Implications of COVID-19 for the Electricity Industry in China

Haiwang Zhong

Department of Electrical Engineering, Tsinghua University，China

zhonghw@tsinghua.edu.cn

Oct 7，2021

Outline

1. Influence of COVID-19 on China’s electricity sector
2. Carbon neutrality and emission peaking in China
3. Power system with renewable energy as mainstay
4. Power system coupled with hydrogen energy

1.1 Influence of COVID-19 on electricity demand and supply

Influence on electricity demand

- Factories and shops **closedown**
- Social distancing, regions **lockdown** and travel **bans**
- Industry demand **decreases** & residential demand **increases**

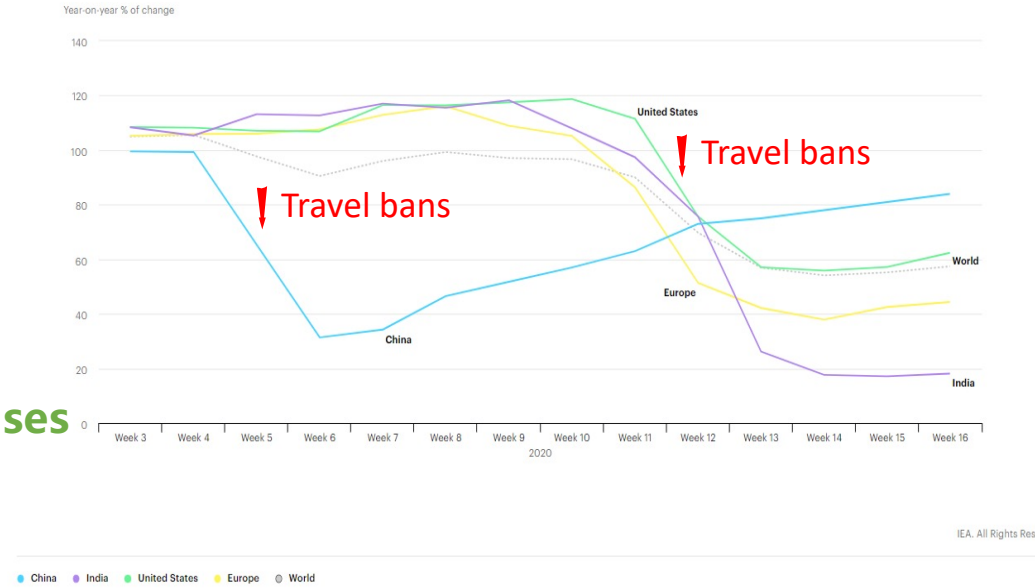
Influence on electricity supply

- Total generation **decreases** & renewable generation share **increases**
- Coal-fired and gas power generation **decreases**

Power balance

- Peak-to-valley difference of daily load profile **increases**
- During COVID-19, generation dispatch requires more **flexibility** margin to cope with the fluctuation of demand and renewable energy power generation.
- The importance of **elasticity** of the smart grid, such as **energy storage** and **demand response**.

Road passenger transport activity in early 2020

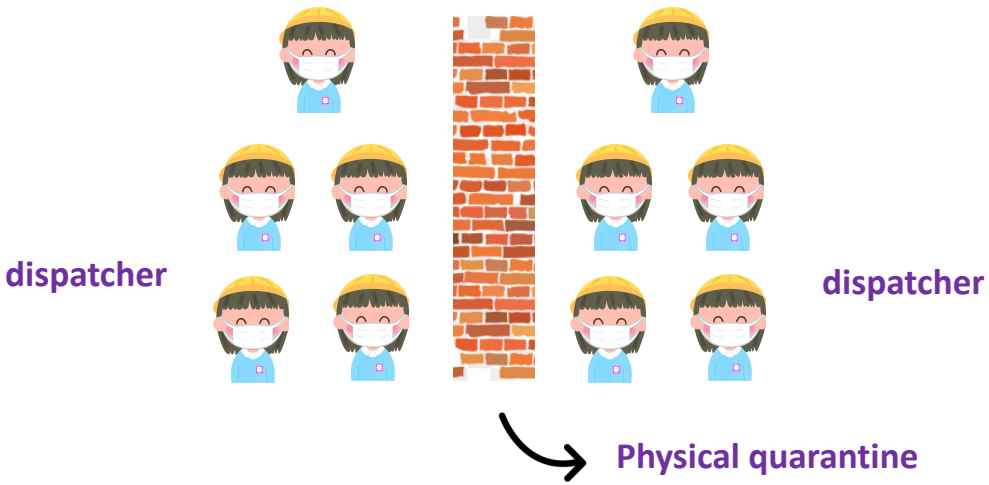


Source: IEA, Reductions of electricity demand after implementing lockdown measures in selected regions, weather corrected, IEA, Paris https://www.iea.org/data-and-statistics/charts/reductions-of-electricity-demand-after-implementing-lockdown-measures-in-selected-regions-weather-corrected

1.2 Influence of COVID-19 on the power grid

Operation and maintenance

- Dispatchers on duty receive stricter quarantine measures
- Dispatchers work by turns with 14 days in each turn
- Initiate online dispatch systems for partial power distribution network below 100kV
- **New tech in operation and maintenance of the power system, such as AI-assisted dispatch and unmanned substation.**



1.3 Influence of COVID-19 on the environment

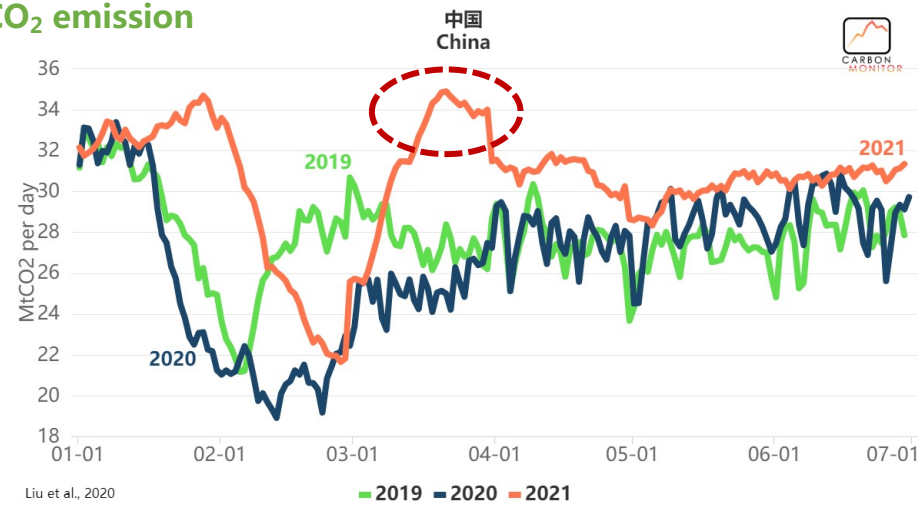
Energy mix change on the generation side

- Great influence on carbon emission: an **8% decrease** in the first quarter of 2020 in China
- **Decrease** in major air pollutants such as NO_x and PM 2.5

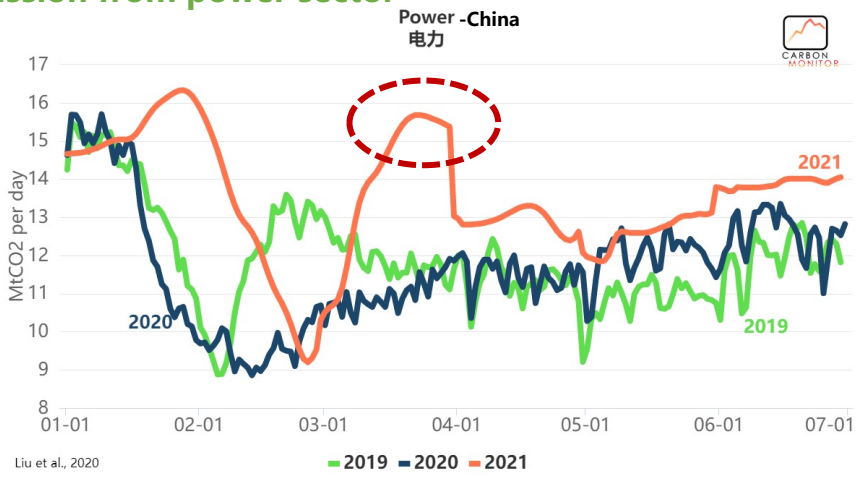
This may be a short-term effect

- **Clean energy transition** is more promising than restrictions on human activities on the act of environmental protection

Total CO_2 emission



CO_2 emission from power sector



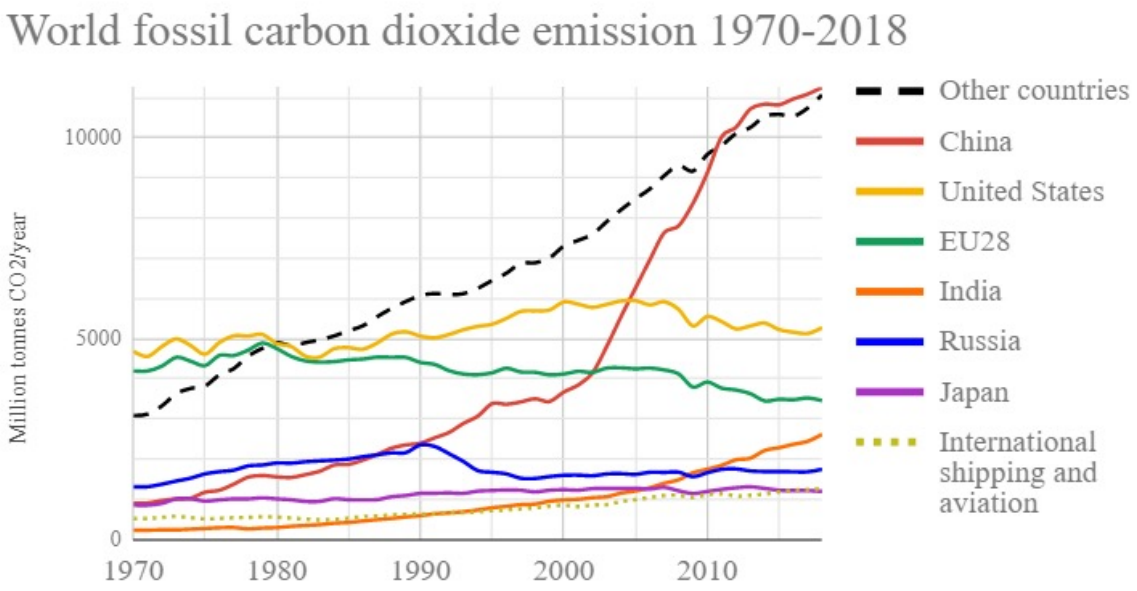
Source: https://www.carbonmonitor.org.cn/

Outline

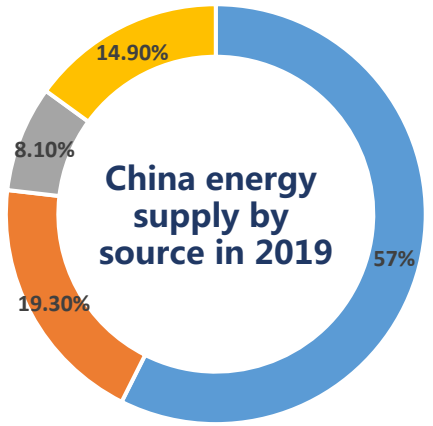
1. Influence of COVID-19 on China’s electricity sector
2. Carbon neutrality and emission peaking in China
3. Power system with renewable energy as mainstay
4. Power system coupled with hydrogen energy

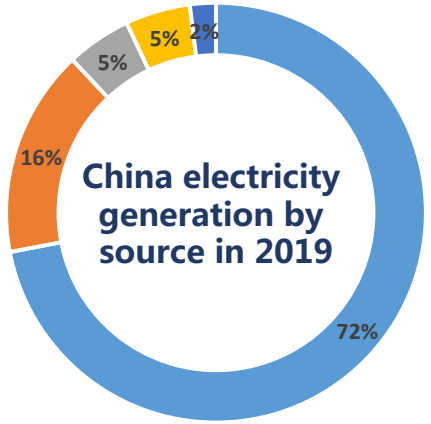
2.1 Major issues to the Carbon Neutrality

- China ‘s annual carbon dioxide emissions **rank 1st** in the world.
- The energy mix has long been **dominated by coal**.
- The task of optimizing China’ s energy mix and the evolvement to carbon neutrality is arduous.



Source:https://commons.wikimedia.org/wiki/File:World_fossil_carbon_dioxide_emissions_six_top_countries_and_confederations.png





2.2 Overall framework for carbon neutrality

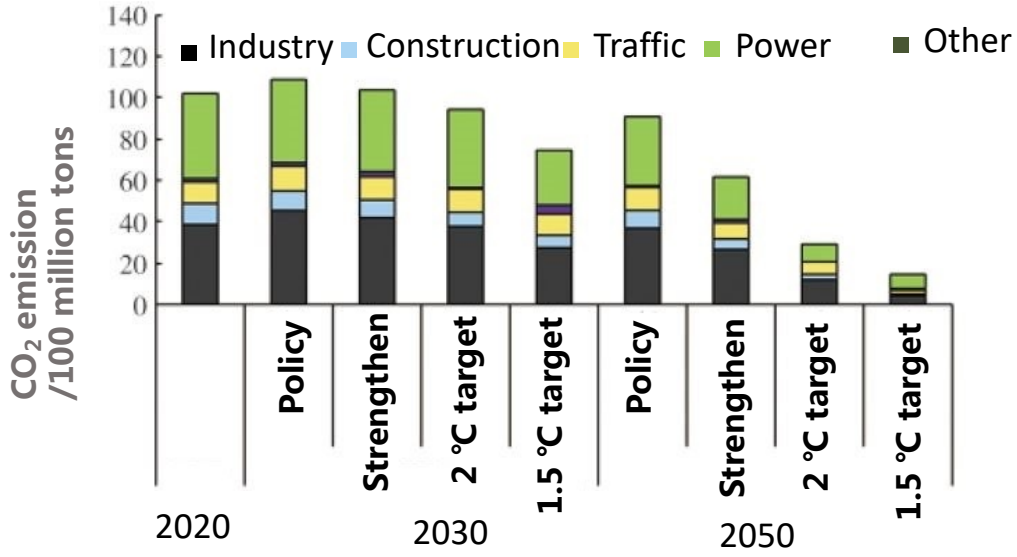
The Paris Agreement

- Goal: to limit global warming to well below 2, **preferably to 1.5 degrees Celsius**, compared to pre-industrial levels.
- Countries aim to **reach global peaking of greenhouse gas** emissions ASAP to achieve a climate neutral world by the middle of the 21st century.

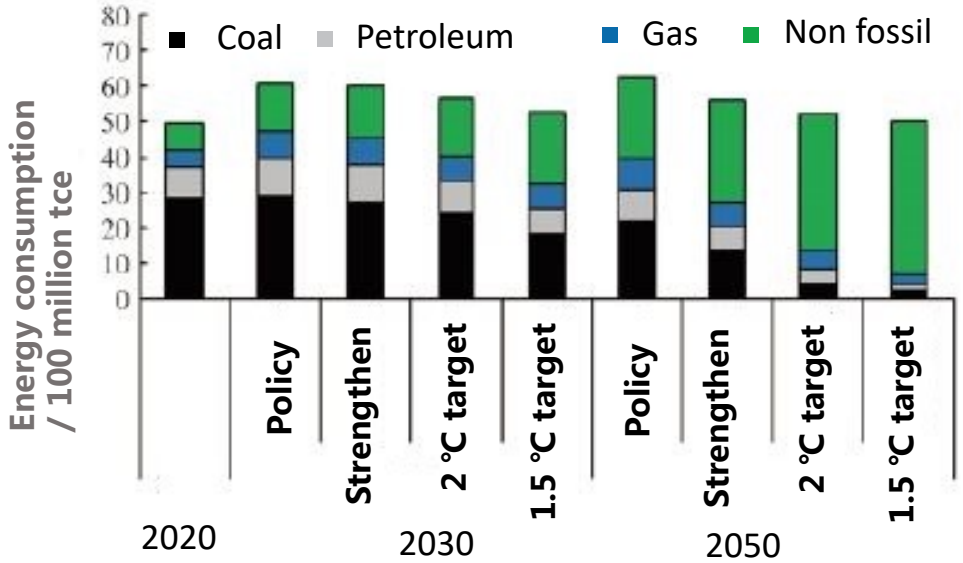
The meeting of the Central Committee for Financial and Economic Affairs

- **Peak its carbon emissions by 2030** and **attain carbon neutrality by 2060**.
- Establish a clean, low-carbon, secure and efficient energy system, control the overall use of fossil fuels .
- A new type of power system **with renewable energy as mainstay** will be fostered.

2.3 Scenarios for long-term low-carbon transition



Composition of CO_2 emission by sector under different scenarios

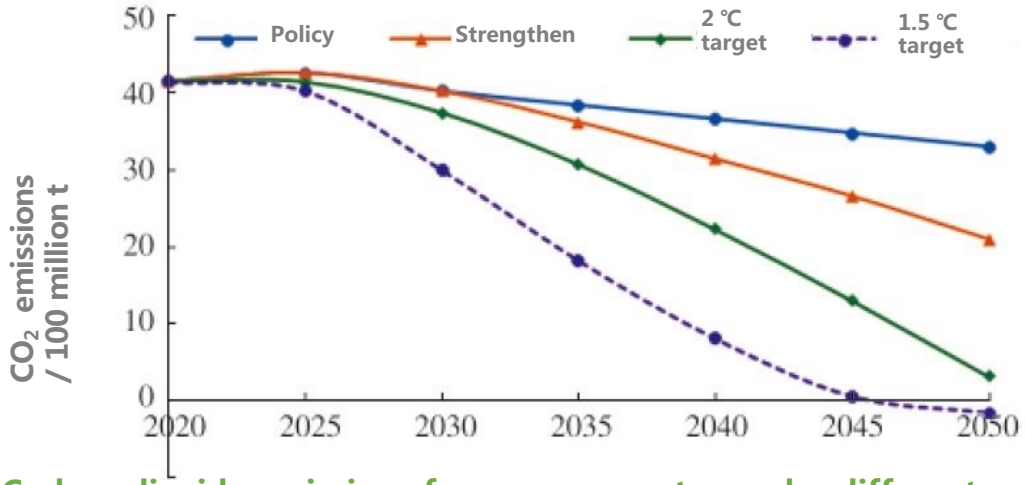


Composition of primary energy consumption in 2030 and 2050

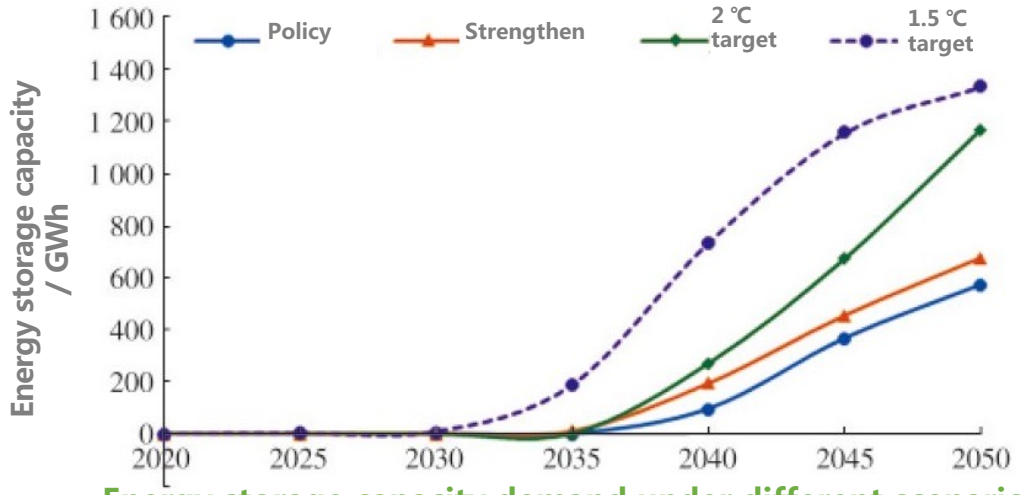
- **Policy scenario:** Based on the NDC objectives, action plans and related policies proposed by China under **the Paris Agreement**, continue the current low-carbon transition trend and policy scenario;
- **Strengthen the policy scenario:** on the basis of the policy scenario, **further strengthen the intensity and extent** of reducing the energy intensity and carbon dioxide intensity of GDP, and further increase the proportion of non fossil energy in primary energy consumption and other indicators;
- **2 ℃ temperature control target scenario:** to achieve the goal of global temperature control of **2 ℃**;
- **1.5 ℃ temperature control target scenario:** guided by the goal of controlling **1.5 ℃** temperature rise, we will strive to achieve zero net carbon dioxide emission and deep emission reduction of other greenhouse gases by the middle of the 21st century;

Source: China’s Long-term Low-carbon development strategy and pathway

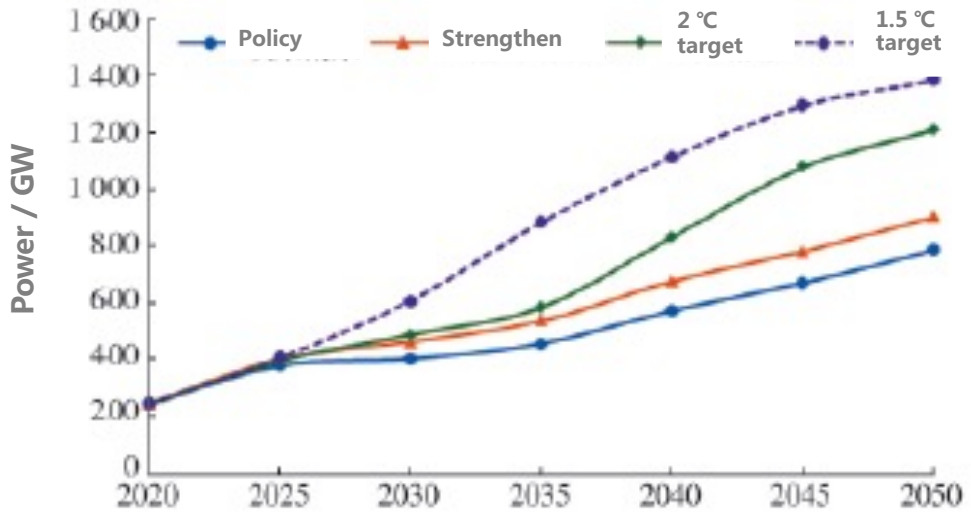
2.4 Results under different scenarios



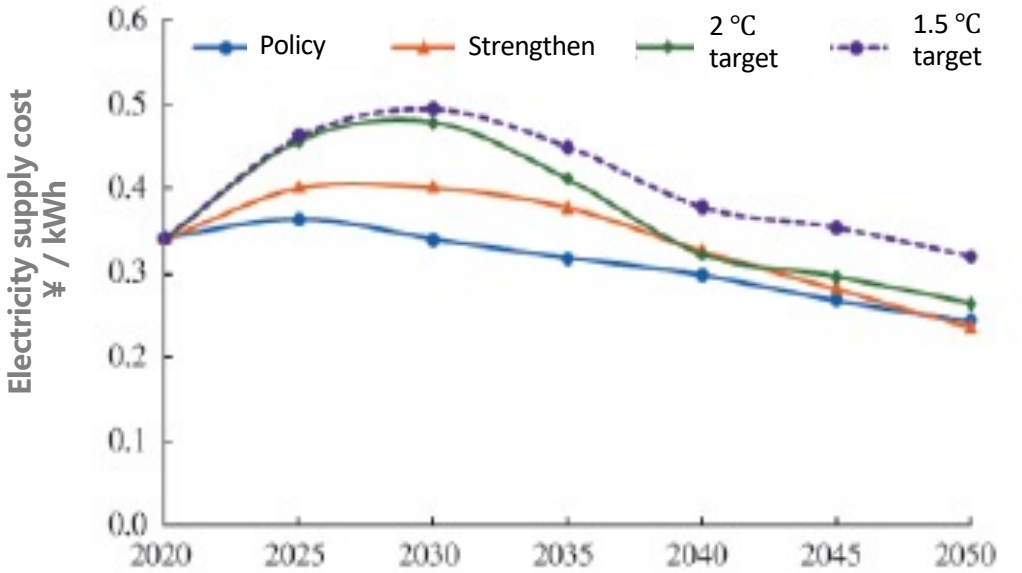
Carbon dioxide emissions from power sector under different scenarios (including CCS)



Energy storage capacity demand under different scenarios



Total capacity of cross-regional power exchange under different scenarios



Trends of power supply costs under different scenarios

Source: China’s Long-term Low-carbon development strategy and pathway

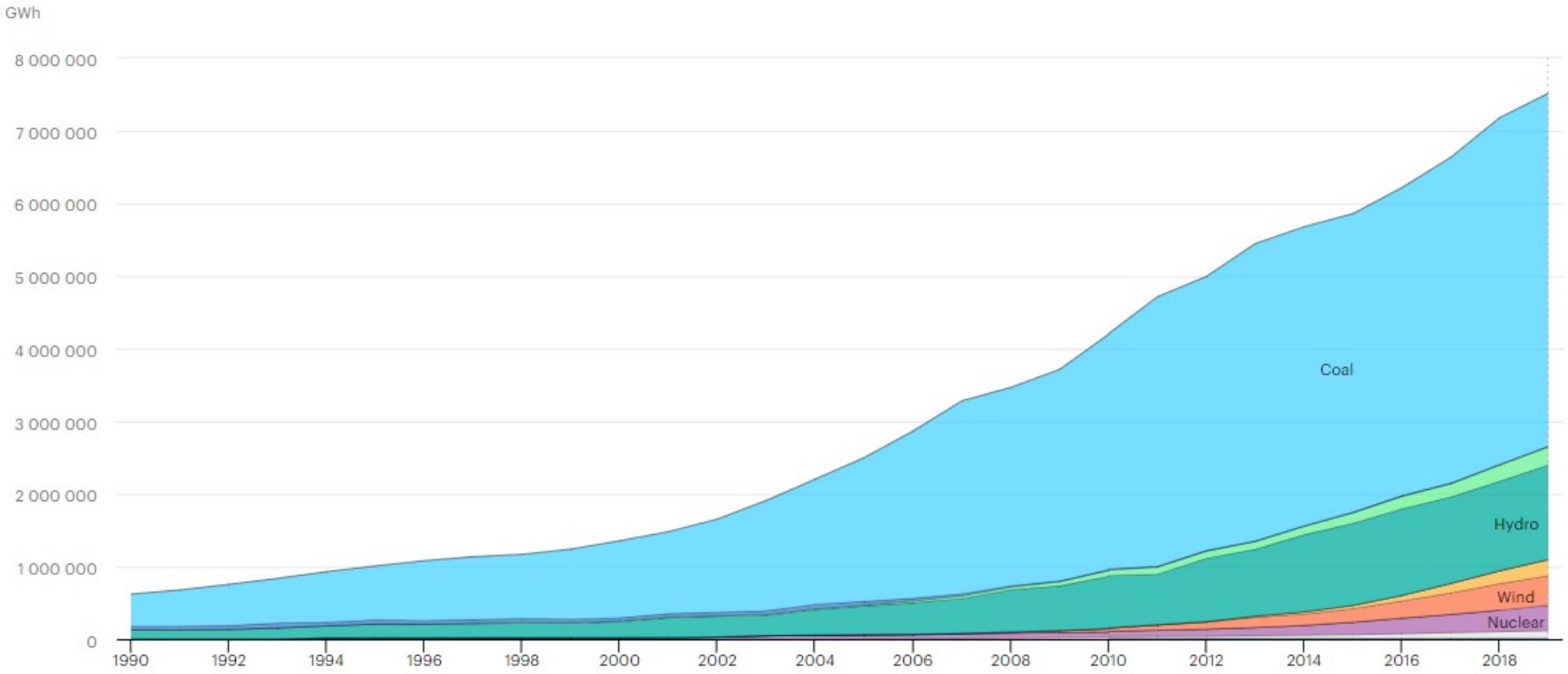
Outline

1. Influence of COVID-19 on China’s electricity sector
2. Carbon neutrality and emission peaking in China
3. **Power system with renewable energy as mainstay**
4. Power system coupled with hydrogen energy

3.1 Penetration of renewable energy in Power System

Energy Intelligence Laboratory
智慧能源实验室

Electricity generation by source, People's Republic of China 1990-2019

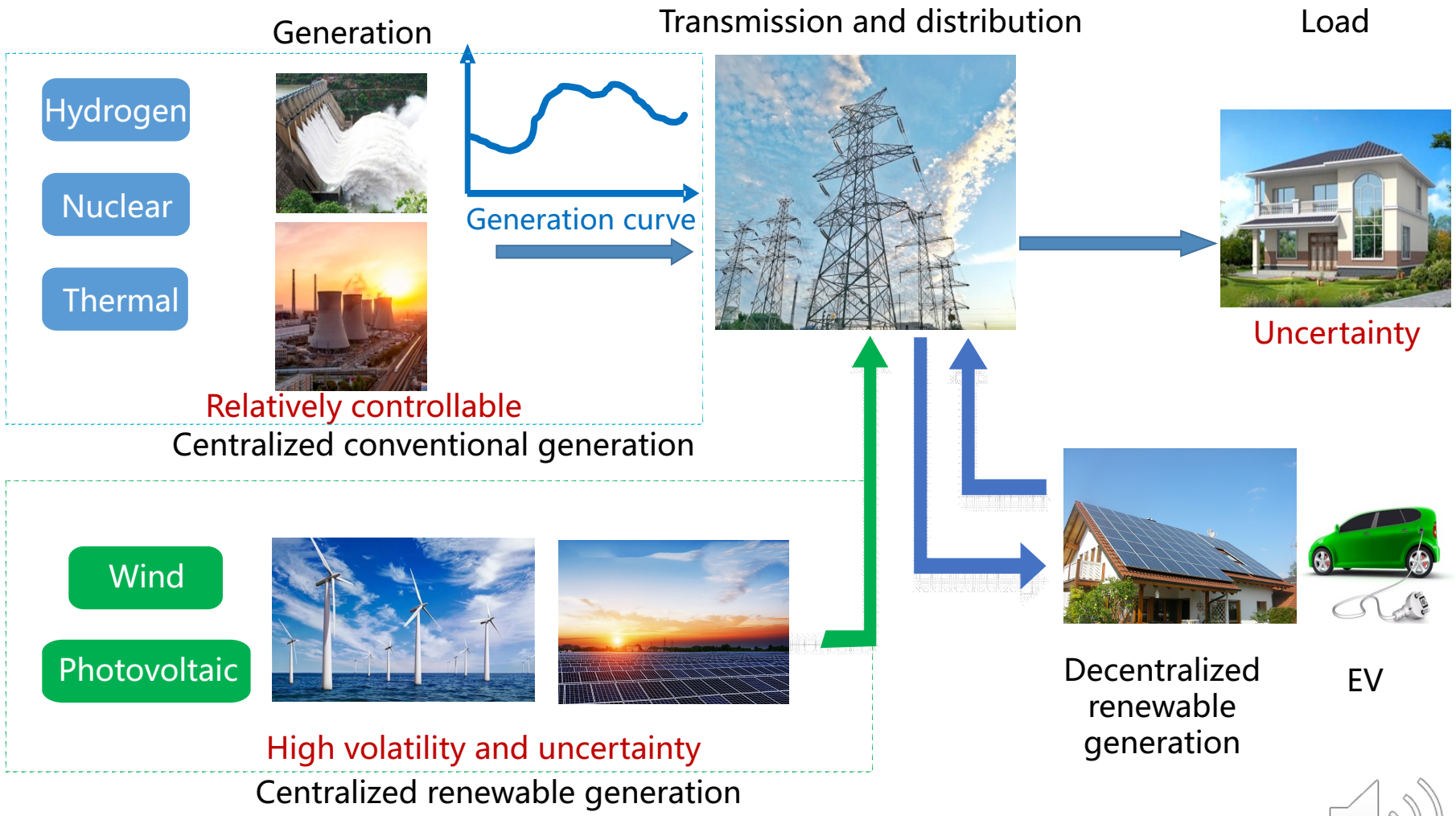


Coal Oil Natural gas Hydro Geothermal Solar PV Wind Tide Nuclear Biofuels Waste Solar thermal

Source: IEA, https://www.iea.org/countries/china

3.2 Generation

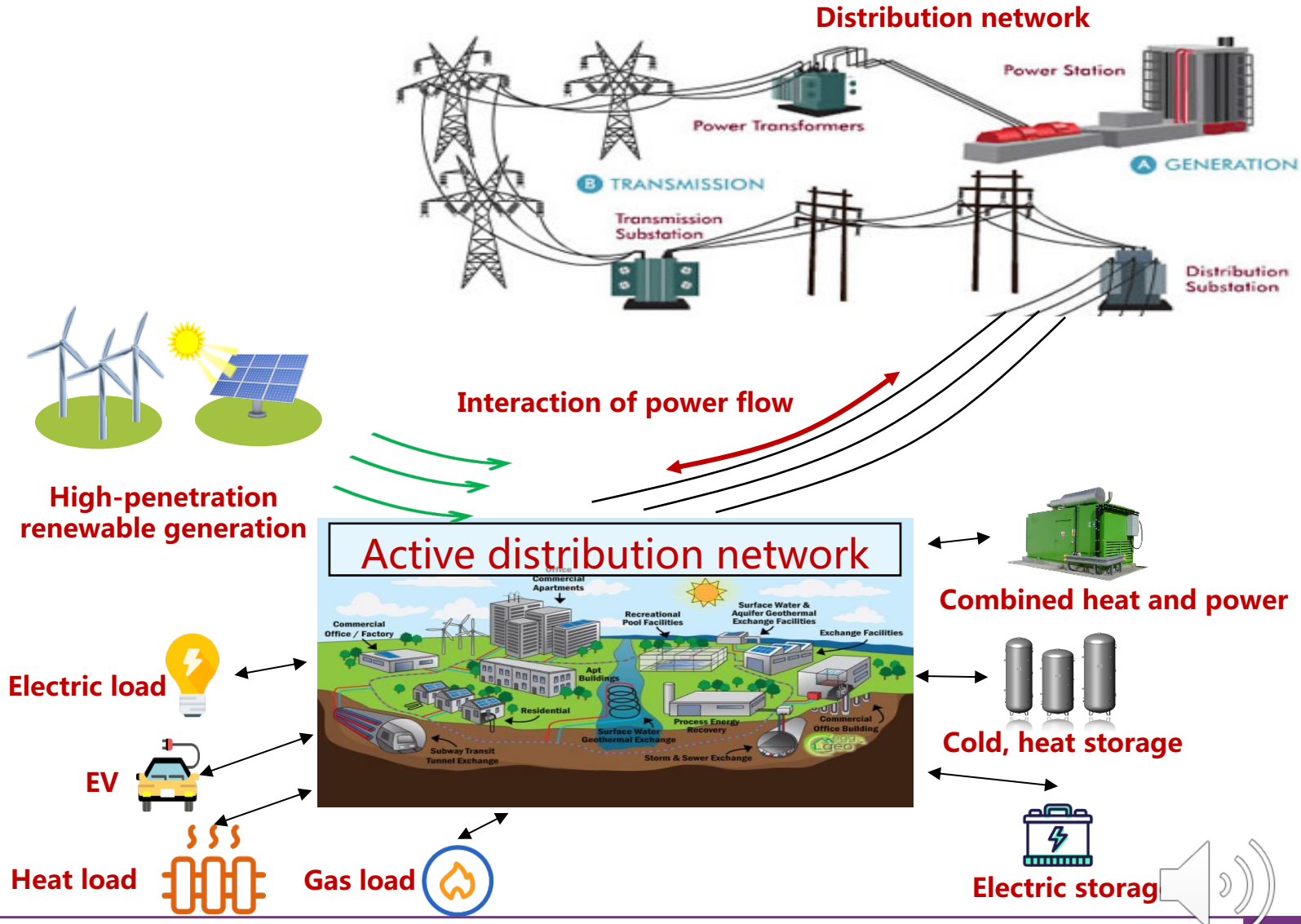
- **Clean replacement** of the energy system is a key countermeasure to ensure energy supply while reducing carbon dioxide emissions.
- Centralized and distributed renewable generation complement each other.



3.3 Network

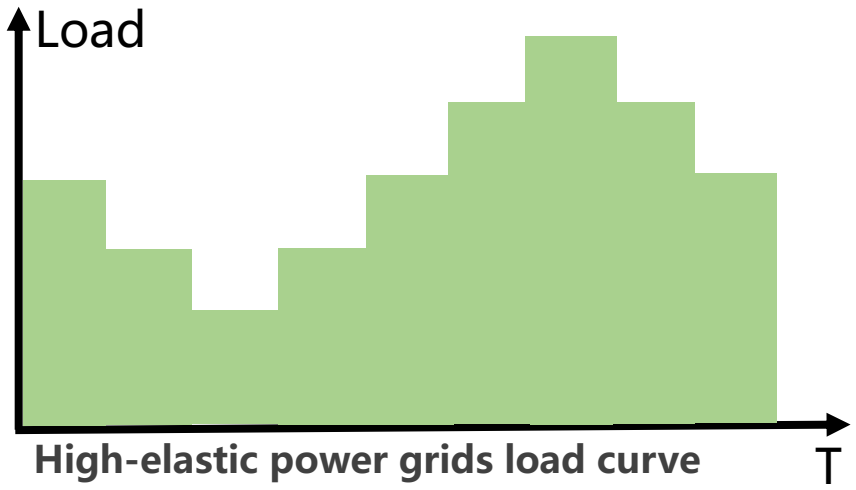
- The conventional distribution network needs to evolve to active ones. **Efficient coordination and interaction of transmission and active distribution networks** will become the main form of future grid development.

- Through the interconnection with the gas network and heating network, the active power distribution network will form a **comprehensive energy system**.

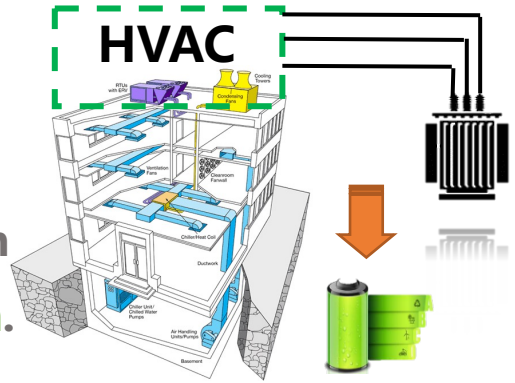


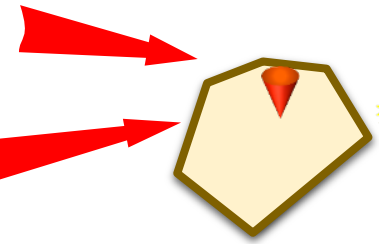
3.4 Load

- Massive amounts of data can be collected, transmitted, stored and processed on a large scale without delay
- Industrial and commercial loads and residential users can effectively participate in **demand response.**
- Multi-energy integration allows different energy sources to substitute each other, which can **produce a larger feasible region.**



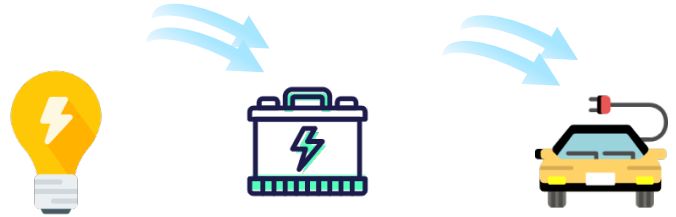
High-elastic power grids load curve





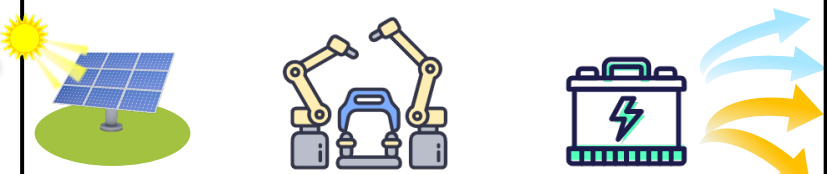
Equivalent to virtual energy storage participating in grid operation

Valley hour



Load | Electricity, cold, heat Storage charging | EV charging

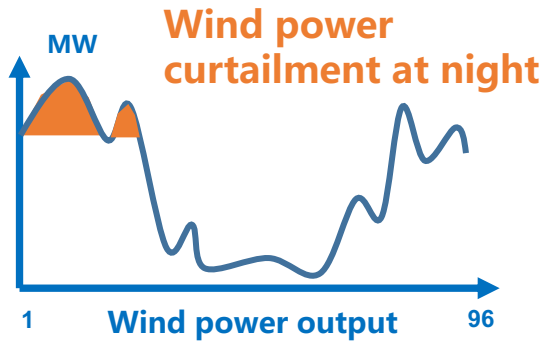
Peak hour

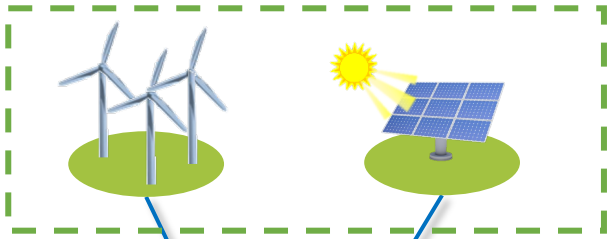


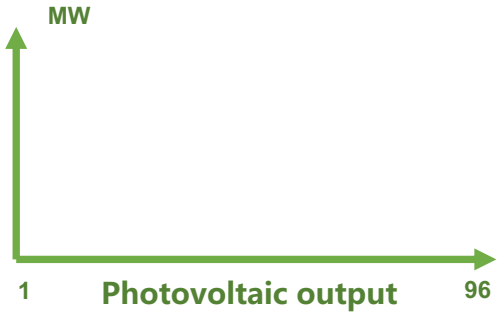
Distributed sources | Factory assembly line shifting | Electricity, cold, heat storage discharging

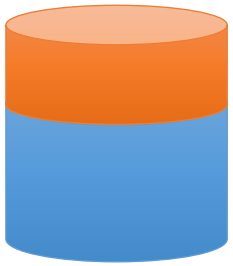
3.5 Energy Storage

- Significant cost reduction of energy storage
- Uncertainty and volatility resulted from the increasing penetration of renewable generation



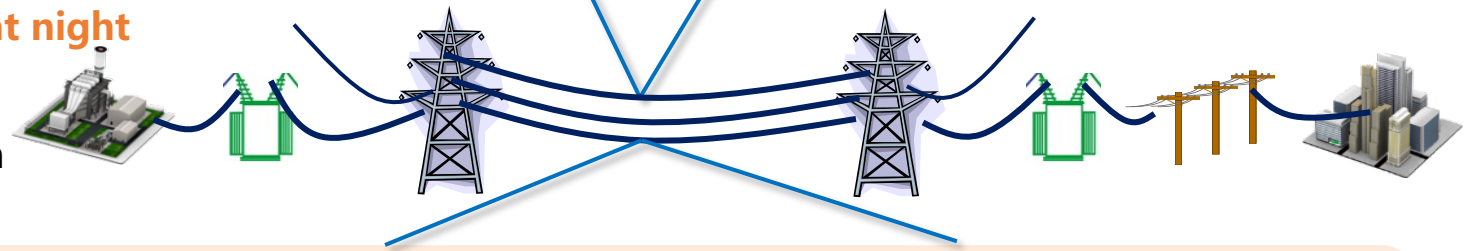






Wind power curtailment at night

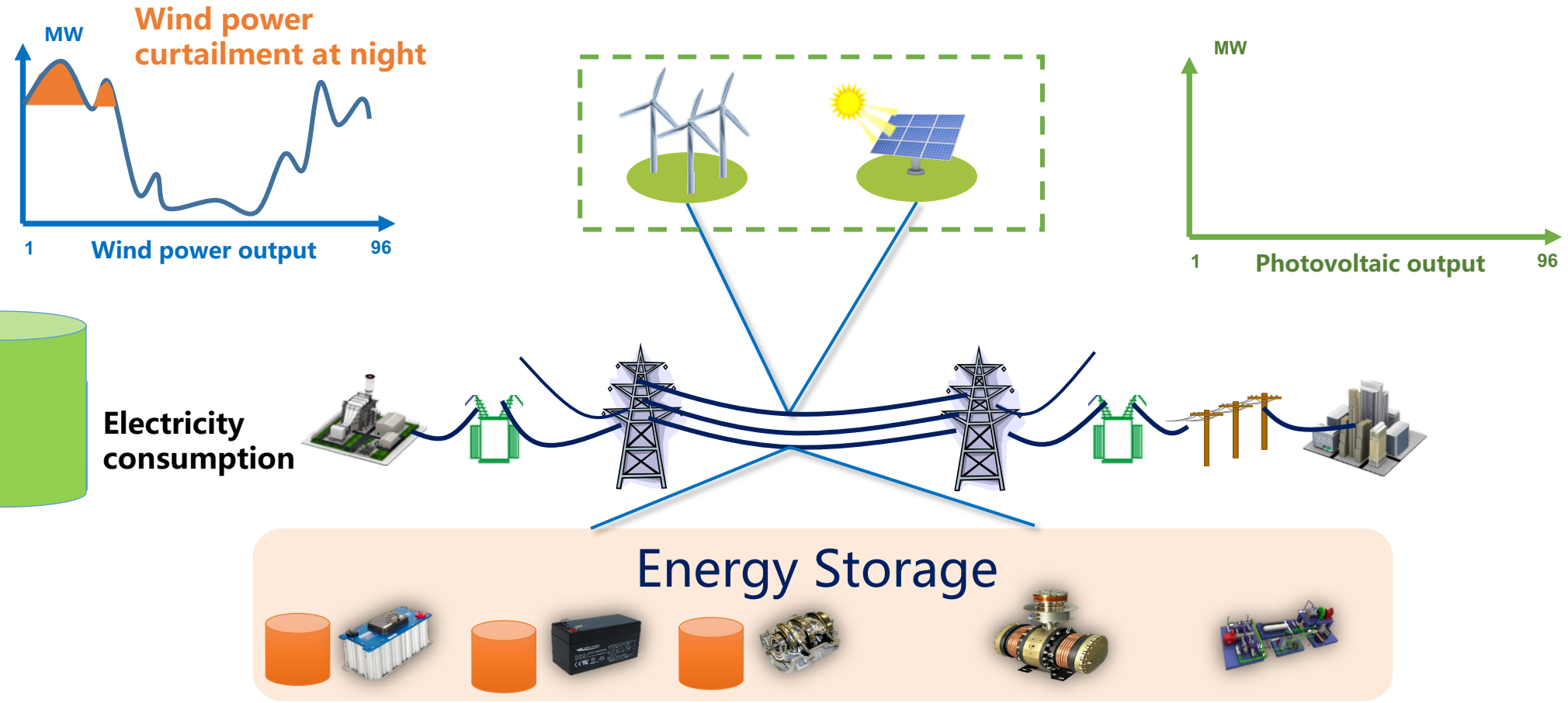
Electricity consumption



Energy Storage

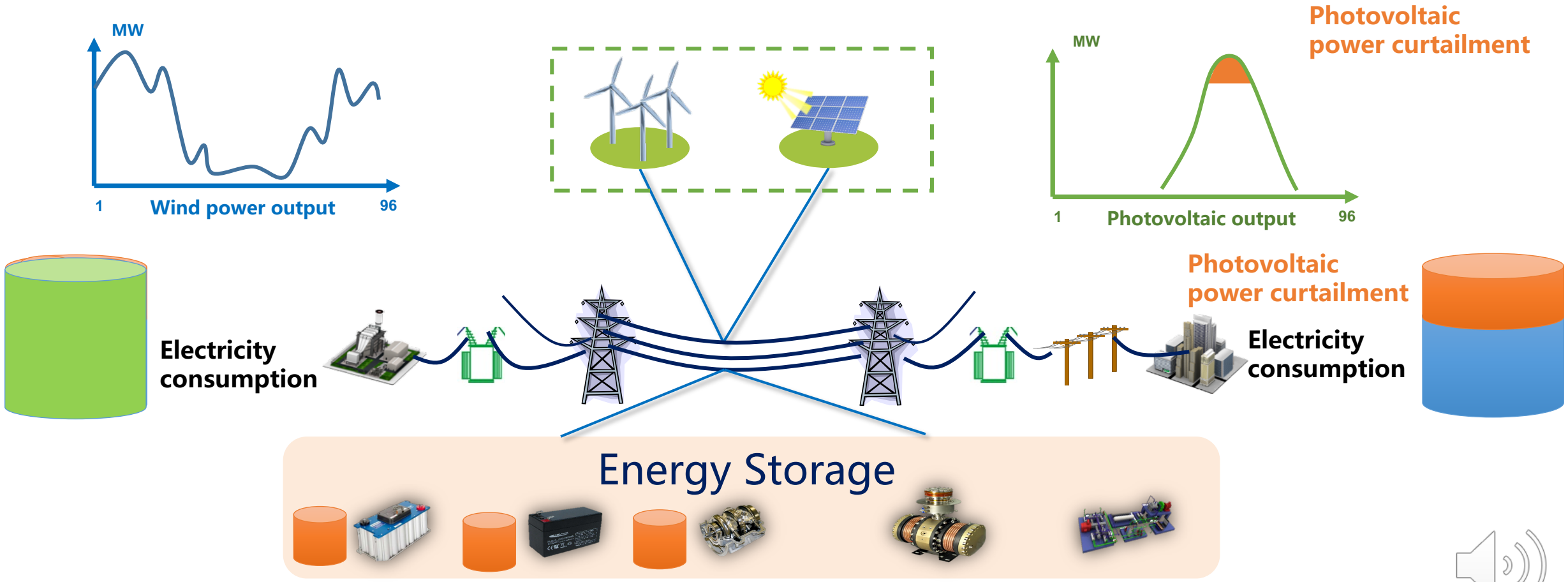
3.5 Energy Storage

- Significant cost reduction of energy storage
- Uncertainty and volatility resulted from the increasing penetration of renewable generation



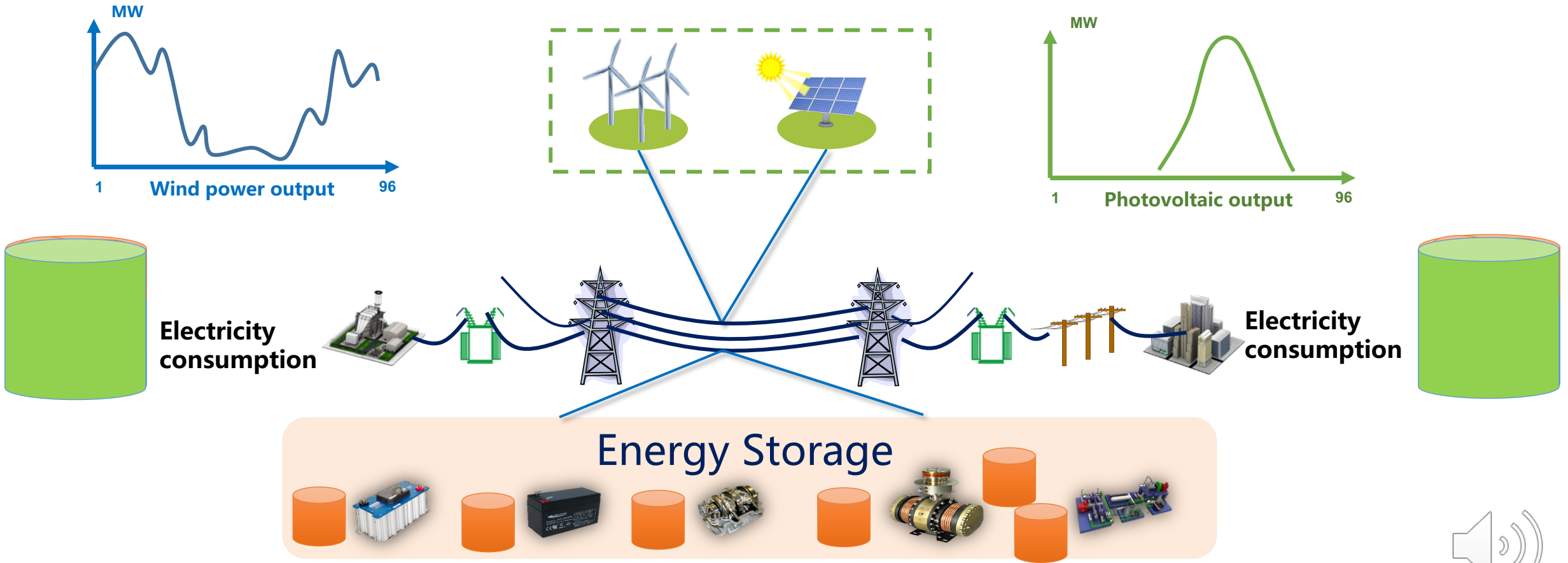
3.5 Energy Storage

- Significant cost reduction of energy storage
- Uncertainty and volatility resulted from the increasing penetration of renewable generation



3.5 Energy Storage

- Significant cost reduction of energy storage
- Uncertainty and volatility resulted from the increasing penetration of renewable generation



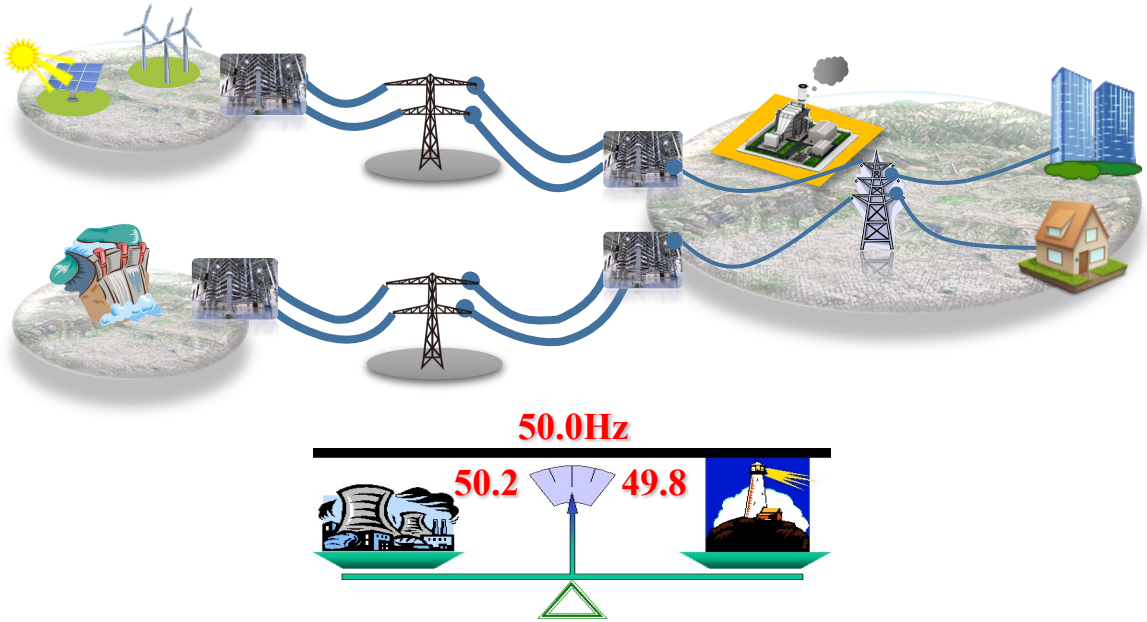
Outline

1. Influence of COVID-19 on China’s electricity sector
2. Carbon neutrality and emission peaking in China
3. Power system with renewable energy as mainstay
4. Power system coupled with hydrogen energy

4 Power system coupled with hydrogen energy

- **Electricity** distribution system has low cost and high reliability, but it requires instantaneous balance between power generation and consumption.

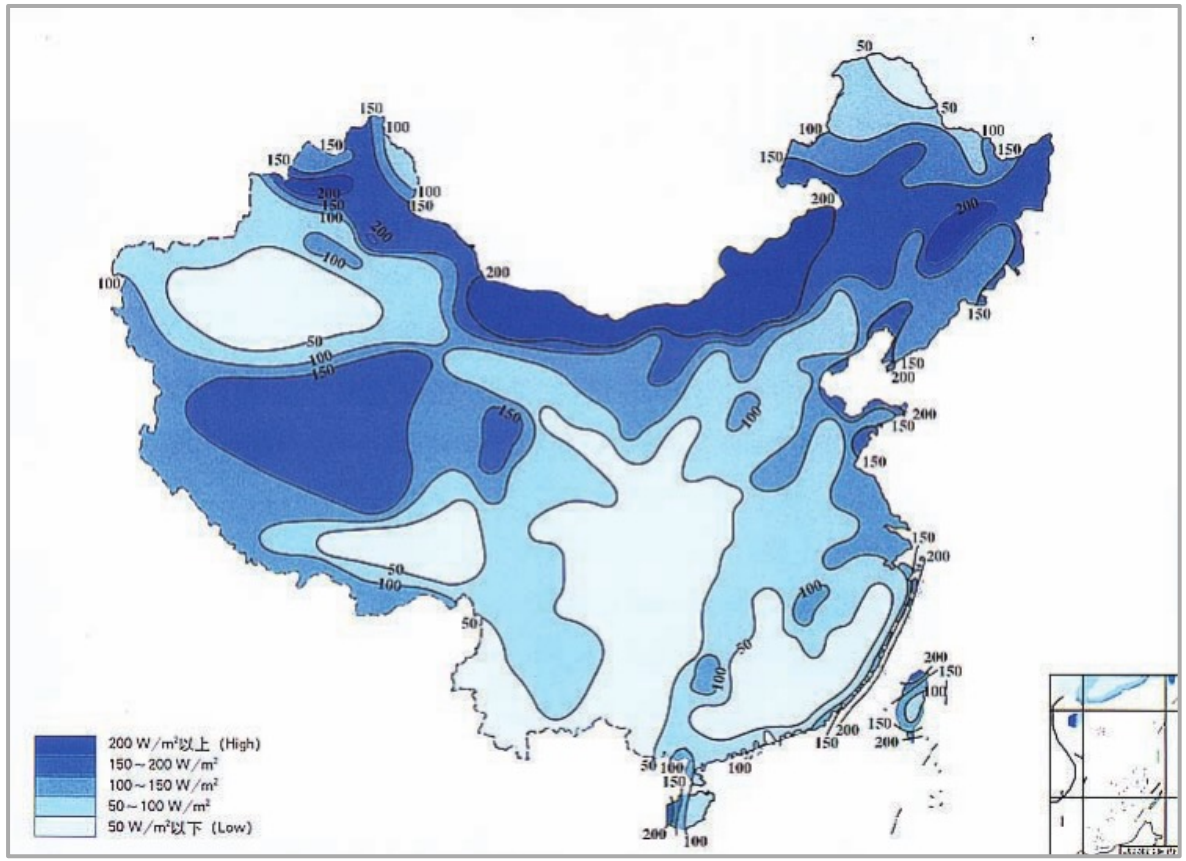
- **Hydrogen energy** has high energy density and is an efficient carrier for large-scale electricity energy storage, which provides flexibility for balance between power generation and consumption.



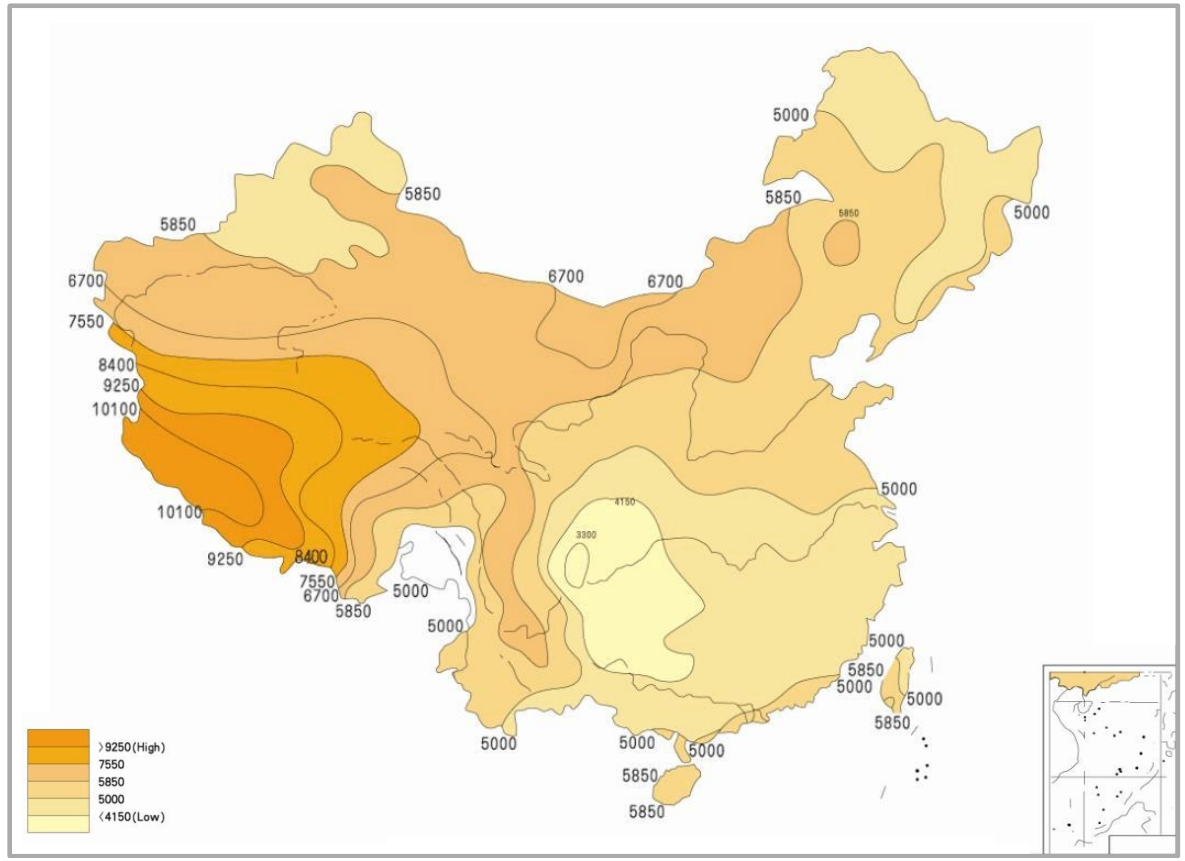
4 Power system coupled with hydrogen energy

Energy Intelligence Laboratory
智慧能源实验室

Annual distribution of wind energy resources in China



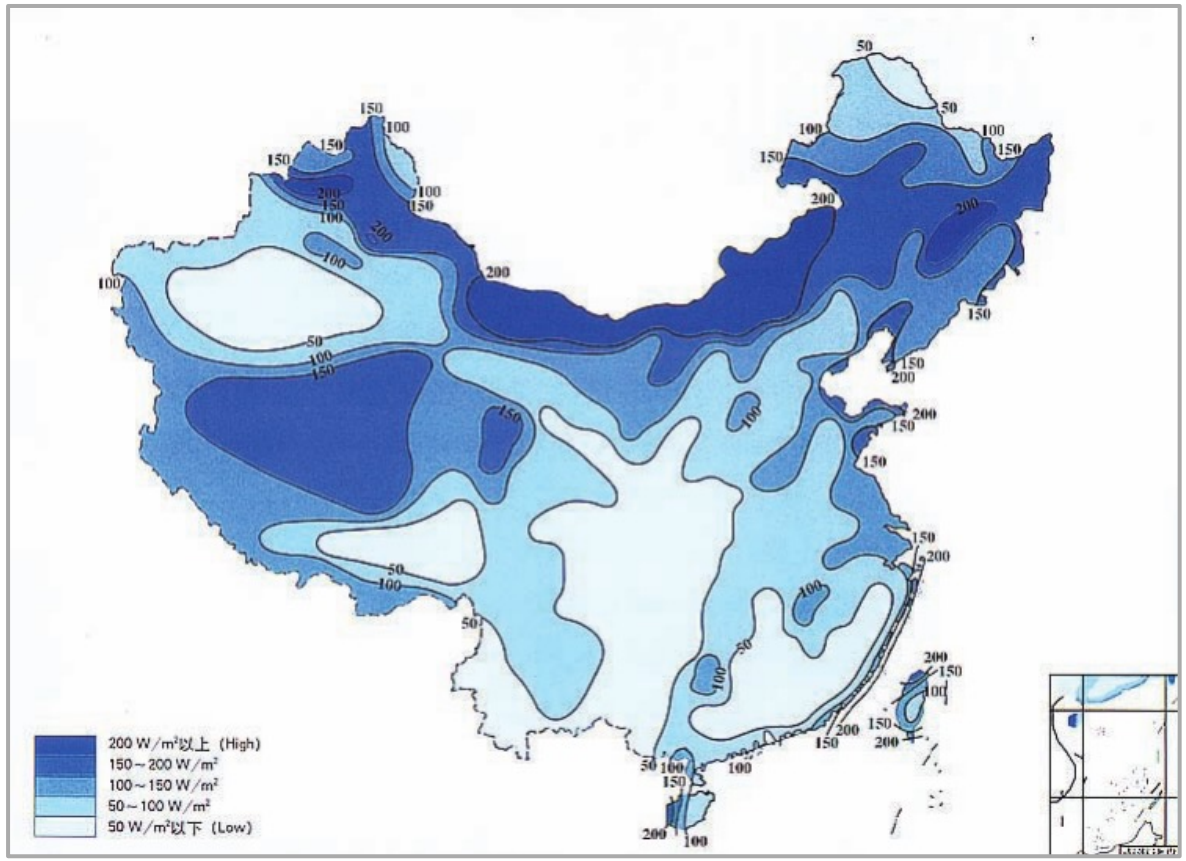
Annual distribution of solar energy resources in China



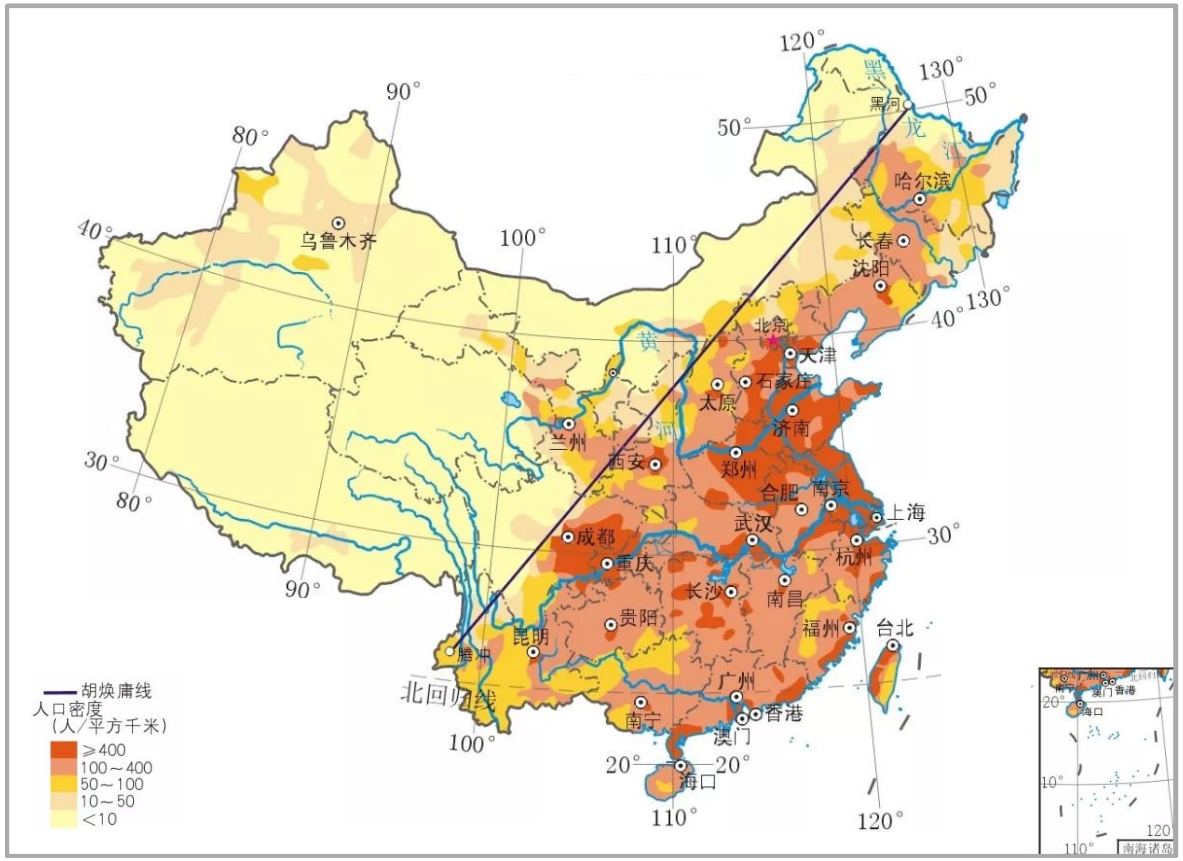
Western provinces: rich in wind and solar energy resources, low energy demand

4 Power system coupled with hydrogen energy

Annual distribution of wind energy resources in China



Population density distribution in China

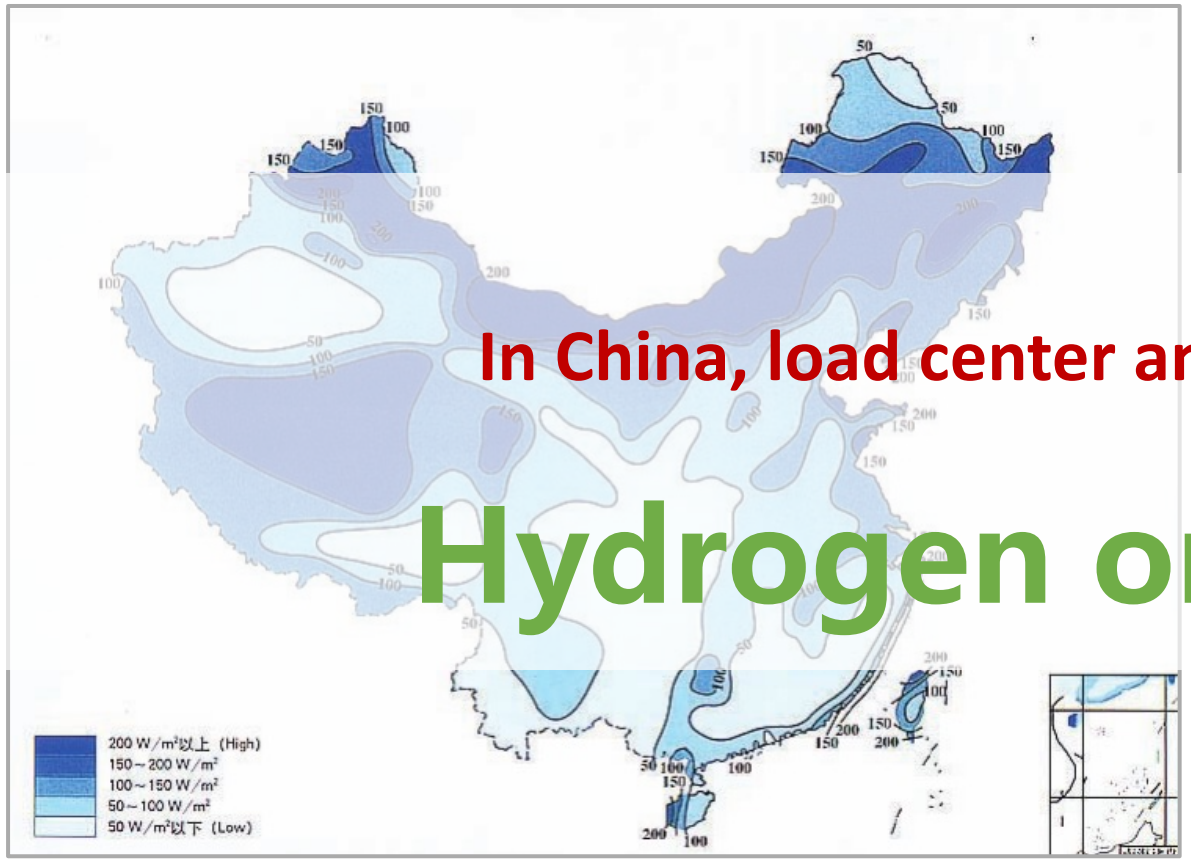


Eastern provinces: high population density, high energy demand

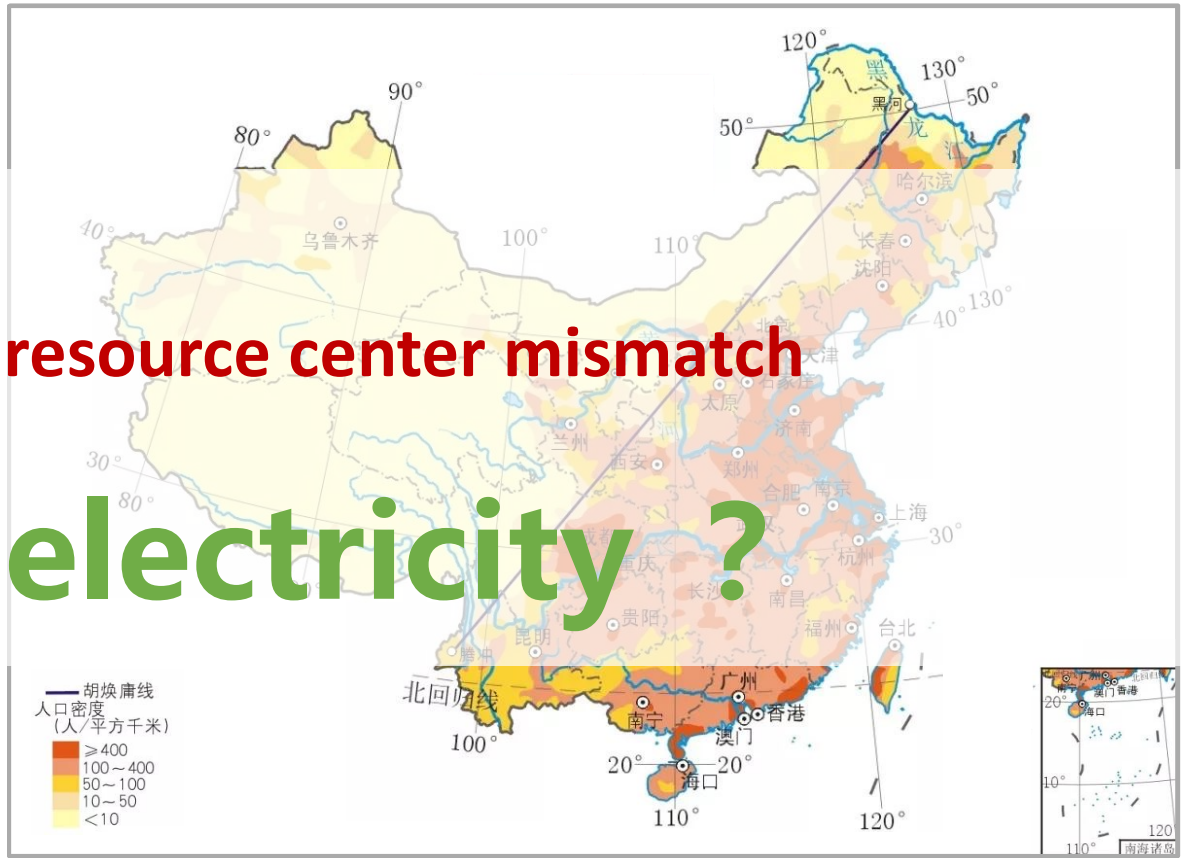
4 Power system coupled with hydrogen energy

Energy Intelligence Laboratory
智慧能源实验室

Annual distribution of wind energy resources in China



Population density distribution in China



In China, load center and resource center mismatch

Hydrogen or electricity ?

Eastern provinces: high population density, high energy demand

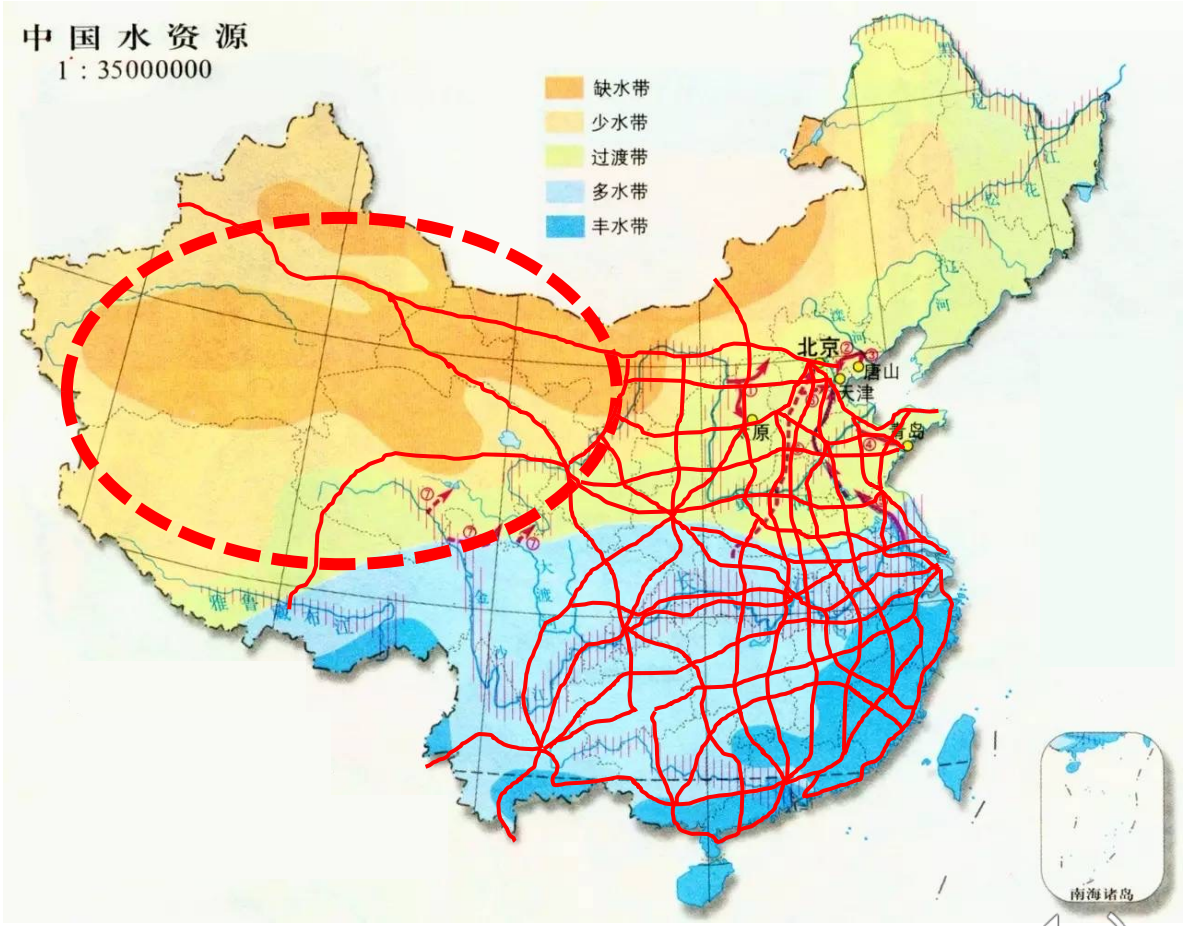
4 Power system coupled with hydrogen energy

Hydrogen transport: hydrogen is produced locally in the west and then transported to the east to generate electricity.

Problems:

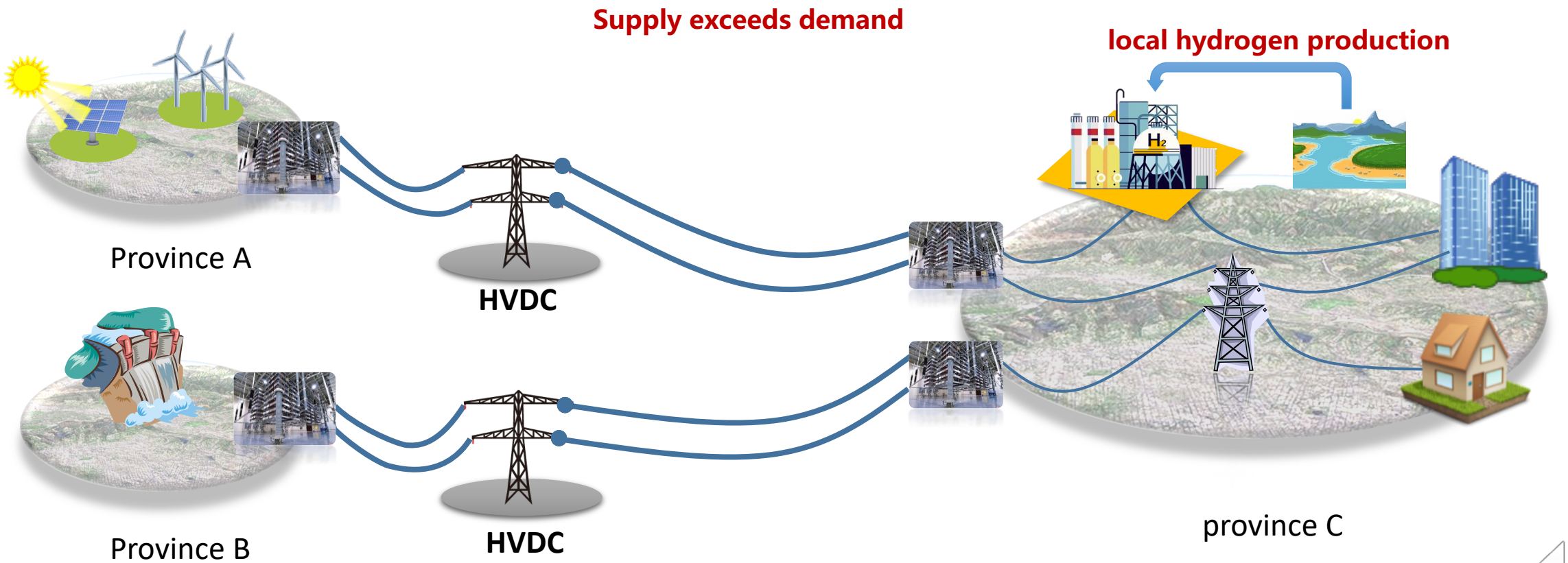
- Where does the raw material come from when water is scarce in the west?
- It is equivalent to sending water from the west to the east, which will worsen the ecology of the west and is **not sustainable.**
- Assuming enough groundwater is tapped, a bigger problem arises: **hydrogen transport.**
- Long-distance, large-scale hydrogen transport: **high cost, high risk!**

Water resources distribution map of China



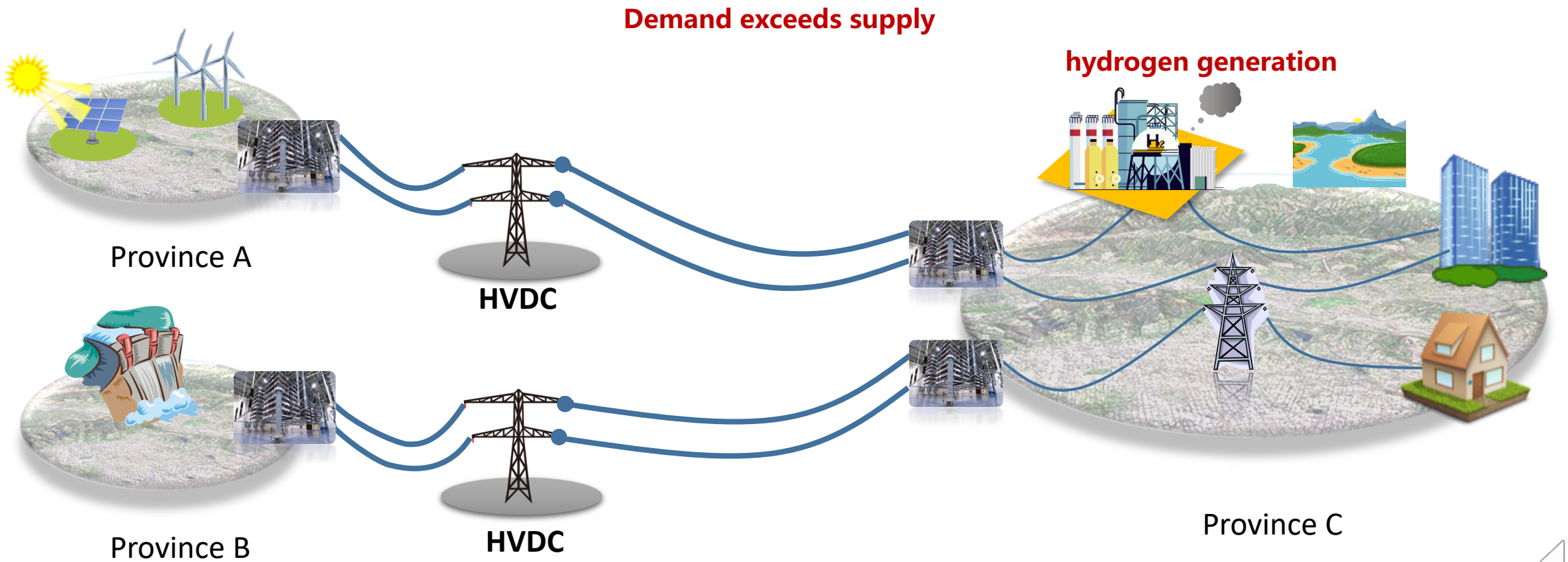
4 Power system coupled with hydrogen energy

Transport: renewable energy power generation **in the west** is transmitted to the east through high-voltage lines, and hydrogen energy is used to generate electricity **in the east**.



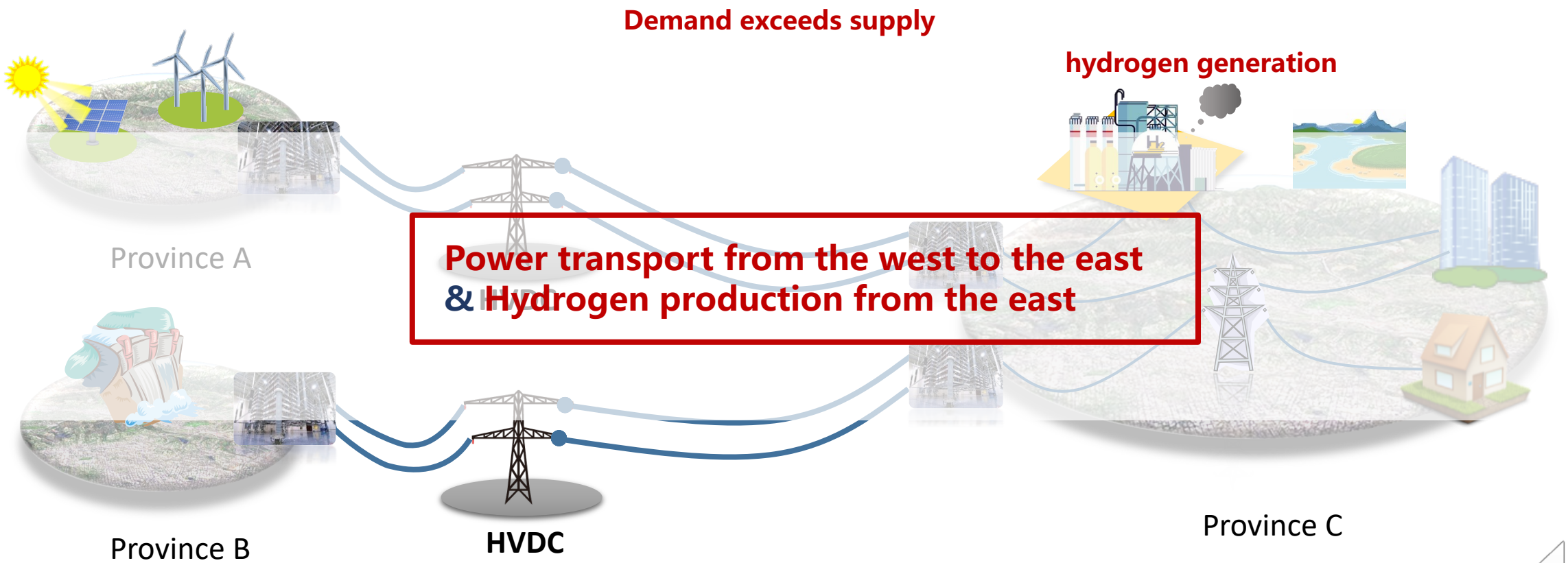
4 Power system coupled with hydrogen energy

Transport: renewable energy power generation **in the west** is transmitted to the east through high-voltage transmission lines, and hydrogen energy is used to generate electricity **in the east**.



4 Power system coupled with hydrogen energy

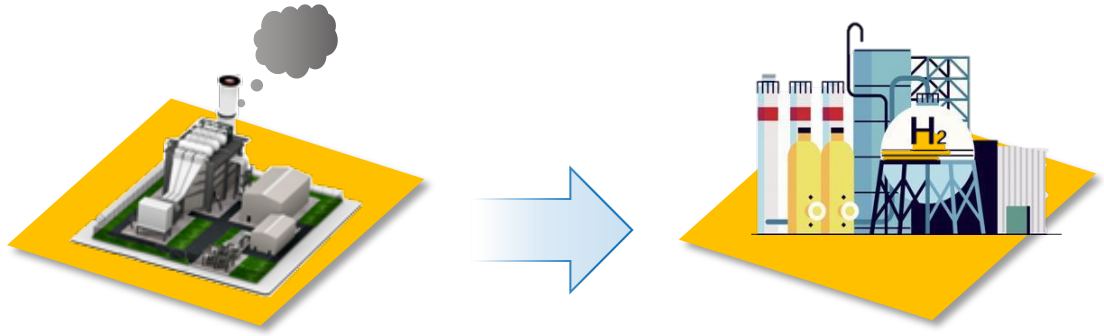
Transport: renewable energy power generation **in the west** is transmitted to the east through high-voltage transmission lines, and hydrogen energy is used to generate electricity **in the east**.



4 Power system coupled with hydrogen energy

Advantages of the scheme:

- **Water resources:** No need to worry about water resources in central and eastern China.
- **Resource reuse:** The base and equipment of the thermal power plant can be retained after decommissioning, and the water resources of the original power plant base can be recycled.



Decommissioning of thermal power plants

Resource reuse

4 Power system coupled with hydrogen energy

Energy Intelligence Laboratory
智慧能源实验室

Advantages of the scheme:

- **Water resources:** No need to worry about water resources in central and eastern China.
- **Resource reuse:** The base and equipment of the thermal power plant can be retained after decommissioning, and the water resources of the original power plant base can be recycled.
- **Improve utilization rate:** Hydrogen production can realize power peak shaving and valley filling, improve the utilization rate of UHV transmission lines, and reduce wind and solar energy curtailment.
- **Economic feasibility:** Lower cost than hydrogen transport, and with the increase of transmission line utilization, transport costs will further decrease.

Power transport - Hydrogen production - Electricity generation using hydrogen

0.46 ￥/degree

Power transport - Hydrogen production - Hydrogen storage – Electricity generation using hydrogen

1.05 ￥/degree (per week)

Conclusion

The new power system is an energy system that realizes the reconfiguration of power grid with renewable energy as mainstay. It will create a new physical form with electricity as mainstay, hydrogen coupled with electricity as energy storage, and interaction of generation, network, load and energy storage. It will create an open, sharing, competitive and win-win energy ecosystem with Internet Technology.

Thank you !

Haiwang Zhong

Department of Electrical Engineering
Tsinghua University，China

zhonghw@tsinghua.edu.cn

Energy Intelligence Laboratory
智慧能源实验室