国家电网
STATE GRID
国网能源研究院有限公司
STATE GRID ENERGY RESEARCH INSTITUTE CO., LTD.

System Operation with High Shares of Renewables In China

WANG, Caixia

State Grid Energy Research Institute

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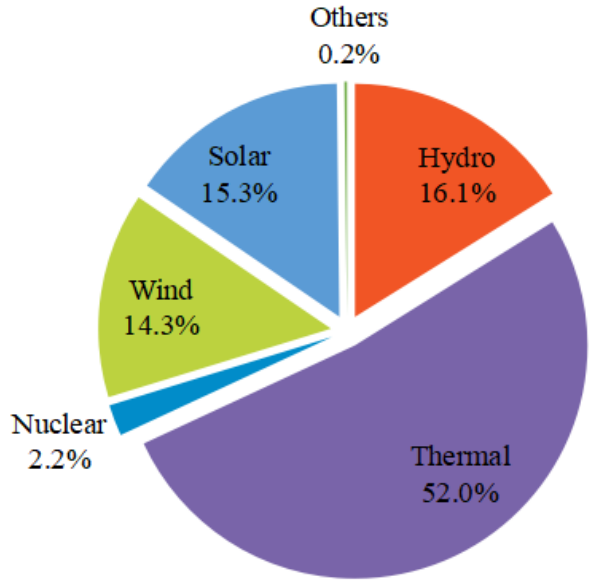
1. Current Development Scale and Utilization

Capacity

- By the end of 2022, the generation capacity structure in China:
- **Total generation capacity**: 2564GW
  - **RE capacity**: 1172GW (45.7% **of the total** installed generation capacity)
  - **VRE capacity**: 758GW (**29.6%** **of the total** installed generation capacity, and **64.7%** **of RE** generation capacity)



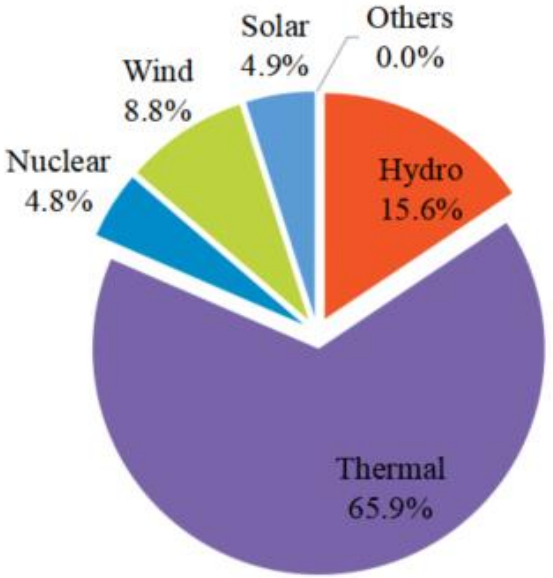
Structure of total generation capacity in China, 2022

- **VRE capacity 758GW**
  - Wind: 356 GW (**14.3%** of total generation capacity)
  - Solar: 393 GW (**15.3%** of total generation capacity)

1. Current Development Scale and Utilization

Generation

- In 2022, the generation structure in China:
- **Total generation**: 8694 TWh
  - **RE generation**: 2545 TWh (29% **of the total** generation)
  - **VRE generation**: 1190 TWh (**13.7% of the total** generation, and **46.8% of RE** generation)

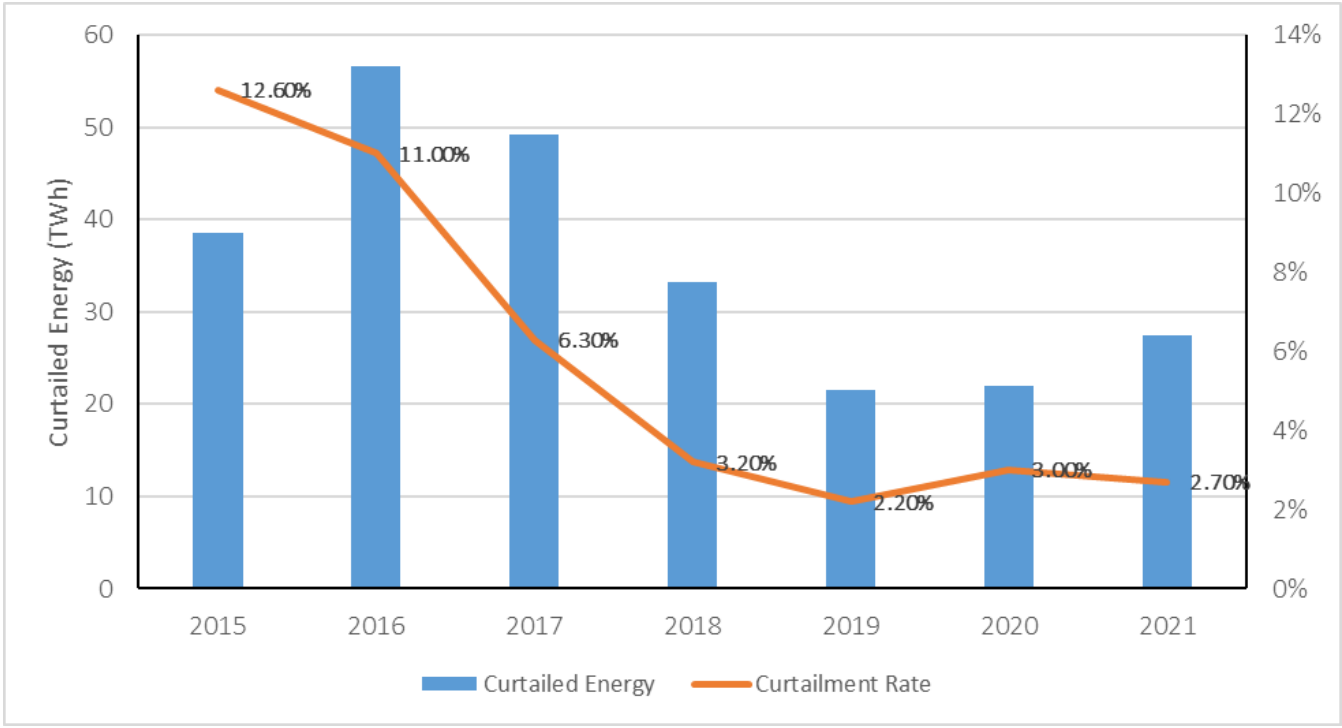


Generation Structure in China, 2022

- **VRE generation 1190 TWh**
  - Wind: 762 TWh (***8.8%*** of total generation)
  - Solar: 428 TWh (***4.9%*** of total generation)

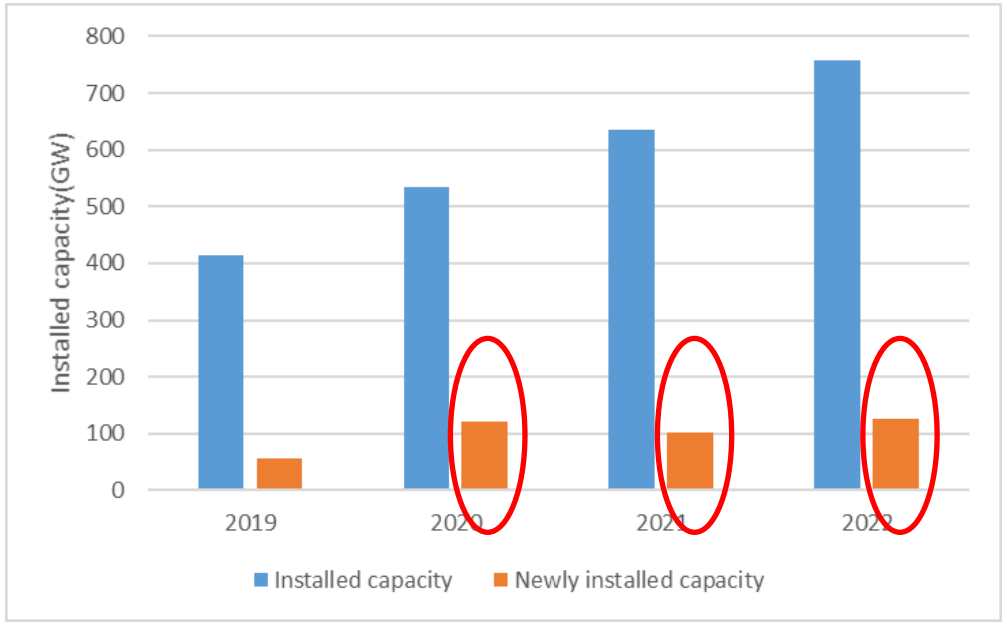
1. Current Development Scale and Utilization

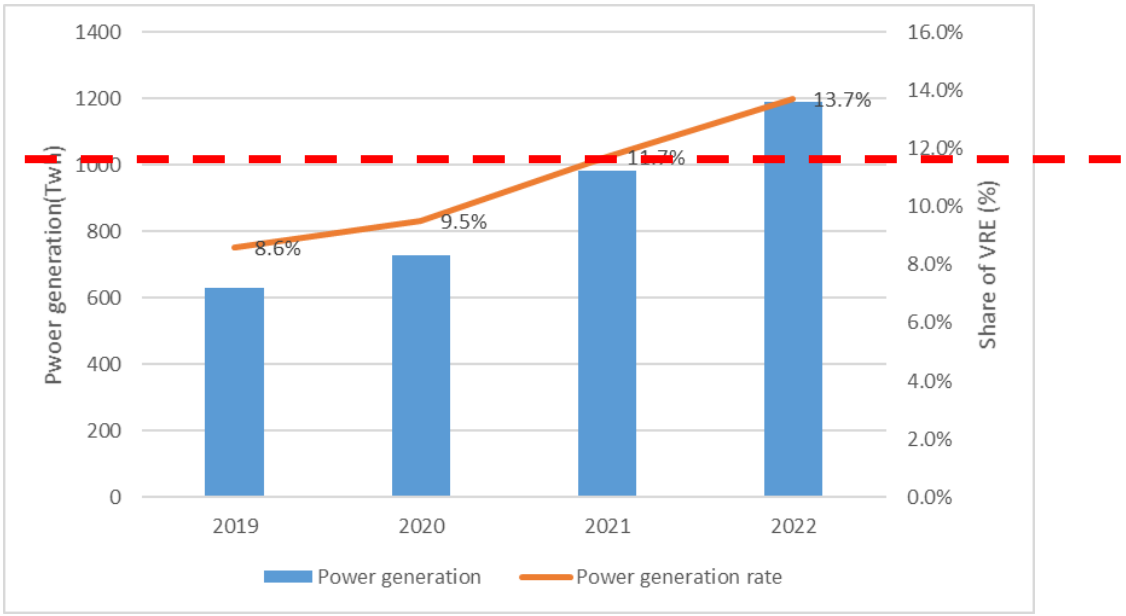
- In 2022, the curtailment rate of wind and solar is 3.2% and 1.7%. The ***curtailment rate*** has remained ***below 5%*** for 5 consecutive years.



2. Characteristics of VRE Development in Recent Years

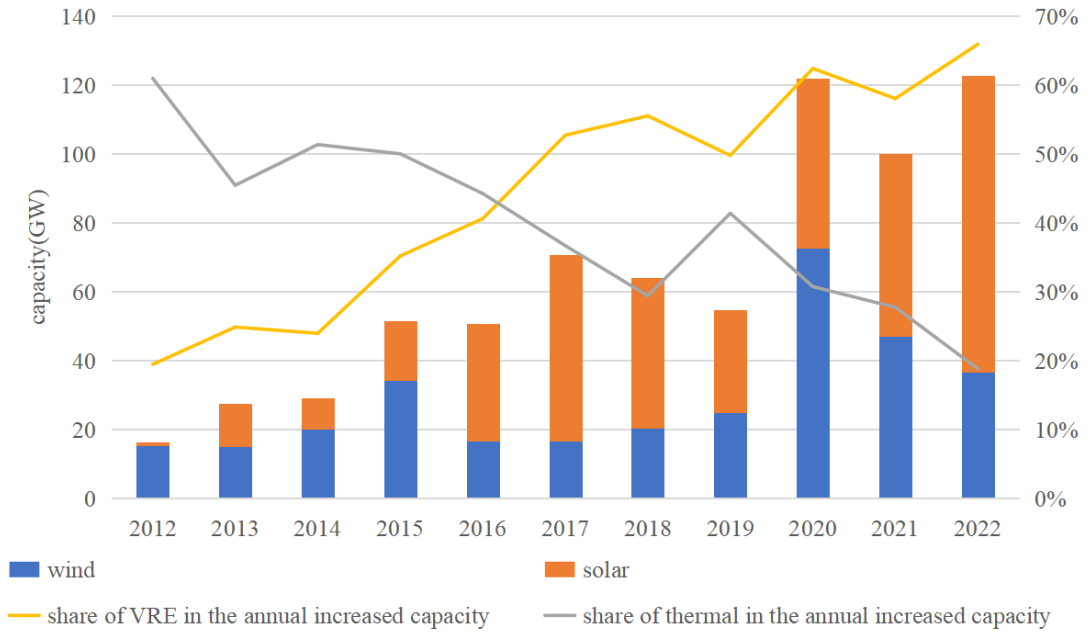
- **Large Scale** - Generally, with the announcement of the “Dual Carbon” goal, China enter a new era of fast and large scale development of wind and solar. The *annually newly installed wind and solar* has *exceeded 100GW* since 2020, and the *annual generation* from wind and solar *surpassed 1000 TWh* in 2022.



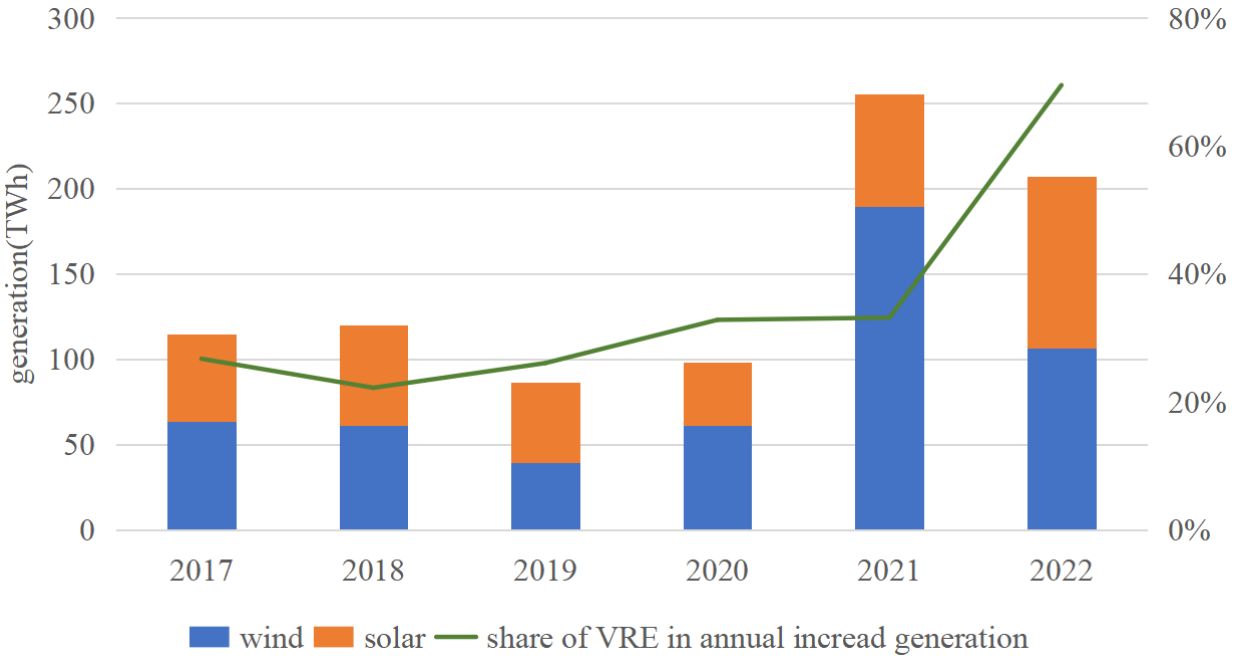


2. Characteristics of VRE Development in Recent Years

- **High Share-** The share of VRE in the annually newly installed capacity surpassed 50% since 2017, and the share of VRE in the annually increased total generation surpassed 50% in 2022 .



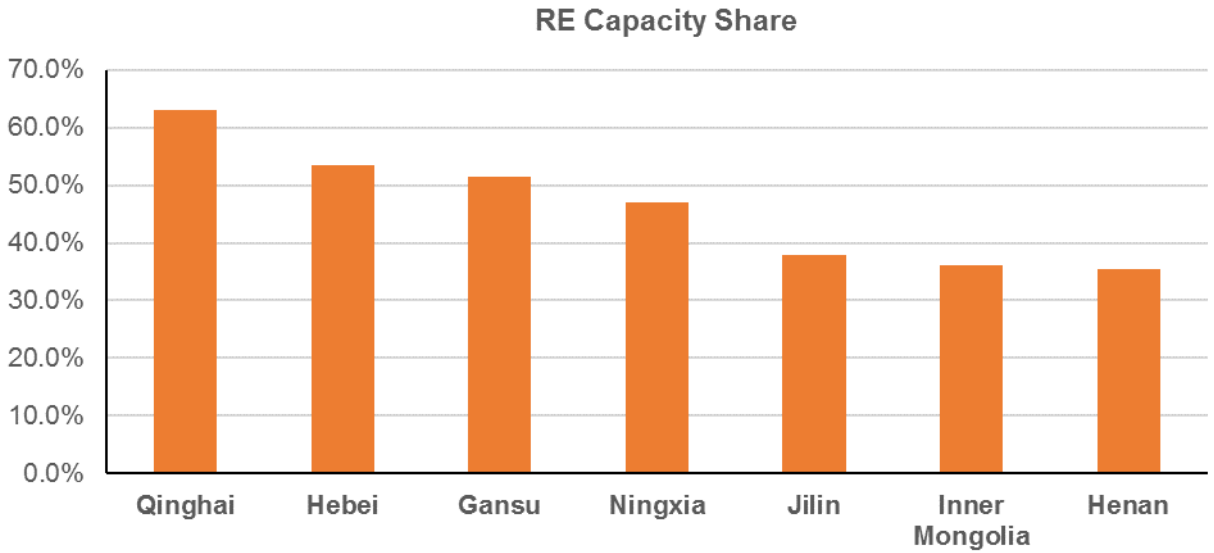
The annual installed capacity of VRE



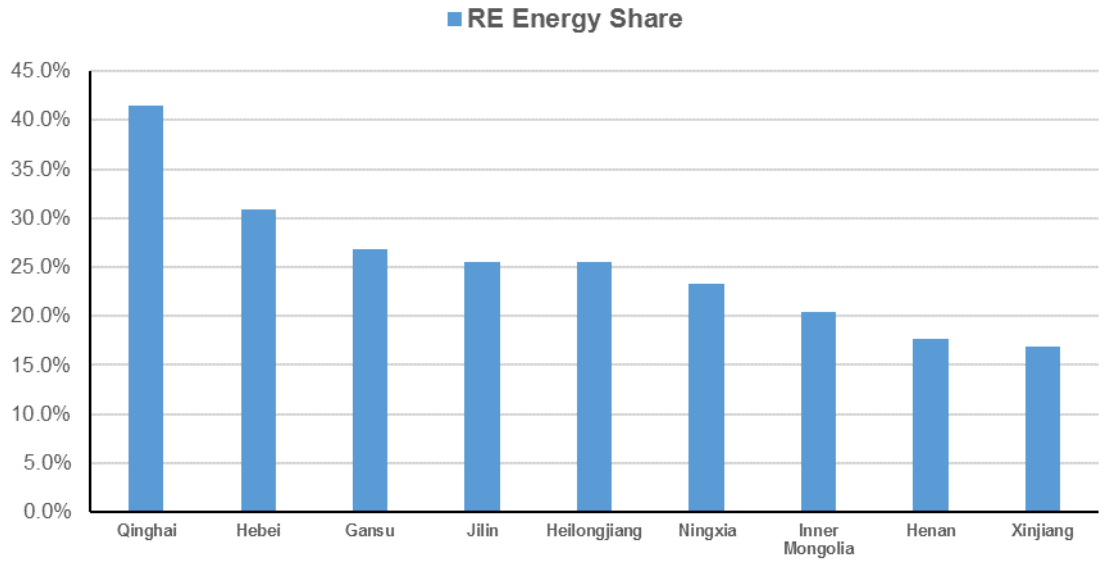
Annual generation of VRE in China

2. Characteristics of VRE Development in Recent Years

- By the end of 2022, the installed capacity of VRE in 9 provinces exceeded 30GW. The ***capacity share of VRE*** in 15 provinces exceeded ***30%***, with the ***highest being 63%(***Qinghai).
- In 2022, the ***share of VRE generation*** in 12 provinces exceeded ***15%***, with the ***highest being 41.5%*** (Qinghai).



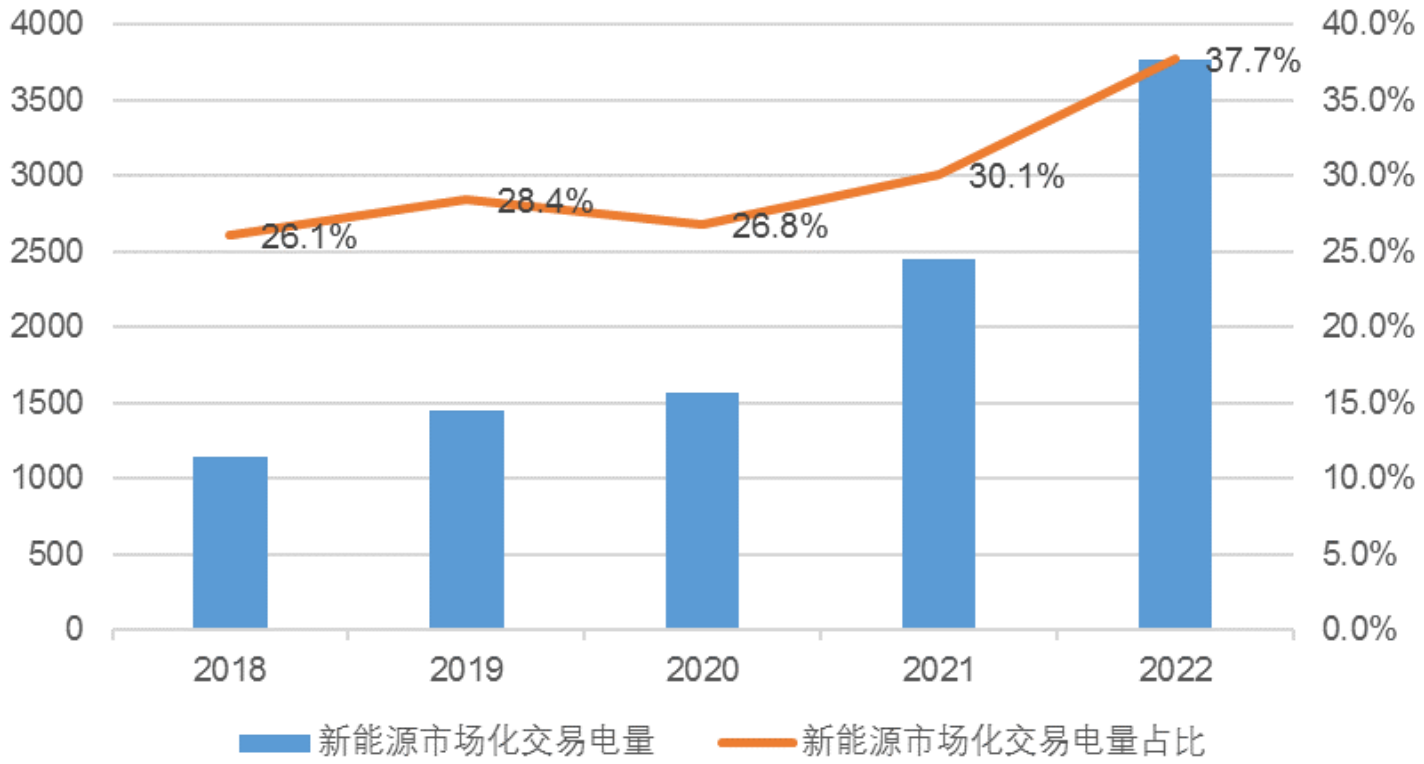
Top 10 provinces with VRE installed capacity by 2022



Provinces with share of VRE generation exceeding 15% in 2022

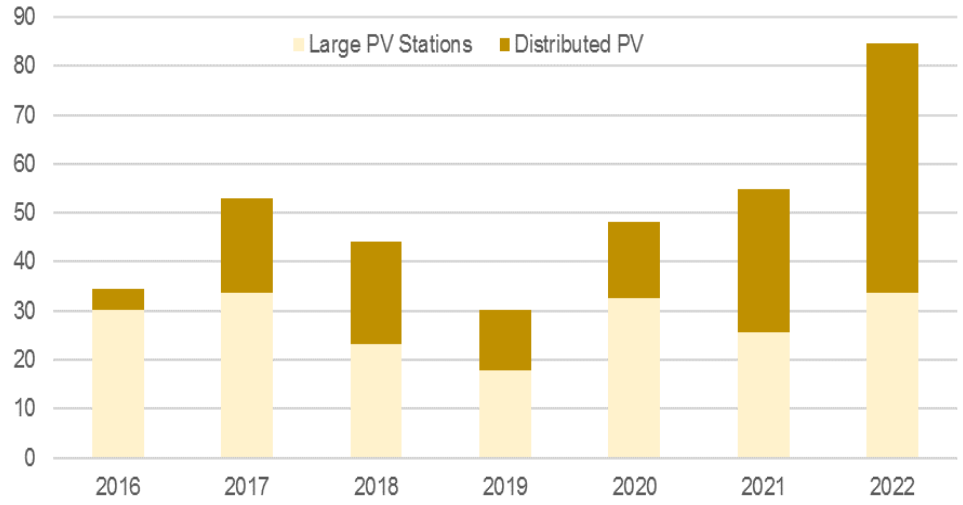
2. Characteristics of VRE Development in Recent Years

- Market Based- **With the phase-out of subsidies, VRE development is entering an era of market-based development and integration.**

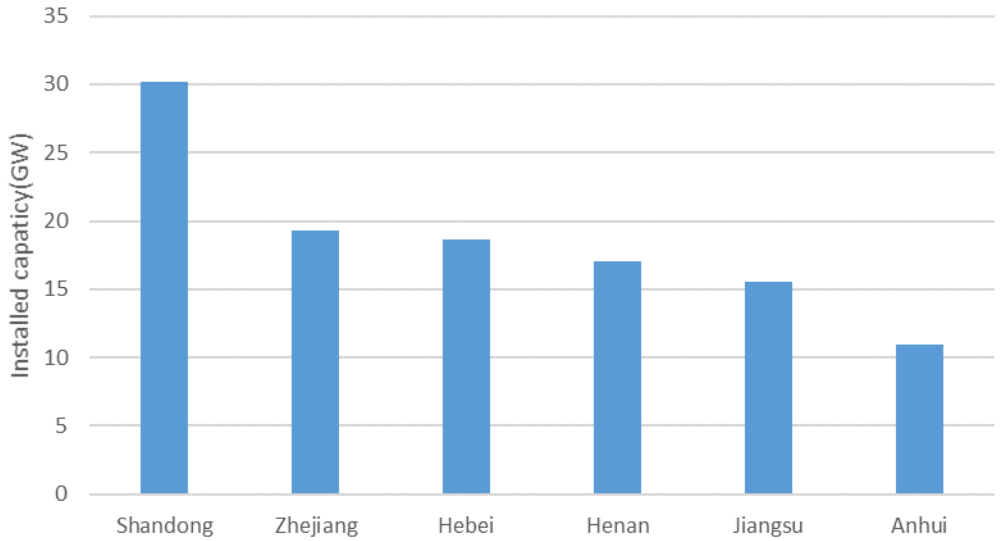


2. Characteristics of VRE Development in Recent Years

- **Fast Development of Distributed PV-** A rapid increase of distributed PV generation capacity is seen, with the share of distributed PV in annually newly installed PV capacity surpass 50% for the past two years.



Newly Installed PV Capacity since 2016

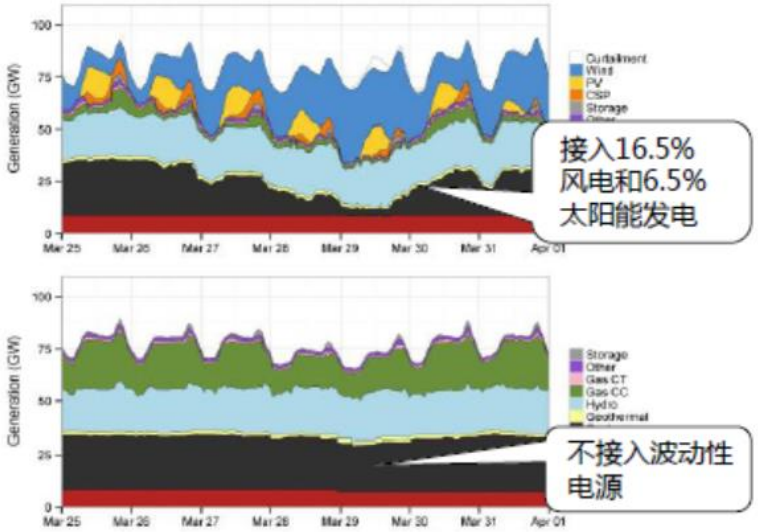


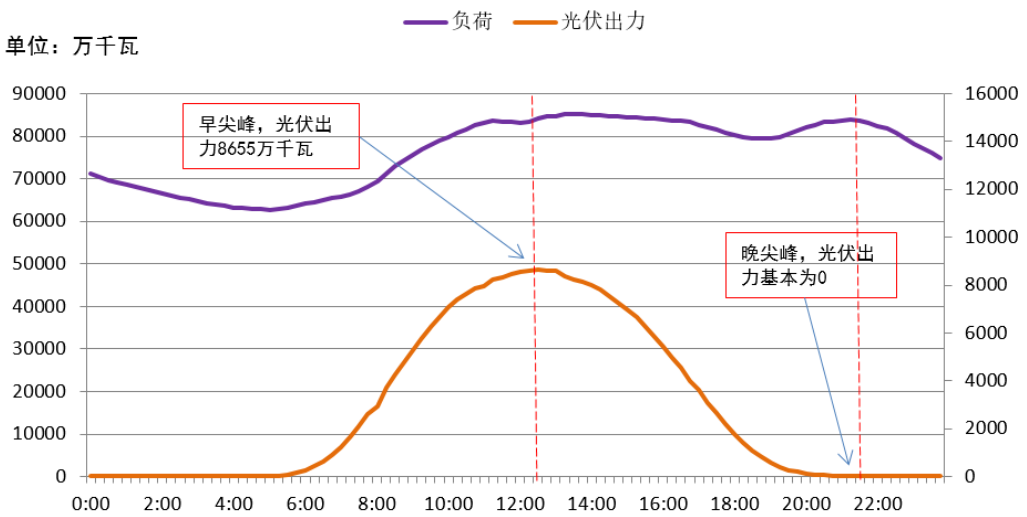
Provinces with the capacity of distributed PV over 10GW

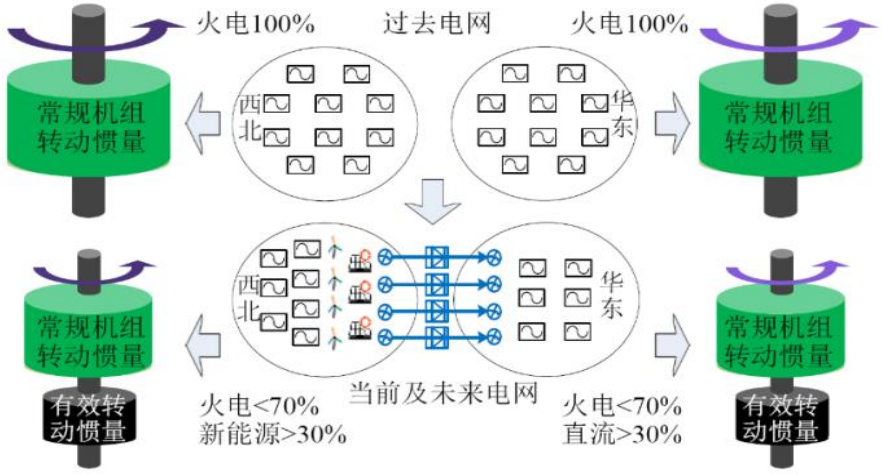
Contents

1. Challenges with High Share of VRE

- Ensure efficient utilization of renewable energy
- Ensure the security of power system operation
- Ensure the secure supply of energy



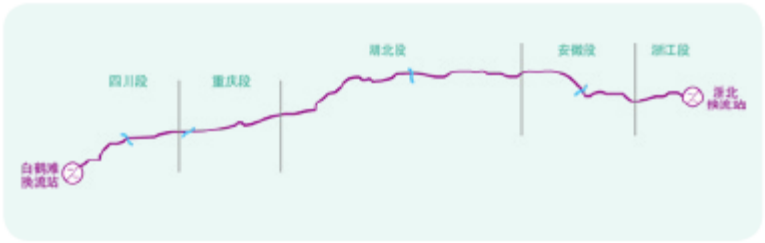




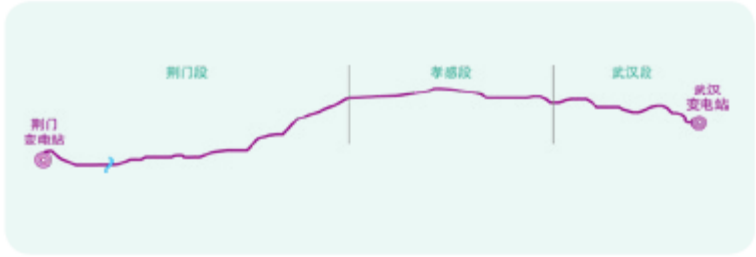
2. System Practices with High Share of VRE

(1) UHV transmission and inner-province transmission lines were constructed to enhance transmission capability of renewable energy.

- **UHV transmission line:** A total of 33 UHVAC and UHVDC transmission projects has been built in China.
- **Inner-province transmission:** more than 100 key inner-province transmission projects were built to enhance the accommodation capability of wind and solar.
- Following the requirement of National Energy Administration, timely and efficiently interconnection of wind and solar power plants to the power grids were ensured.



白鹤滩—浙江特高压直流工程概况图

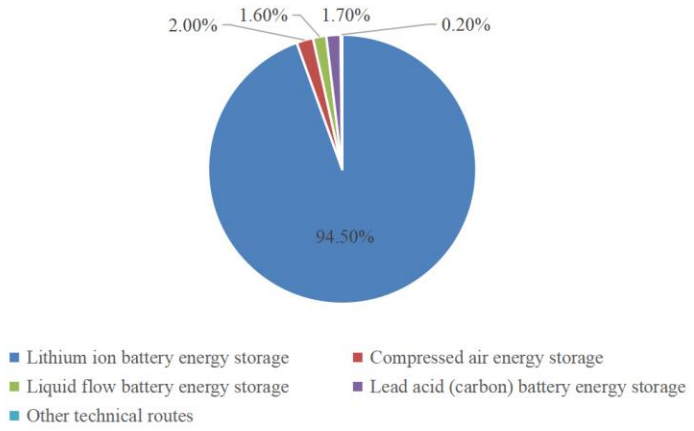


荆门—武汉特高压交流工程概况图

2. System Practices with High Share of VRE

(2) Flexibility of the power systems was promoted with multiple measures.

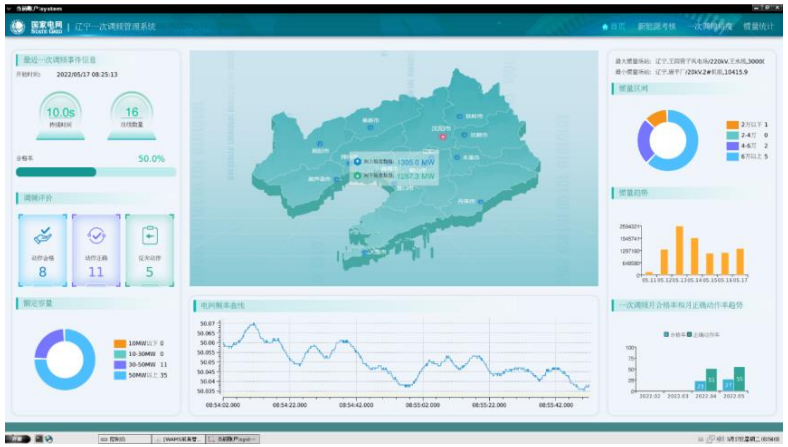
- **Acceleration of ancillary service markets establishment.** By the end of 2022, 26 provincial grids under SGCC officially have the downward regulation ancillary service market in operation.
- **Continuous efforts on the retrofit of thermal generators.** A total of 81GW of thermal generators in the “three north regions” were retrofit to be more flexible.
- **Development of energy storage.** By the end of 2022, the installed capacity of new-type storage reached 8.7 GW, with an average storage duration of about 2.1 hours, an increase of more than 110% over the end of 2021. By the end of 2022, the installed capacity of pumped-storage reached 45.8GW.



Capacity proportion of different new storage technologies

(3) Technologies to support power system dispatch with VRE has been innovated continuously.

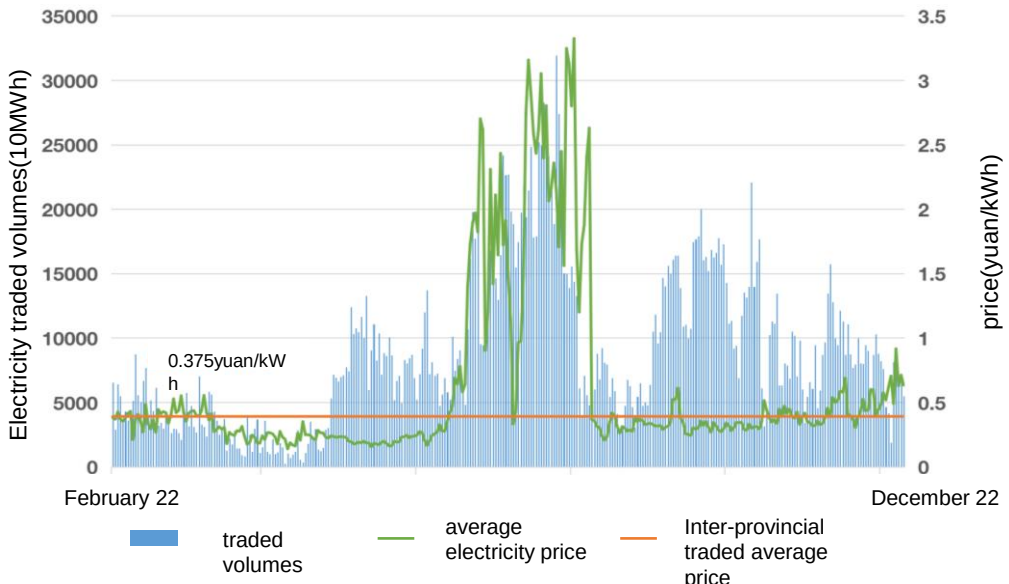
- **Initiating coordinated dispatch of generation, power grid, electric load, and energy storage.** Technologies such as big data, cloud computing, AI, and block chain are applied in power system operation. Multi-timescale coordinated dispatch of generation, power grid and load are initiated. *Flexible load participation is integrated in power grid emergency dispatch*.
- **Innovate grid-friendly technology of VRE**, such as: inertia response, primary frequency modulation, high and low voltage ride through.



Primary frequency management system

(4) The amount of renewable energy traded in the electricity markets were increased to incentivize more customers to use renewable energy.

- **Provincial spot markets**: the 19 provincial-level spot markets in the State Grid have started settlement trial operation or simulated trial operation.
- **Inter-provincial spot market**: in January 2022, the inter-provincial spot market officially started trial operation.



Volume and price of spot transactions between provinces in 2022

Contents

- For power systems with high penetration of VRE, how to guarantee resource adequacy to ensure reliability is increasingly becoming a great concern. Power system operation needs to adapt to this to guarantee both system stability and power supply security.
- While power system flexibility from the generation side still contributes the main part, it is highly necessary and urgent to unlock the flexibility value of demand side resources in power systems.
- Electricity market design needs to be optimized continuously, in terms of both mechanisms and products, to facilitate the participation of various types of generation, demand side resources, and energy storage, into the electricity market.
- With the increasing penetration of distributed PV, integrating distributed energy resources (PV, energy storage, load, etc)in the distribution power grids with self-balanced distribution systems is important. Business model and market mechanism innovation is needed.

Thank you!

（If you have further questions, please contact
wangcaixia@sgeri.sgcc.com.cn）