV is gradually becoming the mainstream technology.

- BAPV installs PV modules on existing buildings. It is mainly attached to the roof, wall and other building structures without affecting the existing building materials.
- BIPV integrates PV modules into the building structure. It serves the function of both PV power generation and building material.

Exhibit 36: BAPV and BIPV comparisons

	Building Attached Photovoltaics (BAPV)	Building Integrated Photovoltaics (BIPV)
Cost	Construction cost: BAPV system unit cost RMB 572/sqm	Construction cost: BIPV costs RMB 408/sqm, cost savings of RMB 164 per sqm
	Lifespan: About 15-20 years	Life span: about 50 years
Structural performance	Safety: under the influence of external wind force, the safety level is compromised	Safety: roof structure level of safety, with good load bearing capacity
	Waterproofness: potential water leakage with deformation caused by stepping during construction, self-weight load, and etc.	Waterproofness: designed with drainage system in place, and the structure is designed with anti-vibration features to prevent roof deformation
Aesthetics	Usually only applicable on flat surfaces, with poor ornamental properties	PV modules are embedded in the building materials, and can be incorporated as ornamental features in the architectural design
Applicable fields	Old buildings - BAPV has cost advantages for buildings with a large amount of demolition work	New buildings - BIPV can be designed and installed directly, mainly for buildings with high roof utilization rate such as commercial and industrial buildings
		Old buildings - suitable for retrofitting projects with low cost of demolition works such as steel structure buildings

Source: China Energy Network, MioTech Research

BAPV has been the mainstream PV building application in China up to now partially because it can be directly retrofitted to the old buildings, while the development of BIPV was limited by the integration and installation technologies in the early days. Right now, BIPV has the obvious edge on economics and performance. It is foreseeable that BIPV will be the preferred choice for new buildings. In the old buildings retrofitting market, BIPV and BAPV will share the market.

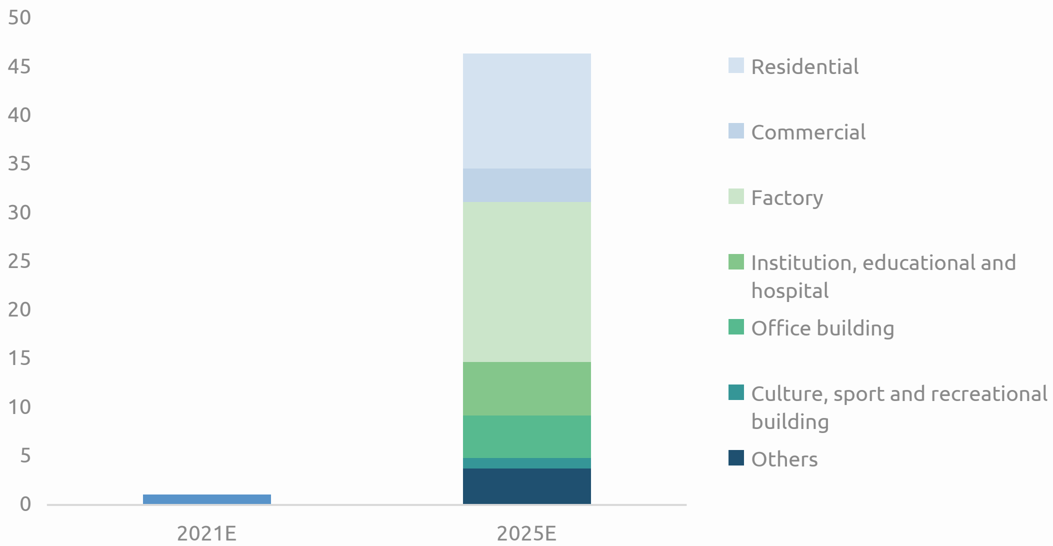
We calculated market size and made a 2025 forecast based on completed construction area data from the National Bureau of Statistics. Industrial and commercial roofs will become the breakthrough area for BIPV installation. We estimate over one-third of BIPV will be installed on industrial roofs. The total market size of BIPV shall reach RMB 110 billion in 2025.

Exhibit 37: BIPV market size projections, 2025

	Completed construction area in 2021 (million m^2)	Roof area (million m^2)	Penetration rate	PV -install-able area (billion m^2)	BIPV installation (GW)	Market size in 2025 (RMB bn)
Residential	2,706	1,177	10%	118	11.8	29.4
Commercial buildings	253	116	30%	35	3.5	8.7
Industrial buildings	564	328	50%	164	16.4	41.0
Institutions, education and hospital buildings	209	138	40%	55	5.5	13.8
Office buildings	167	110	40%	44	4.4	11.0
Cultural, sports and recreational buildings	41	27	40%	11	1.1	2.7
Others	143	94	40%	38	3.8	9.4
Total	**4,083**	**1,989**		**464**	**46.4**	**115.9**

Source: Bureau of Land and Resources, Bureau of Statistics, MioTech Research

Exhibit 38: BIPV installation projections (GW), 2021E and 2025E



Source: Bureau of Land and Resources, Bureau of Statistics, China BIPV Alliance, MioTech Research

The BIPV technology has not yet been implemented on a large scale, mainly due to the fragmentation of supply chains. BIPV integrates building material with PV modules. The two industries have distinctive requirements: For PV, energy generation efficiency is the key, while for the function of building material, the structural strength, aesthetics, and durability are much more important. It is necessary for ministries to issue unified national standards as soon as possible, to standardize the manufacturing and installation of BIPV. The standards need to address topics on raw material performance, construction and installation, safety testing, integrated equipment standards, and compliance requirements for end products.

Exhibit 39: The BIPV value chain segments

Upstream	Midstream	Downstream
PV cell manufacturer (Gross margin of about 25%) Building material manufacturer (Gross margin of about 10%)	Module Integrator Contractor	Developer and Operator (Gross margin of about 25%)

Source： BIPVBoost, MioTech Research

According to the calculation of BIPVBoost, the two segments with the highest rate of return in the value chain are PV module manufacturers and operators, each enjoying a gross profit margin of 25%, and are located in the upstream and downstream of the whole value chain. Therefore, for BIPV rooftop end users, the total cost for installing BIPV mainly comes from the cost of the modules (66%), with project planning and construction accounting for the rest of the total cost.

Exhibit 40: Typical cost structure of BIPV

Module manufacturing cost 66%	Design and other indirect costs 19.50%	Construction and installation costs 14.50%
PV cell - 40%	Sketch planning - 4%	Transportation and warehousing - 2%
Module Assembly - 12%	Technical design - 7.5%	Preparation - 0.5%
Other accessories (inverters, cables, etc.) - 14%	Administrative and overhead - 8%	Installation - 12%

Source: BIPVBoost, MioTech Research

For BIPV contractors wishing to expand their business, vertical integration pathways are possible in both backward and forward directions:

- Backward integration: BIPV contractors can cooperate with PV cell manufacturers to gain advantages on energy generation efficiency. Just like other distributed PV plants, the economics of BIPV is largely determined by its power generation efficiency. Expanding business to PV module manufacturing provides cost reduction potential on this key component.
- Forward integration: BIPV contractors can also expand their business to the investment and operation of this electricity generation device. This enables construction companies to earn long-term stable operating income. On the other side, expanding to investment and operations requires construction companies to have higher risk-taking ability and strong financial support.

Assuming the form of power generation for self-consumption and residual power supply, we analyzed the economics of BIPV installed on a steel structure factory with a rooftop area of 1,000 square meters. The project's internal rate of return is 13% and the payback period is 6.56 years. Although the initial investment of BIPV is higher than the conventional roof, the end user can recover the cost in a relatively short amount of time.

Exhibit 41: Economic analysis of a BIPV project

Indicators	**Assumptions**		
BIPV installation cost (yuan/sqm)	RMB 408/sqm		
Annual sunlight hours (h)	1000		
Roof utilization rate	100%		
PV power generation (W/m²)	100		
Lifespan	The project life time is assumed to be 25 years		
Electricity price	The price of electricity for self use is calculated as RMB 0.64/kWh; Benchmark tariff is RMB 0.46/kWh.		
Operation and maintenance costs	3% of the initial investment.		
Subsidy	RMB 0.05/kWh		
Proportion of electricity sold back to the grid	20%		
Upfront Cost			
Roof area	1000 sqm		
BIPV unit cost	RMB 408 per sqm		
Total cost	RMB 408,000		
Operation Cost		**Return**	
Operation and maintenance	3% of the initial investment	Electricity bill saving	RMB 51,200
Annual operation cost	RMB 2,280	Sale of excess electricity	RMB 9,200
Annual depreciation	RMB 25,840	Subsidy	RMB 5,000

Source: MioTech Research

Promoting the integration of solar PV with new buildings has been an inevitable trend for property developers in 2021. We saw 57 companies install PV in their commercial/industrial property developments in 2021 in comparison to only 27 in 2020.

Company Implications

Zhejiang Chint Electrics Co Ltd（601877.SH）

The company's main businesses include low-voltage electrical device manufacturing and PV power plant operation. In 2020 and the first half of 2021, the company newly installed 1.8GW and 1.05GW of capacity for households, accounting for 17.82% and 17.84% of the total domestic households installed capacity, ranking first in China's market.

Arctech Solar Holding Co Ltd（688408.SH）

Arctech Solar Holding Co Ltd is a high-tech company focusing on solar PV brackets. The main products are PV tracking brackets and fixed brackets. Tracking brackets are mainly composed of three parts: structural system (rotatable bracket), drive system and control system. Fixed brackets are composed of columns, main beams, purlins, foundations and other components. It is also involved in the development of BIPV products. The company distributes its products within the domestic market and to overseas markets. By the end of 2020, the company has installed nearly 1,100 projects in 40 countries around the world.

Changzhou Almaden Co., Ltd. (002623.SZ)

The company is principally engaged in the research and development of PVglass coating technology, as well as the production and sale of PV coated glass. The Company distributes its products in both domestic and international markets.

Trina Solar Co Ltd (688599.SH)

Trina Solar Co Ltd is a company mainly engaged in research, development, production and sales of photovoltaic products. The company operates five segments, comprising PV modules, system products, PV power plant engineering construction management, PV power plant sales and smart energy. The PV modules segment operates R&D production and sales of monocrystalline and polycrystalline PV modules. The system products segment provides customers with Trina intelligent optimal distribution, commercial systems and household systems. The PV power plant engineering construction management segment's businesses involve power generation of PV power plants and its operation and maintenance, as well as energy cloud platform operation. The company sells its products and services to both domestic and international markets, including the United States, Europe, Japan and Latin America.

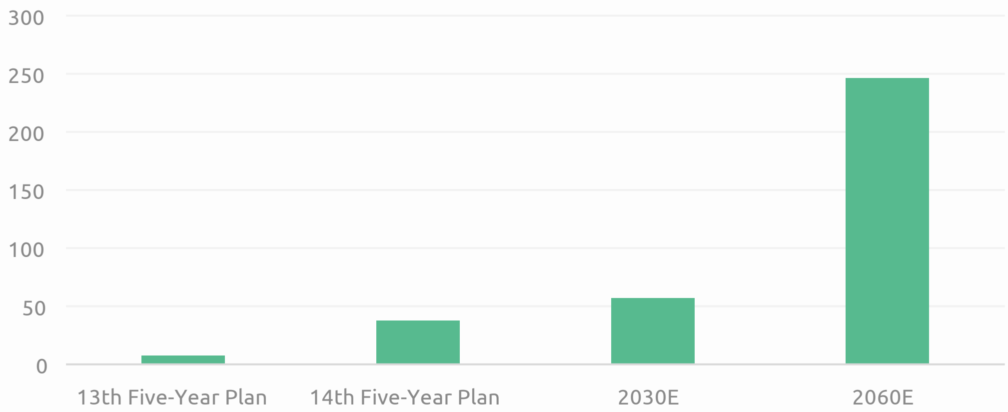
Energy-saving building materials

Passive building is a building form driven by low-carbon design, selecting building materials and electrical appliances of outstanding energy-saving performance, and integrated with renewable energy generation. With the help of efficient external wall thermal insulation systems, high-performance windows (double or triple-paned) and doors, heat and moisture recoverable ventilation systems, and shading systems, passive buildings can achieve constant temperature, humidity, and temperature in the indoor environment, relying on just natural heat gains such as solar radiation, human body heat, and heat dissipation by appliances.

The concept of passive building was first put forward by Germany and promoted with the name ultra-low energy consumption building in China. Its application in residential and commercial buildings is gradually shifting from demonstration projects to commercial projects. A number of real estate companies, such as Landsea Group, Longfor Group and Yuanda Housing, have incorporated passive houses into their product offerings. Benefiting from this trend, nice markets such as high-performance windows, shading systems, thermal insulation products will gain traction and promote the innovation and development of upstream energy-saving materials.

In the 14th FYP for the Development of Building Energy Efficiency and Green Building the Ministry of Housing sets the target for the ultra-low energy consumption building area during the 14th FYP period of 50 million square meters, compared with 10 million square meters for the 13th FYP period. Based on the incremental cost of ultra-low energy consumption buildings of RMB500-1,000 per square meter, it is estimated that the domestic market size for the application of energy-saving building materials in ultra-low energy consumption buildings will increase nearly RMB40 billion, or an average of 38% CAGR from now to 2025. In addition, we predict that energy-saving building materials will continue the rapid growth from 2025 to 2030, and maintain an average annual growth rate of 5% after 2030, reaching a market size of RMB246 billion in 2060.

Exhibit 42: Projections of application scale of energy-efficient building materials for ultra-low energy buildings (RMB billion)



Source: MioTech Research

Furthermore, the improvement of the living comfort of passive buildings has made the related products penetrate rapidly in the domestic high-end housing and the foreign developed countries market in Europe and North America. We expect that the revenue of leading enterprises in the value chain will maintain a sustained growth of more than 25% CAGR in the next few years.

Company Implications

Jiangyin Haida Rubber and Plastic Co., Ltd (300320.SZ)

The company is principally engaged in R&Dt, production and sale of rubber and plastic parts for high-end equipment. The company's product offerings revolve around two main functions - sealing and vibration damping, which are applied in construction and transportation sectors. The construction applications include building exterior window seals, curtain wall seals, aluminum alloy doors and window rubber strips. In addition, the company's rubber products have also been integrated to the BIPV products, with leading comprehensive performance.

Shandong Yuma Sun-Shading Technology Corp Ltd (300993.SZ)

The company is principally involved in the research and development, production and sales of functional shading materials. Its main products include shading fabrics, dimmable fabrics and sunlight fabrics. The company's products are mainly used in the fields of home interior shading, public construction engineering interior shading and exterior shading. The company distributes its products both in the domestic market and overseas.

Asia Cuanon Technology (Shanghai) Co., Ltd. (603378.SH)

The company is a China-based company principally engaged in R&D, manufacturing, sales and service-providing of building insulation decoration integrated products, building insulation materials, functional architectural coatings and its application systems. The company operates through two main segments. The main business segment is principally involved in the sales of building decoration materials, including insulation decorative panels, insulation board and functional architectural coatings, among others. The other business segment is mainly engaged in the sales of related supporting materials.

Beijing Oriental Yuhong Waterproof Technology Co., Ltd. (002271.SZ)

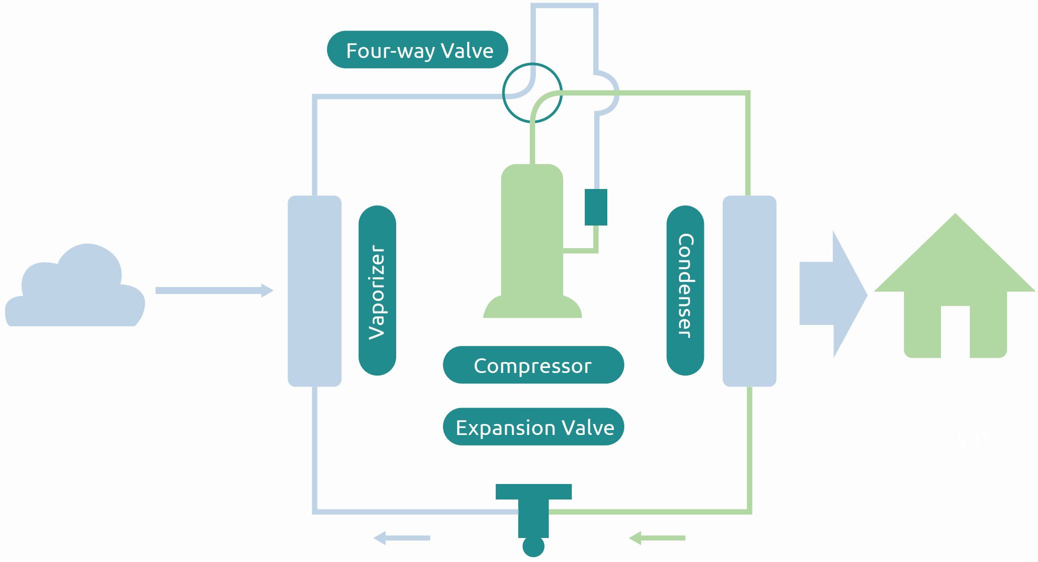
Beijing Oriental Yuhong Waterproof Technology Co., Ltd. Is the leading company in the research, development, manufacture and distribution of waterproof materials. In the past few years, the company successfully extended its business fields, to energy-saving and heat preservation, civil building materials, non-woven fabrics, architectural coatings, building repair, mortar powder, and special films. The company went public in 2008. Its operating income in 2021 exceeded RMB32 billion, which is a 40-fold increase from 2008 to 2021.

3. Air source heat pumps - the key driver for space heating electrification

Building energy use, such as cooling, lighting, and household appliances, has been mostly electrified. The use of high-efficiency air conditioners and energy-saving LED lamps has also greatly improved the overall energy efficiency. At the same time, the energy consumption for space heating is still dominantly supplied by traditional fossil fuels, i.e., coal-fired power plants for central heating in Northern China and household natural gas boilers in the southern region. To keep up with overall electrification progress in the building sector, the application of air source heat pump technology for space heating is the key.

An air source heat pump works by absorbing heat from outside a structure and releasing it inside using the same vapor-compression refrigeration process and much the same equipment as air conditioners but used in the opposite direction. The air source heat pump can have flexible configurations at the end point of heat transfer, including hot air blower, radiator, floor heating, or directly supply domestic hot water. In the summertime, the air source heat pump can also be used as a cooling system.

Exhibit 43: The working principle of air source heat pump

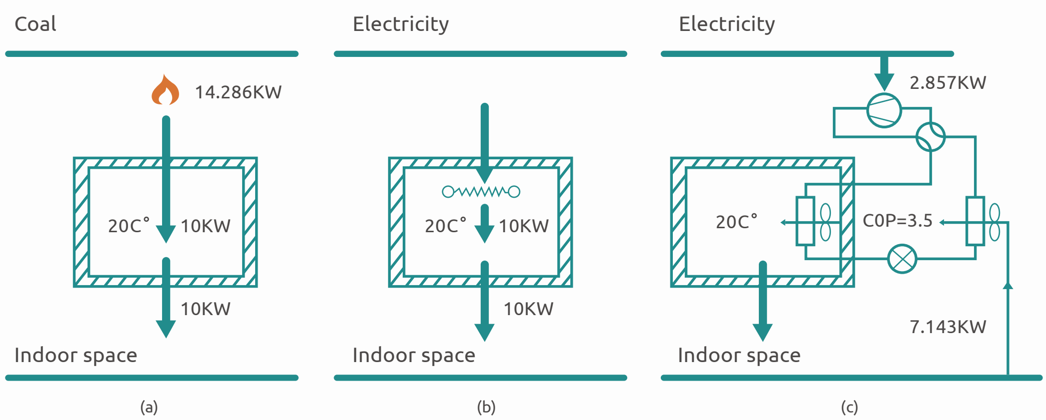


Source: China Energy Conservation Association Heat Pump Special Committee, MioTech Research

Heat pumps for heating can be widely used in commercial buildings and residential homes. These products directly replace traditional boilers burning coal, natural gas and other fossil fuels, reducing the use of fossil fuels to achieve electrification. In addition, heat pumps are much more energy-efficient, consuming only electricity to drive the compressor by absorbing "free heat" from the air. In theory, an air source heat pump can produce more than 3-4 units of heat for every 1 kWh of electricity consumed, implying a coefficient of performance (COP) value of 3-4), compared with a traditional electric heating device using resistance heating, which has a COP value of about 1), or a 75-80% of energy consumption saving under the same circumstances.

Taking the energy consumption of indoor heating as an example, the results of the three heating schemes are significantly different. If 10kW of heat output is needed for this room to maintain an air temperature of 20 degrees Celsius, using coal-fired heating requires 14.286kW of energy input and emits a lot of pollutants from the process; using a resistance heater to directly heat the air in the room requires about 10kW of electrical power; using a heat pump of COP value of three in the same scenario consumes only 2.857kW of electrical energy.

Exhibit 44: Energy consumption under coal-fired, electric heating and heat pump heating schemes



(a) Coal-fired boiler (b) Resistance heater (c) Heat pump

Source: China Energy Conservation Association Heat Pump Special Committee, MioTech Research

Accelerated introduction in domestic and international retail markets

After more than a decade of iterations, the performance of air source heat pump heating products has improved significantly. Early products were limited to poor low-ambient-temperature performance, mediocre energy efficiency, and high equipment and installation costs, and were only used in temperate regions in parts of East and Central China, where winters are warm and summers are cool. With the improvement of defrosting technology and sub-zero low temperature performance, air source heat pumps now can operate at -20 degrees Celsius or even lower temperature while achieving an energy efficiency performance of about COP 2, which means that they can still guarantee 50% energy saving relative to resistance heaters under extreme weather conditions. Product life and reliability have also been improved. Today's residential air source heat pump can work efficiently for 15-25 years. On the other hand, insulation of the new buildings has improved in the past decade, guided by the national government requirements, which works in favor of heat pump heating as it is greatly affected by the insulation performance of buildings.

Following the technology and product advancements, big players started to enter the heat pump market and actively promote standards development. Two new national standards for heat pump heating were introduced in 2019, setting specific standards on energy efficiency, heating performance, reliability, maintenance, etc. The standards played a great role in promoting the development of the heat pump industry.

Exhibit 45: National standards on air source heat pump heating products

Water chilling (heat pump) packages using the vapor compression cycle	GB/T 18430-2016	Provides specifications on air source heat pump heating and cooling products for the Southern China market.
Minimum allowable values of energy efficiency and energy efficiency grades for low ambient temperature air source heat pumps (water chiller) packages	GB 37480-2019	Mandates the energy efficiency requirements of low-temperature type air source heat pump water heating machine.
Low ambient temperature air source heat pump (water chilling) packages	GB/T 25127-2020	Provides specifications on air source heat pump products for the northern China market

Source: China Air Energy Industry Development Report, MioTech Research

The International Energy Agency (IEA) emphasized in its report that under the global net-zero emissions scenario by 2050, sales of new gas-fired boilers should stop after 2025, and the number of heat pump installations needs to reach 290 million and 600 million units in 2025 and 2030, respectively. As of 2020, only 180 million heat pumps have been installed worldwide, a far cry from the target figure.

In Europe and North America, the market share of air source heat pumps has grown significantly. In the United States, annual air source heat pump sales have grown from 2.3 million units in 2015 to 3.4 million units in 2020. Heat pumps now account for more than 40% of new homes. In Europe, between 2015 and 2020, the sales of heat pumps have an average annual growth rate of 12%. In 2020, the EU member states will reach a total of 1.8 million sales.

China's decentralized heating market is mainly composed of 1) buildings that have not been covered by the central heating system in northern cities and towns, mainly rural residential buildings, and 2) commercial and residential buildings with heating needs in the southern parts of China. Air source heat pumps are suitable for the weather conditions in these areas, with either hot summer and cold winter, or severe cold climate conditions.

Both markets have large potential for development. At present, the building area of distributed heating in rural areas in northern China is 7 billion square meters. Aiming at a clean heating rate of 50%, there are still 3.5 billion square meters of rural buildings that need to be retrofitted in the future. Apart from gas and direct electric heating, if 40% of them are retrofitted with air source heat pumps, then this is the market of 1.4 billion square meters. In the southern areas with hot summer and cold winter climate, there are about 18 billion square meters of building area with potential heating demand. At present, the heating system installation rate is not high and the average household energy consumption is at a relatively low level. But the heating demand is exerting fast growth, with an average annual growth rate of more than 50%.

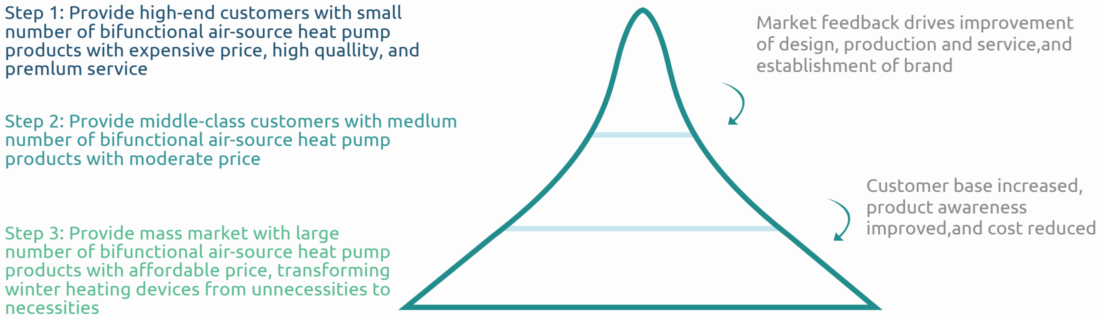
It is also worth mentioning that heat pump air conditioners are also being introduced to the electric vehicle (EV) market rapidly, replacing traditional PTC resistance heating. The energy efficiency advantage of heat pump air conditioners is also the main reason for its share growth in the EV market. The demand from EV will also drive the development progress of heat pump technologies and products.

The Existing market and outlook

In 2021, the total sales of air source heat pumps is RMB20.33 billion, an increase of 29% year-on-year, of which products supplying the domestic heating market account for RMB 7.77 billion. With the overall flat growth of the HVAC industry, air source heat pumps have shown a significant trend of increased penetration. Based on an average price of RMB15,000 per set of heat pump servicing 100 square meters of indoor heating, the heating area of the air source heat pump application is about 52 million square meters. Combined with the national commercial housing sales area of 1.79 billion square meters in 2021, the current penetration rate has not exceeded 3%.

According to the above discussion, the air source heat pump market consists of two segments: distributed heating needs in the northern part of China and in the southern part with hot summers and cold winters. The development of the distributed heating market in the northern part of China mainly relies on policy planning and support. According to the 14th FYP Building Energy Efficiency and Green Building Development Plan, 350 million square meters of existing buildings will be retrofitted with energy-saving measures during the 14th FYP period. The hot summer and cold winter areas in the south will be mainly driven by the market itself, and air source heat pump products will further improve their product performance and service capabilities while reducing costs, similar to the path of EV market expansion, and achieve a steady growth in penetration rate.

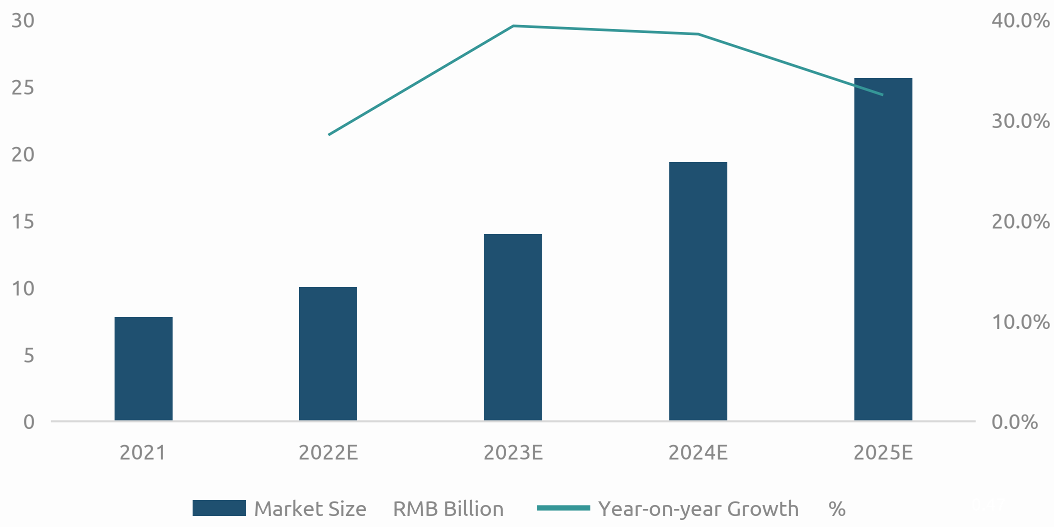
Exhibit 46: Potential expansion path of air source heat pump heating products in Southern China



Source: RMI

We expect that by 2025, 5%/9%/14%/20% of new housing in the southern hot summer and cold winter climate areas will be heated by air source heat pumps, i.e., about 136 million square meters, and the annual sales size of air source heat pumps in this market will reach 20.4 billion yuan. In addition, the 14th FYP period is expected to complete 350 million square meters of energy-saving renovation of existing buildings, which will also contribute to the annual average of RMB 5.3 billion of sales for air source heat pump heating. The two together, China's air source heat pump heating market size is expected to reach RMB25.7 billion in 2025, corresponding to an average annual growth rate of 35%.

Exhibit 47: China air source heat pump heating market size projections, 2021-2025



Source: MioTech Research

The fast-growing export market will also boost the sales of air source heat pumps. In 2021, the export value of air source heat pump products reached RMB4.5 billion, up 100.7% year-on-year. It can be seen that exports directly benefit from the rapidly growing market demand in Europe and the United States. In those regions, the rapid growth of air source heat pumps for domestic and commercial applications will likely continue. We believe China's export of air source heat pumps can also maintain a compound annual growth rate of more than 40% over the next few years.

Company Implications

Zhejiang Sanhua Intelligent Controls Co., Ltd (002050.SZ)

The company is a global leader in the production and development of control components and parts for air conditioners, heat pumps and appliances, and has established a leading position in the industry after more than 30 years of development. Its main products, four-way reversing valves and electronic expansion valves, are the core components of heat pump systems and rank first in the world in terms of market share. In 2021, the company achieved operating revenue of RMB16 billion and net profit of RMB1.68 billion.

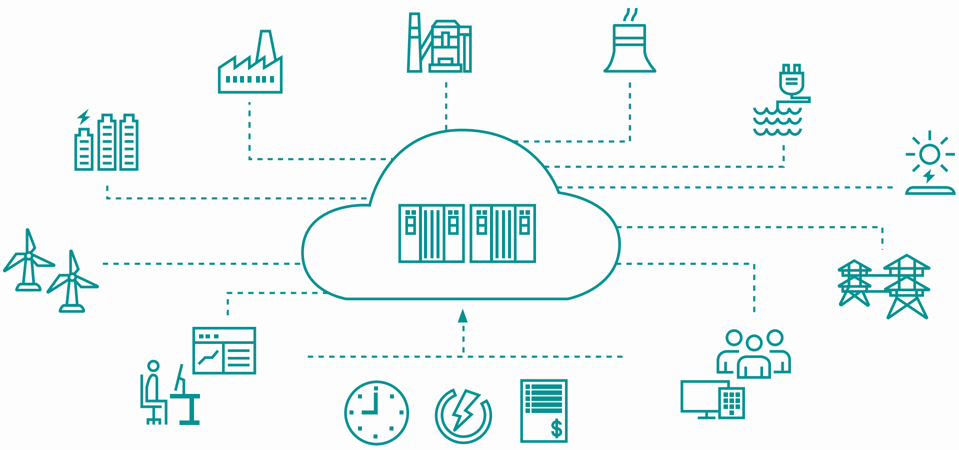
Shanghai Hanbell Precise Machinery Co Ltd (002158.SZ)

The company is mainly engaged in the research and development, production and sales of screw compressor application technology and after-sales service for commercial central air conditioning compressors, heat pump compressors and air pressure products. In recent years, the company has expanded its business to the vacuum compressor field, which is widely used in the PVc and semiconductor industries.

Virtue Power Plant and V2G accelerate in application

The use of virtual power plants (VPP) is one of the important means to realize clean energy aggregation, form interactions between power supply and demand, and promote power market reform. Variable Renewable Energy (VRE) power generation is variating, intermittent and fluctuating. In the new generation of power system with a high proportion of VRE capacity, the grid system itself cannot effectively handle the real-time load balance with limited flexibility resources available on the power generation side. Therefore, it is necessary to tap the potential of flexible resources on the demand side, and virtual power plants came into play. Compared with traditional demand-side management, virtual power plants realize the two-way interaction between user and grid measurement, and enable intelligent scheduling according to grid supply side signals and electricity spot price signals. The system is programmed for spontaneous automatic load control, and promoting the interactive operations of power generation, grid distribution, demand load and storage device in the new power system.

Exhibit 48: supply-side and demand-side flexibility resources in virtual power plants



Source：ABB

The essence of VPP serves as the central control of a regional power grid. At one end of this system, the VPP combines the distributed clean power generation resources, controllable loads and energy storage systems to become a "special power plant", thereby achieving effective power supply coordination and regulation similar to conventional power plants. At the other end, the VPP reduces or shifts the electricity load for a certain period of time, without the need for users to disconnect the power supply. The realization of VPP is inseparable from the application of advanced communication technology, artificial intelligence, edge computing, blockchain and other emerging technologies.

VPPs are expected to further promote electricity market reform as distributed power generation, power grid operations, energy service providers, and end users can participate in electricity market transactions and operators and users in all links have the opportunity to gain revenue. The virtual power plant, as a single entity, participates in power market transactions and assists in the operational safety of the power system, while providing auxiliary services such as peak shaving and valley filling, frequency regulation and emergency control. The profits earned by the whole virtual power plant are then distributed according to the contribution of various internal resource adjustments. From this means, scattered demand side resources of typically small capacity can obtain actual economic benefits from the electricity market.

For example, when electricity consumption is tight in some areas, the charging mode of EVs in surrounding buildings can be changed from fast charging to slow charging through AI algorithm scheduling and remote control; the temperature of air conditioners can be adjusted without affecting human comfort; the operation mode of elevators can be adjusted without affecting building safety; the energy storage equipment, and heating and air conditioning units in buildings can be adjusted, so that idle electricity can be pooled through a VPP, thereby alleviating the shortage of electricity tension in some areas. The buildings that provide the electricity are compensated in the form of selling electricity.

The economics of the virtue power plant

The State Grid once calculated that in order to meets the 5% peak load demand in its operating area, the investment in building new thermal power plants and supporting grid system is about RMB 400 billion; while in the case of VPP, the capital expenditure can be reduced to RMB 40 billion to RMB 57 billion for its setup, operation and incentive cost. This shows the economic benefits of VPP.

On the other hand, resources that are available for VPP operation are in a period of rapid expansion. The total installed capacity of distributed power generation is expected to reach 270GW by the end of the 14th FYP. If these scattered resources can be effectively aggregated, the capacity is equivalent to new construction of 270 power plants of megawatt capacity. In addition, adjustable load resources in the industrial, building and transportation sectors have great potential as well. Taking electrical vehicles as an example, by the end of 2021, the number of EVs in China reached 6.4 million units, which is equivalent to about 400 GWh of capacity if calculated at an average of 60 kWh per vehicle. For comparison, we expect the total capacity of energy storage in China to reach 66 GWh in 2025.

Guiding policies have recently landed one after another to promote the development of virtual power plants.

Exhibit 49: National level policies related to virtual power plants

Date	Ministry	Policy	Contents related to VPP
Dec-21	National Energy Agency	Regulations on the Administration of Integration and Operation of Power Generation, Measures for the Administration of Electricity Auxiliary Services	New technical guidance and management requirements are added for renewable energy, new energy storage, demand-side flexibility, etc., so as to adapt to the characteristics of the new power system with interactions between source, network, load and storage.
Jan-22	National Energy Agency	Highlights of Energy Regulatory Work in 2022	Establish the sharing mechanism of auxiliary services with the participation of users, and promote the participation of high energy-carrying industrial loads, commercial and industrial adjustable loads, new energy storage, EV charging networks, VPP, etc. in providing auxiliary services.
Jan-22	National Development and Reform Commission, National Energy Agency	Guiding Opinions on Accelerating the Construction of a National Unified Electricity Market System	Strongly encourage the investment and construction of pumped storage, energy storage, VPP and other flexible resources.
Jan-22	National Development and Reform Commission, National Energy Agency	Opinions on Improving Institutional Mechanisms and Policy Measures for Green and Low-carbon Energy Transition	Support user-side energy storage, electric vehicle charging facilities, distributed power generation and other user-side adjustable resources, as well as load aggregators, VPP operators, integrated energy service providers, etc. to participate in power market transactions and system operation regulation.

Source: MioTech Research

China's VPP industry is looking to extend beyond the demonstration stage with increasingly mature practices. In recent years, State Grid and China Southern Power Grid have successively explored the establishment of several VPP demonstration projects in Jiangsu, Zhejiang, Hebei, Shanghai, Guangzhou, Shenzhen, and elsewhere, and achieved good economic and emission reduction benefits.

Taking the State Grid "Northern Hebei VPP" pilot project as an example, in 2020, the summer air conditioning load of the North Hebei Power Grid was over 6 GW, of which 10% responded in real time through the VPP, equivalent to a 600MW-capacity traditional power plant. In addition, the regenerative electric heating load responds in real time through the VPP, which generated 720 MWh of clean energy and reduced carbon emissions by 636,500 tons. It can be seen that the operation mode and technology of a VPP is becoming more mature. It is expected that commercialization of VPP will accelerate along with the policy-driven and widespread access of distributed energy to the grid.

Exhibit 50: Summary of VPP demonstration projects

Company	Project Name	Project Date	Project Highlights
China Southern Power Grid	Shenzhen integrated virtual power plant platform	Nov-21	The platform is deployed in the dispatching system of China Southern Power Grid (CSPG), and can be dispatched directly at both the CSPG and provincial levels. The biggest highlight of the platform is the quasi-real-time control function of the platform. After the load-side resource receives the emergency regulation demand dispatched by the system, the load power will be lowered to the target value within 10 minutes.
State Grid	Zhejiang Pinghu County virtual power plant	Jun-21	The VPP demonstration achieved peak shaving of 20 to 30 MW.
State Grid	Wuhan virtual power plant	Jun-21	It lowered the peak load by 700 MW in the region, equivalent to RMB1.28 billion investment in grid infrastructure, and carbon emission reduction of 3 million tons.
State Grid	Shanghai virtual power plant	May-21	The demonstration lasted one hour and generated 150,000 kWh of electricity. The accumulative adjusted grid load was 562 MW, reducing carbon emissions by about 336 tons. Shanghai has maintained a virtual power plant of 1 million kWh, which is 6% of the annual installed capacity, and will gradually increase the virtual power plant capacity in the future.
State Grid	Zhejiang Lishui green energy "virtual power plant"	May-21	It is estimated that the VPP demonstration increased renewable energy consumption by 10.8 MWh, saved RMB1.3 million in demand-side response cost, and reduced coal consumption by 94 tons.
State Grid	North China State Grid integrated virtual power plant	Dec-20	The virtual power plant aggregated 154 MW of adjustable resources to participate in the North China electric power auxiliary service market.
State Grid	Hebei Provincial State Grid Jibei virtual power plant	Dec-19	The demonstration project accessed and controlled 19 adjustable resources in 11 categories, including regenerative electric heating, adjustable industrial and commercial, smart buildings, smart homes, energy storage, electric vehicle charging stations, and distributed photovoltaics in real time, with a capacity of about 160 MW, covering the three cities of Zhangjiakou, Qinhuangdao and Langfang.

Source: Public information, MioTech Research

Spearhead applications

Integrated Energy Services

The integrated energy service provider is one of the m ost important participants in the virtual power plant system. It receives revenue from participating in electricity trading, auxiliary services market and demand-side response, and helps to enhance the unified coordination and control of the virtual power plant.

1. Electricity trading

The integrated energy service provider acts as trading brokers, pooling individual controllable load resources and participating as a single entity in the electricity trading market. The integrated energy service provider can charge service fee to the controllable resources for participating in the electricity market transactions, and/or collect demand flexibility service charge from the grid operator.

2. Grid auxiliary services

Integrated energy service providers can provide peak-shaving and valley-filling services and temporary electricity capacity by adjusting various controllable loads. The agreement to provide auxiliary services and obtain corresponding compensation is obtained by bidding according to the quantity value and response time requirements.

3. Demand-side response optimization

Integrated energy service providers can provide intelligent power consumption solutions for end users to optimize production processes or consumption and achieve energy saving. For example, they can act as an agent to purchase electricity for controllable loads, forecast price fluctuations in the electricity market, and make decisions on the electricity consumption behavior of controllable loads, and guide customers to optimize their response behavior and achieve the goal of reducing electricity bills by minimizing the energy cost of controllable loads.

Company Implications

NARI Technology Co., Ltd. (600406.SH)

Founded in 2001, The company is principally engaged in the development, production and sales of hardware and software products related to the power industry. The company is also engaged in the provision of related system integration services. The company has formed a complete technology and product system on virtual power plants, which can support a variety of new business models in the market.

State Grid Information & Communication Co Ltd. (600131.SH)

The Company's businesses include cloud network infrastructure, cloud platforms, cloud applications and enterprise operation support services. The software includes power marketing systems and enterprise portals. The company is aiming to become the leading cloud-network convergence technology product provider and operation service provider, and has already landed a VPP demonstration project in Binhai New Area, Tianjin, with an installed capacity of 75MW and an adjustable load of 36MW. The company plans to build larger VPP systems in Beijing, Jiangsu, Shanghai, Hunan and Hubei in the future.

Beijing E-techstar Co Ltd (300513.SZ)

The company is mainly engaged in the provision of information technology services for the power grid companies. The Company provides solutions for intelligent control centers, as well as the comprehensive monitoring and production process management solutions in smart grid related fields. The company is actively developing new VPP business models, playing three roles in the market at the same time as aggregator, investor and operator and participating in power market trading, energy transformation and complementary optimization operation.

Previously, the company participated in the construction of State Grid's "Jibei VPP project o, and has rich operational experience in the formulation of rules for virtual power plants, signing of user agreements, installation and commissioning of intelligent terminals and market operation.

Vehicle to Grid (V2G) and smart charging piles

With policy support and increasing demand, the charging pile market is developing rapidly. An EV charging system is a necessary energy replenishment facility. With the increasing penetration of EVs in recent years, the demand for charging has increased significantly. The investment and construction of charging piles and power exchange stations are expected to become one of the key areas of infrastructure growth in 2022.

With the maturity of V2G technology, intelligent two-way charging piles become the future direction of development. The two-way electricity charging between EVs and the power grid is realized through charging stations, so that EVs can act as energy storage systems when needed and power the grid with their stored electrical energy in the battery. V2G makes it possible for EVs to participate in the auxiliary service market as a distributed micro-power source.

For grid operators, EVs can participate in real-time regulation and peak shaving of the grid. V2G response time can reach millisecond level, much faster than the traditional flexible resource. It can improve the utilization rate of charging piles while providing useful services for the power grid. For example, in 2018 the State Grid Electric Vehicle Company selected six demonstration areas with high transformer loads and an increasing number of EVs and built 160 smart charging piles. Through optimized charging control, the communities reduced peak net load by more than 30% on average. It has increased the capacity of distribution substations to accept charging piles four-fold.

For car owners, during the valley load period, they can use the smart charging pile to charge at lower electricity cost. During the peak load period, EVs can deliver power to the grid, gaining incentives for participating in peak shaving and valley filling. The lithium-ion battery installed on EVs can be fully charged and discharged about 3,200 times before it is retired, and the user can almost offset the battery cost by participating in the electricity trading and auxiliary service market.

At present, pilot studies on two-way smart charging have been carried out, and relevant support policies have been introduced. In June 2019, Shanghai incorporated EVs into the demand response system for the first time, opening up commercial opportunities for V2G. In April 2020, the North China Power Market officially included V2G charging pile resources in the market settlement of auxiliary services for the first time. In May 2021, NDRC issued the Implementation Opinions on Further Improving the Service Guarantee Capability of Charging and Switching Infrastructure, promoting V2G collaborative innovation and pilot demonstration.

As the infrastructure for smart charging applications, EVs and charging piles have reached reasonable scale. The number of EVs reached 6.4 million by the end of 2021 in China, equivalent to a storage capacity of about 400 GWh. According to data released by the China Electric Vehicle Charging Infrastructure Promotion Alliance (EVCIPA), by the end of 2021, the number of charging piles nationwide reached 2.6 million units, a year-on-year increase of 56%, of which 1.1 million units were public charging piles.

Company Implications

Qingdao TGOOD Electric Co., Ltd.（300001.SZ）

Established in 2004, the company is mainly engaged in three major fields: power equipment manufacturing, vehicle charging stations and new energy micro-grid. The company is involved in the manufacture and sale of EV charging equipment, the construction and operation of new energy vehicle (NEV) charging stations, finance leasing and solid heat storage businesses. Through its subsidiary, the company has developed the first V2G project in Shanghai.

XJ Electric Co Ltd (000400.SZ)

Established in 1993, it is a leading enterprise in China's electric power equipment industry. At present, the company has proprietary 800V high-voltage charging and a set of V2G core technologies. Its V2G products have been demonstrated and applied in Tongli Integrated Energy Demonstration Station in Jiangsu, and the Hangzhou Asian Games Village.

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