水电水利规划设计总院
China Renewable Energy Engineering Institute

中国可再生能源与新型电力系统发展现状及前景展望

China‘s Renewable Energy Development and Building New Type of Power System

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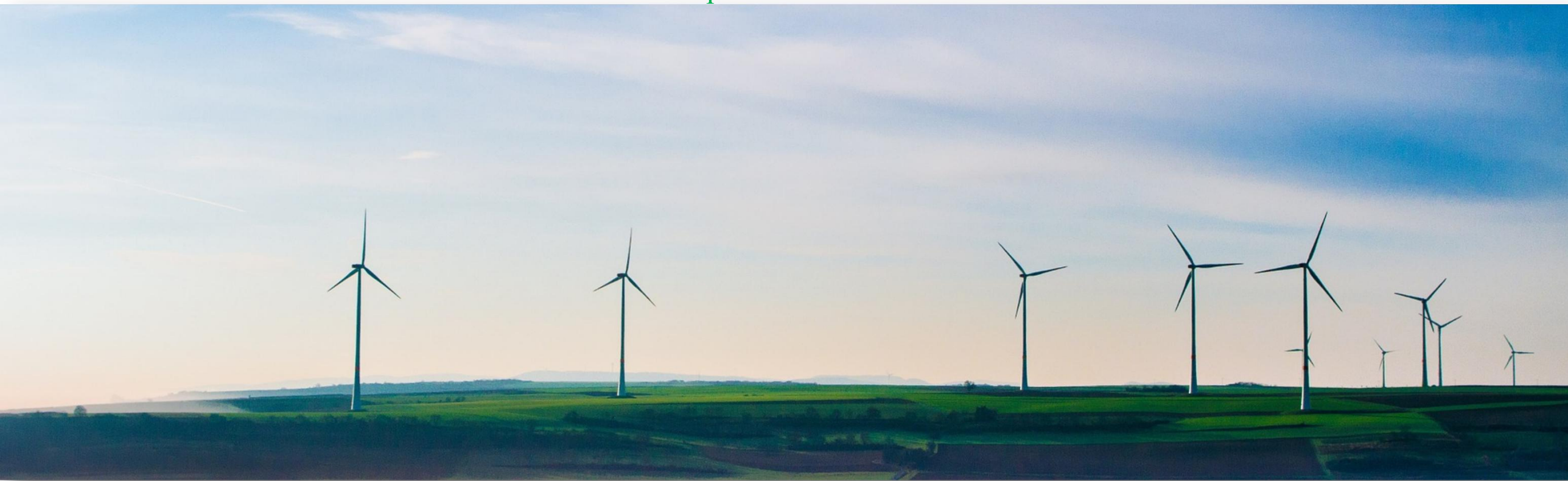


01

中国可再生能源发展总体形势

Overview of renewable energy development in China

1.1 2022年基本情况

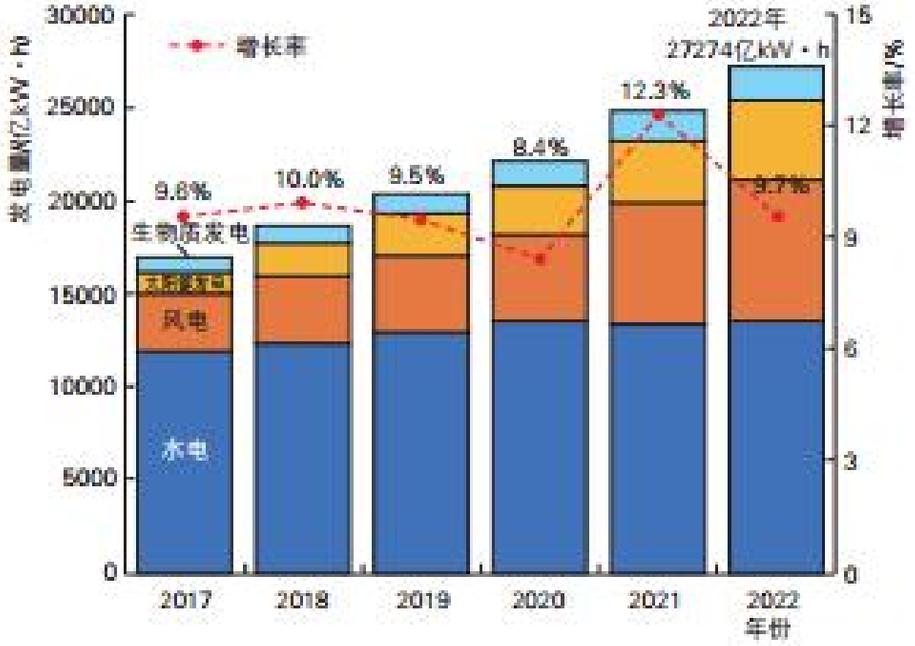
中国可再生能源发电装机突破12亿kW

- 可再生能源发电装机容量占全部发电装机容量的47.3%， 较2021年提高2.5个百分点。
- 可再生能源发电新增装机容量占全国新增装机容量的76.2%，成为电力新增装机的主体。

可再生能源发电装机容量变化情况和增长率（2017—2022年）

中国可再生能源发电量超过2.7万亿kW·h

- 2022年可再生能源发电量占全社会用电量的31.6%，较2021年提高1.7个百分点。
- 可再生能源较去年新增发电量2410亿kW·h，占新增发电量的80.8%。



可再生能源发电量变化情况和增长率（2017—2022年）

1.1 Basic Situation for 2022

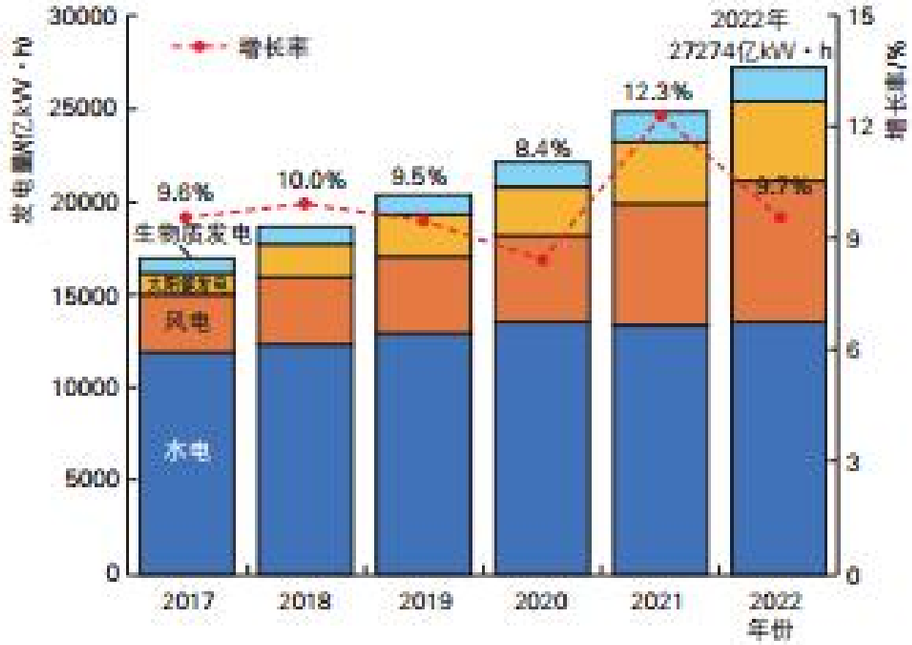
Installed renewable energy generation capacity in China exceeds 1.2 billion kW

- The installed renewable energy power generation capacity accounted for 47.3 per cent of all installed power generation capacity, an increase of 2.5 percentage points over 2021.
- The newly installed capacity of renewable energy power generation accounted for 76.2 per cent of the country's newly installed capacity, becoming the mainstay of newly installed.

Changes in Installed Renewable Energy Generating Capacity and Growth Rates (2017-2022)

Renewable Energy Power Generation in China surpasses 2.7 Trillion kW·h

- In 2022, renewable energy will account for 31.6 per cent of the total electricity consumption of society, an increase of 1.7 percentage points compared with 2021.
- Renewable energy will add 241 billion kW-h of new power generation capacity compared with last year, accounting for 80.8 per cent of the new power generation capacity.



Changes in Renewable Energy Generation Capacity and Growth Rate (2017-2022)

1.2 水电和抽蓄 Hydropower and Pumped Storage

常规水电 Conventional hydropower

- 已建装机容量36771万kW
- 年新增投产1507万kW，主要为白鹤滩、苏洼龙等电站
- 在建装机容量约2700万kW，主要分布在金沙江、雅砻江、大渡河等流域，2022年新增核准300万kW。
- 待开发水力资源主要集中在西南地区
- The built installed capacity is 367.71 million kW
- The annual new investment capacity of 1.57 million kW, mainly in power stations such as Baihetan and Suwulong
- The installed capacity under construction is about 27 million kW, mainly distributed in Jinsha River, Yalong River, Dadu River and other basins, with an additional 3 million kW approved in 2022.
- Hydraulic resources to be developed are mainly concentrated in the southwestern region

抽水蓄能 Pumped storage

- 投产规模、年度核准规模创历史新高
- 年新增投产880万kW。
- 核准48座，总规模6890万kW
- 抽水蓄能电站已建投产总规模4579万kW，核准在建1.21亿kW。
- The scale of investment in production capacity and annual approved hit a record highs
- Annual new investment in production capacity is 8.8 million kW.
- Approved investment in production capacity is 48 stations, with a total scale of 68.9 million kW
- The scale of investment in pumped storage stations have been built is 45.79 million kW, and The scale of investment in approved ones under construction is 121 million kW.

1.3 风电 Wind Power

陆上新增装机平稳增长，海上新增规模短期下降

Stable growth in new onshore installations, short-term decline in offshore additions

- 新增并网装机3763万kW；其中，陆上风电新增3258万kW，海上风电新增505万kW。
- 风电累计装机36544万kW，同比增长11.5%。
- New grid-connected installed capacity is 37.63 million kW. Onshore wind power added 32.58 million kW and offshore wind power added 5.05 million kW.
- The cumulative installed capacity of wind power was 365.44 million kW, an increase of 11.5 per cent year-on-year.

2012—2022年中国风电装机容量变化趋势

Trend of Installed Wind Power Capacity in China, 2012-2022

发电量持续提升

Power generation continues to rise

- 2022年全国风电发电量达7624亿kW•h，同比增长16.3%，占全部电源总年发电量的8.8%，较2021年提高1个百分点。
- In 2022, the national wind power generation capacity reaches 762.4 billion kW-h, a year-on-year increase of 16.3%, accounting for 8.8% of the total annual generation capacity of all power sources, an increase of 1 percentage point compared with 2021.

“三北”地区积极推进大型风电基地建设，沿海地区积极推动海上风电基地开发建设，装机规模占比逐步提升

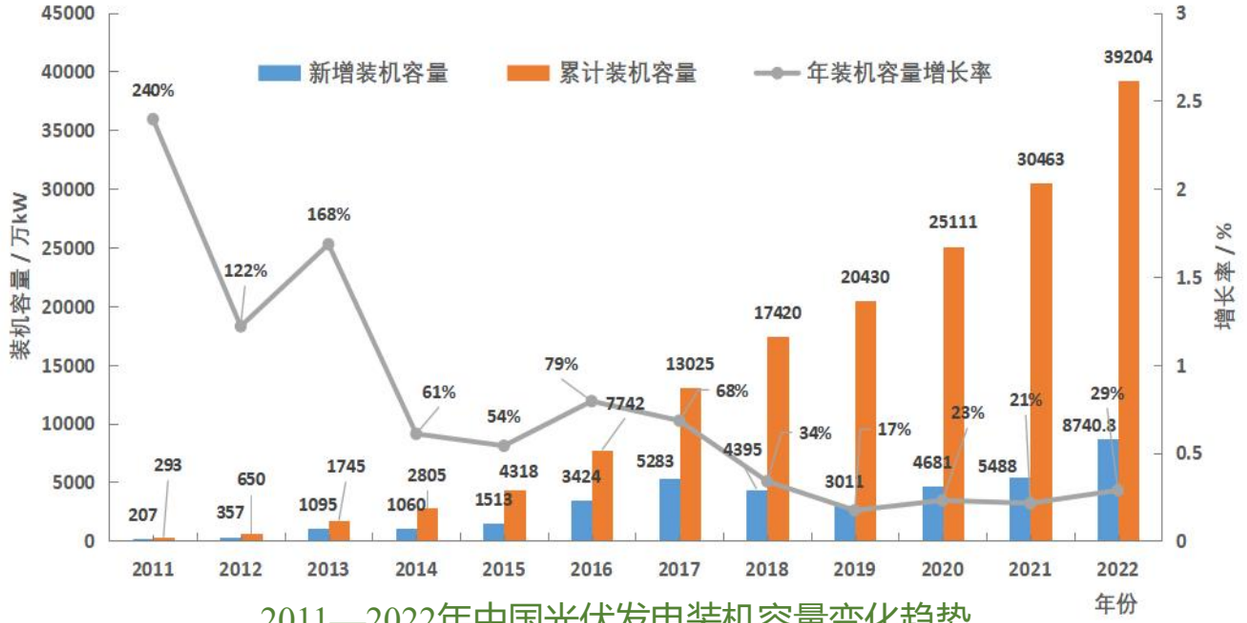
The "Three North" region is actively promoting the construction of large-scale wind power bases, and the coastal region is actively promoting the development and construction of offshore wind power bases, with the proportion of installed capacity gradually increasing.

1.4 太阳能 Solar Energy

装机规模保持快速增长

The installed capacity maintains rapid growth

- 新增装机8741万kW，全部为光伏发电。
- 累计装机容量达到39261万kW，同比增长28.6%。
- Newly installed capacity of 87.41 million kW, all of which is photovoltaic power generation.
- The cumulative installed capacity reached 392.61 million kW, an increase of 28.6 per cent year-on-year.



2011—2022年中国光伏发电装机容量变化趋势

Trend of Installed Photovoltaic Power Generation Capacity in China, 2011-2022

发电量大幅度提升

Substantial increase in power generation

- 全国太阳能发电量达4276亿kW·h，同比增长30.8%，占全部电源总年发电量的4.9%，较2020年提升1个百分点。
- National solar power generation amounted to 427.6 billion kW-h, up 30.8 per cent year-on-year, accounting for 4.9 per cent of the total annual power generation of all power sources, up 1 percentage point from 2020.

产业规模保持快速增长

Industry scale maintains rapid growth

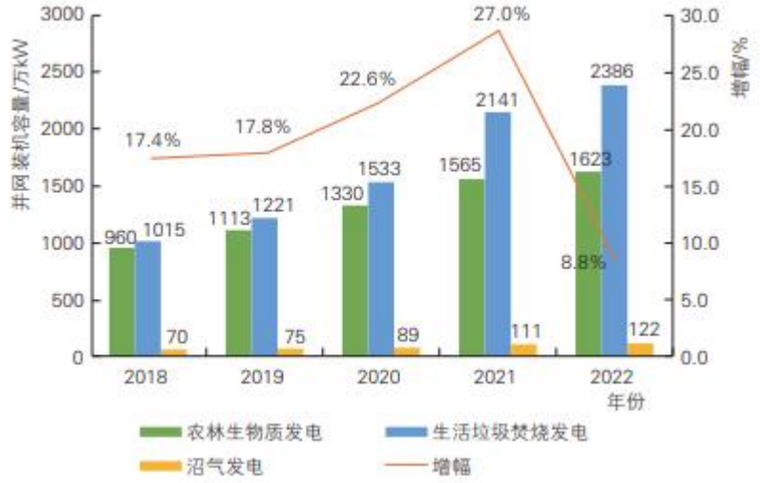
- 光伏产业保持快速增长势头，多晶硅产量为82.7万t，硅片产量为357GW，电池片产量为315GW，组件产量为288.7GW。
- The PV industry maintained the momentum of rapid growth, with polysilicon output of 827,000t, silicon wafer output of 357GW, cell output of 315GW and module output of 288.7GW.

1.5 生物质能 Biomass

生物质发电新增装机规模同比下降

The scale of newly installed biomass power generation declined year-on-year

- 新增装机334万kW，同比下降58.7%；
- 累计并网装机容量达到4132万kW，同比增长8.8%。
- Newly installed capacity was 3.34 million kW, down 58.7 per cent year-on-year;
- Cumulative grid-connected installed capacity reached 41.32 million kW, up 8.8% year-on-year.



2018—2022年生物质发电并网装机容量变化趋势

Trend of installed grid-connected biomass power capacity, 2018-2022

发电量显著提升

Significant increase in power generation

- 年发电量达到1824亿kW·h，较2021年增加11.4%，占全部电源总年发电量2.1%。
- Annual electricity generation reaches 182.4 billion kW-h, an increase of 11.4 per cent compared to 2021, accounting for 2.1 per cent of total annual electricity generation from all power sources.

垃圾焚烧发电仍是主要增长引擎

Waste-to-energy incineration remains the main growth engine

- 生活垃圾焚烧发电新增装机占累计新增装机76.9%，较2021年提高5个百分点。
- 生物天然气、固体成型燃料、燃料乙醇等非电利用稳步增长
- New installations of domestic waste-to-energy incineration account for 76.9% of cumulative new installations, an increase of 5 percentage points from 2021.
- Non-electricity uses such as biogas, solid moulded fuels and fuel ethanol grow steadily.

1.6 储能及氢能 Energy Storage and Hydrogen

新型储能进入规模化发展新阶段

New energy storage enters a new stage of scale development

- 2022年，新增投运新型储能项目规模约7GW，累计装机规模约13.1GW/27.1GWh 。
- In 2022, the scale of new energy storage projects will be about 7GW, and the cumulative installed capacity will be about 13.1GW/27.1GWh.

锂离子电池主导地位进一步提升

The dominant position of lithium-ion battery is further enhanced

- 新增投运项目中，锂离子电池储能占比达97%。累计装机占比达到94%，较2021年提升3.1个百分点。
- Among the newly commissioned projects, lithium-ion battery energy storage accounts for 97%. The cumulative installed capacity accounts for 94%, up 3.1 percentage points from 2021.

新型储能产业规模不断壮大

The scale of the new energy storage industry continues to grow

- 全国锂离子电池行业总产值突破1.2万亿元，锂离子电池产量达750GWh，同比增长超过130%，其中储能型锂电产量突破100GWh 。
- The total output value of the national lithium-ion battery industry exceedes 1.2 trillion yuan, and the output of lithium-ion batteries reaches 750GWh, a year-on-year increase of more than 130%, of which the output of lithium-ion batteries for energy storage exceedes 100GWh .

可再生能源制氢初具规模

Hydrogen production from renewable energy is taking shape

- 已有超过100个规划、在建和已建电解水制氢项目，制氢总规模12.1GW。
- There are more than 100 planned, under-construction and constructed electrolytic water hydrogen production projects, with a total hydrogen production scale of 12.1GW.

绿氢工业领域替代应用已显成效

Substitute application of green hydrogen in industrial field has shown results

- 合成氨、氢冶金、煤化工、石油炼化等行业开启了绿氢替代灰氢的碳中和变革。
- Ammonia, hydrometallurgy, coal chemical, petroleum refining and other industries begin the carbon-neutral change of replacing grey hydrogen with green hydrogen.

02

新型电力系统建设发展

Development of new power system construction

2.1 新型电力系统发展现状

电力供应保障能力稳步夯实

- 截至2022年底，我国各类电源总装机规模25.6亿千瓦，全社会用电量达到8.6万亿千瓦时，总发电量8.7万亿千瓦时，形成了以“六大区域电网为主体、区域间异步互联为主”的全国大电网格局。

电力绿色低碳转型不断加速

- 截至2022年底，非化石能源装机规模达12.7亿千瓦，占总装机的49%；非化石能源发电量达3.1万亿千瓦时，占总发电量的36%。

电力系统调节能力持续增强

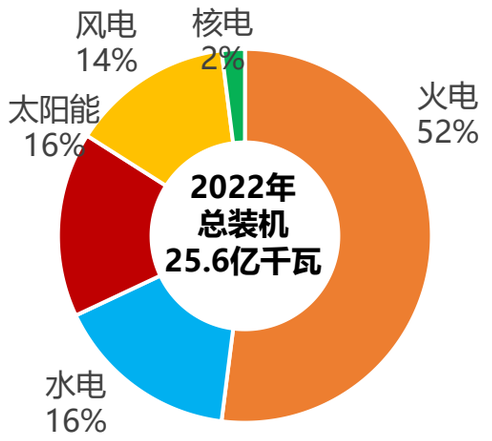
- 截至2022年底，煤电灵活性改造规模累计约2.57亿千瓦，抽水蓄能装机规模达到4579万千瓦，新型储能累计装机规模达到870万千瓦。新能源消纳形势稳定向好。

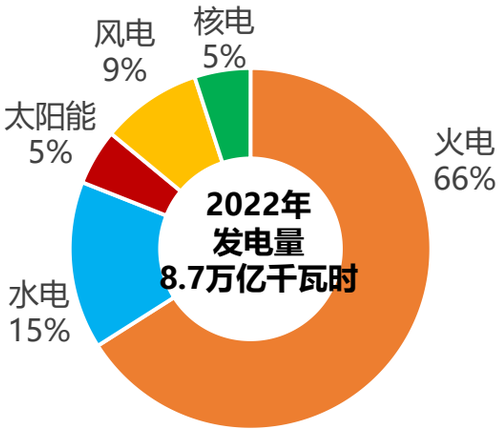
电力技术创新水平持续提升

- 清洁能源装备制造产业链基本完备，全球最大单机容量100万千瓦水电机组投入运行，晶体硅光伏电池转换效率创造26.8%的世界纪录。

电力体制改革成效突出

- 2022年完成市场化交易电量5.3万亿千瓦时。电力中长期、辅助服务市场机制和规则体系全面建立，分时电价、阶梯电价机制逐步健全。





2.1 Status of Development of New Power Systems

Steady consolidation of power supply security capacity

- By the end of 2022, in China, total installed capacity of all types of power supply will be 2.56 billion kilowatts, the total electricity consumption of the whole society will reach 8.6 trillion kilowatt-hours, and the total power generation capacity will be 8.7 trillion kilowatt-hours, which will form a national grid pattern with "six regional grids as the main body, and asynchronous interconnections between regions as the main part".

Green and low-carbon transition of electricity continues to accelerate

- By the end of 2022, the installed capacity of non-fossil energy sources will reach 1.27 billion kilowatts, accounting for 49 per cent of the total installed capacity; and the power generation capacity of non-fossil energy sources will reach 3.1 trillion kilowatt-hours, accounting for 36 per cent of the total power generation capacity.

Power system regulation capacity continues to grow

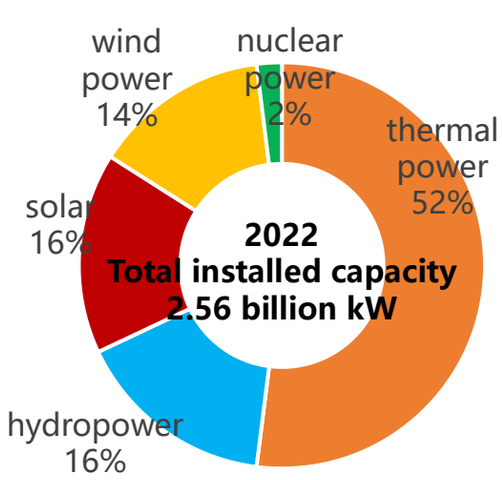
- By the end of 2022, the cumulative scale of coal power flexibility transformation will be about 257 million kilowatts, the installed scale of pumped storage will reach 45.79 million kilowatts, and the cumulative installed scale of new energy storage will reach 8.7 million kilowatts. The situation of new energy consumption is stable and favourable.

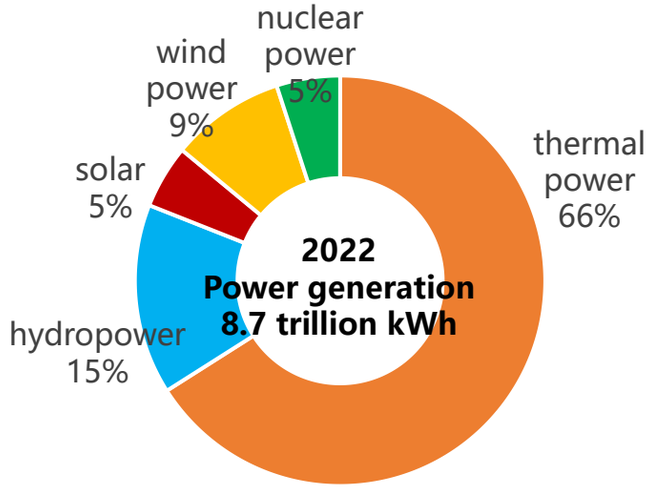
Power technology innovation level continues to improve

- The clean energy equipment manufacturing industry chain is basically complete, the world's largest single-capacity 1 million-kilowatt hydropower unit is in operation, and the conversion efficiency of crystalline silicon photovoltaic cells has set a world record of 26.8 per cent.

Outstanding results in the reform of the electricity system

- In 2022, 5.3 trillion kilowatt-hours of electricity will have been completed through market-based trading. The mechanism and rule system of the electricity auxiliary service market in the medium and long term will be fully established, and the mechanism for time-sharing tariffs and ladder tariffs will be gradually improved.





2.2 新型电力系统建设面临的问题与挑战
Issues and Challenges Facing the Construction of New Power Systems

1 保供压力突出
The pressure to preserve supply is prominent

多重因素叠加，部分地区电力供应紧张，保障电力供应安全面临突出挑战。

Multiple factors are superimposed, power supply is tight in some areas, and there are outstanding challenges to guaranteeing the security of power supply.

2 调节能力短缺
Shortage of regulatory capacity

新能源快速发展，系统调节能力提升面临诸多掣肘，新能源消纳形势依然严峻。

With the rapid development of new energy, system regulation capacity enhancement faces many constraints, and the new energy consumption situation is still severe.

3 “双高” 特性凸显
Highlighted "Double-high" characteristic

高比例可再生能源和高比例电力电子设备的“双高”特性日益凸显，系统运行压力持续增加。

The "double-high" characteristics of a high proportion of renewable energy sources and a high proportion of power electronic equipment are becoming more and more prominent, and the pressure on system operation continues to increase.

4 调控难度骤增
Difficulty of regulation soars

传统电力调度方式难以完全适应新形势新业态，调控技术手段、调度机制、信息安全防护等亟待升级。

Traditional power scheduling methods are difficult to fully adapt to the new situation and new business model. The technical means of control, scheduling mechanism and information security protection need to be upgraded.

5 技术亟待升级
Technology need to be upgraded

电力关键核心技术装备尚存短板，电力系统科技创新驱动效能需持续提升。

Power key core technology and equipment is still short board, and power system science and technology innovation driving effectiveness needs to be continuously improved

6 改革任务艰巨
Difficulty of reform mandates

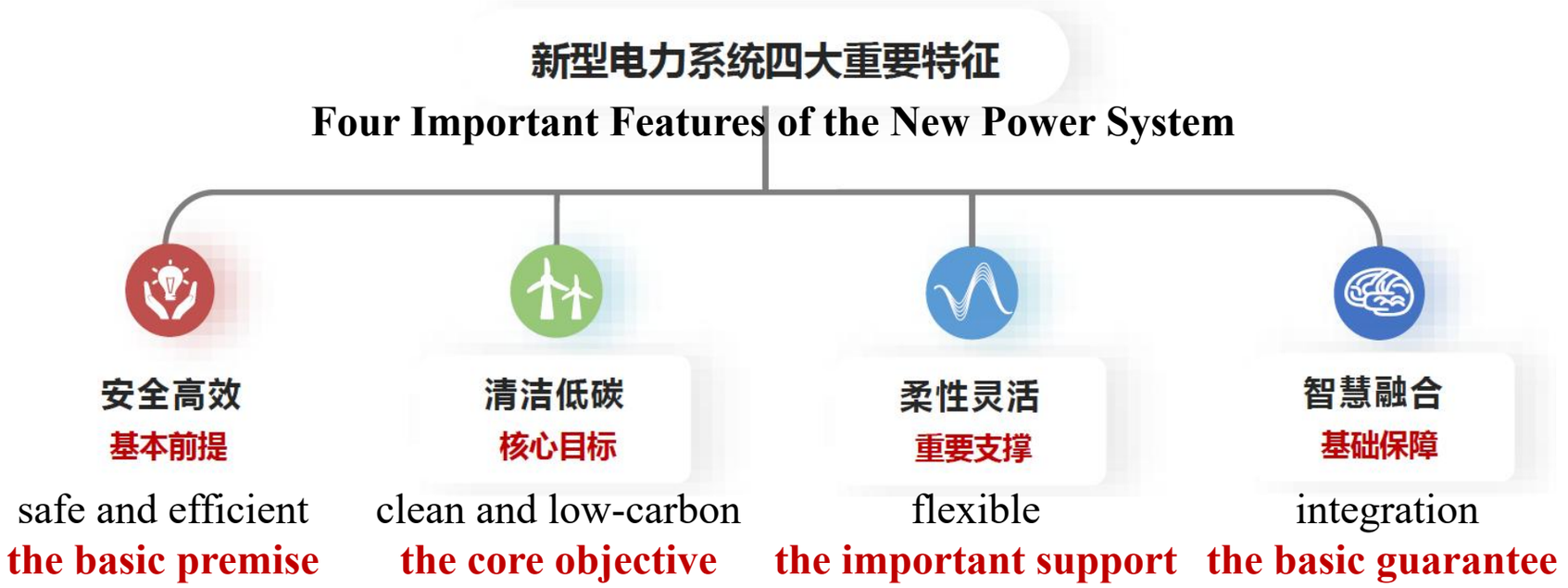
电力系统转型发展过程中仍然面临诸多障碍和风险挑战，适应新型电力系统的体制机制亟需完善。

The process of power system transition and development still faces many obstacles and risks and challenges, and the institutional mechanism for adapting to the new power system needs to be improved.

2.3 新型电力系统特征

新型电力系统的四大特征 Four main features of the new power system

- 新型电力系统是新型能源体系的重要组成和实现“双碳”目标的关键载体。
- 新型电力系统具备安全高效、清洁低碳、柔性灵活、智慧融合四大重要特征。安全高效是**基本前提**，清洁低碳是**核心目标**，柔性灵活是**重要支撑**，智慧融合是**基础保障**，共同构建了新型电力系统的**“四位一体”**框架体系。
- The new power system is an important component of the new energy system and a key vehicle for achieving the "dual-carbon" goal.
- The new power system has four important features: safe and efficient, clean and low-carbon, flexible and intelligent integration. Safe and efficient is **the basic premise**, clean and low-carbon is **the core objective**, flexible is **the important support** and integration is **the basic guarantee**. They construct the new power system of the "four-in-one" framework system together.



2.4 三个发展阶段及显著特点 Three stages of development and salient features

新型电力系统建设发展阶段“三步走”
"Three steps" in the development phase of the new power system construction

加速转型期（当前-2030年）
Accelerated Transition Period (current - 2030)

新能源成为发电量增量主体，煤电仍是电力系统“压舱石”。电网形态以区域互联电网为主，分布式智能电网进入发展起步期。储能多场景多技术路线规模化发展。

New energy has become the main body of power generation, and coal power is still the "ballast" of the power system. Grid form is dominated by regional interconnected grid, and distributed smart grid has entered the initial development period. Energy storage is developing on a large scale with multiple scenarios and technical routes.

总体形成期（2030-2045年）
General Formation Period (2030-2045)

新能源成为装机主体，煤电加速清洁低碳转型。电网柔性化、数字化、智能化转型，大电网与分布式并举。规模化长时储能技术突破。

New energy becomes the main body of installed capacity, and coal power accelerates clean and low-carbon transition. Grid flexibilisation and digitalisation, intelligent transition, and Co-development of large grids and distributed. Scale and long-time energy storage technology breakthroughs.

巩固完善期（2045-2060年）
Consolidation and Improvement Period (2045-2060)

以新能源为电量供给主体的电力资源与氢能等其他二次能源融合利用。新型输电组网技术突破，电力与能源输送深度耦合协同。用户侧与电力系统高度灵活互动，多类型储能协同运行，电力系统实现动态平衡。

Integrate the use of electric power resources with new energy as the main source of power supply with other secondary energy sources such as hydrogen. Realise breakthroughs in new transmission network technology and deep coupling and synergy between power and energy transmission. Enhance the highly flexible interaction between the user side and the power system, operate multiple types of energy storage and achieve dynamic balance in the power system.

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